Indhold og kilder

- **Hvordan smelter is?**
  http://isskolen.dk/wp/wp-content/uploads/Hvordan-smelter-is.pdf

- **Hvorfor stiger havet ikke når isen på Nordpolen smelter?**
  http://isskolen.dk/wp/wp-content/uploads/Hvorfor-stiger-havet-ikke-nar-isen-p%C3%A5-Nordpolen-smelter.pdf

- **Hvor stor er Grønlands indlandsis?**
  http://isskolen.dk/wp/wp-content/uploads/Hvor-stor-er-Gronlands-Indlandsis.pdf

- **Internettet forurener lige så meget som flytrafik: Streaming er den helt store synder**
  http://nyheder.tv2.dk/samfund/2018-12-03-internettet-forurener-lige-saa-meget-som-flytrafik-streaming-er-den-helt-store

- **Introduktion til IBSE-didaktikken**
  https://astra.dk/sites/default/files/Introduktion%20til%20IBSE-didaktikken.pdf

- **Rapport: Datacentre vil stå for en tredjedel af Danmarks elforbrug**
  https://ing.dk/artikel/rapport-datacentre-vil-staa-tredjedel-danmarks-elforbrug-211697

- **This is how your personal consumption affects the climate**
  http://sciencenordic.com/how-your-personal-consumption-affects-climate

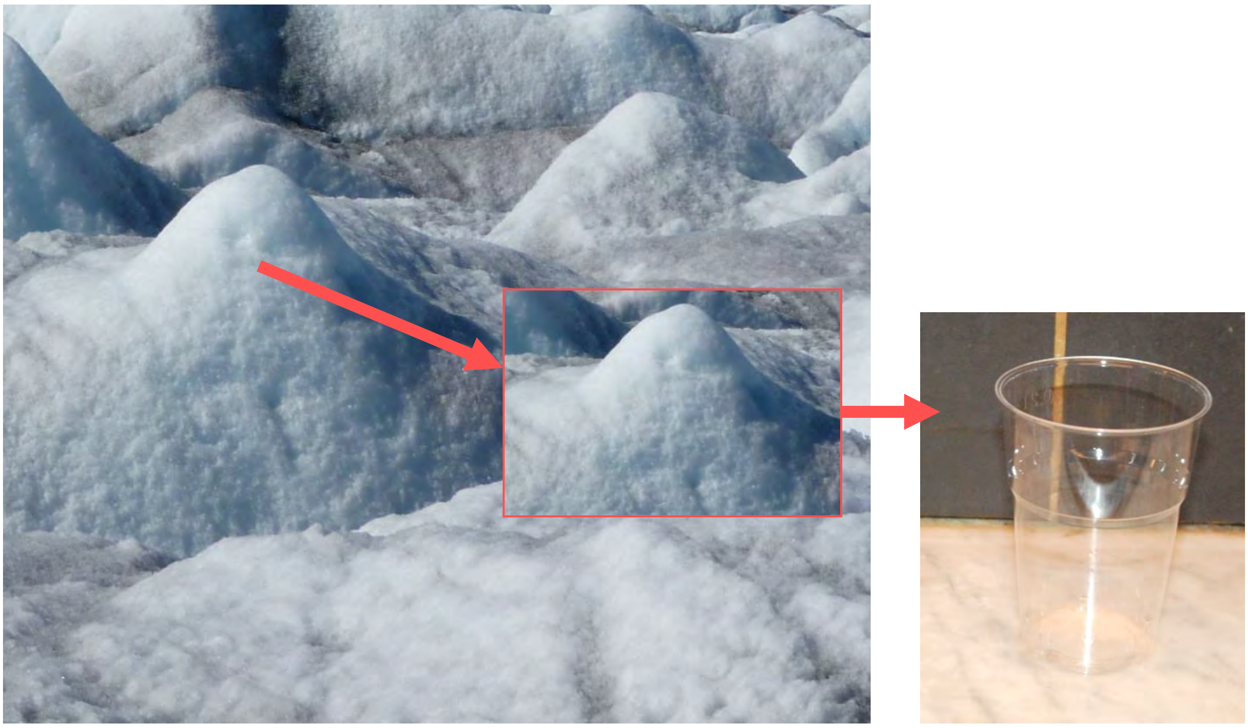
- **Smeltende isbjerge –forsøg med isblok**
  http://isskolen.dk/wp/wp-content/uploads/Smeltende-isjerge-forsog-med-isblok.pdf

- **The Climate Impact of Swedish Consumption**
  https://www.naturvardsverket.se/Documents/publikationer/978-91-620-5992-7.pdf

Hvordan smelter is?

Hvordan kan man hurtigst smelte en isklump?

Nu skal du prøve at smelte isklumper. Isklumpen skal forestille at være et stykke indlandsis. Du skal finde ud af, hvordan du hurtigst kan få isklumpen til at smelte . . .



Vi skal afprøve 5 forskellige metoder til at smelte en isterning i

1. Almindelig stuetemperatur
2. Varm luft
3. Koldt vand
4. Varmt vand
5. Saltvand

Skriv ned hvad I tror der går hurtigst. Overvej f.eks.

- Smelter is hurtigere i kold eller varmt luft?
- Smelter is hurtigst i varmt eller koldt vandt?
- Smelter is hurtigst i saltvand eller i ferskvand?
- Smelter is hurtigst i vand eller luft?

Forsøg

Hver gruppe skal bruge:

- 5 isterninger, vent med at tage dem ud af fryseren til alt det andet er klar
- 5 glas, glas eller plastik
- 1 teske Salt
- Stopur
- Et varmt sted f.eks. en varm radiator




Glas 1: Skal være tomt
Glas 2: Skal være tomt, men placeres et varmt sted, f.eks. tæt på radiatoren.
Glas 3: Skal fyldes ca. halvt op med koldt vand fra vandhanen, gør det så koldt som I kan
Glas 4: Skal fyldes ca. halvt op med varmt vand fra vandhanen, gør det så varmt som I kan
Glas 5: Skal fyldes ca. halvt op med koldt vand fra vandhanen og en teske salt røres i

Når alle glas er klar henter I isterningerne fra fryseren og putter 1 isterning i hvert glas og starter stopuret. Nu skal i bare vente og holde øje med isklumperne. Skriv tiden ned fra stopuret når en isklump er helt smeltet.

Resultater:

	Glas 1	Glas 2	Glas 3	Glas 4	Glas 5
Tid					

Diskussion:

Hvilken isklump smeltede hurtigst? Stemmer det overens med hvad i forventede?

Diskutér hvad det betyder i den virkelige verden:

- Hvad betyder det for isen på land, hvis luften bliver varmere?
- Hvad betyder det for det is, der er i havet at havet bliver varmere?

- Hvad betyder det for det is, der er i havet, at havet er meget salt?
- Hvad betyder det for smeltningen af en klump is om den er i havet eller på land?

Hvorfor stiger havet ikke når isen på Nordpolen smelter?

Når indlandsisen smelter stiger verdenshavene. Faktisk ville havniveauet stige med ca. 7.4 meter hvis hele Grønlands indlandsis smeltede – det gør den heldigvis ikke inden for de næste mange tusinder år. Men isen oppe på Nordpolen smelter meget hurtigere. Den is der ligger på Nordpolen er havis. Stiger havet når isen på Nordpolen smelter? Vi skal i dette forsøg teste hvad der sker med vandstanden når is smelter.

Øvelsen er bygget op således:

1. Opstilling af hypotese
2. Forsøg
3. Evaluering
4. Arkimedes princip

1. Opstilling af hypotese

Se på de to billeder herunder og besvar følgende spørgsmål:

- Tror du vandet løber over kanten af glasset når isterningerne smelter?
- Hvad tror du der sker med vandstanden når isbjerget smelter?

På baggrund af dine besvarelser skal du skrive hvad du tror der vil ske med havniveauet når havisen på Nordpolen smelter.

Figur 1: Et glas med vand og isterninger, og et isbjerg i havet ud for Grønland.

2. Forsøg

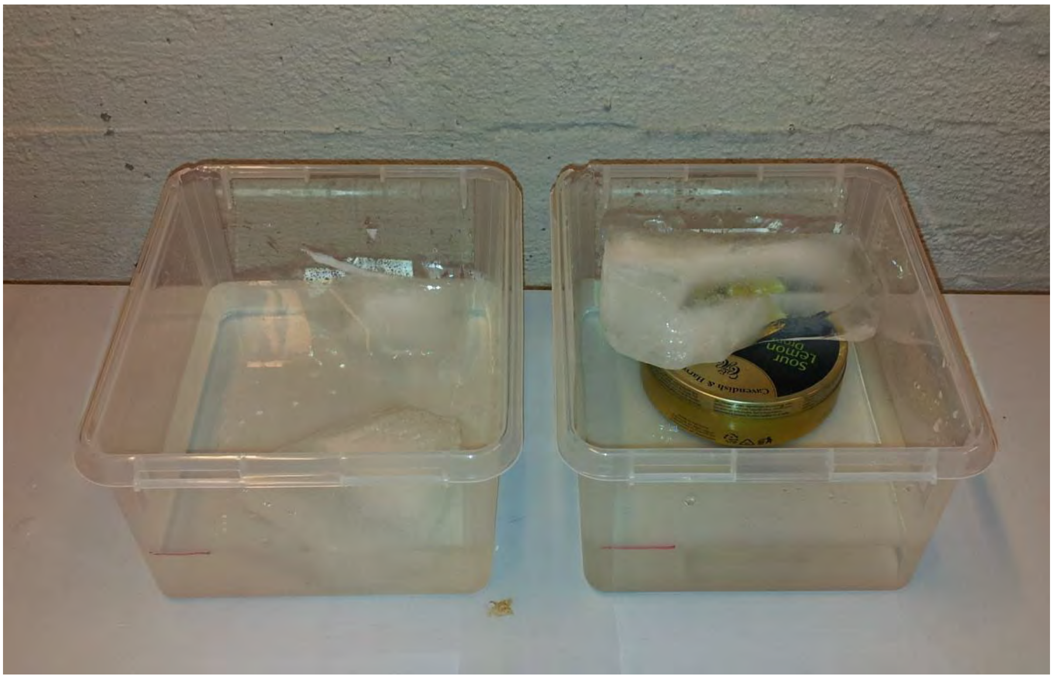
Du skal bruge:

- 2 store klumper is (lad dem blive i fryseren indtil du har resten af forsøget opstillet)
- 1 flad sten
- 2 gennemsigtige plastbeholdere hvor der er plads til både sten og is
- Et målebånd

Sådan gør du:

a) Stil de to baljer på et bord og læg en sten i hver balje. Tag nu dine 2 isklumper og læg en i hver balje således at den ene isklump ligger oven på stenen og den anden bare ligger på bunden af baljen.
b) Nu skal du til at fylde vand på, men der skal ikke lige meget vand i begge baljer:
   - I den balje hvor isen ligger på stenen fyldes der nu vand i op til stenen således at vandet kun lige rører ved bunden af isen. Denne balje kalder vi for balje A.
   - I den balje hvor isen ligger på bunden fyldes der vand på ind til isen begynder at flyde, men ikke helt til kanten. Denne balje kalder vi for balje B.
c) Mål hvor dybt vandet er og skriv det ned.
d) Nu er det bare at vente på at isen smelter... der kan godt gå flere timer alt efter hvor store isklumperne er.
e) Når isen er smeltet i begge baljer måler I igen hvor dybt vandet er.

Balje A forestiller Grønlands indlandsis, som den ligger oven på Grønland. Balje B forestiller havisen på nordpolen, som den flyder rundt ved siden af Grønland.



3. Evaluering

Hvor stor er forskellen på hvor meget vandet steg i balje A og balje B? Hvad kan du herudfra sige der sker med havniveauet når havisen smelter? Havde du ret i din hypotese? Og tror du stadig at vandet vil løbe over kanten på glasset på figur 1?

4. Arkimedes princip

At vandet ikke stiger i baljen, hvor isen flyder, skyldes det, der kaldes for Arkimedes (ca. 287 - 212 f.Kr.) princip. En genstand, som er helt eller delvist nedsænket i en væske, føler sig lettere end på land. Det har du nok selv bemærket i svømmehallen. Arkimedes princip siger, at genstanden føler sig det antal kg lettere som det antal kg af væske den fortrænger. Genstanden har ligesom taget væskens plads. Så hvis en isklump der flyder, eksempelvis vejer 1 kg, så fortrænger isen altså 1 kg vand, hvilket er det samme som 1 liter vand, da 1 liter vand vejer 1 kg. Vand udvider sig, når det fryser, og 1 kg is fylder altså mere end en liter. Derfor vil noget af isen stikke op over vandet. Når isen smelter fylder den mindre, men vejer stadig det samme, og den ”fortrænger" derfor samme mængde vand - derfor stiger vandstanden i glasset ikke.

Hvor stor er Grønlands indlandsis?

Øvelsen kræver et atlas og en lommeregner samt internetadgang til spørgsmål 5

Spørgsmål 1: Indlandsisens areal

Indlandsisens areal er på 1.799.850 km^2. Hvor mange gange større end Danmark, tror du, at det er? Skriv hvad du tror. Om lidt skal du regne det ud med hjælp fra din lommeregner.

Danmarks areal er ca. 42.850 km^2. Hvor mange gange er indlandsisen større end Danmark?

Spørgsmål 2: Indlandsisen længde

Isens længde fra nord til syd er ca. 2.400 km. Hvis du lægger indlandsisen ovenpå et Europakort, og den øverste kant hviler på Danmarks sydlige grænse, hvor langt ned vil du så komme?

Spørgsmål 3: Indlandsisens bredde

Isens bredde er 950 km. Hvis du måler 950 km ned i Europa fra Danmarks sydlige grænse. Hvor langt kommer du så?

Spørgsmål 4: Indlandsisens tykkelse

Isen er mere end 3 km tyk på midten. Hvor meget er det, hvis du sammenligner med din afstand til skolen?

Spørgsmål 5: Indlandsisens volumen

Hvis hele indlandsisen smeltede, ville havet stige med 7 meter. Brug dette lille program til at finde ud af hvor meget af Danmark ville ligge under vand hvis hele indlandsisen smeltede: http://flood.firetree.net/

SAMFUND

Internettet forurener lige så meget som flytrafik: Streaming er den helt store synder

03. dec. 2018, 12:42

Streamingtjenester som for eksempel Netflix påvirker miljøet negativt på linje med flytrafik og produktion af oksekød. Foto: Mike Blake / Ritzau Scanpix

af **Jacob Carlsen**

Vores forbrug af underholdning bidrager i høj grad til verdens samlede CO2-udslip.

Streaming af film og serier på Netflix og andre streamingtjenester er en klimasynder på højde med flytrafikken. Det viser beregninger foretaget i samarbejde mellem DTU, Aarhus Universitet og Dansk Energi for Politiken.

Det skyldes energiforbruget i form af den strøm, det kræver at afspille indhold på sin mobiltelefon, tablet, computer eller smart-tv.

En times streaming i hd-kvalitet på for eksempel Netflix bruger den samme mængde energi, som det vil koste at koge otte liter vand på en elkedel, hvilket vil resultere i et udslip på 163 gram CO2, viser eksperternes beregninger.

- Det vil sige, at hvis man ser to timers Netflix hver dag året rundt, svarer CO2-udslippet til at flyve 384 kilometer i en flyvemaskine, spise seks kilogram oksekød eller køre lidt under 1000 kilometer i en ny bil, siger Torsten Hasforth, seniorøkonom i Dansk Energi, til Politiken.

Generelt har vores store aktivitet på internettet stor betydning for miljøet, viser en model udarbejdet af professor Leif Katsuo Oxenløwe fra DTU.

Her kan man se, at cirka ti procent af hele verdens elektricitetsforbrug kommer fra internetaktivitet og udleder over to procent af det menneskeskabte CO2-udslip.

Derfor udleder internettrafikken lige så meget CO2 som verdens samlede flytrafik.

Datacentre er den store synder

Størstedelen af det strømforbrug, der er i forbindelse med at streame sin yndlingsfilm eller favoritserie, foregår i de datacentre, der er placeret flere steder i verden.

Det er herfra, at for eksempel Netflix' indhold bliver leveret hjem i stuen. Datacentrene sender en filmfil til Danmark gennem lyslederkabler med en hastighed på 200.000 kilometer per sekund, og det er denne transport, som bærer en stor del af strømforbruget.

- Det at flytte data fra et sted til et andet koster energi, ligesom jeg bruger energi, hvis jeg løfter en kuglepen op fra bordet og flytter den et andet sted hen, siger professor Leif Katsuo Oxenløwe fra DTU til Politiken.

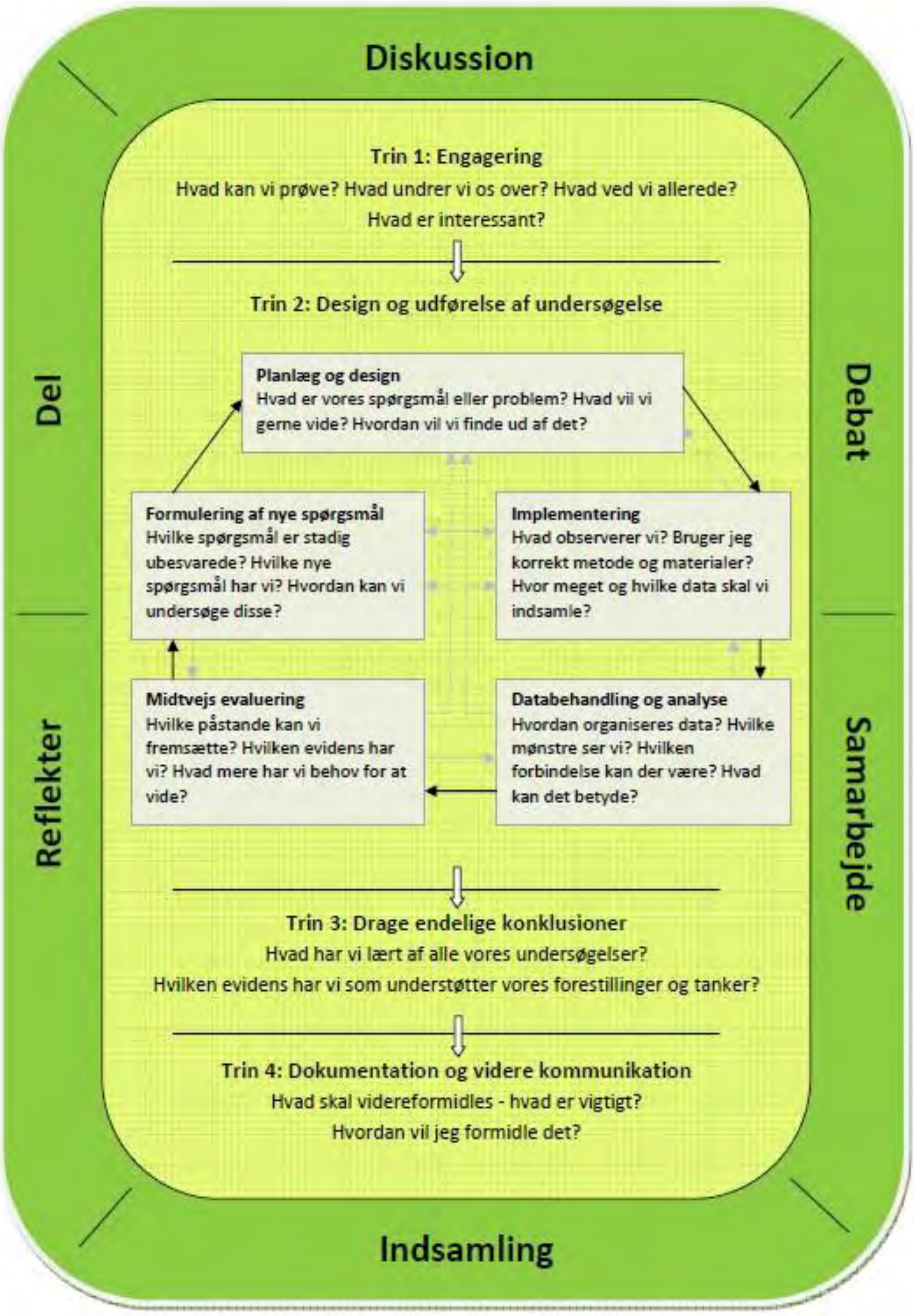
Samtidig bruger datacentrene energi på at køle servere ned, så de ikke overopheder.

Eksperterne understreger, at beregningerne har taget udgangspunkt i en dansk kontekst, hvor 70 procent af strømmen stammer fra vedvarende energi.

Udover energiforbruget ved streaming er der også foretaget beregninger for, hvor stort CO2-udslippet er, ved at dele en 60 sekunder lang video på Facebook samt at spille computerspillet Fortnite i to timer sammen med tre venner.

Inquiry-Based Science Education – procesmodel

https://astra.dk/sites/default/files/Introduktion%20til%20IBSE-didaktikken.pdf



Rapport: Datacentre vil stå for en tredjedel af Danmarks elforbrug

(Illustration: Facebook)

Ni store datacentre vil fra 2040 sluge enorme mængder el, men til gengæld levere store mængder overskudsvarme.

Af Morten Egedal Følg @mortenegedal 13. apr 2018 kl. 14:54 8

Danmark vil i fremtiden have seks datacentre i 2030 - og ni i 2040, som i gennemsnit har et effekt-forbrug på 150 MW alene for drift af it-udstyr.

Det betyder et samlet elforbrug i datacentre på dansk grund på cirka 7 TWh i 2030 og 11,4 TWh i 2040, hvilket svarer til 20 og 33 pct. af det samlede elforbrug for 2017.

Det forudser Cowi i en ny rapport om netop datacentre, som rådgiveren har udarbejdet for Energistyrelsen som del af Energistyrelsens basisfremskrivning 2018 .

Cowi-analysen skal kaste lys over potentialet for store datacentre i Danmark og deres rolle i det danske el- og varmenet.

Ifølge rapporten kan store dele af det danske fjernvarmeforbrug potentielt dækkes af overskudsvarme fra datacentrene, når de nu alligevel er her. Der skal dog være en række betingelser til stede for, at dette sker.

Halvdelen af fjernvarmen kan komme fra datacentre

Det laver meget varme at have de store serverhaller kørende, og denne overskudsvarme kan bruges som varmekilde til store elvarmepumper, der producerer varme til fjernvarmeselskaberne.

Cowi konkluderer, at der ikke er stort udsving i datacentrenes elforbrug og overskudsvarmeproduktion.

De har derfor kigget på potentielle placeringer både på Fyn og i Jylland, hvor opførelsen af datacentre allerede er planlagt. Ud af de ni potentielle placeringer var de otte af dem rentable for at indpasse overskudsvarme.

Rapporten understreger dog, at der her er tale om generelle vurderinger, og at det enkelte systems rentabilitet vil kræve en dybere analyse.

Fjernvarmesystem	Transformer-station	Afstand [km]	Varme-behov, maks. [MW]	Varmebehov [MWh]
Aarhus Fjernvarme	Trige og Malling	10	980	3.323.000
Odense Fjernvarme	Fraugde	5	780	2.646.000
Aalborg Fjernvarme	Vester Hassing	4	563	1.910.000
TVIS	Landerupgård	10	518	1.756.000
Esbjerg-Varde Fjern-varme	Endrup	16	344	1.167.000
Holstebro-Struer Fjern-varme	Idomlund	4	159	538.000
Viborg Fjernvarme	Tjele	10	97	329.000
Aabenraa - Rødekro - Hjordkær Fjernvarme	Kassø	9	84	284.000
Bjerringbro Fjernvarme	Tjele	14	27	91.000
Hinnerup Fjernvarme	Trige	5	25	86.000
Hadsten Fjernvarme	Trige	8	22	74.000
Ringe Fjernvarme	Fraugde	8	19	64.000
Hjallerup Fjernvarme	Vester Hassing	12	13	44.000

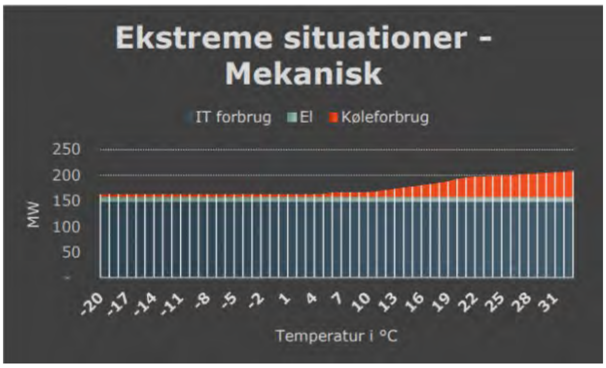
Oversigt over potentielle relevante fjernvarmesystemer, afstande og varmebehov (Illustration: Temaanalyse om store datacentre, Cowi)

Et datacenter på 150 MW forventes som eksempel at kunne levere omtrent 4.300 TJ til Fjernvarme Fyns system, hvilket svarer til 45 pct. af den årlige varmeproduktion.

Hvis datacenterets overskudsvarme bliver prioriteret over affald, kan tallene komme helt op på 5.100 TJ - eller 54 pct. af den totale varmeproduktion.

Anderledes krav

Mens it-udstyret generelt står for 95 pct. af datacentrenes elforbrug, så bliver det meget dyrere at nedkøle serverne, hvis det danske sommervejr pludselig for alvor sætter ind.



Elforbrug på datacentre med mekanisk køling ved forskellig temperatur (Illustration: Temaanalyse om store datacentre, Cowi)

Samtidig skal der også tages hensyn til både skat, elpriser, risiko for naturkatastrofer, forsyningssikkerhed og en række andre parametre. Samlet set er Danmark mest attraktiv, men Sverige og Irland er ikke langt bagefter, vurderer

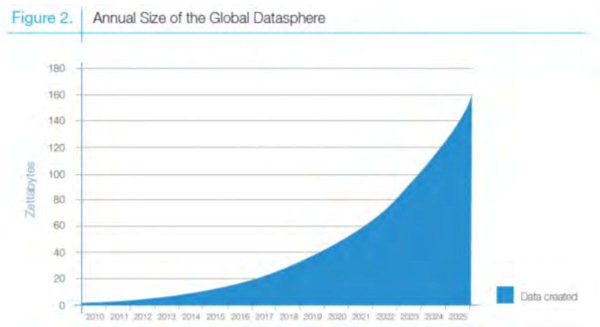
Cowi.

Uanset hvad vil etableringen af datacentre have så stor påvirkning på markedet, at både kraft-varmeværker og affaldsforbrændingsanlæg risikerer at skulle tilpasse deres produktion efter den kommende nabo.

Fremtidssikring

Både el- og varmetallene ligger i en størrelsesorden, som vi slet ikke endnu kan genkende i Danmark, men det er et område, der er i enorm udvikling.

Apple har varslet, at deres datacenter i Viborg vil gå fra et effektforbrug på 7 MW til 30 MW fra 2019 til 2024.



Datamængden på verdensplan (Illustration: IDC's Data Age 2025, Seagate, April 2017)

Datacentrene er vigtige, da vi på verdensplan simpelthen producerer og forbruget flere og flere data.

Når mængden af data udvikler sig eksponentielt, er det er derfor nødvendigt med datacentre.

Især indførelsen af cloud-services har gjort datacentre vigtige, da både lagring og udregninger før skete lokalet på den enkelte maskine, hvorimod meget i dag kan klares på dedikerede cloud-servere i datacentre.

Er man nysgerrig omkring datacentre, så har Google en side, hvor de forklarer yderligere.

Emner : Datalagring , El , Fjernvarme

se emner samlet

Relateret jobannonce: Data Engineer

This is how your personal consumption affects the climate

Environment[1]
Environment[1]Climate [2]Norway [3]Forskning.no [4]

You won?t make big cuts in your environmental impact by taking shorter showers or turning out the lights. The real environmental problem, a new analysis has shown, is embodied in the things you buy.

The world's workshop — China — surpassed the United States as the largest emitter of greenhouse gases on Earth in 2007. But if you consider that nearly all of the products that China produces, from iPhones to tee-shirts, are exported to the rest of the world, the picture looks very different.

“If you look at China's per capita consumption-based (environmental) footprint, it is small,” says Diana Ivanova, a PhD candidate at Norwegian University of Science and Technology's Industrial Ecology Programme. “They produce a lot of products but they export them. It's different if you put the responsibility for those impacts on the consumer, as opposed to the producer.”

That's exactly what Ivanova and her colleagues did when they looked at the environmental impact from a consumer perspective in 43 different countries and 5 rest-of-the-world regions. Their analysis, recently published in the Journal of Industrial Ecology, showed that consumers are responsible for more than 60 per cent of the globe's greenhouse gas emissions, and up to 80 per cent of the world's water use.

“We all like to put the blame on someone else, the government, or businesses,” Ivanova says. “But between 60-80 per cent of the impacts on the planet come from household consumption. If we change our consumption habits, this would have a drastic effect on our environmental footprint as well.”

The analysis allowed Ivanova and her colleagues to see that consumers are directly responsible for 20 per cent of all carbon impacts, which result from when people drive their cars and heat their homes.

But even more surprising is that four-fifths of the impacts that can be attributed to consumers are not direct impacts, like the fuel we burn when we drive our cars, but are what are called secondary impacts, or the environmental effects from actually producing the goods and products that we buy.

A good example of this, Ivanova says, is water use.

Cows, not showers

When you think about cutting your individual water use, you might think about using your dishwasher very efficiently, or taking shorter showers.

Those aren't bad ideas on their own, but if you look deeper, like the NTNU researchers did, you'll find that much of the water use on the planet is gulped up by producing the things that you buy.

Consider beef. Producing beef requires lots of water because cows eat grains that need water to grow. But because cows are relatively inefficient in converting grains into the meat that we eat, it takes on average about 15,415 litres of water to produce one kilo of beef.

Dairy products require similarly large amounts of water to produce.

When a group of Dutch researchers looked at the difference in producing a litre of soy milk with soybeans grown in Belgium compared to producing a litre of cow's milk, they found it took 297 litres of water to make the soy milk (with 62 per cent of that from actually growing the soybeans) versus a global average of 1050 litres of water to produce a litre of cow's milk.

Processed foods, like that frozen pizza you bought for dinner last night, are also disproportionately high in water consumption, Ivanova said. Making processed foods requires energy, materials and water to grow the raw materials, ship them to the processor, produce the processed food items and then package the final product.

This is particularly bad news when it comes to chocolate, which is one of the most water-intensive products we can buy. It takes a shocking 17,000 litres to produce a kilo of chocolate.

Richer countries, larger impacts

The researchers also looked at environmental impacts on a per-capita, country-by-country basis.

While the information is sometimes surprising—Luxembourg has a per capita carbon footprint that is nearly the same as the United States—it mostly follows a predictable pattern. The richer a country is, the more its inhabitants consume. The more an individual consumes, the bigger that person's impact on the planet.

But the differences between individual countries are extremely high, Ivanova said.

"The countries with the highest consumption have about a 5.5 times higher environmental impact as the world average," she said.

The United States is the overall worst performer when it comes to per capita greenhouse gas emissions, with a per capita carbon footprint of 18.6 tonnes CO_2 equivalent, the unit used by researchers to express the sum of the impacts of different greenhouse gases, such as carbon dioxide, methane, nitrous oxide and sulphur hexafluoride.

The US was followed closely by Luxembourg, with 18.5 tonnes CO_2 equivalent, and Australia, with 17.7 tonnes CO_2 equivalent. For comparison, China's per capita carbon footprint was just 1.8 tonnes CO_2 equivalent. Norway, at 10.3 tonnes CO_2 equivalent per capita, was three times the global average of 3.4 tonnes CO_2 equivalent per capita.

The results for individual countries also reflect the effects of the electricity mix, or the fuel source that countries rely on for electric power. The prevalence of nuclear or hydroelectric power in countries such as Sweden, France, Japan and Norway means that these countries have lower carbon footprints than countries with similar incomes but with more fossil fuels in their energy mix.

For this reason, Ivanova says, a significant portion of household impacts from Sweden and France come from imports (65 and 51 per cent respectively), because the products that are imported are mostly produced with fossil fuels.

An enormous database allows comparisons

The researchers relied on an extremely large and detailed database that NTNU developed in partnership with colleagues from the Netherlands, Austria, Germany, the Czech Republic and Denmark called EXIOBASE.

The database describes the world economy for 43 countries, five rest-of-the-world regions and 200 product sectors, which allows researchers to ask questions about how different products or countries affect the environment.

They were also able to ask how an average consumer in each of the countries or regions affects the environment as measured by greenhouse gas emissions (tonnes CO_2 equivalent), water use (in cubic metres), land use (in 1000 square metres) and material use (in tonnes).

The 43 countries represent 89 per cent of the global gross domestic product and between 80-90 per cent of the trade flow in Europe, as measured by value.

No surprises: take the bus, eat vegetarian or vegan

The advantage of identifying the effects of individual consumer choices on the different environmental measures is that it pinpoints where consumers in different countries can cut back on their impacts.

“Households have a relatively large degree of control over their consumption, but they often lack accurate and actionable information on how to improve their own environmental performance,” the researchers wrote in the journal article reporting their results.

Eventually, the goal is to be able to use this information to guide policy, Ivanova said. The effort is a part of the GLAMURS project, an EU-funded effort designed to promote greener lifestyles and environmentally responsible consumption in Europe.

In the meantime, two easy ways to cut your environmental impact are to stop eating meat, and cut back on your purchases, she said.

Currently, EU consumers spend 13% of their total household budget on manufactured products. If the average EU consumer switches away from spending money on these manufactured products to paying for services instead, this would cut close to 12 per cent of the EU’s current household carbon footprint, Ivanova said.

“Any activity where we have a choice of buying a product or using a service, the service will have much less impact,” she said.

Read the Norwegian version of this article at forskning.no [5]

Sure, governments and corporations need to do their part to reduce their environmental impact. But overconsumption by consumers also has a tremendous environmental cost. (Photo: Colourbox.) [6]
shopping.jpg [7]

Gemini, NTNU Trondheim - Norwegian University of Science and Technology [8]
What does the average Norwegian think about climate-related issues? [9] Aerosols are wild cards in climate models [10] A southern European climate in the North [11] 1.4 billion years old forces are causing climate change today [12]
Diana Ivanova's profile [13]
Abstract: Diana Ivanova, Konstantin Stadler, Kjartan Steen-Olsen, Richard Wood, Gibran Vita, Arnold Tukker and Edgar G. Hertwich. 2015. Environmental Impact Assessment of Household Consumption. Journal of Industrial Ecology. DOI: 10.1111/jiec.12371

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February 23, 2016 - 05:25
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Brug:
Mælkekarton (1 l), koldt vand, frugtfarve (fx grøn), fryser, akvarium (fx 5 l) og varmt vand.

- Fyld mælkekartonen med koldt vand. Tilsæt frugtfarve så vandet er tydeligt farvet. Sæt kartonen i fryseren til næste dag, eller til alt vandet er frosset.
- Fyld varmt vand i akvariet, så vanddybden er minimum 20 cm. Tag isblokken ud af kartonen og placér den midt i akvariet.
- Betragt isen, mens den smelter.

Prøv, om du kan finde svar på følgende spørgsmål:

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- Hvad vejer mest – is eller vand?
- Hvor kan man opleve dette fænomen i naturen?
- Hvad sker der med det grønne vand, når isen smelter?
- Hvad vejer mest – koldt eller varmt vand?
- Hvor kan man opleve dette fænomen i naturen?
- Hvornår kipper et isbjerg?
- Hvad betyder dette fænomen i naturen?

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The Climate Impact of Swedish Consumption

REPORT 5992 • JANUARY 2010

The Climate Impact of Swedish Consumption

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ISBN 978-91-620-5992-7.pdf
ISSN 0282-7298

Digital Publication
Cover photographs:
Photograph of house: Susanne Jacobsson/Engströms med flera
Photographs of train and market: iStockphoto

Foreword

The problem of climate change is global but requires solutions at all levels. In this report we ask the question ”What do the greenhouse gas emissions from consumption look like? ”The consumption perspective provides new insights as it aspires to include all emissions caused by consumption and increases understanding of the impact different patterns of consumption have on greenhouse gas emissions.

The fact that the Swedish Environmental Protection Agency discusses greenhouse gas emissions from consumption in this report does not mean that we consider consumers to be entirely responsible for reducing greenhouse gas emissions. There are many different stakeholders who must share this responsibility.

The work was undertaken as a project in the Climate Change Department of the Swedish Environmental Protection Agency during 2008. The project leader was Sven Hunhammar.

This report is a translation of report 5903, *Konsumtionens klimatpåverkan.*

Stockholm, November 2008

Martin Eriksson
Director
Swedish Environmental Protection Agency

Contents

Summary

This report analyses what greenhouse gas emissions are caused by Swedish consumption regardless of where in the world or in the production chain the emissions occur. The aim is to create an overview and identify the consumption activities that have the largest greenhouse gas emissions. The study includes emissions of carbon dioxide, methane and nitrous oxide.

The analysis is principally done using environmental accounts from Sweden and other countries. The report describes emissions in orders of magnitude. It does not analyse policy instruments or the costs of measures that are discussed to reduce greenhouse gas emissions. The data are consistently from 2003 as this is the most recent year for which data are available.

The consumption perspective means that emissions that take place in all stages of production *from cradle to grave* are allocated to the final consumers of goods and services. Emissions that have been caused by exports are therefore deducted from emissions that take place in Sweden, and emissions that have been generated by imports in other countries are added in order to estimate emissions from Swedish consumption.

Greenhouse gas emissions in Sweden, including from international transport, totalled around 76 million tonnes of carbon dioxide equivalents (Mtonnes CO_2e) in 2003. Production in Sweden meets the needs of both domestic consumption and of goods exported to other countries. From a consumption perspective, emissions of around 24 Mtonnes CO_2e caused by the production of exports are therefore allocated to the people in other countries who consume the products. Manufacturing and transportation of imports to Sweden are estimated, partly on the basis of the environmental accounts in other countries, to lead to emissions of the order of 43 Mtonnes CO_2e.

Swedish consumption in 2003 caused greenhouse gas emissions of the order of 95 Mtonnes CO_2e. In comparison with the emissions that take place in Sweden, emissions in the consumption perspective are at least 25% higher.

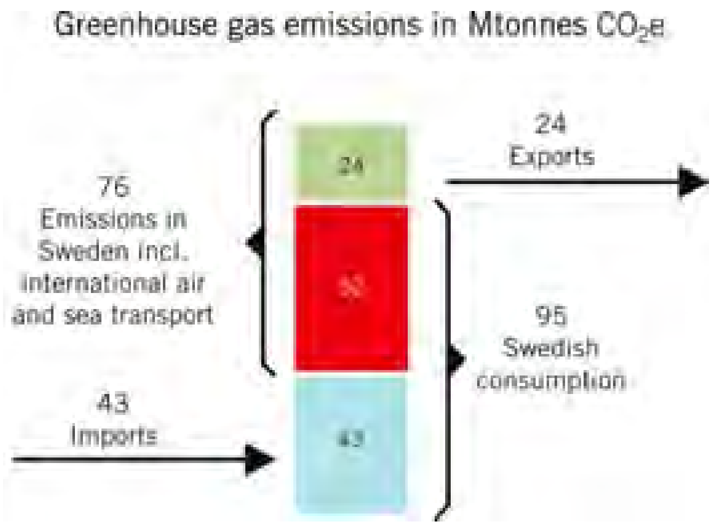

Figure 0: Greenhouse gas emissions in 2003: 76 Mtonnes CO_2e in Sweden including international transport, 24 Mtonnes CO_2e in Sweden to produce exports to other countries, 43 Mtonnes CO_2e in other countries to produce imports to Sweden, and finally 95 Mtonnes CO_2e both in Sweden and in other countries to meet the needs of Swedish consumption.

Measured in terms of the population of Sweden, emissions from a consumption perspective are equivalent to just over 10 tonnes CO_2e per capita. Just over 80% of emissions are caused by private consumption and just under 20% by public consumption. Private consumption in the report is divided into the activities of *eating,* with just over 25% of emissions, *housing* with just over 30%, *travel* with just under 30% and the residual item of *shopping* with just under 15%, with purchasing of clothes and shoes being the largest sub-item.

The following five activities together account for around half of greenhouse gas emissions and are therefore significant if Sweden is to reduce emissions:

- How much do we drive and in what sort of car,
- How do we heat our homes,
- How much electricity is used at home,
- How much meat do we eat and what type,
- How far do we fly and how often.

Individual consumers do influence emissions today, and there are great differences between the emissions associated with different activities. A number of examples with data from life-cycle assessments for various alternatives in the activities of eating, housing and travel are presented in the report to show that the variation between different patterns of consumption is very large. Some examples are:

- Driving a car with a petrol engine may emit 2-3 tonnes of carbon dioxide equivalents per year, while one person's return holiday flight to Asia produces roughly the same emissions.

- Eating a piece of beef a day may signify emissions of more than one tonne of carbon dioxide equivalents per person a year, while a different diet might cause only a tenth the level of emissions.

- Heating a poorly insulated detached house with oil results in several tonnes more of carbon dioxide emissions per year than an energy-efficient home with ecolabelled district heating.

Global emissions need to decrease in the very near future and be largely eliminated during this century if the world is to reduce the risks of very extensive climate effects. Such a trend would reduce the risks of very extensive climate effects throughout the world. Emissions for an average Swedish consumer need to decrease from the present-day level of the order of 10 tonnes per capita to half that level in 2020 and to a fifth in 2050 if emissions from Swedish people's own consumption are not to exceed the desirable level of global emissions calculated per person.

The report discusses how these emision reductions can be achieved in qualitiative and general terms, and in what areas difficulties must be overcome As emissions from food production are difficult to change, we need to change our eating habits. Housing can be made highly energy-efficient with new technology and emissions will be small if the energy system has low emissions. Daily travel can be accomplished in an energy-efficient manner on public transport or by walking or cycling. It is also possible for cars to become relatively energy-efficient in the foreseeable future, with low emissions per kilometre. On the other hand, the situation is more difficult for longer journeys, and there do not appear to be any technical solutions at present to limit the climate impact of aviation to a sufficient extent for extensive flying to be possible.

The report concludes that it is important to analyse the greenhouse gas emissions from total consumption and not just those emissions that take place within the country. The perspective of total consumption provides a more complete picture of how our patterns of consumption affect climate.

Introduction

This introductory section describes the background, purpose and delimitation of the project and also discusses some key terms and the methods used in the report.

Background

There is great interest in the consumption perspective. In 2008, both the Climate Committee and the Environmental Objectives Council[1] in the in-depth evaluation of the environmental quality objectives highlighted the need to supplement and broaden the reporting done on emissions within the country. The Committee noted that there are significant methodological problems but nevertheless wished to establish an all-embracing view with the aim of improving understanding of how large our total climate impact is[2].

In other parts of environmental policy, there has long been a clear link to the impact of products on climate and the environment. The Swedish environmentally oriented product policy[3] and the EU's integrated product policy[4] are based on attempting to reduce the environmental impacts of products wherever in the world the impacts occur. Further steps were taken in 2008, when the EU presented an action plan for sustainable consumption and production[5].

Work is also under way within the UN system, and the consumption perspective features in the international negotiations on global agreements to follow the Kyoto Protocol.

Purpose and delimitation

The purpose of this report is to obtain an overview of how Swedish consumption affects greenhouse gas emissions in Sweden and beyond its borders. The idea is that such an overview should make it easier to analyse what activities have a large impact on climate.

In addition, there is discussion of what level of greenhouse gas reductions is required and of possible measures that can be taken to bring emissions down. The aim is to continue the discussion of how a transition to a society with a low climate impact and sustainable development can occur. This report does not contain any information on the costs of changes and measures. Nor does the report cover the policy instruments that are needed to bring about this change.

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1 Environmental Objectives Council (2008)
2 Climate Committee (2008)
3 Swedish Government Communication 1999/2000:114
4 EU COM (2003) 302
5 EU COM (2008) 397

Statistics on greenhouse gas emissions and other processes are rarely presented according to the divisions employed in this report. The data processing therefore represents broad calculations in an attempt to present a comprehensive picture.

The analysis includes the greenhouse gases carbon dioxide, methane and nitrous oxide. It is also intended that environmental quality objectives other than the climate objective will be touched on where possible and relevant. There is, however, a shortage of data for other environmental problems. Energy use is a key factor in reducing climate and environmental impact, which is also touched on where relevant.

The same emissions can be classified according to different principles

The greenhouse effect is a global problem, and it does not matter where in the world the greenhouse gas emissions take place. The emissions come chiefly from the burning of fossil fuels and changes in land use. In order to analyse the cause of emissions in more detail and discuss various ways of reducing them it is necessary to break the global problem down to lower levels.

A common way of classifying emissions is according to the geographical area or country where the emissions occur. The emissions that occur in different production sectors are then added together: energy, industry, agriculture etc. within the country. This is therefore known as a production perspective. Emissions can also be classified from the point of view of consumption if the emissions that have taken place in the production of goods and services are divided among the consumers who use them. This is known as a consumption perspective.

It is often the same processes and emissions in both cases, but analysed from different perspectives. At the global level everything that is produced is consumed, but this does not apply at national level, and in particular it does not apply in countries with a large amount of international trade. At national levels, or lower, it therefore makes a big difference whether emissions are analysed from a production or a consumption perspective.

Production perspective

All emissions that occur in a geographical area are included in a production perspective. Emissions from industrial production and agriculture, for example, are counted regardless of who uses the final products. This geographical or production perspective is the basis for the international efforts to limit greenhouse gas emissions in the UN and under the Kyoto Protocol[6]. Sweden's environmental quality objective *Reduced Climate Impact* and the interim target that Sweden is to

[6] UNFCC (1998)

reduce its national emissions by 4% by 2008-2012 in comparison with 1990 levels, is also based on emissions within the country[7]. Emissions are therefore reported in this way.

This perspective is advantageous in international negotiations as a country has control over the emissions that take place within the country's borders. In the negotiations and the global agreements it has been more difficult to deal with international aviation and shipping and emissions caused by manufacturing of products consumed in other countries.

As energy systems and industrial structures, for instance, look different in different parts of the world, the distribution of emissions between the production sectors also looks different when the geographical scale is changed, see Table 1. Globally, emissions from energy supply and forestry dominate the problem, the latter principally due to the felling of tropical rainforests, while emissions from industry and transport account for the greatest shares of the emissions that take place in Sweden.

Table 1: In a production perspective (what is emitted within a geographical area) the breakdown between sectors differs greatly between different geographical areas. In the EU15 and Sweden the forests bind carbon, while globally deforestation is a problem that contributes to emissions (Swedish Energy Agency and Swedish Environmental Protection Agency 2008).

Sector	Globally	EU 15	Sweden
Energy supply	25 %	25 %	13 %
Transport	13 %	21 %	31 %
Residential and commercial premises	8 %	16 %	8 %
Industry*	14 %	26 %	32 %
Agriculture	14 %	9 %	13 %
Forestry	17 %	removals	removals
Waste	3 %	3 %	3 %

* Including refineries, flaring and coke plants

If the production perspective is taken to its extreme and emissions are looked at in terms of a smaller geographical area such as a municipality, the link to consumption in the same area is increasingly left behind. Assume, for example, that there is a large industrial site in a small municipality so that the municipality has high emissions. Even if the production methods and the manufactured products are effective with comparatively low emissions of greenhouse gases, the industrial site emits large quantities of greenhouses gases due its production volume. The owners have control over the emissions and therefore have a responsibility, but the link to the people who live in the municipality is weak. Figures relating to the emissions *per capita* that take place in the municipality are not related to the emissions actually entailed by the inhabitants’ consumption.

[7] Swedish Government (2006).

Consumption perspective

Consumption means the final use of goods and services. The principle underlying a consumption perspective is that greenhouse gas emissions are broken down according to final use regardless of where in the world or in the production chain they have occurred.

To calculate the total emissions from a consumption perspective for persons resident in Sweden, the emissions caused by exports from Sweden have to be deducted from national emissions in Sweden. Emissions from exports are allocated to consumers in other countries. Equivalent emissions caused by imports and peoples' foreign travel, on the other hand, are to be added. In that way the consumption perspective reflects all emissions generated by people who live in Sweden.

Consumption is usually broken down into private and public consumption according to who the consumer is. Everything we consume ourselves as consumers through purchases directly from our own wallets or through the tax-funded public sector is thus counted as consumption.

Just over 9 million people live in Sweden, of whom half a million are foreign nationals and more than a million were born in other countries. To make linguistic usage simpler in this report, their consumption is encompassed in the report by the term *Swedish consumption*. Swedish consumption thus does not just mean consumption *in* Sweden but global emissions caused by consumption among people resident in Sweden. Consumption by people born in Sweden who live abroad, numbering at least 300 000, is not included.

Greenhouse gases may be emitted during all phases of the life cycle, *from cradle to grave,* of a product or service. All emissions from the preparation of raw materials, production, distribution and use to waste management are allocated to the consumed product or service. Emissions from the production sectors are thus allocated to final consumption and do not exist as separate items in the consumption perspective.

An advantage in describing emissions from a consumption perspective is that it describes more accurately the effect of our lifestyles and standard of living. This perspective would therefore be able to bring about a better understanding of what our climate impact is like and, it is hoped, be a factor in persuading consumers to choose patterns of consumption with less climate impact. At the same time it must be clear where the consumers can actually choose and where other stakeholders must contribute in order to make climate-effective choices possible. All emissions being allocated to the final consumer does not mean that so too is full responsibility. Producers and legislators have great responsibility and must create the necessary basis for changes to come about.

The consumption perspective also has several drawbacks. Great uncertainty prevails in the statistics for example when they are sorted according to these principles. As the final consumer has less control over emissions the further away in the production chain and the world the emissions occur, there is therefore a risk of policy instruments based on the consumption perspective being very poorly aimed.

Supplementary perspectives

There are advantages and drawbacks to both perspectives, and both should be used for a better understanding and to reduce greenhouse gas emissions. Table 2 below shows the difference. The same activities and emissions are allocated in different ways. It is important that the perspectives neither count emissions twice nor omit any emissions. The production perspective includes the whole of the first column as the activities take place in Sweden. The consumption perspective includes the whole of the first line as the activities are caused by persons resident in Sweden. The fourth cell represents activities that take place in other countries caused by persons who live in other countries. As greenhouse gas emissions have a global impact, Sweden and its possible share of global emissions are greatly affected by these activities.

Table 2: Greenhouse gas emissions can be viewed in a production perspective (cells 1+3) and in a consumption perspective (cells 1+2).

	Emissions in Sweden	**Emissions in other countries**
Consumption by persons resident in Sweden	1) E.g. commuting and heating of houses	2) Imports and foreign travel
Consumption by persons resident in other countries	3) Exports, through-traffic and tourists in Sweden	4) Activities in other countries that affect global climate impact

Methods

The report has been written by a project group at the Swedish Environmental Protection Agency who have benefited from consultancy studies from Statistics Sweden, the Swedish Defence Research Agency and the Royal Institute of Technology, among others[8]. The analysis is done principally using the environmental accounts of different countries. The methodology is rough and has some shortcomings, but is nevertheless the most suitable for this type of analysis. The report provides a picture of total emissions from Swedish consumption. It also provides some examples of important choices the consumer can make to broaden the picture from the total figures that only show the consumption of the individual as averages. Data in the examples are taken from life-cycle assessments that follow individual products, both goods and services, *from cradle to grave.*

[8] Statistics Sweden (2008), Royal Institute of Technology (2008), Swedish Defence Research Agency (2008) and Möllersten (2008).

The national Swedish economic statistics are known as national accounts and describe Sweden's economic activities in a consistent and comprehensible way using input-output methodology. Economic statistics on production of goods and services and how they will be used in different parts of society, how incomes are spent and what transactions are made with other countries are used in the material on which this report is based. The Swedish national accounts are based on a UN recommendation which is the result of cooperation between the UN, OECD, EU, IMF and World Bank. This means that the same principles apply to the economic statistics of all countries.

The input-output methodology is based on supply and use tables for the economy. The tables report supply and use in economic terms and in some cases also in physical terms. They show who manufactures a product and who then buys the product to make use of it in some way. These tables underlie the input-output tables that describe the product flows through the national economy. The input-output tables show what raw materials or services arrive at an economic actor (input) and what processed products then leave (output). The input-output tables are suitable for analysis of how different industries collaborate with one another. The tables provide a picture of the economy and provide a uniform framework for the presentation of product flows.

In the environmental accounts environmentally related data for energy and emissions are linked to the input-output tables. It is then possible to see the level of direct emissions a company's increased production gives rise to and the level of indirect emissions the company's suppliers cause when they supply in several stages what is required to make increased production possible. This means that the input-output methodology can be regarded as a very rough life-cycle assessment. It is this characteristic that is used to deduce which products contribute to differing degrees to the problem of greenhouse gases in this report.

Environmental accounts are thus an information system which, with the aid of statistics, describes relationships between the environment and economics. Like the National Accounts, the Environmental Accounts are based on industries, households and public authorities. In a pilot project from which this project benefits, Eurostat has gathered environmental accounts for eleven countries. The same accounting principles apply in these countries as in Sweden. At the national level the tables containing combined economic statistics and environmentally related statistics are known as NAMEA (National Accounting Matrix including Environmental Accounts). There are also NAMEA statistics for other countries. Finland, France, Austria, Australia, the United States, South Korea and China follow this method.

Input-output analysis is based on cash flow. Different sectors trade with one another, and consumers buy products. Emissions are linked to cash flows. For each krona produced in a sector there is a related emission, and an emission can be deduced for each krona of product consumers buy. Emissions per krona are known as emissions intensity. Emissions can be high due to a large cash flow, large emission factors or both.

The principal benefit of the input-output analysis is that it is consistent. Everything adds up correctly if it is done in the framework of input-output analysis. The drawback of input-output analysis is that it is so broad and paints with such large brush strokes that at a detailed level no figures are really correct, precisely because there are only a certain number of sectors and a certain number of products into which all companies and their often special products are forced. Each company is unique, and every type of product made there is unique. The figures agree at the national level with the total emissions figure reported by the country, but if more detailed analyses are done and comparisons are made with results from life-cycle assessments, for example, it is often found that the figures do not agree so well for a specific article and instead reflect orders of magnitude.

What are the emissions from total Swedish consumption?

A rough estimate is made in this section of the global greenhouse gas emissions caused by Swedish consumption. The data are taken from the environmental accounts of Statistics Sweden and other sources such as the survey of travel habits by the Swedish Institute for Transport and Communications Analysis (SIKA). The Swedish Environmental Protection Agency has commissioned special data analysis for this report[9].

Greenhouse gas emissions in a consumption perspective

To estimate global greenhouse emissions caused by Swedish consumption, it is necessary to deduct export-related emissions from, and add import-related emissions to, the emissions that take place in Sweden.

Emissions within Sweden
- Exports from Sweden
+ Imports into Sweden
= Emissions from Swedish consumption

These items are analysed and quantified in the sections below. The statistics come from various sources and are presented for 2003, as this is the latest year for which data from the various sources are available. The data have therefore had to be supplemented by rough estimates and assumptions where better material is lacking. The result is therefore to be interpreted as representing orders of magnitude.

This section is based on data from the environmental accounts. Emissions from changed land use and forestry and part of foreign travel are lacking in the input-output tables. It is not possible to add emissions to the tables afterwards without completely re-balancing them. Assessments of orders of magnitude of emissions from land use and all foreign travel are therefore presented separately, without being included in the final total. To add them it is necessary for the emissions caused by land use and international transport to be linked to specific industries and countries.

Emissions within Sweden and from international transport

Like other countries that have signed the UN Framework Convention on Climate Change, Sweden reports emissions that take place within the country. The statistics are used in the international negotiations and agreements on emission commitments. Sweden also reports on the level of re-fuelling by international shipping and aviation in Sweden.

[9] Statistics Sweden (2008)

Greenhouse gas emissions in Sweden, including from international transport, totalled around 76 million tonnes of carbon dioxide equivalents (Mtonnes CO_2e) in 2003[10].

The emissions are broken down between the production sectors as shown in Figure 1 below. Carbon dioxide accounts for just under 80 % of total greenhouse gas emissions in Sweden. This is a significant proportion, but it is nevertheless important to include more greenhouse gases in the analysis.

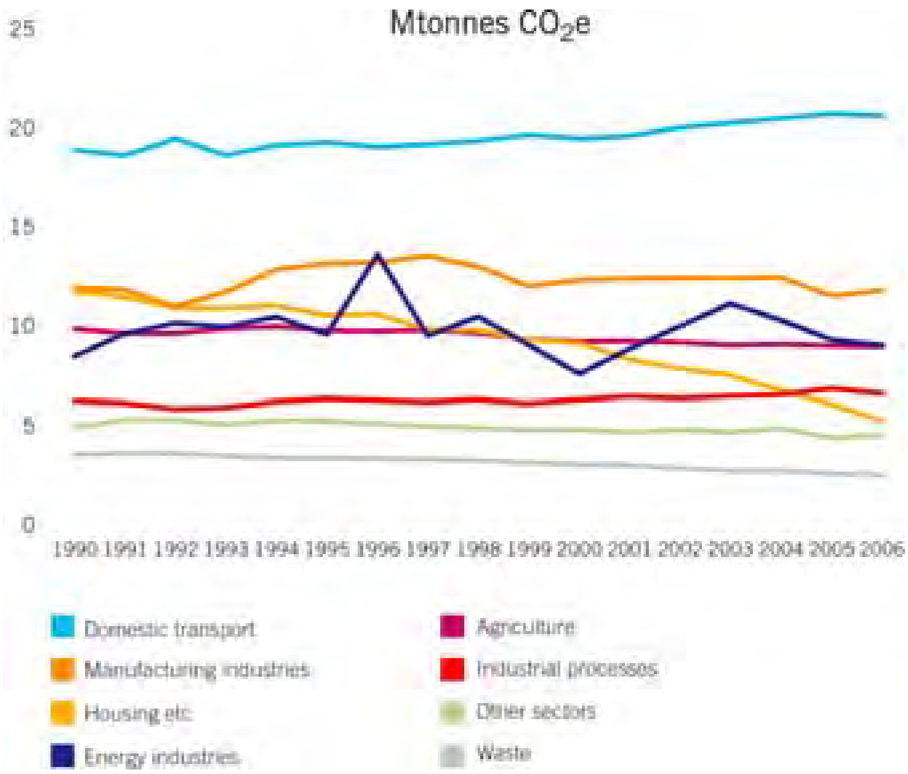

Figure 1: Greenhouse gas emissions in Sweden are presented in accordance with the emissions statistics in a geographical production perspective (Swedish Environmental Protection Agency 2008a).

INTERNATIONAL TRANSPORT

Emissions from ships and aircraft in international traffic that re-fuel in Sweden (known as bunkering) are large and amount to more than 7 Mtonnes in 2003, see Figure 2. Part of international transport is thus included in the input-output analysis, but is difficult to monitor, partly because the companies both undertake cargo transport under their own auspices and purchase transport services. Shipping dominates the Swedish statistics but bunkering has grown more rapidly than foreign trade, and it may therefore be suspected that bunkering is not solely due to Swedish trade. Other ships passing by may opt to re-fuel with bunkering oil in Sweden.

[10] Swedish Environmental Protection Agency (2008a)

The fuel consumption of aviation for international transport produced emissions of just under 2 Mtonnes CO_2e in 2003. However, an in-depth analysis below suggests that passenger air travel in a consumption perspective is likely to give rise to higher emissions. This may be due, for example, to passengers on long-haul journeys from Sweden flying via hub airports in Europe and the emissions being reported in these countries.

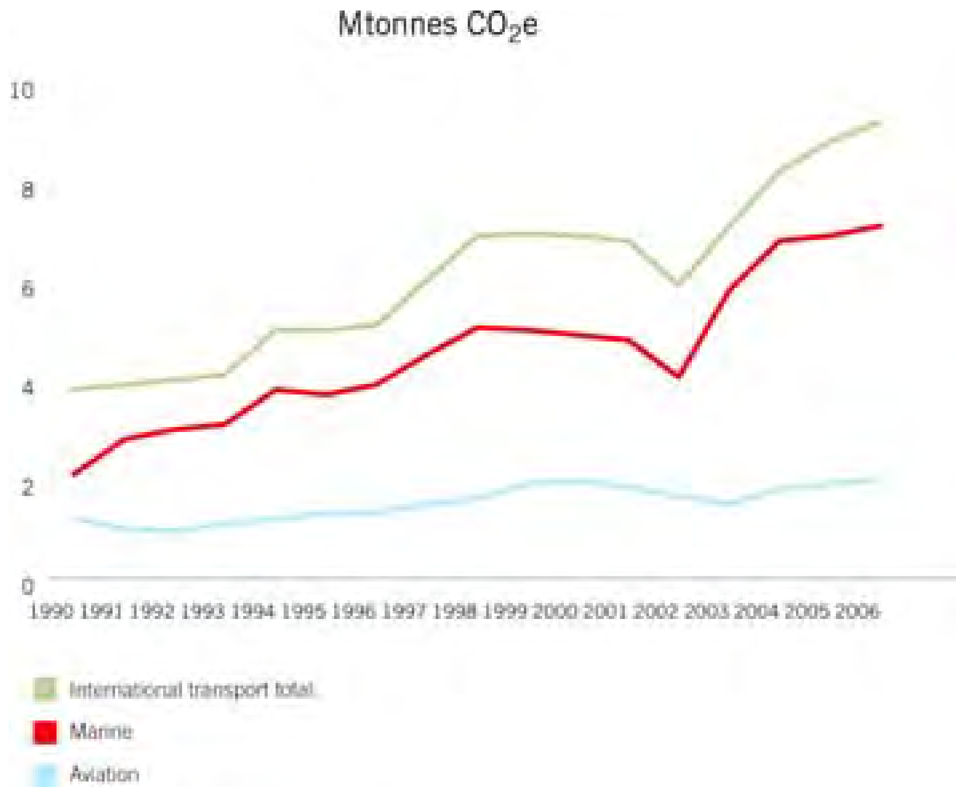

Figure 2: Emissions from ships and aircraft in international traffic that have refuelled in Sweden (Swedish Environmental Protection Agency 2008a).

The emissions as above are separately reported in the international statistics and are thus included in the Statistics Sweden environmental accounts. There are great uncertainties, and trends in international transport must be subjected to further analysis in the future.

In 2003, carbon dioxide emissions were thus 62 Mtonnes in Sweden, including from international transport. Methane emissions were 6 Mtonnes CO_2e and nitrous oxide emissions were 8 Mtonnes CO_2e. This makes a total of around 76 Mtonnes CO_2e. The uncertainty is relatively small.

Exports from Sweden

Swedish exports are extensive and include products that cause significant greenhouse gas emissions in Sweden. For example, around 80% of the production of the steel industry, 60% of that of the forest industry and 50% of that of the cement industry is exported. As these products are consumed by persons who are resident outside Sweden, the associated emissions calculated from a consumption perspective are deducted from the emissions that take place in Sweden.

Carbon dioxide emissions from the production of exports from Sweden are estimated at 21 Mtonnes of carbon dioxide in 2003[11]. Steel and products containing steel dominate. The production of refined oil products and paper and pulp that are exported also cause large carbon dioxide emissions in Sweden.

The production of goods for export also causes emissions of greenhouse gases other than carbon dioxide in Sweden. The proportions of methane, nitrous oxide and carbon dioxide have been assumed to be equal in the industries concerned regardless of whether the goods are produced for export or for domestic consumption. Methane emissions from exports were estimated at 0.5 Mtonnes CO_2e and nitrous oxide emissions at 2 Mtonnes CO_2e. The emissions come from agriculture.

Emissions caused in Sweden by Swedish exports are thus estimated at 24 Mtonnes CO_2e. There is greater uncertainty for methane and nitrous oxide than for carbon dioxide.

Imports into Sweden

Sweden also has extensive imports of goods and services. Manufacturing and transporting of imports has led to emissions in other countries which, in the consumption perspective, are to be added to our emissions.

The emissions from imports have been taken from a world trade model that shows the emissions in all countries and their trade with Sweden. The emission figures are, however, unrefined as they indicate the country's average emissions and Sweden's imports do not consist of average products. However, the EU's statistics agency Eurostat has input-output data for eleven European countries at an industry level, just as in Sweden. These countries account for around half of Swedish imports[12]. Using this calculation methodology, aggregate carbon dioxide emissions of 36 Mtonnes are obtained for the whole of Sweden's imports.

Unfortunately, there are only figures for carbon dioxide emissions. Methane and nitrous oxide emissions are to a great extent associated with the agriculture and waste sectors. The order of magnitude of these emissions has been estimated by assuming that that they would have been just as large if all the goods had been manufactured in Sweden. On this assumption, emissions of methane and nitrous oxide caused by imports are estimated to be of the order of 7 Mtonnes CO_2e.

There is greater uncertainty in the estimation of methane and nitrous oxide emissions than carbon dioxide emissions. Methane and nitrous oxide to a great extent are emitted through natural processes. These emissions are therefore more

[11] Statistics Sweden (2008)
[12] Statistics Sweden (2008)

difficult to estimate in the environmental accounts than the carbon dioxide emissions, which are more closely associated with the use of fossil fuels.

Our largest imports come from countries nearby. Germany, Denmark and Finland together account for 34% of total emissions associated with imports. See Table 3, which also shows the value of imports. If the value is higher than the share of emissions accounted for by emissions, the imports from the country concerned are associated with lower than average emissions per krona. Quality-assured statistics come from the eleven countries shown in bold.

Table 3: The breakdown of greenhouse gas emissions from Swedish imports and value between different countries. NAMEA data are available for countries shown in **bold**. **Portugal, Hungary and Bulgaria** all contribute less than 1% each to both aggregate emissions of imports and the aggregate value of imports (Statistics Sweden 2008).

	Share of emissions from imports	Share of value of imports
Germany	**14%**	**16%**
Denmark	**10%**	**9%**
Finland	10%	5%
United States	6%	8%
Russia	6%	1%
UK	**6%**	**8%**
Norway	**6%**	**7%**
Netherlands	**6%**	**6%**
Poland	4%	2%
Belgium	4%	4%
China	3%	2%
France	3%	5%
Estonia	**2%**	**1%**
Italy	**2%**	**3%**
Spain	**1%**	**2%**
Iran	1%	1%
Japan	1%	2%
Canada	1%	1%
Ireland	1%	2%

UNCERTAINTIES

The calculations are based on the value of the goods multiplied by a specific emissions intensity. Only 2% of the value of Swedish imports comes from China, and it may be suspected that the emissions are underestimated. The estimation of emissions from low-wage countries therefore ought to be supplemented by an analysis of the weight or volume of imports to obtain a better estimate.

A further source of uncertainty is that some of the other member states of the EU, particularly those with large ports, trade more with China, for example, than Sweden does. It is possible that some of these goods are exported onward to

Sweden without us registering the correct country of origin and emissions intensity. In addition, there may be components from low-wage countries built into assembled products we import from other countries.

Imports into Sweden are thus calculated to have caused carbon dioxide emissions in other countries of around 36 Mtonnes and methane and nitrous oxide emissions of approximately a further 7 Mtonnes CO_2e, giving a total of around 43 Mtonnes CO_2e in 2003. There is great uncertainty in the estimation, particularly for methane and nitrous oxide.

Share of emissions from changed land use and forestry in other countries

Nearly a fifth of the aggregate global climate impact is due to changed land use and forestry, principally the felling of tropical rainforest[13]. Some of these emissions are caused by Swedish consumption, but they are not included in the input-output tables.

Sweden imports foods, animal feeds, timber products and fuels from tropical countries, particularly Brazil and Malaysia. Rainforest is being felled on a large scale in Brazil, Malaysia and Indonesia. In Brazil savannah is additionally being converted to land for grazing and cultivation. In Malaysia and Indonesia former rainforest land with a high peat content is being used for cultivation. These activities give rise to large greenhouse gas emissions, principally of carbon dioxide. Greenhouse gas emissions from these countries are also among the highest in the world. Non-sustainable forestry, beef production, soya cultivation and cultivation of palm oil in particular contribute to these emissions.

Sweden imports between 0.08% (Brazilian beef) and 0.7% (palm oil from Malaysia) of the total production of these products in the country concerned.

It is difficult to put a figure on the level of emissions caused specifically by the part of production that goes to Swedish imports. Data on the level of emissions to which changes in forestry and land use actually give rise to, are very uncertain. In addition, an assessment needs to be made as to whether Swedish imports contribute to new land being brought into use which leads to high emissions. This is because Swedish imports of agricultural products from Brazil and Malaysia are principally stated to come from areas other than those that have been deforested in recent years or where the savannah has recently been broken up.

If it is assumed that Swedish imports contribute to the large emissions that occur due to aggregate production increasing and new rainforest land is utilised, the size of this impact can be estimated with some example calculations[14]. The examples are based on the principle that Swedish imports can be ascribed a share of aggregate emissions which is equal to the part of total production in the market

[13] IPCC (2007)
[14] Swedish Environmental Protection Agency (2008c), Möllersten (2008)

accounted for by Swedish imports. The calculations by this methodology indicate the emissions from changed land use linked to Swedish imports might amount to 2-3 Mtonnes CO_2e per year. The emissions are estimated to be principally due to purchases of beef from Brazil and palm oil form Malaysia.

As these emissions are not associated with any industry or group of products in the input-output analysis they are reported separately here and are not added to the final total.

Foreign passenger travel

This section deals with foreign travel by persons resident in Sweden. This travel too is included in a consumption perspective. As mentioned earlier, emissions from the bunkering of international aviation and shipping are included in the input-output tables. This does not mean that all international passenger traffic is included, but it is separately studied here[15]. However, this estimate is not added to the final total in this report. All modes of transport are included here, although air travel accounts for nearly 90% of the carbon dioxide emissions of these journeys. The volume of journeys is principally based on data from the travel habits survey RES[16]. The survey of travel habits was carried out in 2005-2006 and comprised 27 000 telephone interviews.

Foreign travel during a period of one year by the population resident in Sweden is shown in Table 4. The aggregate foreign transport performance is around 37 billion passenger-km, and air travel accounts for a clear majority of this. Air travel is relatively unevenly distributed across the population, but on average it amounts to the equivalent of a return trip from Stockholm to London per person per year. Travel data according to RES have been corrected using airport statistics on the number of Swedes departing on international flights and data on the proportion of Swedes in ferry traffic between Sweden and other countries.

Aviation also accounts for a dominant share of carbon dioxide emissions (including those that arise in fuel production), at 87%. Shipping and cars each account for 6%, while emissions from international coach and rail traffic are largely negligible. If other greenhouse gases are also included in the calculation the dominance of aviation becomes even greater.

[15] Royal Institute of Technology (2008)
[16] SIKA (2007)

Table 4: The international travel of the Swedish residents in one year (Oct. 2005 to Sept. 2006 inclusive) and the associated emissions of carbon dioxide (incl. fuel production) and other greenhouse gases. An estimate of the uncertainty interval is given in brackets (Royal Institute of Technology 2008).

	Travel bn p-km	**Carbon dioxide emissions** Mtonnes CO_2	**Total greenhouse gas emissions** Mtonnes CO_2e
Air	31	4.1	7.3 (5.7–11)
Car	3.0	0.3	0.3
Ship	1.6	0.3	0.3
Coach	1.3	0.04	0.04
Rail	0.4	0.02	0.02
Total	**37**	**4.7**	**7.9 (6.3–12)**

Total carbon dioxide emissions for foreign travel are just under 5 Mtonnes or, if other greenhouse gases are also included, just under 8 Mtonnes CO_2e. The difference between these two figures can be attributed almost exclusively to the emissions of water vapour and nitrogen oxides by aviation which have a significant climate impact when they occur at high altitude. It is uncertain precisely how great a climate impact these other emissions together have. An estimate of the uncertainty interval is given in brackets in the table.

The emissions associated with foreign visitors to Sweden are not included when emissions from Swedish consumption are added up. The visitors' turnover is estimated at around 50 billion krona, which would be equivalent to around a million tonnes of carbon dioxide. No correction has been made as there is no estimation of the emissions of Swedish tourists abroad.

Global emissions of greenhouse gases caused by Swedish consumption

If the above items are added together, Table 5 is obtained with an assessment of the uncertainties.

Table 5: Global greenhouse gas emissions caused by the aggregate consumption of persons resident in Sweden in 2003. The estimates of changes in global land use or all foreign travel have not been added in the table.

Emissions	**Mtonnes CO_2e per year**	**Uncertainty**
Emissions in Sweden, incl. international transport	76	Small
– Exports from Sweden	– 24	Small
+ Imports into Sweden	+ 43	Small for 18 Mtonnes Large for 25 Mtonnes and nitrous oxide and carbon dioxide from non-NAMEA countries
= Emissions from Swedish consumption	**95**	**Large**

The emissions according to the consumption perspective add up to 95 Mtonnes CO_2e in 2003. 70 Mtonnes CO_2e of these are estimated with a comparatively smaller uncertainty from Swedish statistics and statistics of equivalent quality in other countries. The remaining 25 Mtonnes CO_2e have greater uncertainty and the result can therefore be stated as 85-105 Mtonnes CO_2e. With a population in Sweden of just over 9 million, this is equivalent to emissions caused by consumption of around 10 tonnes CO_2e per capita per year.

The difference between the emissions that take place in Sweden including international transport and those calculated to arise due to Swedish consumption is relatively large. The emissions in the consumption perspective, of the order of 95 Mtonnes CO_2e in 2003, are 25% higher than the 76 Mtonnes CO_2e emitted in Sweden including international transport in the same year. If emissions from aviation and shipping in international traffic that refuel in Sweden are deducted, emissions instead are 35% higher in a consumption perspective.

The order of magnitude of the results in this report is in agreement with other estimates made previously. It is, however, difficult to compare the results from different studies. They may have used different model approaches, including carbon dioxide only or, as here, other greenhouse gases, and the reference year may vary[17].

Most industrialised countries are allocated greater emissions in a consumption perspective in comparison with the accounts of how large the emissions are within the borders of the country. Industrialised countries such as Sweden with large trade and low domestic per capita emissions are calculated to have the greatest supplement to emissions in relative terms with a consumption perspective[18]. Sweden's domestic per capita emissions are among the lowest among the industrialised countries. The equivalent average for the industrialised countries was around 16 tonnes per capita in 2004. An average figure for emissions from Swedish consumption of around 10 tonnes per capita is still a relatively low figure compared with per capita emissions solely from the domestic emissions in many other industrialised countries.

[17] Carlsson-Kanyama *et al* (2007), WWF (2008)
[18] Peters and Hertwich (2008)

Emissions from different activities

Greenhouse gas emissions can be allocated to goods and services through input-output analysis. The statistics, as previously, are from 2003. In this way emissions for around 100 groups of products can be presented. This can be done for products manufactured in Sweden. However, it is unknown precisely how foreign industries trade with one another to produce the goods they then export to us. A comparison has therefore been made of what level of emissions Swedish industries give rise to for each krona they produce in comparison with foreign ones. Each imported product has then been attributed to a specific industry. There is no input-output model for the imported goods, and not all imported emissions can therefore be attributed to a product. Those imported emissions that cannot be allocated are shared out proportionally among all imported goods[19].

Statistics on Sweden's total emissions are normally allocated to private and public consumption and exports. The investments have only been broken down into private and public consumption in this study, and not into exports. This is offset by the foreign investments that have made imports possible not having been included among imported products, as there are no data to use as a basis for this calculation.

Private and public consumption

Aggregate consumption is broken down into private and public consumers. Consumption by industry and commerce is counted as an addition of value to goods and services and is therefore allocated to the final private or public consumers. Emissions from private consumption are estimated at just over 80% of total emissions, see Figure 3.

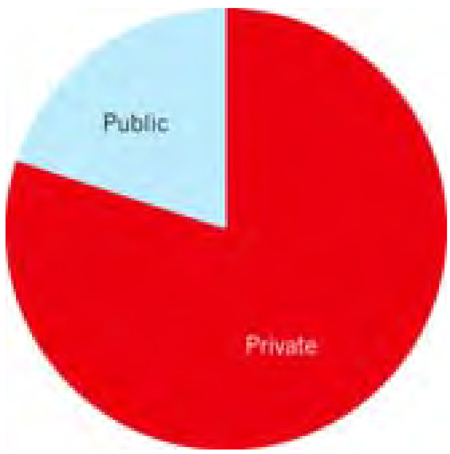

Figure 3: Greenhouse gas emissions from total consumption in 2003, broken down into private and public consumption (Statistics Sweden (2008) and Swedish Environmental Protection Agency (2008b)).

[19] Statistics Sweden (2008)

Four activities in private consumption

Private consumption can be broken down into a small number of activities. The breakdown here is made into four general activities, *Eating, Housing, Travel* and *Shopping*. The latter is a residual item containing a number of different goods and services, for example purchases of clothing, pets and IT services. The activity of *eating* includes all emissions caused by the food reaching the shop. *Housing* is dominated by heating and household electricity for all purposes within the home. *Travel* is personal travel for all different purposes. The four activities encompass all private consumption.

The dividing lines between the different activities are not stipulated. Shopping trips and household electricity are examples of components that can be added to different activities. Shopping trips are both part of travel and an essential requirement in order to be able to eat. Household electricity is used in the home but also to cook and operate IT equipment. This is one reason for the different percentages that may be stated in other reports for the proportion of total emissions for a particular activity. Another is that they vary according to what comparisons are made, and what is actually represented by the hundred per cent.

Figure 4 shows the breakdown of the private consumption totalling just under 80 Mtonnes CO_2e in 2003. Consumption is broken down into the activities of eating, which accounts for just over 25%, housing just over 30%, travel just under 30% and shopping just under 15%.

The consumption perspective also includes emissions in other countries from Swedish consumption. The activities of eating and shopping have the largest share of emissions in other countries but there are also emissions in other countries for housing and travel.

Figure 4: Greenhouse gas emissions from private consumption broken down into the activities of eating, housing, travel and shopping. Private consumption in 2003 accounted for just under 80 Mtonnes CO_2e (Statistics Sweden (2008) and Swedish Environmental Protection Agency (2008b)).

Eating

In total, the activity of eating produces emissions of around 20 Mtonnes CO_2e or just over 2 tonnes CO_2e per person in 2003. The production of food in agriculture and the food industry and freight transport are included. Restaurant visits are also included, but not household shopping trips or household electricity for storing and cooking foods.

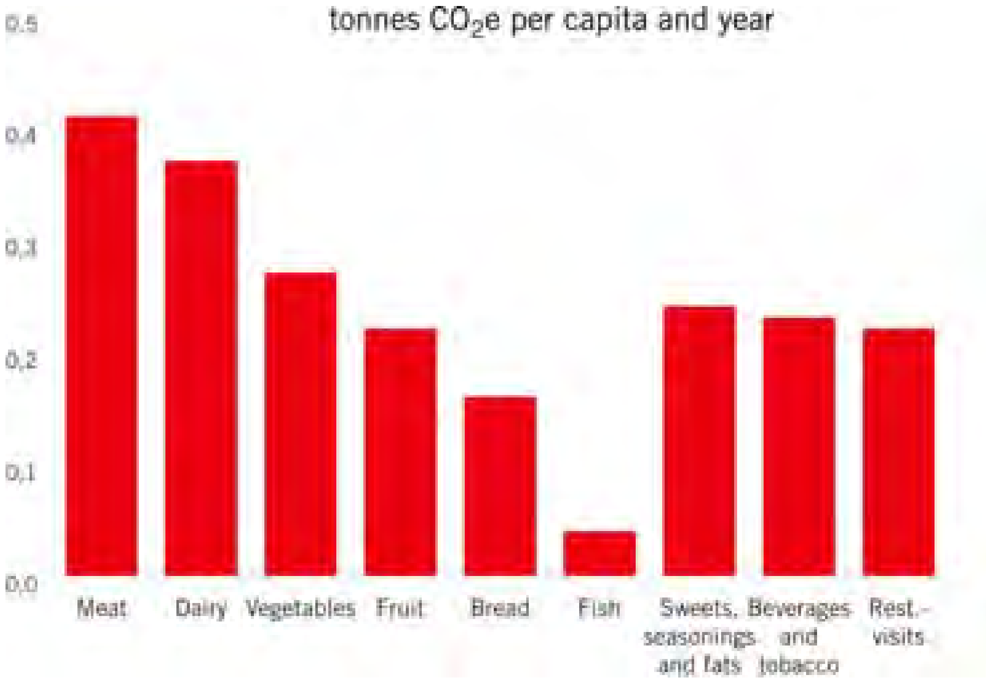

Figure 5: The activity of eating generated a total average of just over 2 tonnes CO_2e per capita in 2003 (Statistics Sweden (2008) and Swedish Environmental Protection Agency (2008b)). Emissions from meat are underestimated as emissions from changed global land use are not included.

Meat accounts for the largest item in the activity of eating. The figure is a mean value as different types of meat entail different levels of emissions. In addition, the figure is an underestimate. In the case of imported meat, particularly from Brazil, the raising of livestock for meat may be associated with some deforestation, which ought to be allocated to the meat that is consumed. If the livestock for meat production are fed concentrates, the emissions from soya cultivation required to produce the concentrates ought to be allocated to the final consumer of the meat.

Dairy, such as milk, butter and cheese, is heavy on emissions because they are animal products. It is the animals' feed, and all the other emissions associated with livestock husbandry, just as for meat above, that makes the emissions high.

Different *vegetables* have differing emissions, depending on the method of cultivation, application of fertilisers etc. The same applies to *fruit* and the cereals baked to produce *bread.* In addition, some vegetables are grown in heated greenhouses, both in Sweden and in other countries. Depending on the season and growing conditions, fruit in particular, but also vegetables, may be transported long distances to reach the Swedish consumer.

Fish account for large emissions per krona in Sweden, but this intensity is lower for imported fish. Large imports mean that fish does not end up as high as it would have if only Swedish intensities had been used.

Sweets, seasonings and fats is a collective group. Emissions per krona (intensities) in this group are not as high but the sums of money spent on these products are large. The emissions when multiplied are therefore high.

Beverages and tobacco also have low emissions per krona, but expenditure on this group is high.

Restaurant visits include all “eating out”, that is to say burger bars, hot-dog stands and cafés as well as restaurants.

Housing

Swedish housing gives rise to emissions of around 25 Mtonnes CO_2e in total or just over 2.5 tonnes CO_2e per capita in 2003. Construction, heating and all household electricity have been added to this activity.

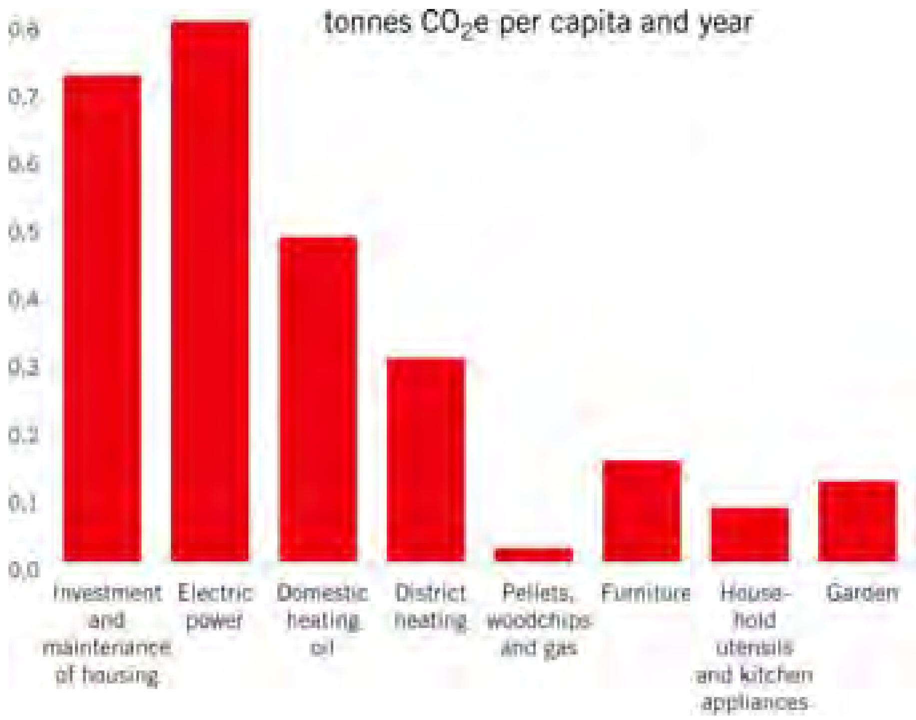

Figure 6: The activity of housing generated a total average of just over 2.5 tonnes CO_2e per capita in 2003 (Statistics Sweden (2008) and Swedish Environmental Protection Agency (2008b)).

Investment and maintenance of housing consists of, among other things, rent and interest payments for the construction and maintenance of housing. Emissions per krona are very low, but the amounts are large, giving a high total figure. The construction, care and renovation of the building, i.e. all expenditure on the building itself which is not concerned with the household's electricity bill or heating costs, are included in this item.

Emissions from *use of electricity* vary from year to year, depending on access to fossil-free production. 2003 was a year of extremely low availability of hydropower in the Nordic and northern European electricity systems, so that emissions from electricity consumption were around 20 per cent higher this year compared with the average in the 2000s. The fact that Sweden both imports and exports electricity daily is also part of the picture. In some years Sweden is a net exporter of electricity and in some years it is a net importer. Viewed over several years, net imports and exports have been approximately equal. Some of the emissions in Sweden occur when electricity produced from coal and oil, but also electricity produced from blast-furnace gas and waste fuels, is also included.

The use of heating fuel oil for the heating of homes, known as *domestic heating oil,* is rapidly declining. In 2003, emissions were as shown in Figure 6, but the use of oil has decreased sharply since then. Use of heating fuel oil halved between 2003 and 2006 and has since continued to decline.

Use of district heating is increasing in households. Most plants are biofuel-fired or use waste fuels. Emissions from the use of district heating are principally due to the use of blast-furnace gas, a residual gas from iron and steel production, and to coal, peat and oil still being used to some extent.

For the item of *pellets, woodchips and gas* there are emissions associated with the processes that produce pellets or woodchips.

Furniture could have been classified under shopping, but has been placed here because it is located in the home. The item of *household utensils and kitchen appliances* could have ended up under shopping or eating, but has also been placed here, as kitchen equipment is often included in apartment rents or housing purchases.

Emissions for *garden products* are due in part to the fact that fertiliser is often applied to plants and that plants are sometimes grown in greenhouses.

Travel

The activity of travel is calculated in 2003 to have given rise to total emissions of just under 25 Mtonnes CO_2e or around 2.5 tonnes CO_2e per capita. Only passenger travel is included as freight transport according to the input-output analysis is allocated to the various groups of products.

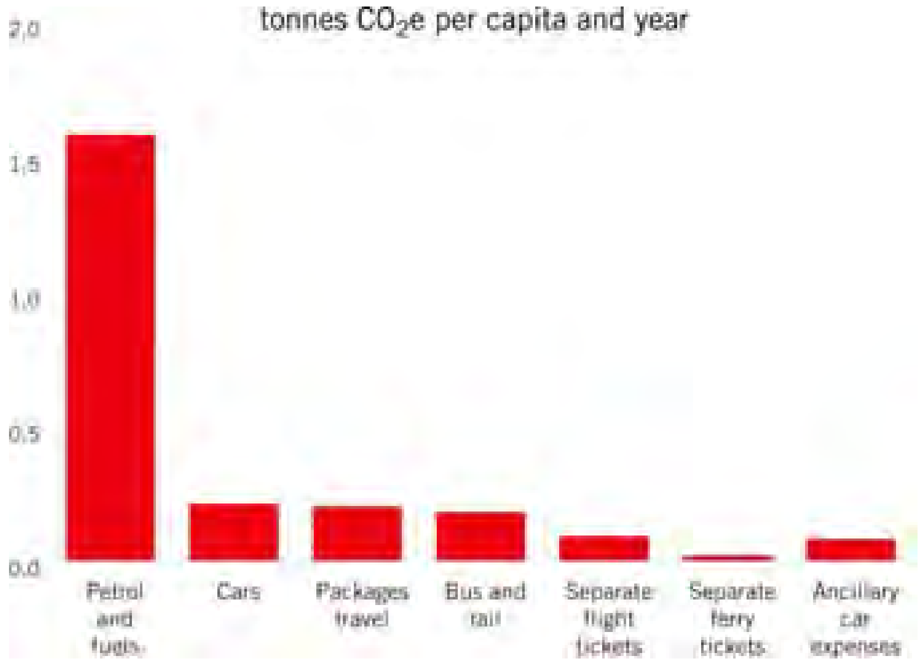

Figure 7: The activity of travel generated a total average of around 2.5 tonnes CO_2e per capita in 2003 (Statistics Sweden (2008) and Swedish Environmental Protection Agency (2008b)). Note that emissions from aviation in the diagram only include part of private travel.

The emissions item of *petrol and fuels* comprises household purchases of vehicle fuels, most of which is petrol and diesel for cars. This item additionally includes emissions from an increasing proportion of ethanol and biogas.

The item of *cars* also includes emissions from other wheeled vehicles as well as snowmobiles and comprises emissions from the stages of manufacturing a car.

Package travel comprises the travel bought with a holiday trip, accommodation and other elements included. Pure hotel stays have also been placed in this item.

Bus and rail includes public transport locally, regional bus routes and the emissions of SJ and other train operators that can be attributed to passenger traffic.

Separate flight tickets are only reported as part of private travel. The estimate does not show the total emissions of aviation. As it is based on input-output analysis, companies' expenses and emissions for air travel are allocated to production in the industry concerned. Travellers on public duty are counted among public consumption. In addition, the figure is underestimated as only the first part of longer journeys is included. Emissions from total international travel were estimated in previous sections, partly using the survey of travel habits, at just over 0.8 tonnes CO_2e per person if account is taken of other greenhouse gases and emissions at high altitude. Aviation would then be second largest emissions item.

The item of *separate ferry tickets* contains ferry traffic, which is mostly to other countries.

The residual item which here has been called *ancillary car expenses* contains driving licence expenditure, parking charges, bridge tolls and everything else that makes up ancillary expenses for a car owner over and above vehicle purchase and fuel.

The infrastructure expenses are a public activity and are placed in that category.

Shopping

The residual item of shopping includes, for example, purchases of clothing and shoes and IT equipment such as computers, phones and televisions. Care of pets also forms part of this group. This activity altogether accounts for just over 10 Mtonnes CO_2e or just over 1 tonne CO_2e per capita in 2003.

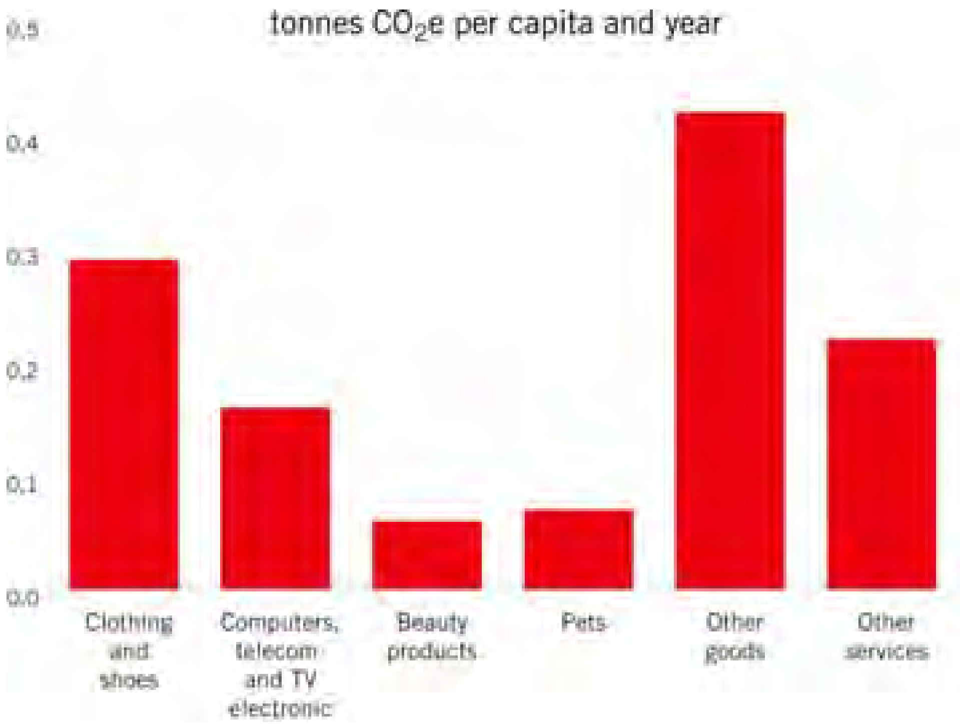

Figure 8: The activity of shopping generated a total average of just over 1 tonne CO_2e per capita in 2003 (Statistics Sweden (2008) and Swedish Environmental Protection Agency (2008b)).

Clothing and shoes also includes fabrics and repairs, but clothing is by far the largest item. Shoes are the second largest with higher emissions per krona than clothing.

Computers, telecom and TV electronics consists of manufacturing. Electricity use during operation has been placed under housing.

Beauty products consists of three groups of products which are notable for the relatively high emissions intensity in belonging to the activity of shopping.

The item of *pets* includes pet food.

Other goods contains around twenty groups of products that cannot be attributed to the activities of eating, housing or travel. Sports equipment is an example. They do not each account for particularly high emissions, due to emissions per krona being low.

Other services consist of just under twenty services that cannot be assigned to eating, housing or travel. Emissions per krona are also low for these services, but the amounts spent on services are relatively high. Examples are cinema and museum visits and private care charges.

Activities in public consumption

A large part of public consumption could also be broken down into the activities of eating, housing, travel and shopping. In schools, health care and social care food is served, premises are used, journeys are made and various organisations purchase goods and services. The only difference is that this consumption is paid for and financed through taxes. These activities are also to be found in other public organisations such as the armed forces and the police.

Eating, housing, travel and shopping could thus serve as a basis of classification in the public sector, but data was not available to make this allocation. Data on public consumption have not been allocated to different goods. Emissions from the public sector are therefore calculated as the difference between the total emissions that can be attributed to Swedish consumption and the emissions of private consumption. On the other hand, it is possible to monitor what purchases the public sector has made from different industries, and what level of emissions these purchases are calculated to have entailed. The investments have been divided among the investment purchases of the goods-manufacturing industries and are also included here. The three areas of business whose sales to the public sector have by far the largest carbon dioxide emissions are the construction industry, purchases of vehicle fuels and heating oil, and electricity and heating. Purchases of medicines and aircraft are also prominent, but what could be termed public shopping otherwise consists of a large number of smaller items, just as in the private activity of shopping.

Public sector emissions altogether are estimated at just over 15 Mtonnes CO_2e, or just under 2 tonnes of carbon dioxide equivalents per person in 2003. The uncertainty of this estimate is high.

The most important activities

The following five activities together account for around half of emissions and are therefore of key significance if it is to be possible to reduce emissions:

- How much do we drive and in what car (travel),
- How do we heat our homes (housing),
- How much electricity do we use in the home (housing),
- How much meat do we eat and what type (eating),
- How far do we fly and how often (travel).

Many small changes taken together can lead to large reductions in greenhouse gas emissions. There are therefore large numbers of activities that together are of significance but that do not feature in the five activities above. Nor is there any single solution that is sufficient to reduce emissions sufficiently. There is a need for both large and small changes both in the technology that is used and in our behaviour. The activities itemised in the bullet points above must be changed if emissions are to be noticeably reduced.

There is no bullet point relating to shopping in the list above, despite shopping altogether accounting for just under 15% of emissions. This is due to it not being possible to identify an individual product or service as having a particular impact in this group. Greenhouse gas emissions also become smaller if the same amounts are spent in the activity category of shopping as for example in paying for a flight. The reason for this is that intensity, emissions per krona spent, is relatively low in the category of shopping. Expenditure in Swedish krona for the four activities is broken down very differently than the greenhouse gas emissions as the emissions intensities are different. The breakdown of spending on the activities by Swedes, as a percentage of income, was: eating just over 20%, housing just under 30%, travel just over 15% and shopping just under 35% of the total sum of just over 1 110 billion krona spent on private consumption in 2003. See Figure 9.

Figure 9: Differences in breakdown between emissions on the left and expenditure on the right for the four activities (Statistics Sweden (2008) and Swedish Environmental Protection Agency (2008b)).

The five bullet points above apply principally in the short term. In the longer term it is principally food and long-haul travel that appear to be most significant with regard to changes in behaviour, but more about this is later sections.

Where is the trend heading?

The statistics in the report are from 2003. Is it possible to say anything about how emissions from our aggregate consumption may have developed in the meantime? Five important activities that together are estimated to account for just over half of emissions were identified in the section above. By studying how this part of consumption has developed since 2003 it is possible to obtain a rough indication of how aggregate emissions may have developed[20].

The use of fossil fuels for heating has more than halved since 2003, with regard to both the use of domestic heating oil and the use of coal, oil and peat for district heating production. Household use of electricity is at approximately the same level now as in 2003, but the proportion of carbon-free electricity production has increased somewhat in the Nordic electricity system since 2003. Car emissions have decreased since 2003 despite the fact that we are driving more today. To date in 2008, emissions from car transport have decreased in comparison with 2007. The reason is that we now use somewhat more fuel-efficient cars and more biofuels in the transport sector than in 2003. Emissions from freight transport, on the hand, increased between 2003 and 2007. Consumption of foods has increased somewhat in recent years, but consumption of beef and milk are decreasing, while consumption of other meats, such as poultry, is increasing. Foreign travel is increasing.

[20] Henryson and Westander (2008)

The trends taken together are towards emissions from our combined consumption possibly having decreased somewhat in recent years, but the input-output tables have not yet been updated to evaluate this by the same methodology as in other calculations.

No one consumes in average

The estimates of emissions are based on the total emissions in a consumption perspective, which are then shared out among all residents of Sweden, resulting in average values per person. However, no one in principle consumes the average value, and the spread from low to high emissions is large. The spread between different groups can be analysed according to several dimensions. Some examples of dimensions where there are differences follow below.

INCOME

Greenhouse gas emissions clearly follow household income. The higher the income, the higher the emissions[21].

GENDER

Men cause greater emissions than women. A significant reason for the difference is the differing patterns of travel of men and women. Men drive more, while women travel more by public transport[22]. Emissions differ accordingly.

AGE

Travel varies greatly between different phases of life. The level of greenhouse gas emissions therefore also varies with age.

URBAN OR RURAL AREA

The circumstances for instance for different heating systems and daily travel differ between urban areas of various sizes and purely rural areas.

These brief examples suggest that there are differences in patterns of consumption and consequently greenhouse gas emissions between different groups in society. There are thus groups in Sweden that are already living today in such a way that their greenhouse gas emissions are low.

[21] Statistics Sweden (2008)
[22] Swedish Institute for Transport and Communications Analysis (2007)

Different choices can reduce emissions

Consumers can influence greenhouse gas emissions through specific choices about what and how much they consume. This section gives examples of greenhouse gas emissions resulting from different choices that can be made today. The examples are based on data from life-cycle assessments for individual goods or services. Such data clarify climate impact on the basis of a specific product and not aggregate emissions. There are therefore wide differences and a greater spread of product-specific data compared with the average data presented in the previous section and obtained through input-output analysis.

Situations of choice and the rebound effect

We take simple but significant decisions daily. Some decisions limit the scope for action for a long time to come, for example decisions on major investments. Housing, location of workplace and car purchase are examples of choices that are made less often and can lead to options being limited in the short term. Choice of technology, such as whether heating is to be based on an electric boiler or heat pump, often also falls into this group.

Other choices are made independently of decisions taken previously and might lead to swifter change. These may relate to purchasing of different foods or how technology is utilised, for example whether the indoor temperature is to be 20 or 22 degrees.

An important perspective on change and increased efficiency is how the saved resources or money are used. Are they used to consume more, or is the same level of consumption retained when a new, more efficient technology has been chosen? Experience for example regarding the purchase of more efficient cars shows that car use often increases. This is known as the rebound effect.

Data from life-cycle assessments

A life-cycle perspective is based on all climate and environmental impacts arising *from cradle to grave* of a product or service. This means that all emissions that have arisen from raw-material production, including inputs (e.g. production of fertilisers), as well as production and processing, distribution, sale, consumption and disposal, are allocated to the product under study.

Where the greatest climate and environmental impacts occur varies considerably between different product groups, as illustrated in Figure 10. This is of significance to how and where measures can be taken. Life-cycle assessment can be used to understand whether it is the use of the product that has the greatest impact, as for example for cars or electronic products, or whether it is earlier stages, as for example in the case of foods.

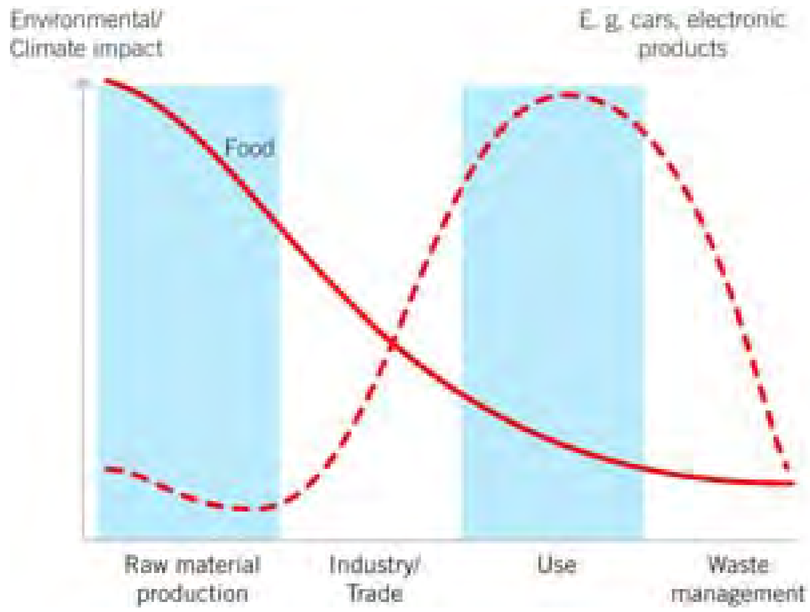

Figure 10: There may be a great difference in environmental and climate impacts between the life cycles of different products (Angerwall *et al* 2008).

Eating

Eating is one of our basic needs, and we wish to be able to eat a nutritious and balanced diet in order to enjoy good health. The choice of ingredients for meals is of great significance to greenhouse gas emissions, and it is possible to have a nutritious diet with a low impact on the climate. The Swedish National Food Administration has developed a scientific basis on which to be able to assess the environmental impact of its dietary advice[23]. Some food groups have a substantially greater impact on climate than others, and this has been reported both nationally and internationally, with a substantial consensus[24].

Swedes on average consume around 800 kg of foods per year, including beverages. Nearly 40% of this quantity may be imported[25]. Foods are among the product groups with the greatest environmental impact, with high energy use and carbon dioxide emissions[26]. In addition to this there are emissions of other greenhouse gases such as methane from livestock husbandry and nitrous oxide emissions from fertiliser production. Agricultural and food production also affect the environment

[23] Lagerberg Fogelberg (2008)
[24] See for example EIPRO (2006), Garnett, (2008)
[25] Carlsson-Kanyama and Engström (2003)
[26] See for example EIPRO (2006)

in other ways. Other environmental quality objectives where the impacts from the food chain are significant are *A Non-Toxic Environment* and *Zero Eutrophication.*

Some foods have a particularly great impact on climate. Meat often has more of an impact than other alternatives, particularly a vegetarian diet. Swedes on average eat substantially more meat and meat products than are considered sufficient for health, 180 grams instead of 140 grams daily according to conclusions drawn by the National Food Administration. There are also substantial differences between different types of meat, so that replacing beef with meat from poultry, for example, can reduce the impact on climate. The situation regarding aims is, however, complex. To attain the environmental quality objective of *A Rich Diversity of Plant and Animal Life* it is necessary to have sheep and cattle grazing in the Swedish landscape. A new study from several European countries has shown that permanent grassland binds carbon in the long term and becomes what is known as a carbon sink[27]. The conclusion that can be drawn for the animals that graze Swedish natural grassland is that they probably cause lower climate impact than previously thought. A large proportion, nearly 70%, of the beef produced in Sweden comes from dairy cows and young cattle and calves. This means that the climate impact is also allocated to the milk and that this meat production has a lower impact than the meat that comes from beef cattle. Meat from wild ruminants is judged to produce the same level of greenhouse emissions as beef and lamb[28].

Something that has also attracted increasing attention is the wastage that occurs in all parts of food handling and that contributes to large quantities of waste and greenhouse gas emissions. It was estimated on the basis of a study in the United Kingdom[29] that this wastage is equivalent to 1.9 Mtonnes CO_2e for Sweden or 200 kg CO_2 equivalents per person per year. This is equivalent to around 100 kg of food per person[30]. It is likely that we in Sweden, just like people in Britain, throw away large quantities of vegetables, fruit and bread. Wastage occurs at all stages[31].

Some choices for eating

The whole food chain “*from field to waste”* is complex, but more conscious choices can be made, based on available research in the area of food.

ANIMAL OR VEGETABLE PROTEIN

Compared with meat, food from the plant kingdom often, but not always, has less of an impact on climate and the environment[32]. Emissions of climate-changing gases from the production of chicken and pork are lower than those from lamb and beef. Meat has a great environmental impact, which is due among other things to nitrous oxide from the production of mineral fertilisers and application of nitrogen fertilisers to arable land which is used to grow animal feedstuffs, methane

27 Soussana *et al* (2007)
28 Lagerberg Fogelberg (2008)
29 WRAP (2008)
30 Sonesson (2008)
31 Leander (2008)
32 Olsson (1998)

emissions from the digestion of feedstuffs by livestock and the energy required to grow and transport feedstuffs and for raising livestock. Alternative livestock raising systems with substantial grazing can reduce energy use and increase biodiversity[33]. Climate impact can be reduced by reducing present-day food portions or replacing some meat dish from the weekly menu.

FRUIT AND VEGETABLES BASED ON SEASON

Cultivation of fruit and vegetables in heated greenhouses often requires greater energy use than outdoor cultivation, although the latter may entail longer transport distances[34]. From 2008, around 60% of the growing area in Swedish greenhouses for tomatoes is heated with renewable fuels, and in 2009 it is estimated that this proportion will rise to 80%, resulting in a reduction in greenhouse gas emissions. Emissions from the tomatoes grown in fossil-free greenhouses are estimated to be the same as those for example from Spain. However, cultivation of root vegetables outdoors, such as carrots, still results in far lower greenhouse gas emissions.

FISH FROM ROBUST STOCKS OR FARMED SUSTAINABLY

The climate and environmental impacts from fish arise principally in the actual catching of the fish[35]. The climate impact per kg of raw fish fillet is on a par with emissions from raw chicken and pork free of bones and fat. The catching method is of great significance to energy consumption. Fishing affects several environmental quality objectives, such as *A Rich Diversity of Plant and Animal Life,* for instance through by-catches which result in undersized fish that are caught being thrown back as dead fish. The climate impact of farmed fish principally depends on how large a proportion of animal-based feed (e.g. fish feed) is fed to them.

ENERGY-EFFICIENT STORAGE AND REDUCING WASTAGE

A calculation of the life-cycle costs of refrigeration and freezing appliances in the home may justify the purchase of more energy-efficient alternatives. Storage and cooking may also be of great significance to total energy consumption. This applies in particular to the relatively high level of wastage[36]. Energy-efficient and adapted methods of cooking with the right quantities result in better quality and less wastage.

EFFICIENT TRANSPORT

Transport may be of significance to climate impact and energy use from an LCA perspective for certain groups of products, e.g. for fresh fruit and vegetables. Foods with a short shelf life are transported internationally by air. In Sweden, transportation of foods by truck accounts for 15-20% of total truck transport. Transport by consumers to their homes is estimated to account for almost the same level of energy use as truck transport. The significance of transport to environmental impact increases for those products that have been kept refrigerated

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[33] Cederberg and Darelius (2000)
[34] Carlsson-Kanyama (1998)
[35] Ziegler (2001)
[36] Mattson (1999) and Carlsson-Kanyama and Boström-Carlsson (2001)

or frozen, such as frozen fruit and vegetables, meat and dairy products and ready meals[37].

Examples of orders of magnitude

Some examples of orders of magnitude are given here to show more clearly the effect of possible choices. They are based on data from life-cycle assessments converted to emissions per eating portion and on both individual analysis and combined data. The examples presented for meat and fish do not cover the whole life cycle, but only emissions from production. This means that energy emissions from transport to processors, retail outlets and peoples' homes has to be added, as well as emissions from storage and cooking. The portion for animal products relates to meat free of fat and bones and to filleted fish.

Table 6: Examples of estimated greenhouse gas emissions for different food choices in kg carbon dioxide equivalents per year. The portions relate to meat raw material free of fat and bone and to fish fillets (Lagerberg Fogelberg (2008), Ziegler (2008), Sonesson (2008) and WRAP (2008)).

	Total per year, in kg CO_2e	
	Once per week	**7 times per week**
Beef from Swedish dairy cows, young cattle and calves of dairy cows, 140 g	120	870
Beef from Swedish suckler cows, young cattle and calves of suckler cows, 140 g	170	1 200
Pork, Swedish, 140 g	35	250
Chicken, Swedish, 140 g	10	70
Wild-caught cod, 140 g	50	370
Farmed salmon (Canada), 140 g	40	270
Pickled herring, 140 g	15	110
Vegetarian pea soup, 350 g	2	11
Beans/chickpeas in can, large portion, 350 g	9	60
Apples, Sweden, 150 g	1	4
Apples, France, 150 g	2	14
Apples, New Zealand, 150 g	4	28
Wastage of foods, excl. beverages, 1.3 – 2 kg wastage per week		140-200

[37] Lagerberg Fogelberg (2008)

Housing

Energy use in the home has an impact on the climate. The greatest changes in greenhouse gas emissions from housing to which a household in Sweden can give rise are by replacing oil-fired heating with alternatives with lower carbon dioxide emissions and by reducing electricity use and total energy use. It is also significant how great the household's total heating needs are and what use is made of appliances.

Only some of the electricity we use today is produced from renewable energy sources. Swedish electricity production has low greenhouse gas emissions, but the proportion of electricity from fossil fuels remains high in the Nordic and Northern European electricity network to which we are connected.

Buildings and energy use

If we look at the entire life cycle of a building, by far the greater part of its energy use arises in the phase of use. Most greenhouse gas emissions in a life-cycle perspective also come from the phase of use for buildings constructed in northern Europe[38]. In second place comes construction. Around 60% more energy is needed to build one square metre in an individual house than to build one square metre in an apartment block. Maintenance, renovation and demolition of a building do not have as great an impact.

The greatest difference can often be brought about as a consumer in connection with renovation or replacement of equipment. Nevertheless, anyone do a great deal through changing their behaviour and habits. Examples are reduced use of hot water, lowered indoor temperature, reduced stand-by through the use of multi-socket extension leads for electronic devices, energy-efficient behaviour using electrical cooking and washing devices, low-energy lamps as well as switching off lights when leaving a room.

In the same way that we buy goods from abroad, we also buy electricity on the Nordic or Northern European electricity market. Anyone who either increases or reduces their electricity use therefore affects the system at the margin. Marginal production today is generally based on coal-condensing power, but marginal electricity in future may change and become less carbon dioxide-intensive[39]. All consumers of electricity in Sweden cannot have the same level of impact on emissions from the electricity system, as a calculation of a marginal effect may suggest.

A relevant discussion also applies to whether electricity efficiency improvements in the short term actually contribute to reduced greenhouse emissions, as electricity production facilities are included in the European emissions trading scheme. Efficiency improvement means that the demand for electricity from coal-

[38] Nemry and Uihlein (2008)
[39] Swedish Energy Agency (2008a)

condensing power stations, for example, decreases. Emission allowances from the installations can be freed and used to cover other emissions in the scheme, while the price of emission allowances drops. This effect arises within a trading period (e.g. between 2008 and 2012). In the longer term, however, more efficient use of electricity improves the prospects of attaining ambitious climate targets, as it becomes easier to lower the allocation of emission allowances in subsequent trading periods.

Some choices in housing

A number of rough example calculations of changed heating, residential floor area, energy-efficient appliances and behaviour have been made, see Table 7. They are based on the choices faced by an individual consumer and how this situation can alter behaviour and technology today. The electricity calculation is therefore based on coal condensing at the margin, but if electricity producers were to go over to using natural gas combined-cycle power plants instead, the consumer's reducing effect would decrease by a little more than half (the results are shown in brackets in the table).

Structural changes can also be made, not just improvements in the efficiency of energy use and replacing heating sources. Small households that live in large accommodation could reduce the heating needed per person by moving to smaller accommodation. The size of the reduction depends on the heating technology used and the indoor temperatures but as an example, a household of three people who live in an individual house with more than 120 m^2 of floor space could reduce emissions by 0.4-0.5 tonnes CO_2 per person by moving to an apartment of between 50 and 80 m^2 in size.

Consumers can also choose to buy the most environmentally friendly energy possible by choosing production-specified energy. It must then be possible to verify the supplier’s commitment. Production-specified energy must also be used efficiently. Saved energy can be used by someone else and the total impact can decrease. This applies both to the electricity or heating used in the home and to the electricity and fuels used for travel.

Table 7: Examples of different emissions resulting from different housing choices, calculated on marginal electricity production. The numbers cannot be deducted from the mean values presented earlier in the report, as they were based on average emissions.

Present pattern of consumption	A choice that results in lower emissions	Gain, CO_2 tonnes per year given carbon-condensing electricity (or electricity from natural gas in brackets)	Remark
Oil-fired domestic boiler	District heating[40]	1.3 – 8.8 tonnes	Based on a 140 m^2 older detached house. Construction of the district-heating line is not included.
Free-standing electric radiators [41]	Additional insulation of roof/attic[42]	1.1 – 2.1 tonnes	Life-cycle reduction
	Installing an air-heat pump	3.4 tonnes (1.3 tonnes)	Addable to other measures
	Replacing windows	2.9 tonnes (1.1 tonnes)	Addable.
	Lower the indoor temperature one or two degrees	0.7 -1.4 tonnes	
	Complete package of measures	15 tonnes (5.7 tonnes)	Additional insulation, air-heat pump, windows, lower temperature one degree, water-saving tap inserts, solar heating, better control systems and electronics not in standby
Water-born electric heating and complete package of measures	Change to district heating, geothermal heat pump or pellet firing. Complete package of measures and geothermal heat pump reduce emissions	Just under 18 tonnes (6 tonnes)	Assumed building 120 m^2 with water-borne electric heating. Not life cycle. Pellet firing causes increased local emissions of air pollutants.
10 most used light bulbs	Replace with low-energy lamps[43]	Just under 0.5 tonnes (0.2 tonnes)	Direct energy gain.
White goods	Replace with most energy-efficient refrigerator, washing machine and dishwater when it is time to do so[44]	Just over 0.5 tonnes (0.2 tonnes)	Life-cycle perspective
Tumble-dry all washing	Air-dry washing	980 kg CO_2 per year or approx. 28 kg per week	No life cycle but direct energy
Shower ’as usual”[45]	Do not keep water running all the time.	380 kg CO_2 per year or 0.9 kg per shower	Shower sequence of 42 l hot water is reduced to 24 l

[40] Which technology produces district heating at the margin varies over the year and is unique to each individual district-heating network. Two different simplified typical networks have been assumed here, one of which is based on a large amount of bioenergy, waste heat and incineration of solid waste, while the other has a large proportion of fossil fuels by Swedish standards. Calculations from the Swedish Energy Agency (2008a).
[41] Calculations based on material for the Become Energy-Smart campaign in 2007.
[42] Johansson and Kanellos (2007)
[43] Calculations based on material for the Become Energy-Smart campaign in 2007.
[44] Calculations based on Become Energy-Smart and Steiner *et al* (2008)
[45] Calculations based on Swedish Energy Agency (2008b)

Travel

Greenhouse gas emissions from different journeys vary greatly. The traveller is able to choose how often, how far and in what way a journey is to be made. It is sometimes also possible to fulfil the purpose of the physical journey by videoconferencing, for example. The climate impact of travel is dominated by daily car use and long-haul flights.

Climate impact per person and journey depends on the type of vehicle used and a number of other factors. Millions of short trips are made by car every day in Sweden. Just under 25% of all car journeys are leisure trips, compared with just under 50% of work-related trips and just under 25% of shopping trips. Just over half of work-related trips are made by car and 45% of work-related journeys made by car were shorter than 5 km[46].

Use of materials and energy in the manufacturing of vehicles and infrastructure also leads to greenhouse gas emissions. Indirect emissions, excluding those generated by the infrastructure, are estimated to amount to 25% of those emitted in operation of the vehicle[47]. It is also important to look at climate impact from the point of view of vehicle manufacturing and fuel production for the green car alternatives.

Choice of route for travel

Lower greenhouse gas emissions can be attained in various ways. Short journeys by car of 2–5 km, can sometimes be replaced by public transport, cycling or walking. In an area with good public transport, car use generally tends to be lower than in an area with worse public transport, for example in a rural area. Proximity to public transport and personal preferences also play a significant role. An alternative to having one's own car may be a car pool or using a rental car when necessary[48].

Other ways of improving the energy efficiency of travel by car are economical driving habits or car-sharing. The car may also be energy-efficient or run on renewable fuels. An ethanol car today is assumed to result in a 53% reduction in emissions provided it is refuelled with E85. If petrol and E85 are refuelled alternately, as today, there is a reduction of 43% in comparison with a car that runs on petrol[49]. There is a great difference between different types of cars, for instance between a large petrol car (for example a Volvo V70) and medium-sized car (such as a Ford Focus) which can run on E85. The large car has specific carbon dioxide emissions for mixed driving of 220 g/km and the medium-sized one of 167 g/km. A car that has emissions of 180 g/km and travels 15 000 km a year emits 2.7 tonnes CO_2 in one year.

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46 Swedish Institute for Transport and Communications Analysis (2007)
47 WTW (2007), EIPRO (2006) and Nemry *et al* (2008)
48 Ornetzeder *et al* (2008)
49 Swedish Environmental Protection Agency (2008d), based on WTW (2007)

Table 8 shows some important examples of the difference between different travel alternatives. Cycling instead of driving or travelling by train instead of flying within Europe results in a substantial decrease in climate impact. Long-haul flights, for example to Asia, have a significant climate impact. In these cases there are no alternative modes of transport that result in lower emissions. If one wishes to reduce one's emissions, it is necessary to either choose less far-away destinations or to travel a little more rarely and perhaps stay away longer when a journey is actually made.

Table 8: Examples of common transport services and their climate impact per occasion, person or year. Daily commuting to work is assumed to be around 225 days per year. It has been assumed for flights that the total climate impact is 1.8 times higher than that caused by carbon dioxide alone, except for Göteborg-Stockholm, where the factor of 1.4 has been used due to lower altitude (KTH 2008).

			Emissions per occasion, CO_2e.	**Emissions per year, CO_2e.**
Short trip	Cycle or walk		≈0	≈0
	Drive to/from out-of-town shopping centre, 10 km return trip, once a week.		2 kg	0.1 tonnes
	Order home delivery of food products, once a week		<0.5 kg	<0.025 tonnes
Commuting	Commute 5 times a week by car, 20 km return trip	Volvo V70, petrol	25 kg	1 tonne
		Ford Focus, E85	8 kg	0.3 tonnes
	Commute 5 times a week by bus, 20 km round trip		10 kg	0.4 tonnes
Longer trips per person	Göteborg-Stockholm, return flight		160 kg	
	Göteborg-Stockholm, train return trip (average Swedish electricity mix)		3 kg	
	Stockholm-Mediterranean (Croatia), return flight		450 kg	
	Stockholm-Mediterranean (Croatia), train return journey (average electricity for country concerned)		160 kg	
	Sweden-Thailand, return flight		2.2 tonnes	

Emissions in the longer term

This section discusses how low *per capita* emissions must be achieved as a global average to reduce the risk of serious climate impact according to Swedish and international experts. The section also discusses in overall and qualitative terms where the greatest problems lie in attaining these low emissions in the conditions that prevail in Sweden.

How much and when do greenhouse gas emissions need to decrease?

Emissions and climate impact

The objective of the United Nations Framework Convention of Climate Change is *"stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system".* The EU has attempted to put this objective into a practical form as an acceptable maximum change in temperature. The objective is formulated as a limitation of the increase in global temperature to a maximum of 2°C compared with the pre-industrial level.

The IPCC's analyses also show that a temperature increase of 2°C to some extent represents a threshold value above which the effects of climate change would probably be more difficult to manage and would increase at a quicker pace. Climate effects already occur with an increase in temperature of less than 2°C. There are also great uncertainties regarding both the sensitivity of the climate to the level of greenhouse gases in the atmosphere and the relationship between temperature increase and effects.

A temperature target needs to be translated into a target for the maximum acceptable concentration of greenhouse gases in the atmosphere, known as a stabilisation level. This is set on the basis of scientifically noted relationships between increasing concentrations of greenhouse gases and increases in temperature. The Scientific Council on Climate Issues believes that a maximum stabilisation level of 400 ppm carbon dioxide equivalents is required for the two-degree target to be *probably* achievable[50]. The EU's focus is on pressing for a maximum level of 450 ppm carbon dioxide equivalents.

The carbon dioxide concentration in the atmosphere at present is approx. 380 ppm. In addition to this, other greenhouse gases are equivalent to a carbon dioxide concentration of around 70 ppm. The aggregate concentration of greenhouse gases is thus already 450 ppm carbon dioxide equivalents.

[50] Scientific Council (2007)

A stabilisation level of 400 ppm can only be attained if the greenhouse gas concentration is first allowed to exceed the desired stabilisation level before it heads downward. Such development necessitates sharp reductions in emissions of all greenhouse gases in the very near future. This is made easier by the fact that the greenhouse gases methane and nitrous oxide have a relatively short residence time in the atmosphere.

If the concentration of greenhouse gases in the atmosphere is to be stabilised, it is necessary for global emissions in the long term to fall to very low levels. With time, emissions must come down on a par with the processes that naturally balance the greenhouse level in the atmosphere (approx. 5 Gtonnes CO_2 equivalents per year). Global net emissions may need to be even lower for a period, even negative, if it is to be possible for stabilisation levels to be achieved. Negative emissions can be brought about by capturing and storing the carbon dioxide formed in the burning of biofuels but also through measures that increase carbon removal such as growing biomass.

The Scientific Council's view is that global greenhouse gas emissions need to decrease by around 10 per cent by 2020 in comparison with the 2004 level for it to be possible for the concentration of greenhouse gases to be stabilised at 400 ppm carbon dioxide equivalents. In comparison with the 1990 level, this is equivalent to an increase in emissions of around 10 per cent. This means that average emissions per person globally need to decrease to 5.6 tonnes per capita per year in 2020 (including changes in land use) if the earth's population over this period is assumed to have increased to 7.6 billion.

Global emissions need to have decreased by 55-60% by 2050 in comparison with the 1990 level according to the Scientific Council. This is equivalent to average emissions of between 1.7 and 1.9 tonnes per capita per year if the world's population at this time is assumed to have increased to 9.2 billion.

Global greenhouse gas emissions need to be close to zero by 2100, according to the Scientific Council. This means that technology which can bring about *lowered* levels of greenhouse gases in the atmosphere in a robust way needs to be developed to offset emissions, for example from land use, which are very difficult to avoid.

Allocation of global responsibility

The United Nations Framework Convention Climate Change, which has adopted a production perspective on emissions, refers to there being a common but differentiated responsibility between countries. The industrialised countries are to take the lead in efforts to implement the decreases in emissions. Distribution models are used to calculate the level of emission reduction different countries should make on the basis of different principles, for example equal per capita emissions at 2050 or at 2100. The commitments are not limited to reducing emissions within the country but also cover measures in other countries. Results of calculations using allocation models may guide the international negotiations on a new climate agreement after Kyoto, but they do not need to be and probably will not be used in full. As the industrialised countries are assumed to take greater responsibility for reducing emissions, the emissions commitments of countries in the longer term may result in rich countries needing to undertake to contribute to emissions reductions globally which are even greater than the countries' own domestic emissions[51].

How low emissions per person do we need to get down to?

As low as possible and as soon as possible, is the gist of the account given above. A possible basis of comparison is to start from the ambition that emissions from one’s own consumption will not exceed the emission we need to see on average globally in the future, for example according to the Scientific Council. See Table 10.

Table 10: Emission levels per capita necessary according to the Scientific Council.

Sector	2004	2020	2050	2100
Average global emission tonnes per capita	7.6	5.6	1.7–1.9	0

As will be apparent from the following sections, many of us in Sweden can actually meet such a challenge as we probably already have substantially lower emissions from our consumption at the outset than many other people living in rich countries.

Where are the challenges in order to attain emissions from consumption of less than 2 tonnes of carbon dioxide equivalents per capita?

In 2003, Swedish consumption caused emissions of just over ten tonnes of carbon dioxide equivalents per person. A discussion follows in this section on how it might be possible to halve emissions by 2020 and to reduce them to no more than two tonnes in 2050. The challenge from 2008 to 2050 is illustrated by Figure 11.

[51] e.g. SEI (2008)

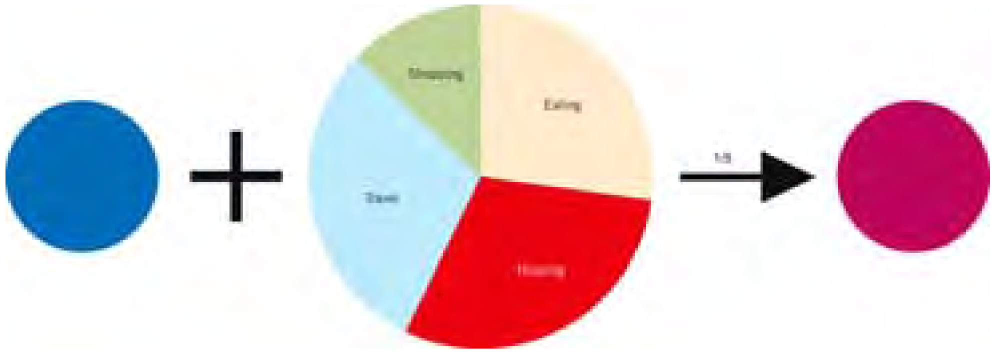

Figure 11: The two pie charts on the left shows emissions in 2003 from public and private consumption. Together they amount to 10 tonnes of carbon dioxide equivalents per capita. The challenge is to shrink emissions so that they fit into a pie mould of just 2 tonnes.

There is a wide spread between different individuals of emissions caused. Many people today do not emit more than five tonnes of carbon dioxide equivalents per person per year from their consumption. If the National Food Administration's dietary recommendations are followed and people eat approximately according to the plate model, the house is heated by something other than an oil-fired boiler, there is a normal electricity bill and people do not commute to work alone in a car with high petrol consumption, emissions will be less than five tonnes per year. This is true as long as people do not have holiday plans involving long-haul flights. Air travel on holiday causes emissions to shoot up.

Eating in the future

The great potential for reducing emissions in the short term rests with the consumer, as different foods lead to different levels of greenhouse gas emissions. One kilogram of beef may have a ten times greater impact on greenhouse gas emissions than one kilogram of chicken. If cattle are fed concentrates produced from soya cultivation that has indirectly displaced rainforest, the difference may be even greater, and the same applies if the land used for grazing has directly and indirectly resulted from deforestation. On the other hand, cattle allowed to graze naturally can eat plants that do not compete with human food, and they can do so on land that is not suited to growing cereals or other human food. Pigs and poultry can also eat concentrates, which may mean that the difference decreases. Reducing wastage in all stages of the food chain might also be a relatively quick way of reducing emissions.

In the longer term, the industry can reduce its climate impact with technology development, changed farming methods, a review of what input materials are used, crop selection and so on. The humus content in arable land consists of carbon, which means that the agricultural landscape can bind carbon. Other environmental quality objectives also need to be weighed up, for example *Zero Eutrophication, A Non-Toxic Environment* and safeguarding of *Biodiversity*. In addition, not only the present-day world population of just over six billion has to be fed, but so too will a further two to three billion by around 2050. Several factors therefore need to be borne in mind in dealing with the climate and environment impacts of eating.

Housing in the future

Housing is characterised by large investments, a long life with few opportunities for replacement, and the large number of behaviour-related decisions the consumer needs to take. Residents can bring about considerable changes by lowering the indoor temperature, reducing their use of electricity etc.

In the passive house barely any heating is needed except on the coldest days of the year. The great question instead is how the buildings with poorer energy performance that exist today and will remain for a long time to come are to be dealt with. It is easier to build an energy-efficient house from scratch than to create energy-efficient solutions by renovating an existing building. On the other hand, most houses will undergo at least one major renovation by 2050, and energy use can then be reduced.

As well as the consumer's choice of level of energy use, the impact of housing on climate is decided by how electrical and energy systems develop in the long term. Fossil-free electricity is limited and must therefore be used very efficiently.

Travel in the future

SHORT-DISTANCE TRAVEL

The average consumption of cars today is falling. The increasing use of renewable vehicle fuels also means that greenhouse gas emissions per kilometre driven are decreasing. There are, however, many other ways of reducing emissions, for example by planning journeys better and using public transport, cycling and walking more.

There are already more efficient car models on the market today. Great hopes are often pinned on plug-in hybrids, which run on electricity until the battery needs to be charged by the hybrid’s internal-combustion engine. These will shortly be on the market but will be relatively expensive. It may therefore take some time before they account for a large proportion of the vehicle fleet, and the climate impact depends on what electricity is available.

Towards 2050, it should be possible for the vehicle fleet to be largely replaced by electric cars with good performance, and just as in the case of housing, it is the electrical system that decides whether everyone can move around as much as today with low emissions. With a systematic transition to rail-mounted traffic, longer journeys too can be made in a more energy-efficient way and with low greenhouse gas emissions.

Biofuels are a solution, but there are limitations on how much biomass can be sustainably extracted from ecosystems. In addition, there is already competition for arable and forest land. The food industry, the paper and pulp industry, the timber industry and the bioenergy sector share the raw materials with the vehicle biofuels industry, and there is a need to set-aside land for recreation and to protect biodiversity. When the world's population increases, it will barely be possible to sustainably meet the fuel needs of transport, which to date have been increasing rapidly. More modern technology, such as second-generation biofuels, will, however, boost available volumes.

LONG-DISTANCE TRAVEL

Although the average Swede's car today is his or her largest emissions item, international travel represents the great challenge in terms of whether someone will be able to reduce their emissions or not. For those who have become accustomed to an annual long-haul holiday flight, it will be very difficult to reduce their emissions to below five tonnes of carbon dioxide equivalents by 2020. A semi-long-haul flight can be accommodated, provided the person concerned is economical with other emissions.

Unlikely technical development is required to attain really low emission levels from aviation in the long term. The aircraft being built today will be flying in 2020 and perhaps even in 2050.

Shopping in the future

Goods and services produced in Sweden should be able to be produced with ever lower emissions if the changes in transport and energy systems outlined above become reality.

Imported goods are often transported long distances, and their emissions are affected by the energy system that exists where they have been manufactured. This also applies to all imported inputs that Swedish industry builds into its products. In the longer term, however, all energy systems must have low greenhouse gas emissions.

One of the difficulties in bringing down the emissions of shopping is that so many goods and services are involved, while it is possible to reduce emissions by making a few strategic choices for the activities of travel and housing. In the areas of housing and travel it is possible to spend money on becoming climate-smart by insulating the house or buying a modern green car, while in the area of shopping more goods are generally bought when people have more money. On the other hand, shopping leads to lower emissions than eating, housing and travel. Other environmental problems, such as a non-toxic environment, are, however, closely related to the use of products.

The public sector in the future

The extent of public consumption also affects the scope for consumption calculated on a per-capita basis. At present just under two tonnes of greenhouse gas emissions per person per year is already accounted for by the public sector. The public sector can also reduce its emissions, for instance by technological shifts, as outlined above.

Measures to also reduce emissions from a production perspective

The discussion in this report has been based on consumption activities. It is clear that change is also required in production. This section therefore reflects the changes from a production perspective. It is a huge challenge to reduce emissions as much and as quickly as is required to stabilise the concentration of greenhouse gases in the atmosphere at sufficiently low levels. The UN's Intergovernmental Panel on Climate Change (IPCC) does, however, consider this possible. The IPCC showed in its evaluation in 2007 that there is extensive economic potential to reduce emissions by 2030, which, if it is attained, may be sufficient to reduce global emissions to below present-day levels instead of continuing to rise sharply, as is otherwise expected. For this a number of technical measures need to be implemented in all sectors of society and regions throughout the world. Existing low-carbon technology needs to come into general use, and there is a need for new technology that is under development to be disseminated over the next few decades. Large investments are required, in electricity production and elsewhere, which do not lead to greenhouse emissions, as well as extensive commitments to technological development in a number of areas. See Table 9 in particular for a production perspective of different sectors.

Table 9: Important technologies and methods to reduce emissions for different global production sectors (IIPC (2007) adapted by the Climate Committee (2008))

Sector	Key technologies and methods already on the market	Key technologies and methods expected to be on the market by 2030
Energy supply	More efficient supply and distribution, replacement of coal with gas, nuclear power, renewable heat and power sources (hydropower, solar, wind, geothermal energy and bioenergy), combined heat and power, early applications of CCS (e.g. storage of carbon dioxide from natural gas)	Carbon capture and storage (CCS) for installations that produce electricity with gas, biomass or coal, enhanced nuclear power, enhanced renewable energy, e.g. tidal and wave, concentrated solar radiation and solar-cell technology.
Transport	More fuel-efficient vehicles, hybrid vehicles, cleaner diesel vehicles, biofuels, change of mode of transport from road to rail and public transport, non-motorised transport (cycling, walking), physical planning and traffic planning	Second-generation biofuels, more efficient air transport, enhanced electric and hybrid vehicles with more powerful and more reliable batteries.
Housing and service	Efficient lighting and daylight ingress, more efficient appliances and heating and cooling installations, better cookers, better insulation, passive and active solar energy use for heating and cooling, alternative refrigerants, collection and recycling of fluorinated gases	Integrated design of commercial buildings with technology such as intelligent meters that permit feedback and control, built-in solar-cell technology in buildings
Industry	More efficient use of electricity for end users; recycling of heat and power, re-use and substitution of materials, control of emission of gases other than CO2, and a number of process-specific technologies	Enhanced energy efficiency, CCS technology for cement, ammonia and steel production, inert electrodes for aluminium processing.
Agriculture	Better management of cultivated and grazing land to increase carbon sequestration in the soil, restoration of utilised peatland and derelict land, better techniques for rice cultivation, cattle raising and manure management to reduce emissions of CH4, better techniques for use of nitrogen-containing fertilisers to reduce N2O emissions, energy crops to replace fossil fuels, better energy efficiency.	Improved crop yields
Land use and forestry	Forest planting, reforestation, forest management, reduced deforestation, better utilisation of harvested forest products, utilisation of forest products for bioenergy that can replace fossil fuels	Improved tree species that can increase production of biomass and binding of carbon dioxide, better techniques for remote sensing of the potential for carbon dioxide binding in vegetation and soil, and analysis of changes in land use.
Waste	Extraction of landfill gas, waste incineration with utilisation of energy, composting of organic waste, controlled treatment of wastewater, recycling and minimisation of waste	Biocover and biofilter to optimise oxidation of methane

Alongside changes in technology, changes in lifestyle and behaviour are also of great significance if it is to be possible for emissions to decrease. This potential could be realised by increased financial control, information, training and other initiatives that can eliminate obstacles to changes in consumption-related behaviour. The Scientific Council additionally notes that it is not at present regarded as possible to reduce emissions from aviation and from food production solely by technological development. The need for changes in consumption-related behaviour is therefore particularly clear in these areas.

In the longer term, the challenge is posed by the need for the entire global energy system to be changed over to a system that does not lead to greenhouse gas emissions, while the use of energy needs to become substantially more efficient and probably decrease in total in comparison with the present. There is also a need for it to be possible for global food supply to take place in a way that leads to substantially lower greenhouse gas emission than today.

Who can influence emissions?

Changes to reduce emissions must take place both in the behaviour of consumers and in relation to the technology used. The technology is both consumer-based and directly related to production. It is evident from the discussion above that efficiency improvements in technology are necessary. Electrical and energy systems in particular must be made virtually fossil-free. Behavioural changes are, however, unavoidable. This applies in particular to changes in food habits and limiting long-haul flights.

Consumers are able to influence their own behaviour and the extent of their activities. Consumers are also able to choose consumer-based technology, for example what car they drive. Private consumers and public procurement officers can also, to the same extent, influence what supply is on offer and what production methods are used. Producers and the business community have the greatest opportunity to influence production-based technology. The business community also decides to some extent what range of consumer products will be on the market. It also influences consumption and behaviour directly, for example through advertising and marketing. The necessary basis and incentives must also be created to a greater extent to bring about changes. Decision-makers and politicians have great responsibility here.

This report has not discussed what policy instruments can be used at different levels to bring about these changes. The fact that various actors have an *opportunity* for change does not signify that there are sufficient incentives to change and actually reduce greenhouse gas emissions.

Concluding remarks

The report points out that it is important to analyse greenhouse gas emissions from the consumption perspective and not solely from the perspective of geographical production. The consumption perspective provides a better picture of how our consumption patterns affect the global climate and what emissions are generated. As emissions are higher for Sweden in a consumption perspective, the challenge of attaining low future levels is even greater.

At the same time we are responsible for emissions within the country and must continue to make efficiency improvements and reduce these. Some of the domestic emissions in the consumption perspective are allocated to export products, but our responsibility and opportunity to reduce them remains. Responsibility for reducing emissions is shared by several actors. Both consumers and producers have their own responsibilities, while politicians must create the necessary basis for change.

Although climate is a priority environmental problem, there are other problems and objectives for society. There are also environmental problems other than the greenhouse effect that have not been discussed in any great detail in this report. There are often synergistic effects between measures to reduce greenhouse gas emissions and other environmental quality objectives. Improvements in energy efficiency, for example, do not just reduce carbon dioxide emissions but air pollutants as well. There are also conflicting aims, for example with excessive extraction of biomass fuels.

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Appendix: What is included in the activities?

A list follows of the product groups attributed to the four activities (eating, housing, travel, shopping) and their respective subgroups[52]. These are items according to the COICOP product codes in the SNI (Swedish Standard Industrial Classification) system.

Eating

Meat = meat

Dairy = milk, cheese and eggs.

Vegetables = vegetables

Fruit = fruit

Bread = bread and cereal products

Fish = fish

Sweets, spices and fats = oils and fats; confectionery; ice cream, jam, marmalade and confectionery, salt, spices, sauces and homogenised baby food.

Beverages and tobacco = coffee, tea and chocolate, soft drinks, juice and mineral water, spirits, wine, full-strength beer, beer classes I and II, tobacco.

Restaurant visits = restaurants, cafes, other food outlets, fast-food stands and dispensing machines.

Housing

Investment in and maintenance of housing – actual rent in rented accommodation, rent without electricity and heating; tenant-owner association, value in use rent without electricity and heating; holiday house, value in use rent without electricity and heating, goods and services for maintenance of the home;

Electric current = electric current

Domestic heating oil = direct emissions from stationary private burning; liquid fuels, oil, paraffin and LPG

District heating = district heating

Pellets, woodchips and gas = gas, solid fuels, wood, coal, pellets and woodchips.

Furniture = furniture, fittings, interior design articles and paintings.

Household utensils and kitchen appliances = larger household appliances as additional equipment, smaller electrical domestic appliances, repair of domestic appliances; household utensils

Gardening = flowers, garden plants, Christmas trees, soil, fertilisers and pots

Travel

Petrol and fuels = direct emissions from mobile private consumption, fuels and lubricants, petrol, diesel, oil, glycol and carburettor spirit;

Cars = cars; motorcycles, scooters, mopeds or motocross; cycles

Package travel = package travel, hotel and other overnight accommodation service

Bus and rail = rail transport, road transport, taxi and long-distance coach; public transport, other transport services, removals

Separate flight tickets = air transport

Separate ferry tickets = sea transport

Car ancillary costs = spare parts and accessories, maintenance and repair; driving licence, learning to drive, driving tests, admin. charges for licence and registration, vehicle inspection, bridge tolls; car parking, car benefit and car hire

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[52] Statistics Sweden (2008)

Shopping

Clothing and shoes = materials for clothing; clothing; clothing accessories, sewing accessories and threads; mending, rental and washing of clothes; shoes; repair and hire of shoes

Computers, telecommunications and TV electronics = telecom equipment, telecom services; landline, mobile and Internet; equipment for receiving, recording and reproducing sound/image, television, radio etc.; cameras; other photographic equipment and optical instruments; IT equipment; PCs, printers, accessories and calculators, typewriters, films, CDs, cassettes; recorded and non-recorded; repair of audiovisual, photographic and IT equipment

Beauty products = hair and beauty care.

Pets = pets, pet food and pet equipment, veterinary and other services for pets, pet boarding facilities etc.

Other products = carpets, incl. laying, household textiles; larger motorised appliances and tools; smaller tools; gardening equipment; accessories, batteries and lamps; consumables and cleaning products; medicines and vitamins, other medical products; spectacles, lenses, etc.; larger durable leisure products; caravans, boas and sports equipment; musical instruments and equipment for indoor activities; repair and maintenance of larger leisure products; toys, games, Christmas decorations, firework equipment and hobby articles, sports, fishing and camping equipment etc.; books including textbooks, excl. stamp albums, newspapers and magazines; other printed matter, stationery; electrical appliances for personal care; other products for body and beauty care; jewellery, clocks and watches including repair; other personal products, e.g. bags, pushchairs, child seats and various accessories.

Other services = furniture repairs, household services; cleaning, washing and hire of household equipment, outpatient healthcare, patient charges; dental care, patient charges; physiotherapist, chiropractor, therapist, etc., patient charges; inpatient medical care, patient charges; postal services; sports and recreational services, hire of equipment, participant charges; cultural services: cinema, museums, television charges, photography and photographic development; games; net of sums staked minus wins paid out; training, holiday home charges, child care’ elderly care, personal assistant, individual care, insurance services, financial services, miscellaneous other services, funerals, charges for certification and service.

The Climate Impact of Swedish Consumption

REPORT 5992

SWEDISH EPA
ISBN 978-91-620-5992-7
ISSN 0282-7298

Food, electricity at home, travel and clothing – emissions from our consumption create some 10 tonnes of carbon dioxide equivalents per person and year. Emissions of greenhouse gases take place both in Sweden and abroad where much of for example the food we eat and products we buy are produced.

The Swedish Environmental Protection Agency has in this report analysed how our consumption affects the climate. A consumption perspective has been used where emissions under the products whole lifecycle, including emissions abroad, are included. The total consumption is divided in private and public consumption. In the report public consumption is in focus and it is estimated to account for 80% of the emissions. The private consumption is divided into four activities Eating, Housing, Travel and Shopping.

The report points at five key areas which dominate the emissions and in these areas there are great possibilities to mitigate the emissions: how much do we drive and in what sort of car; how do we heat our homes; how much electricity is used at home; how much meat do we eat and what type; how far do we fly and how often.

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