




# Policy-relevant Indicators for National Consumption and Environment

Summaries of research  
and scientific papers from  
the PRINCE project



A tall, red and white striped chimney stack is visible on the right side of the image, extending from the bottom to the top. The sky is a deep blue with scattered white clouds. The chimney has a red top section, a white middle section, and a red bottom section.

This summary booklet was prepared by Caspar Trimmer, Stockholm Environment Institute for the PRINCE project.

It is based on texts from the PRINCE website, [www.prince-project.se](http://www.prince-project.se), from case study reports prepared during the PRINCE research and visualizations based on PRINCE data.

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An aerial photograph of a lush green landscape. A winding river flows through the center of the frame, surrounded by vibrant green fields. The fields are marked with numerous curved, parallel lines, likely from tractor tracks, creating a rhythmic pattern across the terrain. The lighting is bright, highlighting the various shades of green and the texture of the vegetation.

## EXECUTIVE SUMMARY

This text is extracted from the Swedish Environmental Protection Agency report *Miljöpåverkan från svensk konsumtion - nya indikatorer för uppföljning Slutrapport för forskningsprojektet PRINCE* (Environmental impacts from Swedish consumption: New indicators for follow-up: Final report from the research project PRINCE), Rapport 6842, Steinbach et al. 2018.

PRINCE (for Policy Relevant Indicators for Consumption and Environment) was a three-year project set up to explore ways to improve and expand the set of indicators used to estimate the environmental impacts linked to Swedish consumption, both within Sweden and abroad. Any new methods and indicators should be policy relevant and easily repeatable, drawing on credible, timely data.

PRINCE was particularly linked to follow-up of the Generational Goal, the overarching goal of Swedish environmental policy, which calls for the major environmental problems within Sweden to be solved within a generation, without causing increased environmental and health problems outside Sweden's borders.

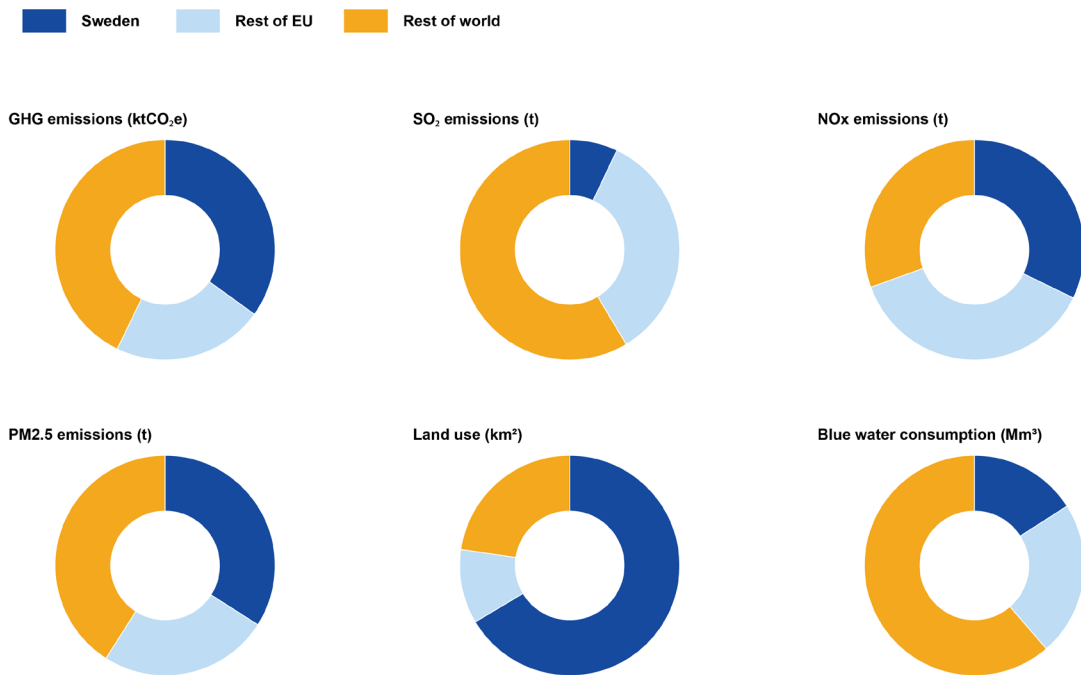
The project consortium of research institutes led by Statistics Sweden developed a new methodology for combining Swedish environmental-economic data with an environmentally extended multiregional input-output (MRIO) model, EXIOBASE. This made it possible to estimate the environmental pressures resulting from producing goods and services consumed in Sweden, based on reliable economic data and "environmental extensions" to reflect the characteristics of productive industries in different parts of the world in a given year.

The MRIO and Swedish data were combined in a hybrid model, which the project used to investigate an unprecedented wide range of environmental pressures associated with Swedish consumption. In addition to greenhouse gas (GHG) emissions and air pollutants, PRINCE investigated pressures resulting from use of a number of natural resources (land use, blue water consumption, and an aggregate measure of materials use) as well as pressures not previously used to generate national-scale indicators, such as aggregate use of chemicals, and GHG emissions from deforestation coupled to consumption. For some pressures, it was possible to develop indicators that can be adopted into calculation of environmental pressure from consumption as part of the environmental accounts. Others were more experimental.

For many indicators, the project was able to generate a time-series of results for the period 2008–2014. These were chiefly for emissions to air often associated with – but not limited to – the use of fossil fuels, along with land use, blue water consumption and materials use.

These time-series revealed that emissions of GHGs, nitrogen oxides (NO<sub>x</sub>), sulphur dioxide (SO<sub>2</sub>) and particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>) associated with Swedish consumption had all decreased during the period. The land area used to produce goods and services consumed in Sweden had also decreased somewhat, while total material flows (by weight) increased.

In order to understand how these changes in environmental pressures from consumption related to changes in the Swedish economy, they were compared with a time-series of value added – an indicator of economic activity – over the same period. This revealed that even as environmental pressures were decreasing, value added grew. This means that there was an absolute decoupling between economic development and several key environmental pressures from consumption during the time period. However, it is important to note that the decreases in GHG emissions were still far short of what would be needed to meet the Paris Agreement goal to keep global warming under 2 degrees.



*Geographic distribution of Sweden's consumption-based environmental pressures, six indicators, 2014. Based on Flourish visualization using PRINCE model data*

While overall Swedish consumption-based emissions decreased in 2008–2014, the ratio between the shares occurring inside Sweden and abroad remained relatively stable. This suggests that developments have been in line with the Generational Goal.

The PRINCE team also studied how the environmental pressures associated with Swedish consumption are distributed among countries/regions, and among categories of products consumed in Sweden.

The results reveal somewhat different patterns for different environmental pressures. However, products from the construction and civil engineering sectors, food and other agricultural products, as well as households' direct use of fuels for heating and vehicles, feature prominently among the top "hotspot" product groups for a variety of emissions to air.

The geographic spread is also somewhat different for different pressures. While Sweden is the top country or region for most emissions and resource use results, other geographic hotspots vary depending on the environmental pressure and the quantities of specific product groups concerned.

A new set of environmental indicators explored by the project concern the use and emissions of hazardous chemicals. PRINCE developed novel data and methods capable of generating aggregate indicators. They cover both use of hazardous chemical products and emissions of hazardous chemicals. This work also produced data for two specific categories of hazardous chemicals associated with agricultural production: veterinary antimicrobials and pesticides.

The chemicals study produced preliminary results for one year, 2014, and revealed some opportunities and difficulties in obtaining data. The results indicate, among other things, that the use and emissions of hazardous chemicals associated with Swedish consumption largely take place abroad. Further analysis and development of these indicators is required.

Another PRINCE case study produced suggestions on how to monitor the consumption of fish so that it becomes clearer what kind of environmental impact may occur, depending on the type of fish and catch method. Further analysis is needed of how this can be developed.

The project also investigated how to deepen the analysis of water use by weighting water use results using an index of water scarcity. The results point to a need for more precise data than what is available; two different methods were tested.

A number of other special studies focused on key product groups such as food and beverages; the information and communications technology (ICT) sector; how to calculate emissions from international transportation with MRIO and a bottom-up method; and socio-economic benefits of Swedish consumption in China.

Below are a number of suggestions for how to take forward the work on consumption-based indicators started under PRINCE.

- In calculating environmental pressures from consumption, Statistics Sweden should change its current method and start using a multiregional model such as EXIOBASE to calculate the environmental pressures from imports.
- The hybrid model developed by PRINCE should be used to follow up the Generational Goal. The data sources for GHGs, NO<sub>x</sub>, SO<sub>2</sub> and particulate emissions are deemed mature enough to generate useful indicators.
- Sweden should support international efforts to achieve harmonized environmental statistics. An important observation during the work of PRINCE was the gaps in available data and statistics, including data on the use and release of chemicals, including use of pesticides in agriculture in developing countries.
- Work started by the project to develop indicators related to natural resources (such as land use and its connection to deforestation and loss of biodiversity, water use, material flows and energy) should continue, for example to make environmental impacts regarding the connections between these indicators and the Generational Goal and potentially for the Sustainable Development Goals.
- Research on and development of the chemical indicators should continue and time series be developed to eventually include them in follow-up of the Generational Goal.
- The methods proposed to assess the environmental impacts of fish consumption should be further developed.
- The methods proposed for calculating emissions from international transport should be further developed.

# SCIENTIFIC ARTICLES



## Environmental pressures from Swedish consumption: A hybrid multi-regional input-output approach

Viveka Palm, Richard Wood, Mårten Berglund, Elena Dawkins, Göran Finnveden, Sarah Schmidt and Nancy Steinbach  
*Journal of Cleaner Production*, vol. 228 (August 2019): 634–44  
DOI: 10.1016/j.jclepro.2019.04.181

Sweden has a policy goal of solving major environmental problems in Sweden within a generation, without increasing environmental or health problems in other countries. Following up on this Generational Goal requires a set of indicators that can measure and compare both the domestic and the external footprints of Swedish consumption.

This article presents such a set of macro-level indicators for the years 2008–2014. These new indicators were generated using the PRINCE hybrid modelling approach that makes them consistent with Swedish statistics from the System of Environmental-Economic Accounts. The approach combines a multiregional input-output (MRIO) database, EXIOBASE3 (to capture the external components of Sweden's consumption and the environmental pressures associated with them) with national input-output, trade and environmental statistics.

Indicators of pressures linked to Swedish household consumption, government consumption and capital formation are given, covering emissions of greenhouse gases, sulphur dioxide (SO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), and particulate matter smaller than 2.5 µm (PM<sub>2.5</sub>), along with land use, materials consumption, and blue water consumption.

Except for land use, the majority (60% or more) of the environmental pressures due to Swedish consumption occurred outside Sweden in 2014; more than 90% of SO<sub>2</sub> emissions and more than 80% of the water consumption occurred abroad.

The environmental pressures from Swedish consumption decreased over this period for all indicators except materials consumption. This suggests an absolute decoupling between environmental pressure due to consumption and economic growth, which rose over the period. It is, however, too early to determine whether this is a genuine trend or a temporary stabilization.

# Understanding GHG emissions from Swedish consumption: Current challenges in reaching the Generational Goal

Sarah Schmidt, Carl-Johan Södersten, Kirsten Wiebe, Moana Simas, Viveka Palm and Richard Wood

*Journal of Cleaner Production*, vol. 212 (March 2019): 428–37

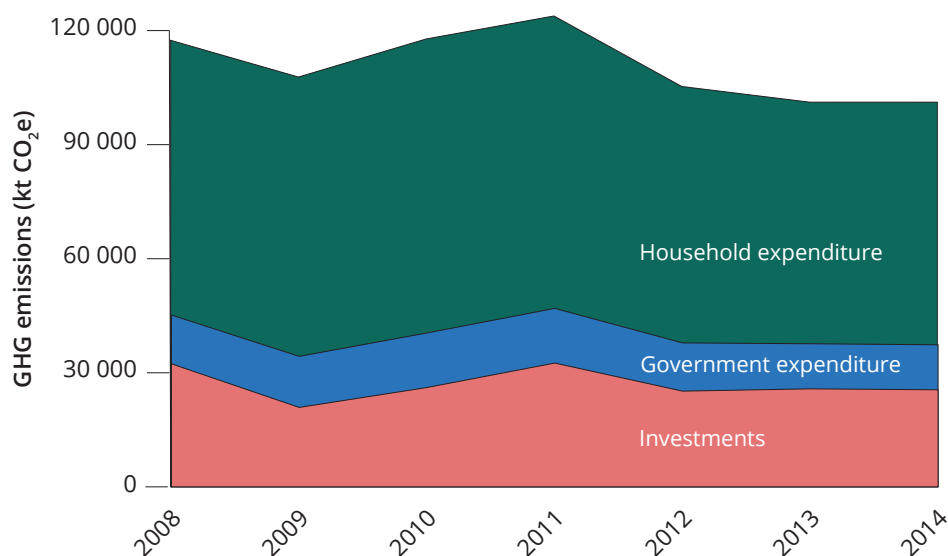
DOI: 10.1016/j.jclepro.2018.11.060

Sweden's Generational Goal, the overarching goal of Swedish environmental policy, is to solve all major domestic environmental problems for the next generation without increasing environmental and health impacts abroad.

Without a good understanding of greenhouse gas (GHG) emissions from Swedish consumption, the formulation of efficient and well-targeted policy initiatives to reach this Generational Goal – particularly its international component – is difficult. The authors analysed the impacts of Swedish consumption in detail, investigating the impacts of different final consumers and different consumption clusters as well as the geographical locations of where GHGs are emitted to satisfy Swedish demand, over a period of 20 years, using the PRINCE model.

The study shows that total consumption-based GHG emissions fluctuated but remained relatively stable over the period. However, while the emissions were predominantly within Sweden at the start of the period, by the end the balance had shifted abroad. A substantial reduction in domestic consumption-based emissions was largely down to falling direct emissions associated with domestic heating and mobility. Extra-territorial emissions increased especially in China and in the rest of Asia.

The authors show that manufactured products are responsible for a large share of this development, displaying a strong trend toward future increases. This calls for policy measures targeting consumption, especially of manufactured products such as textiles, clothing and furniture that cause large impacts in other countries.



Sweden's consumption-based greenhouse gas emissions, 2008–2014  
Based on PRINCE model data

## Environmental pressure from Swedish consumption: The largest contributing producer countries, products and services

Eleonore Fauré, Elena Dawkins, Richard Wood, Göran Finnveden, Viveka Palm, Linn Persson and Sarah Schmidt

*Journal of Cleaner Production*, 231 (September 2019): 698–713

DOI: 10.1016/j.jclepro.2019.05.148

As well as providing national-level macroindicators, the PRINCE model estimated in which countries along Sweden's supply chains the pressures were exerted, and which categories of goods and services consumed in Sweden they were associated with. This article presents the method and headline results concerning which product groups were most responsible for the environmental pressures, and in which countries they occurred. The following environmental pressures are analysed: use of land, blue water and material resources; emissions of greenhouse gases (GHGs), and of the major air pollutants sulphur dioxides (SO<sub>2</sub>), Nitrogen oxides (NO<sub>x</sub>), and particulate matter (PM 2.5 and PM10). The results were calculated using the PRINCE model.

The results show that in 2014 – the latest year for which the model shows results – all of the environmental pressures “embedded” in the products consumed in Sweden occurred overwhelmingly abroad, with the exception of land use. The article also compares these consumption-based pressures with the total pressures occurring on Swedish territory (production-based pressures). In this case, all consumption-based pressures are once more significantly larger than production-based pressures, except in the case of land use and material resource use.

The most important product groups across the different environmental pressures are construction, food products and direct emissions from, or use by, households (except for sulphur dioxide emissions and materials use for the latter product group). Other product groups that are found to have environmental pressures across several indicators are wholesale and retail services, architecture and engineering, real estate, motor vehicles, and other machinery and equipment. However, for the three natural resource pressures – use of water, land and material resources – agricultural products are a relatively important product group, along with products from forestry for the latter two indicators.

Outside Sweden, China is most notable among the countries where pressures from Swedish consumption occur, and is among the top five countries for all emissions to air, as well as blue water and material resource use. Other countries or regions that rank highly for certain product group-environmental pressure combinations are Rest of Asia and Pacific (i.e. Asia and Pacific except Indonesia, Taiwan, Australia, India, South Korea, China and Japan), Russia, Germany, Denmark and Spain. This pattern of geographically dispersed pressures caused by Swedish consumption indicates the need to address the pressures at several levels of collaboration: national, within the European Union, bilateral and international.

## Indicators for national consumption-based accounting of chemicals

Linn Persson, Rickard Arvidsson, Mårten Berglund, Christel Cederberg, Göran Finnveden, Viveka Palm, Louise Sörme, Sarah Schmidt and Richard Wood

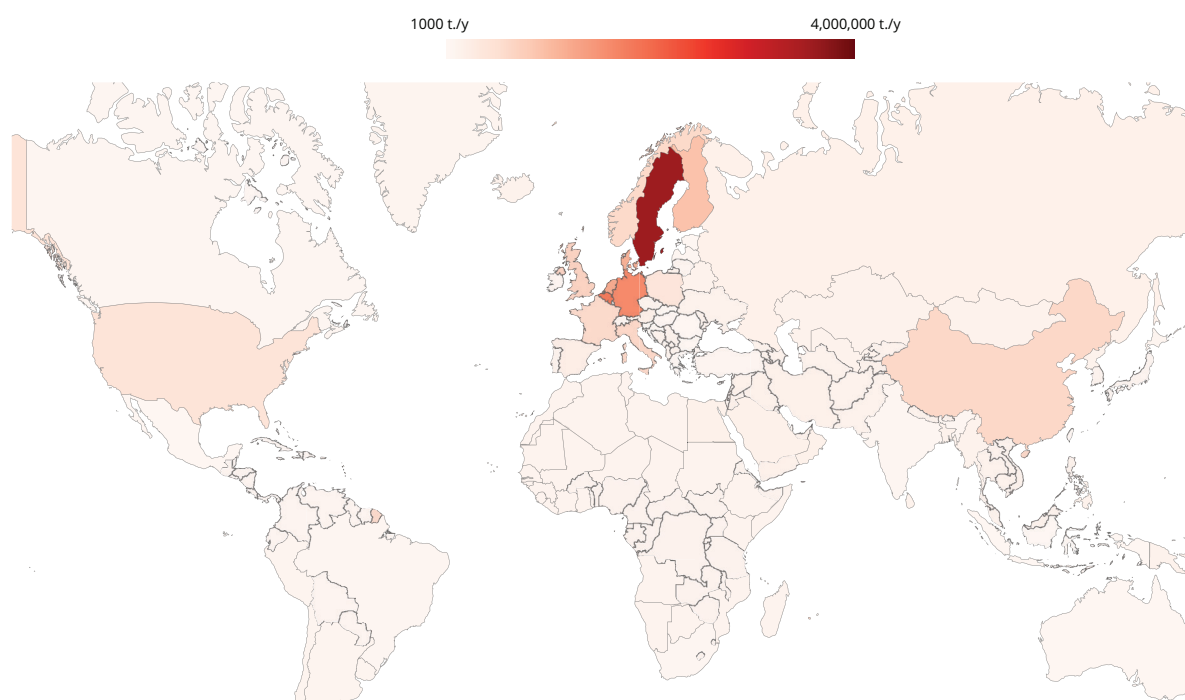
*Journal of Cleaner Production*, vol. 215 (March 2019): 1–12

DOI:10.1016/j.jclepro.2018.12.294

This article presents a new set of for the global use, emissions and impacts of hazardous substances, one of the key outputs from the PRINCE project.

There has been a relentless increase in the quantities and types of chemicals used in producing consumer goods and services around the world. This has caused widespread concern and has been linked to a growing number of environmental problems.

Several countries' national environmental targets, as well as the global chemical-related goals in the 2030 Agenda, call for the monitoring of chemical use and emissions. However, this monitoring is made very complicated by the great variety of production processes and chemicals regulation regimes found in countries along today's global supply chains.



*Geographic distribution of use of hazardous chemical substances embedded in Swedish consumption, 2014.  
Produced in Flourish using PRINCE data*

The paper presents a new set of national indicators that connect the use and emissions of hazardous substances to a country's total consumption, using the case of Sweden.

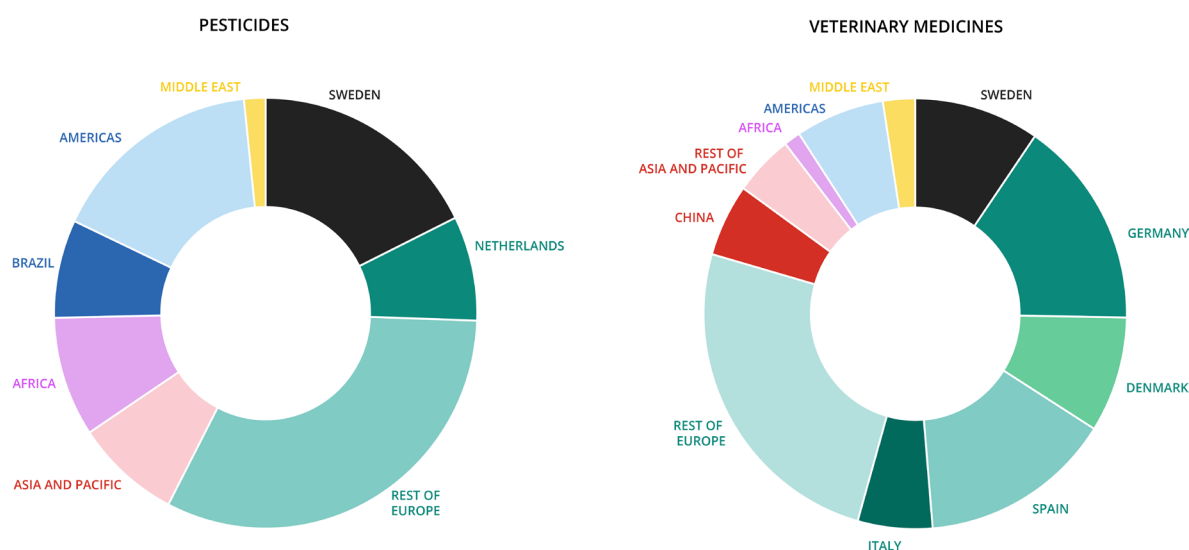
The new indicators make use of the hybrid model developed in PRINCE, combining the multiregional input-output analysis database EXIOBASE with data from the Swedish System of Economic and Environmental Accounts, together with a novel set of environmental extensions. The five indicators are: use of hazardous chemical products, use of pesticides, use of antimicrobial veterinary medicines, emissions of hazardous

substances, and the potential toxicity of these emissions. The indicators further allocate these different pressures to 60 product groups consumed in Sweden, and to the countries and world regions where they occur.

The results suggest that, overall, only 10–24% of the chemicals-related pressures from Swedish consumption occur within Sweden's borders, depending on the indicator. The use of hazardous chemical products and veterinary medicines related to Swedish consumption primarily takes place in other EU countries, whereas the use of pesticides as well as reported emissions of hazardous substances occur mainly outside the EU.

Also presented is a review of chemicals-related databases, discussed in relation to the driver-pressure-state-impact-response (DPSIR) framework for indicators.

The paper highlights the need for improved international accounting of chemical flows, as well as for strengthened policy frameworks to address cross-border impacts of consumption of hazardous chemical products.



Geographic distribution of use of pesticides and veterinary antimicrobials embedded in Swedish consumption, 2014. Produced in Flourish using PRINCE data

### See also two related papers:

#### [Using E-PRTR data on point source emissions to air and water—First steps towards a national chemical footprint](#)

Louise Sörme, Viveka Palm and Göran Finnveden  
*Environmental Impact Assessment Review*, vol.56 (January 2016): 102–112  
 DOI: 10.1016/j.eiar.2015.09.007

#### [Updated indicators of Swedish national human toxicity and ecotoxicity footprints using USEtox 2.01](#)

Maria Nordborg, Rickard Arvidsson, Göran Finnveden, Christel Cederberg, Louise Sorme, Viveka Palm, Kristin Stamy, and Sverker Molander  
*Environmental Impact Assessment Review*, vol. 62 (January 2017): 110–114  
 DOI: 10.1016/j.eiar.2016.08.004

# Beyond the borders: Burdens of Swedish food consumption due to agrochemicals, greenhouse gases and land-use change

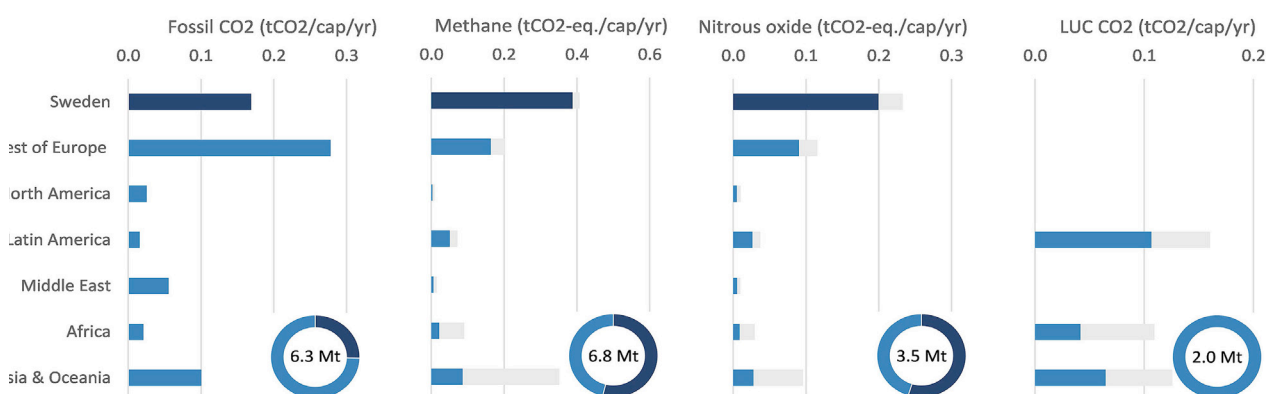
Christel Cederberg, U. Martin Persson, Sarah Schmidt, Fredrick Hedenus and Richard Wood  
*Journal of Cleaner Production*, vol. 214 (March 2019): 644–52.  
 DOI: 10.1016/j.jclepro.2018.12.313

Sweden’s environmental policy aims to solve domestic environmental problems without increasing environmental and health impacts overseas. Realizing this aim requires an indicator system with a consumption-based (or “footprint”) perspective that captures both local and global impacts and their development over time.

This paper presents a set of novel footprint indicators to measure environmental pressures from Swedish food consumption. The indicators are calculated by combining data and statistics on agrochemicals and deforestation-related emissions with EXIOBASE3.

The authors estimate the use of pesticides and antimicrobial veterinary medicines associated with current Swedish food consumption and compare those footprint indicators with the EU-28. Carbon emissions from deforestation are calculated with a land-balance model and included in the overall carbon footprint of food.

The paper finds that Sweden, with its large reliance of food imports, exerts a significant agrochemical and climate footprint overseas, mainly in the EU and Latin America. The authors point to a need for better data and statistics on the use of pesticides, veterinary medicines and agrochemical residues (especially in developing countries) as well as improved spatial data on agricultural activity to further reduce uncertainty in the environmental footprint of Swedish food consumption.



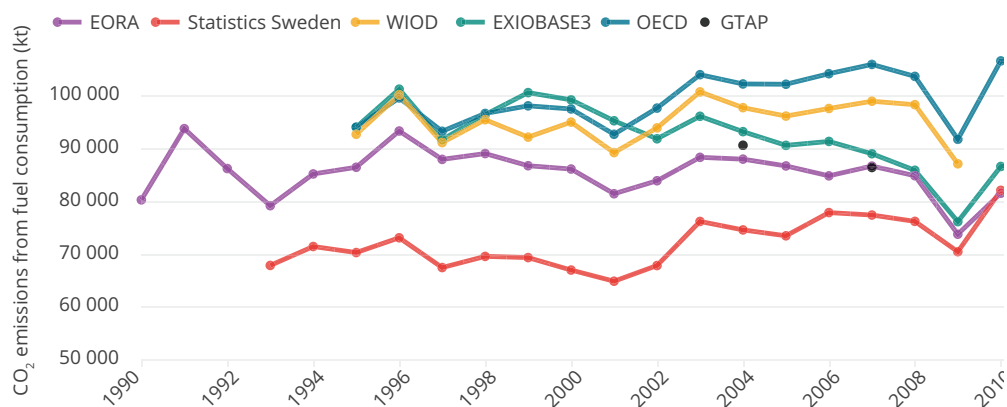
Per capita footprints for Swedish consumption of food and beverages, 2014. Blue bars = footprints for final consumption of food; grey bars = footprint of all final consumption (excluding fossil CO<sub>2</sub>). Circle insets compare the shares of impacts originating from Swedish production (dark blue) versus imports (light blue). Reproduced from Cederberg et al. (2019) CC-BY-NC-ND

## The Swedish footprint: A multi-model comparison

Elena Dawkins, Daniel Moran, Viveka Palm, Richard Wood and Ida Björk  
*Journal of Cleaner Production*, vol. 209 (February 2019): 1578–92  
 DOI: 10.1016/j.jclepro.2018.11.023

Swedish consumers have a disproportionately large per capita carbon footprint, particularly compared to the levels recommended for maintaining a stable climate. Most of that footprint falls outside Sweden's territory – due to the processes involved in producing and transporting products consumed in Sweden – and can thus be considered “embodied” (or “embedded”) in those products.

This article compares the results on Sweden's carbon footprint generated by several available models: the EXIOBASE, GTAP, OECD, Eora, and WIOD multiregional input-output (MRIO) models, along with the single-region model currently used by the national statistical office, Statistics Sweden. The results looked at not only the size and development of the carbon footprint over time, but also the geographic “hotspots” of consumption impacts identified by the different MRIOs – carbon emissions, total greenhouse gas emissions and materials and water use footprints.



*Comparison of Sweden's carbon footprint using different multiregional input-output models and the Statistics Sweden single-region model. Graphic created using Flourish.*

The study aimed to assess the state of knowledge of Sweden's consumption footprint, and to gain insights that could inform the development of the PRINCE model. The article also discusses why the results may differ between models (with their particular assumptions and calculation methods) and between types of environmental pressure.

The authors conclude that given the complexity of creating an entirely new MRIO model, the character of Sweden's economy and the high-quality environmental-economic data Sweden holds about domestic activities, linking the national data with an existing MRIO would be a promising approach to explore for PRINCE, and potentially for other countries. Based on the analysis, they offer recommendations to guide future research and policy-making.

# A spatially explicit data-driven approach to calculating commodity-specific shipping emissions per vessel

Wendela Schim van der Loeff, Javier Godar and Vishnu Prakash  
Journal of Cleaner Production, vol. 205 (December 2018): 895–908  
DOI: 10.1016/j.jclepro.2018.09.053

Ocean-going ships carry approximately 80% of the world's traded goods by volume – more than 10 billion tonnes of traded goods per year. By 2012, average annual greenhouse gas emissions from maritime shipping were estimated at around 1 billion tonnes CO<sub>2</sub>e or around 3% of man-made emissions. By 2050 they are projected to grow by up to 210%. Despite its importance to the world economy and global emissions, the maritime shipping sector was largely neglected in the 1997 Kyoto Protocol and have been overlooked in climate mitigation discussions since.

A lack of reliable emissions data and the difficulty of attributing responsibility for international shipping emissions to the countries, companies and commodities concerned have been key barriers to bringing maritime shipping into global climate mitigation debate and strategies. There is also a perception that too much focus on shipping emissions could affect global trade flows.

This open access paper presents a new method for accurately calculating and attributing emissions from marine cargo shipping, by linking and integrating a variety of rich data sets that are already available. Per-vessel (and even per-container) cargo composition data provide the commodity type, the exporters, shippers and importers. Data from the Automatic Identification System track precise routes a cargo consignment takes, as well as operational detail such as speed, movement and draft that can all affect fuel consumption.

By linking these with the specifications of each vessel, including age, size and motor type, it is possible to estimate emissions accurately, at the level of individual commodities and vessels, and produce bottom-up aggregated estimates for companies, exporting and importing countries and more.

This paper demonstrates the new approach with the case of Brazilian exports in 2014. Maritime shipping of these goods was responsible for 25.99 million tonnes of CO<sub>2</sub>, representing an additional 5% on the total CO<sub>2</sub> emissions for Brazil reported by the World Bank for 2014 (which excluded international shipping and aviation). The study also highlights those commodities and trading routes accounting for the largest shares of these emissions, in relation to those that are most valuable to Brazil's economy.

Finally, the paper discusses the implications of scaling up this methodology for global GHG abatement efforts and demand-side footprint calculations, as well as to improve accountability mechanisms for the maritime sector as a whole.

A separate case study for PRINCE found that in 2016, cargo ships emitted around 2.66 Mt CO<sub>2</sub> during 21,098 individual journeys either arriving in or leaving Swedish ports. About 43% of the emissions were from general cargo vessels, another 27% from oil tankers, 16% from container ships and 14% from bulker vessels. Routes to and from Germany accounted for the largest share (9.1%) of emissions, followed by the UK, Russia, other Swedish ports and the Netherlands.

## Improving consumption based accounting for global capture fisheries

Chris D. West, Emilie Hobbs, Simon A. Croft, Jonathan M. H. Green, Sarah Y. Schmidt and Richard Wood

*Journal of Cleaner Production*, vol. 212 (March 2019): 1396–1408

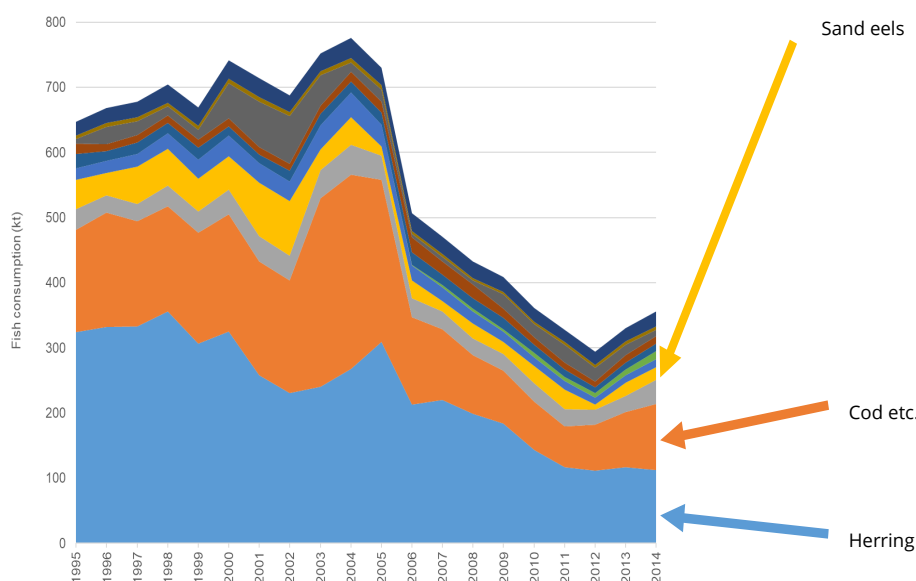
DOI: 10.1016/j.jclepro.2018.11.298

Consumption-based accounting has been used to understand the resource and environmental pressures associated with the consumption of goods and services. Capture fisheries have significant economic, cultural, and environmental importance, yet relatively limited attention has been given to understanding the environmental and biodiversity pressures linked to fish consumption. Where products of marine and inland fisheries are accounted for, it is typically in the context of “material” footprints or in life cycle assessment-based studies.

The sustainability of fisheries products is highly dependent on the catch method, location and species targeted. To date, these aspects have not been taken into account in consumption-based accounts. This paper presents a collation of species-specific information comprising vulnerability and environmental pressure associated with capture. It then links this to a global multiregional input-output (MRIO) model to – for the first time – create a dedicated consumption-based time-series for fisheries.

While the aggregate footprint of global capture fisheries has remained stable in recent decades, the study's results demonstrate that trends in consumption differ between countries and regions. Importantly, there have been significant shifts in the composition of catch within these consumption accounts, and this has potential implications for the sustainability of supply chains.

The paper highlights the fact that material efficiency perspectives are insufficient to estimate the pressures on the marine environment driven by consumption of fisheries products. It also demonstrates that – although challenges remain – there is a growing abundance of information and new methods being developed that could overcome such knowledge gaps in the future.



*Swedish consumption of ocean-caught fish, by taxonomic order, 1995–2014*  
Chris D. West, Emilie Hobbs, Simon A. Croft, Jonathan M. H. Green, Sarah Y. Schmidt and Richard Wood

## **A note on the magnitude of the feedback effect in environmentally extended multi-region input-output tables**

Daniel Moran, Richard Wood and Joao F. D. Rodrigues  
Journal of Industrial Ecology (September 2017)  
DOI:10.1111/jiec.12658

Global multiregional input-output (MRIO) tables have been developed to capture international spillover effects due to demand in one country and production in other countries. International spillovers have been growing and have become so dominant, especially in environmental analysis, that their inclusion is essential when analyzing impacts of consumption.

MRIO tables give full coverage of the world economy, but do not always respect the official data of a given country. When international spillovers also cause increased production in the country of demand, we see what are known as “feedback effects.”

A coupled model such as that developed for PRINCE uses an official foreground national input-output table (IOT) alongside an existing global MRIO (EXIOBASE) but does not use the official foreground information when modeling international feedback loops. The question thus arises: are the feedback loops large enough to compromise the accuracy of results for different environmental impacts generated from the model?

The authors looked specifically at the amount of domestic production that is embodied in imports back into a region. They found that for emissions the feedbacks were small, usually <2% of the total import footprint, though up to 6%+ for some countries in some years for some stressors. The findings reassured them that the effect of the feedback loops on results for Sweden were not significant, and thus using Leontief multipliers from EXIOBASE was an acceptable method for modeling imports into the Swedish IOT for the purposes of PRINCE.

## **Swedish footprints: Policy-relevant indicators for consumption and environment**

Richard Wood and Viveka Palm  
Paper presented at the 24th International Input-Output Conference, 4–8 July 2016, Seoul

This paper concentrates on methods used in the PRINCE project to operationalize the accounts – especially the link between the MRIO models and the available Swedish input-output tables.

## Capturing the heterogeneity of sub-national production in global trade flows

Simon A. Croft, Christopher D. West and Jonathan M. H. Green  
Journal of Cleaner Production, vol. 203 (December 2018): 1106–1118  
DOI: 10.1016/j.jclepro.2018.08.267

The PRINCE footprint indicators treat producer countries and regions as single entities for the sake of estimating environmental impacts. However, within a producer country there may be significant differences between landscapes, meaning that the same activities – for example, farming soy – can have very different sustainability implications.

This open-access article illustrates how consumer markets can be linked back to specific production landscapes using multiregional input-output (MRIO) modeling. This study introduces the hybridized MRIO model IOTA, developed by Stockholm Environment Institute. IOTA utilizes subnational and national-level production, trade and environmental data; national-scale commodity-use data; and a global economic MRIO to link subnational production landscapes and associated impacts to regional final consumption.

The article applies IOTA to Brazilian soy production and related land use for consumption in the European Union. The distribution of production between Brazilian states to meet EU demand is significantly different from that of total production in the country, and each individual EU member state has its own sourcing patterns. Sourcing also varies considerably within a country's consumption profile, depending on the sector purchasing the soy.

Linking consumption to subnational production and trade allows more accurate and meaningful connections to be made between consumer behaviour and the associated impacts and risks. This understanding of consumption-driven impacts in turn informs, and allows for, more targeted and effective policy interventions to tackle the pressures and risks associated with agricultural commodity production for a global market.

# A multi-impact analysis of changing ICT consumption patterns for Sweden and the EU: Indirect rebound effects and evidence of decoupling

P. James Joyce, Göran Finnveden, Cecilia Håkansson, Richard Wood  
*Journal of Cleaner Production*, vol. 211 (February 2019): 1154–61  
DOI: 10.1016/j.jclepro.2018.11.207

Information and communication technology (ICT) has been one of the major areas of growth in consumption over the last two decades.

Falling prices and increasing energy efficiency in ICT may lead to reduced spending on the technologies, and related electricity consumption, in the future. However, history has shown that a drop in one kind of spending can trigger an increase in another kind, offsetting and even overwhelming any environmental benefits. The scale of these “rebound effects” can be difficult to anticipate and to monitor.

This study uses multiregional input-output (MRIO) analysis to investigate trends in the consumption of, and the environmental and social impacts associated with, ICT products in Sweden and the wider European Union.

The authors find that ICT spending is correlated with prosperity, with a clear fall as a result of the 2008 financial crisis, but a recovery since. They present evidence that the environmental impact associated with ICT has begun to decouple from ICT consumption in Sweden, but that this has not happened at the EU level.

The study also finds that environmental rebound effects associated with reduced ICT consumption have been strong – with consumption impacts increasing in most cases far above 100% of the reductions due to reduced ICT consumption. This rebound effect is greatest for energy use and total material footprint, where it reaches close to 200% in Sweden.

These findings imply that increased spending on ICT products and services, if the overall level of consumption remains constant, would reduce environmental impacts.

Compared with ICT spending, environmental rebound effects are much lower for the reduced energy spending – as low as 2% – particularly at the EU level.

The study offers the first analysis of rebound effects in social indicators for ICT products. It finds that value-added in the EU is relatively insensitive to changes in spending patterns related to ICT and energy (rebound effects less than 100%). However, rebound effects are seen in employment, particularly as a result of decreased energy spending. At the EU level, reallocation of spending due to lower energy consumption results in a net increase in employment, while in Sweden the reverse is true.

The study concludes that policies focused on reducing energy spending are likely to have greater overall environmental benefits than measures that result in reduced consumer spending on ICT. However, in light of the conflicting social rebound effects both in Sweden and at EU level, the importance of understanding the broader consequences of policy decisions across a broad range of measures in advance of their implementation is once again highlighted.

## Modeling reductions in the environmental footprints embodied in European Union's imports through source shifting

Bertram F. de Boer, Joao F. D. Rodrigues and Arnold Tukker  
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The European Union is responsible for a disproportionately large global environmental footprint, in particular through its imports. Import embodied footprints (IEFs) vary significantly depending on the country of origin, which suggests that sourcing the same goods from different producer countries could change – and potentially reduce – Europe's IEFs.

This paper explores how far Europe's IEFs could be reduced by sourcing products that are currently imported to the EU from the countries with the lowest impact intensities per million euro. It looks at four environmental pressures: carbon emissions and use of materials, water and land). It does so using environmentally extended multiregional input-output (EE-MRIO) analysis using EXIOBASE, the same MRIO used for the international component of the PRINCE model.

The analysis suggests that just 13 of EXIOBASE's 200 product groups are responsible for more than half of all impacts embedded in imports for each pressure. With only a few exceptions, optimizing sourcing of a product group in order to minimize one pressure reduces footprints in the other three pressures. The pressure with the highest scope for optimization is water. Optimizing carbon emissions and materials use yields the largest reductions in the other environmental pressures.

The paper also reflects on some significant limitations of EE-MRIO analysis for studying the impacts of source shifting. One is the assumption that product groups represent the same mix of products, whichever country they come from. In fact, product groups can be rather broad, and it was notable that four of the top 13 product groups were "n.e.c." (not elsewhere classified) categories, which can be highly eclectic – for example, "chemicals n.e.c." could include anything from fertilizer to pharmaceuticals. Thus, shifting sources could also entail a significant shift in the products imported. Another limitation is the assumption that imports of the same value represent the same quantity of product, whereas in fact imports from different producers (and different products within a product group) are differently priced. The authors discuss how EE-MRIO could be made more credible and policy relevant for exploring the impacts of source shifting on IEFs by disaggregating n.e.c. product groups, and incorporating dynamic effects.

## Agricultural and forestry trade drives large share of tropical deforestation emissions

Florence Pendrill, U. Martin Persson, Javier Godar, Thomas, Kastner, Daniel Moran, Sarah Schmidt and Richard Wood

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Deforestation, the second largest source of anthropogenic greenhouse gas emissions, is largely driven by expanding forestry and agriculture. This agricultural expansion is increasingly driven by foreign demand. However, the links between deforestation and foreign demand have only been partially mapped.

This open-access paper presents a quantification of carbon emissions from agriculture- and forestry-related deforestation across the tropics. It then traces these emissions embodied in traded commodities through global supply chains to the consumers.

The analysis shows that in the period 2010–2014, expansion of agriculture and forestry plantations into tropical forests around the world was associated with net emissions of approximately 2.6 gigatonnes CO<sub>2</sub> per year. Cattle and oilseed products (including soy and palm oil) account for over half of these emissions.

Depending on the trade model used, between 29% and 39% of deforestation-related emissions in the period were driven by international trade. This is substantially higher than the share of fossil carbon emissions embodied in trade, indicating that efforts to reduce greenhouse gas emissions from land-use change need to consider the role of international demand in driving deforestation.

Europe and China are major importers of these products, and for many developed countries, deforestation emissions embodied in imports rival or exceed emissions from domestic agriculture. Additionally, the analysis finds that deforestation-related emissions are similar to, or larger than, other emissions in the carbon footprint of key forest-risk commodities. Similarly, deforestation emissions constitute around one-sixth (~15%) of the total carbon footprint of food consumption in EU countries.

This highlights the need for consumption-based accounts to include emissions from deforestation, and for policy measures that span these international supply chains, if deforestation emissions are to be effectively reduced. The research was partly funded through PRINCE.

## Deforestation displaced: Trade in forest-risk commodities and the prospects for a global forest transition

Florence Pendrill, U. Martin Persson, Javier Godar and Thomas Kastner  
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While many developed countries are increasing their forest cover, deforestation is still rife in the tropics and subtropics. This deforestation is often linked to production of agricultural commodities that are internationally traded and in large part consumed in developed countries. Thus, it is becoming increasingly important to consider inter-country trade links in assessing the drivers of – and possible connections between – forest loss and gain across countries.

Previous studies have shown that countries that have undergone a forest transition (and are now increasing their forest cover) tend to displace land use outside their borders. However, a lack of comprehensive data on deforestation drivers has made it impossible to ascertain whether this displacement has accelerated forest loss in source countries.

To fill this gap, this open access article presents a land-balance model that quantifies deforestation embodied in production of agricultural and forestry commodities at country level across the tropics and subtropics, subsequently tracing embodied deforestation to countries of apparent consumption using a physical, country-to-country trade model.

It finds that in the period 2005–2013, 62% (5.5 Mha yr<sup>-1</sup>) of forest loss could be attributed to expanding commercial cropland, pastures and tree plantations. The commodity groups most commonly associated with deforestation were cattle meat, forestry products, oil palm, cereals and soybeans, though variation between countries and regions was sizeable.

A large (26%) and slightly increasing share of deforestation was attributed to exports, the bulk of which (87%) were to countries that are either slowing deforestation rates or increasing forest cover on their own territories (late- or post-forest transition countries), particularly in Europe and Asia (China, India, and Russia).

About one-third of the net forest gains in post-forest transition countries was in this way offset by imports of commodities causing deforestation elsewhere, suggesting that achieving a global forest transition will be substantially more challenging than achieving national or regional ones.

The work was partly funded through PRINCE, along with the Gordon and Betty Moore Foundation through the Trase programme.

PRINCE was a three-year research project set up to explore ways to improve and expand the set of indicators used to estimate the environmental impacts linked to Swedish consumption.

PRINCE was particularly linked to follow-up of the Generational Goal, the overarching goal of Swedish environmental policy, which calls for the major environmental problems within Sweden to be solved within a generation, without causing increased environmental and health problems outside Sweden's borders.

The project developed a new method for combining Swedish environmental-economic data with an environmentally extended multiregional input-output (MRIO) model, EXIOBASE. This made it possible to estimate the environmental pressures resulting from producing goods and services consumed in Sweden, based on reliable economic data and "environmental extensions" to reflect the characteristics of productive industries in different parts of the world in a given year.

It also explored a wide range of new consumption-based indicators, for chemicals, capture fisheries, shipping emissions, deforestation and more, along with further methodological innovations and related studies.

This booklet presents the English executive summary of the final project report, along with summaries of 16 scientific articles presenting different aspects of the project.

*PRINCE was commissioned by Naturvårdsverket and the Swedish Agency for Marine and Water Management (Havs- och Vattenmyndigheten, or HaV), and funded under a Naturvårdsverket research grant (Environmental Research Appropriation 1:5). The team was led by Statistics Sweden and included experts from Stockholm Environment Institute, Chalmers University of Technology, KTH Royal Institute of Technology, Norwegian University of Science and Technology (NTNU), Leiden University Institute of Environmental Sciences (CML) and the Netherlands Organization for Applied Scientific Research (TNO).*