Chapter 20
Prioritizing Within the Product-Oriented Environmental Policy – The Danish Perspectives

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Background

As a supplement to the site, substance and media specific environmental policies, Denmark has had, since 1998, a product-oriented environmental policy (at the European level known as "Integrated Product Policy"). The policy has been organized as prioritized activities in selected sectors and/or product areas. This prioritization was informed by the results from the project "Environmental prioritization of industrial products" (Hansen 1995). Other previous studies with similar objectives, i.e. to identify the most important product groups from an environmental perspective, include Dall et al. (2002) for Denmark, Finnveden et al. (2001) for Sweden, Nijdam and Wilting (2003) for the Netherlands, Nemry et al. (2002) for Belgium, and Labouze et al. (2003) for the EU. The Swedish and Dutch study use the same general methodology as our study, namely environmentally extended IO-analysis (Miller and Blair 1985), while the remaining studies use a bottom-up process based analysis.

Due to the environmental indicators used (energy consumption and resource loss) the product groups that are ranked high by Hansen (1995) are those with either large energy consumption or which are destroyed or dissipated during use. This includes the main energy carriers, transport activities (represented by the vehicles including their use phases), fertilizers, animal feeds, meat and dairy products, building materials, detergents, newspaper, beer and furniture.

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Dall et al. (2002) have a consumption perspective and include only private consumption. The study focuses mainly on energy consumption and concludes that food, car driving, and housing are the most important product groups. Also clothing and personal hygiene appear high in energy consumption.

The product groups that are ranked high by Finnveden et al. (2001) for the emissions of CO_2, SO_2 and NOx, are electricity and heat, food, dwellings, transport activities, and hotels and restaurants. The fact that retail trade and public services, such as waste handling and recreational activities, also come out high in the Swedish study is probably due to the specific infrastructure of the Swedish economy. Finnveden et al. (2001) also rank the product groups according to emission intensity, and here we find transport by ship at the top of the list. Also construction materials, fish & seafood, metals, agricultural products, and pulp and paper are ranked high on impact intensity. When considering the ranking by CO_2 and SO_2, it is also not surprising to find electricity and heat among the important products.

Nijdam and Wilting (2003) use a number of environmental indicators, including global warming, acidification, nutrient enrichment and photochemical ozone. For global warming they find the most important consumption groups to be food (30%), followed by leisure (22%, mainly due to transport for holidays), and housing (17%; mainly for heating and electricity).

Nemry et al. (2002) and Labouze et al. (2003) find dwellings and transport to be the most important product areas. Nemry et al. (2002) do not include food products in their ranking, while Labouze et al. find food products to be the largest source of eutrophication (due to fertilizer application) and a large source of global warming and photochemical oxidation (due to enteric fermentation and manure management). Nemry et al. (2002) furthermore point to packaging and electrical appliances as important products, while Labouze et al. (2003) find textiles among the largest sources of acidification and photochemical oxidation.

At the European level, the Commission has initiated in 2003 a project "Evaluation of environmental impact of products" (EIPRO), which includes a review of the above-mentioned studies and aims at identifying the products with the largest environmental improvement potentials (Tukker et al. 2004).

As a Danish contribution to this, the Danish Environmental Protection Agency commissioned an updated and more detailed method, to provide a well-documented decision basis for planning and selecting products for future product-oriented activities. The method is based on a combination of environmental statistics and the Danish national accounts, also known as environmentally extended IO-analysis (Miller and Blair 1985).

The method has been applied to provide prioritized lists of those product groups and industries where Danish environmental measures will give the largest environmental improvement, both for the products currently produced in Denmark (for domestic consumption or for export) and the products currently consumed in Denmark (domestically produced as well as imported). The result of this prioritization is presented in this paper, along with some considerations on the importance of applying different perspectives on the data.

Method

This section provides a short presentation of our methodology for prioritizing product groups. This is to be seen mainly as background information, since the main focus of this paper is on policy implications, not on methodology (see Miller and Blair 1985, and Weidema et al. 2004 for details).

The project takes its starting point in the Danish national accounts of the economic flows between Danish enterprises and institutions, i.e. their mutual purchases and sales, imports and exports, and supply to final consumption. This is also known as national input-output tables or short: IO-tables. These are then combined with data from different environmental statistics, starting with the Danish NAMEA (Danmarks Statistik 2003), which are adjusted to the same level of detail as the industries and product groups of the national accounts.

The assessment has been performed for the year 1999, since at the start of the project this was the most recent year for which comprehensive data were available. It has been checked and confirmed that 1999 was not an atypical year for any specific product group, so that the conclusions from the project will also be valid more generally. Obviously, trends in production and consumption change over time, so we would recommend the study to be repeated every 5 year to keep the policy information relevant. With the applied method, and given the current availability of data, such updating is not complicated.

The study includes all substances that contribute significantly to the eight environmental impacts that are normally included in product life cycle assessments, i.e. global warming, ozone depletion, acidification, nutrient enrichment, photochemical ozone formation, ecotoxicity, human toxicity and nature occupation.

Results are calculated for each impact category separately, using characterization factors expressing the contribution of each emitted substance to each impact category, as given by Hauschild and Wenzel (1998) and later updates (Olsen 2003, see also Weidema et al. 2004). An overall score for environmental impact is constructed by normalizing the results for each of the eight impact categories to the total impact from Danish production and consumption, and then adding these normalized results. Thus, the eight environmental impact categories all participate with equal weight in the overall score.

By taking the economic flows between all enterprises as a starting point, the chosen method ensures a high degree of completeness – avoiding the omission of processes with small contributions to many products, e.g. transport processes.

Nevertheless, to use IO-tables or NAMEAs as a basis for environmental analysis involves a number of limitations, some which are inherent to the methodology, and some have to do with data availability. Most of these limitations have been satisfactorily overcome by adjusting and expanding the NAMEA.

In terms of data availability, the main limitation of the official Danish NAMEA is the coverage of environmental exchanges, which is limited to specific air emissions. We have added more environmental exchanges, aiming for the same degree of completeness as in the normalization reference for Denmark provided by the Danish "EDIP" life cycle assessment methodology (Hauschild and Wenzel 1998).

The life-cycles of each product group have generally been constructed by linking the upstream processes proportionally to the monetary value of the flows between the processes, as is traditionally done in economic input-output analysis and product life cycle assessment. This implies the assumption that a change in demand for a product will lead to a proportional change in production volume in the entire supply chain. To take into account that not all industries can change their production volume in response to a change in demand (for example, because of the European quotas on milk production, a change in the output of milk from the dairies will not be able to influence the amount of milk produced in agriculture, and therefore not the environmental impacts from agriculture either), we analyzed all industries systematically for long-term production constraints, i.e. constraints that influence investment decisions, like the one mentioned for dairy farms. For the most important constrained industries we have divided the industry into a constrained and a non-constrained part, transferred the constrained supplies to the alternative non-constrained industry and added the constrained outputs as separate products in new final consumption group, typically named "industry name (constrained)". Since a constrained production is still relevant for non-market-based environmental measures, a constrained product takes part in the same way as any other product in the prioritization in the supply perspective.

An important limitation of IO-tables is the implicit assumption of homogeneity of the industries, i.e. that all products from an industry are assigned the same environmental impact per monetary unit. The higher the level of aggregation of industries, and the more diverse the industry in question, the more erroneous this assumption will be. Based on an uncertainty analysis, we subdivided the most important of such inhomogeneous industries, using hybrid techniques (see e.g. Joshi 2000; Suh et al. 2004; Suh et al. (2004).

Some of the accounting conventions applied in the national accounts are also less appropriate for environmental IO-analysis, and have therefore been corrected (classifying previously unclassified imports, including tourism expenditures, redistributing investments to the industries supplying the investment goods, and redistributing financial intermediation services to the financial industries supplying the loans).

An important assumption of traditional IO-analysis is that imported products are produced in the same way as the similar domestic products, although it is well-known that emission factors (e.g. CO_2/DKK) can vary significantly from country to country due to differences in geographic and administrative conditions, industries composition, applied technology, management systems and sizes of production units. This assumption was applied in an initial analysis, and showed that the imports to Denmark resulted in an average environmental impact of a size approximately one third of the environmental impact from the Danish production and use stages. As Denmark has very little raw material extraction and primary processing, it is to be expected that applying Danish emission factors to foreign production will result in an underestimation of the actual environmental impact. This expectation was confirmed in a later analysis, where emission factors from the USA were used for the foreign industries. This resulted in an average environmental impact of a simi-

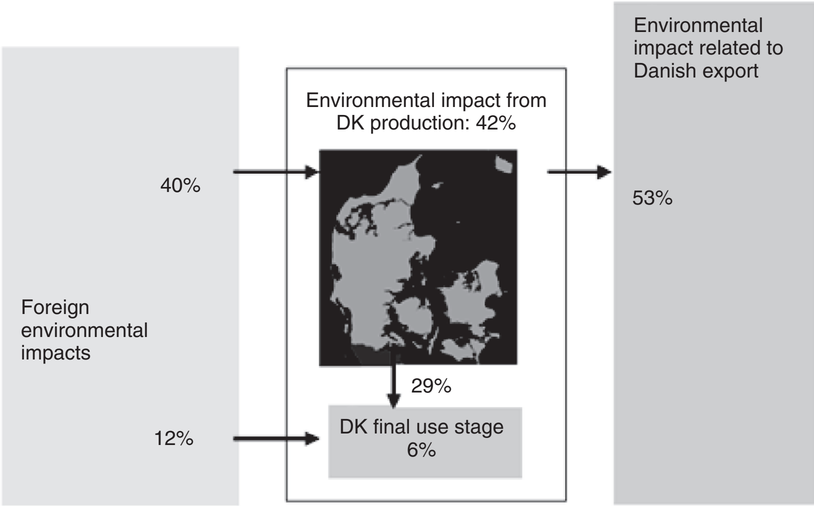

Fig. 20.1 The Environmental Impact Potential Related to Danish Production and Consumption, in Percentage of the Total Environmental Impact, Expressed as an Average of Eight Environmental Impact Categories, Which All Participate with Equal Weight. From a Supply Perspective, the Total Environmental Impact (100%) can be Divided in the Part That is Related to Danish Industry (40% for the Products Used by Danish Industries and 42% from Danish Production) While the Remaining 18% are Environmental Impacts Abroad Related to the Products Imported to Denmark for Direct Consumption (12%) and from the Final Use Stage (6%). From a Consumption Perspective, the Same 100% Can Be Divided in the Part Related to Danish Final Consumption (12% + 29% + 6% = 47%) and the 53% Related to the Exported Products Consumed Abroad

lar size as the environmental impact from the Danish production and use stages (see Fig. 20.1), i.e. three times the original result. It was decided to use the US-American data after an initial analysis of available NAMEA data. Contributing to this decision was the relatively low level of aggregation of the US table (493 industries), the high number of emissions available (more than in the Danish NAMEA) and the relatively high completeness of the US-American economy in terms of industries covered (due to the size of the country, practically all kind of industries are found within the country). We compared the emission factors from the US data (as provided by Suh 2003) to the emission factors from the closest corresponding Danish industries. In general, we found the original US data to provide a reasonable proxy for imports to Denmark, while in some instances we found it necessary to make adjustments to the US data.

Finally, using monetary IO-tables to represent physical flows of commodities between industries implies an assumption of proportionality of monetary and physical flows. Only for energy related air emissions, does the Danish NAMEA relate to physical flows of specific fuels based on the Danish energy matrices, which are provided in both economic and physical units. In connection to the above-described subdivision of industries, we have sought to minimize this problem by isolating physical product flows related to specific emissions, such as ozone depleting substances from refrigeration.

The Importance of Different Perspectives

When asking for which product groups the Danish product-oriented environmental policy would give the largest environmental improvement, the system boundaries must be drawn from a life-cycle perspective, i.e. for each product group including all upstream processes from the "cradle", i.e. material extraction from nature, and downstream to the "grave", i.e. waste treatment. Furthermore, it is necessary to look both at the products produced in Denmark (as the policy could influence the Danish industries directly) and at the products consumed in Denmark (as the policy could influence foreign producers through supplier requirements and influence the Danish consumers directly).

This provides the two basic perspectives applied in this study[1]:

The *supply* or *net production* perspective looking at the total environmental impacts caused by the supply of products *from Danish industries* going either *to final consumption or export*, i.e. equivalent to the net production of Danish industries.[2] To avoid double-counting, production for internal use in Danish industries is only included as upstream processes for the net production. This is a "cradle to gate" perspective, where the gate is the point where the product leaves the Danish industry. It includes the foreign products imported for use internally in Danish industry. Compared to the consumption perspective (see below) it excludes products imported to Denmark directly for final consumption (i.e. outside of Danish industries) and the final use, but includes production for export from Denmark.

The *consumption* perspective, looking at the total environmental impacts caused by the products *from foreign or Danish industries* going *to final consumption in Denmark*, both private and public. It is a complete "cradle to grave" perspective on these products. This implies that the use stage is included, unless specifically excluded. Compared to the supply perspective, the consumption perspective excludes products exported from Denmark (and their upstream processes), but includes products imported to Denmark directly for final consumption.

A third perspective combines the supply and consumption perspectives. This is:

The *process* perspective, looking at the environmental impacts, separately from each single process within both *foreign and Danish industries and Danish households*, caused by the products going *to final consumption in Denmark or export*. This is a "gate to gate" perspective of each process, scaled to the size determined by *Danish production and consumption*. It thus includes all products imported to Denmark, also those for direct consumption,[3] and all products produced in Denmark, also those exported. It also specifically includes products that are solely produced for use internally in Danish industries and therefore not separately reported by either of the two perspectives, because they are neither going to final

[1] The exact mathematical expressions for the applied perspectives are provided in Appendix.

[2] Net production of Danish industries is the products supplied by Danish industry for domestic final consumption or for export, as opposed to the gross production that includes also the products supplied for internal use in Danish industry.

[3] Products for re-export are not included in any of the perspectives applied.

consumption nor export. Like the supply perspective, it also includes constrained processes. Like the consumption perspective, it includes environmental impact from the use stage.

Thus, the three perspectives differ mainly in their system delimitation, as shown in Table 20.1. The data used are the same for all three perspectives, see also

Table 20.1 Three Perspectives on the Influence-Spheres of Danish Product-Oriented Environmental Policy and Their Corresponding System Delimitations

	Supply perspective	Consumption perspective	Process perspective
Life-cycle perspective	"Cradle to gate"	"Cradle to grave"	"Gate to gate"
Policy objective	Reducing life-cycle impacts from Danish industries and their products	Reducing life-cycle impacts from Danish consumption	Reducing impacts from processes contributing most to Danish production and consumption
Sub-division of product groups	According to Danish producing industries	According to consumption groups (need groups/product functions)	According to producing industries and use stage processes according to consumption groups
Captures/includes impacts related to:	• Danish production for Danish final consumption and upstream imports to this • Exported products • Constrained production	• Danish production for Danish final consumption and upstream imports to this • Imports directly to Danish final consumption • The use stages • Consumption of Danes traveling abroad	• All processes in the supply or consumption perspectives • Danish production for use in Danish production, as separate products (also included in the other perspectives, but not separately)
Ignores/excludes impacts related to:	• Imports directly to Danish final consumption • The use stages • Consumption of Danes traveling abroad	• Exported products • Constrained production	

Appendix. However, the differences between the perspectives influence their results in terms of prioritized product groups (see Table 20.2) as well as their policy relevance (as shown in Table 20.4).

The supply perspective results in identification of product groups where Danish industry has a large output volume, for example transport by ship and pork products, disregarding that these products are mainly exported. For an export-oriented economy, like the Danish, the supply perspective is essential for catching that part of the environmental impacts (and improvement options), which are related to the export industry. Also, due to its inclusion of the export products, the supply perspective will identify product groups that are not going to final consumption, i.e. intermediate products used in foreign industries, e.g. transport by ship and wholesale trade. The environmental impact from these intermediate service products contributes to the environmental impact of many different final consumer products, and therefore does not become visible unless these intermediates are regarded as products in their own right. Interestingly, wholesale trade does not appear in the top-ten of the process perspective, since the environmental impacts are not due to the trade process itself, but due to the impacts from its supplying processes, mainly transport and packaging and to a lesser extent advertising and buildings. On the other hand, the process perspective identifies basic ferrous metals as a process with an important product, which reflects this product takes part as an intermediate in many other products. This product does not appear in the supply perspective because it is not produced to any significant extent in Danish industries. Also, the supply perspective does not capture environmentally important products that are imported directly to final use in Denmark (such as textiles, detergents and automobiles), products with important use phase emissions (car driving, heating in dwellings), and consumption of Danes traveling abroad, which are only captured by the consumption perspective.

These examples all show the importance of being able – as in this project – to analyze the environmental impacts from different perspectives.

The total environmental impact of a product group depends partly on its environmental impact intensity (i.e. the impact per monetary unit), partly on the size of the product group in economic terms. When prioritizing product groups according to total environmental impact, it is unavoidable that the result is influenced by how the product groups are defined, and especially their level of aggregation. A highly aggregated product group is more likely to show up among the top ten, and by disaggregating it into a number of smaller product groups, it can be made to disappear from the top ten. For example, in our study, the product group "education and research" only reaches the top-ten of environmental impact (see Table 20.2) because it is a highly aggregated product group. In itself, education has very low environmental impact intensity and would not have reached the top ten if it had been divided into primary, secondary and higher education, and adult education etc.

To counter this inherent arbitrariness in the ranking, it is relevant also to look at the prioritization when impact intensity alone is used as the ranking principle (see Table 20.2), i.e. ignoring the size of the product group. A product with a large impact per economic value will then appear on the top of the prioritization also when disaggregated. In this approach, the only way an important product can disappear

Table 20.2 Top Ten Most Important Product Groups Depending on Perspective and Ranking Principle

System delimitation: Ranking principle	Supply perspective	Consumption perspective	Process perspective
Total impacts (impact intensity * production volume)	• Transport by ship (out of which 99% is for export) • Pork and pork products (out of which 80% is for export) • Cattle and dairy products (constrained) • Electricity and heat (constrained) • Beef and beef products (out of which 71% is for export) • Dwellings (entirely for domestic consumption) • Industrial cooling equipment (entirely for export) • Wholesale trade (out of which 61% is for export) • Restaurants and other catering (out of which 4% is for export) • Defence, justice, public security etc. (entirely for domestic consumption)	• Car purchase and driving in DK, private consumption • Dwellings and heating in DK, private consumption • Meat purchase in DK, private consumption • Tourist expenditures by Danes traveling abroad, private consumption • General public services, public order and safety affairs • Clothing purchase and washing in DK, private consumption • Catering, DK private consumption • Personal hygiene in DK, private consumption • Education and research, DK public consumption • Bread and cereals purchase in DK, private consumption	• Transport by ship, DK and ROW (Rest-Of-World) • Pig farms, DK • Meat animal farms and meat industry, ROW • Dairy farms (constrained), DK • Basic non-ferrous metals industry, ROW • Industrial cooling equipment industry, DK • Electricity production (constrained), DK • Car driving in DK, private • Refining of petroleum products etc., ROW • Detergents and other chemical industries, ROW

(continued)

Table 20.2 (continued)

System delimitation: Ranking principle	Supply perspective	Consumption perspective	Process perspective
Impact intensity alone	• Industrial cooling equipment • Meat and meat products, incl. fish and seafood • Agricultural products in general • Basic non-ferrous metals • Transport by ship • Motor vehicles, parts, trailers, etc. • Tobacco products • Basic plastics • Fertilizers • Cement, bricks, tiles, etc.	• Fireworks, private cons. • Meat purchase, private • Eggs, imported, private • Car driving for holiday abroad, private • Detergents prepared for use, imported, private • Potatoes etc., private • Bread and cereals in DK, imported, private cons. • Pet food, imported, private consumption • Non-durable household goods n.e.c. (includes labels, polishes, minor textile items, wrapping paper, brooms and brushes, carbon dioxide cartridges and pesticides) • Vegetable oils, imported, private consumption	• Not applied

from the top of the prioritization is if it is aggregated with another product with a low environmental impact. This means that it is still possible that very inhomogeneous product groups (in terms of impact intensity) can conceal products with large impact intensities. However, this problem can be solved by appropriate disaggregation.

Thus, arbitrariness in the ranking is reduced partly by studying impact intensity alone, partly by ensuring that the product groups are defined so that producing industries are as homogeneous as possible and so that consumption groups are based on what needs the different products fulfill. In this functional approach to defining consumption groups, the entire consumption is broken down from top down, so that important product groups are not "concealed" and products that functionally belong together (such as car purchase and car driving) are not separated.

Key Results

To be relevant for product-oriented environmental policy, a product group must have both high total impact and high impact intensity. Surprisingly, this is the case for most of the top-ten product groups in Table 20.2. Notable exceptions are "Education and research" which, as already mentioned, has a high level of aggregation that places it high in total impacts in spite of a low impact intensity (and thus with an inherently low relevance for specific policy interventions) and tobacco products and fireworks that have high environmental impact intensity, but a low volume that make them less relevant for a policy intervention. That the last two product groups appear on the top-ten nevertheless points to them as being under-priced compared to their environmental externalities (which are not even completely covered by the impact categories applied in this study, which does not include noise and passive smoking).

In Table 20.2 and Fig. 20.1, environmental impact is expressed as an average of eight impact categories (global warming, ozone depletion, acidification, nutrient enrichment, photochemical ozone formation, ecotoxicity, human toxicity and nature occupation), which all participate with equal weight. For results per impact category, see Weidema et al. (2004). As an example of the information that can be found here, Table 20.3 shows the results for the consumption perspective for the impact category human toxicity.

The top-ten product groups in Table 20.2 account for a surprisingly large share of the total environmental impacts from Danish production and consumption. In the supply perspective, ranked according to total impacts, the top-ten products groups (out of a total of 138) account for 45% of the total environmental impact from Danish production and consumption. In the consumption perspective, ranked according to total impacts, the top-ten products groups (out of a total of 98) account for 57% of the total environmental impact from Danish consumption, and 25% of the total impact from Danish production and consumption.

This implies that the product-oriented environmental policy may result in large improvements by focussing specifically on these product groups. However, it is still necessary to be cautious that any specific measures do not lead to problem-shifting.

For those product groups that have been identified as most important, significant improvement options have been identified and ongoing activities have been reviewed (see Weidema et al. 2004).

A quantitative uncertainty assessment has been performed in order to provide the prioritization results with confidence intervals (see Table 20.3). Generally, the difference between the product groups are so large that their overall position in the prioritization (among the 10 most important, among the 20 most important etc.) is very stable, even for product groups where the environmental impact is determined

Table 20.3 Product Groups Within Danish Consumption with the Largest Human Toxicity Potential (HTP), in Person-Equivalents (PE) and % of Total HTP from Danish Production and Consumption

	HTP (in PE)	In % of total	Accumulated %
Dwellings and heating in DK incl. maint. and repair, private	4.3E + 05 ± 18%	8.0	8
Car purchase and driving in DK, private consumption	3.3E + 05 ± 27%	6.2	14
Tourist expenditures abroad, private, except car driving	1.1E + 05 ± 39%	2.1	16
General public services, public order and safety affairs in DK	1.1E + 05 ± 11%	2.0	18
Economic affairs and services, DK public consumption	9.3E + 04 ± 14%	1.8	20
Education and research, DK public consumption	8.5E + 04 ± 12%	1.6	22
Television, computer etc. in DK, incl. use, private consumption	7.3E + 04 ± 40%	1.4	23
Personal hygiene in DK, private consumption	6.9E + 04 ± 17%	1.3	24
Hospital services in DK, public consumption	6.5E + 04 ± 23%	1.2	26
Catering, DK private consumption	6.5E + 04 ± 14%	1.2	27
Furniture & furnishing in DK, private consumption	6.5E + 04 ± 16%	1.2	28
Transport services in DK, private consumption	6.1E + 04 ± 14%	1.2	29
Clothing purchase in DK, private consumption	5.8E + 04 ± 41%	1.1	30
Toys, DK private consumption	5.8E + 04 ± 105%	1.1	31
Meat purchase in DK, private consumption	5.7E + 04 ± 17%	1.1	32
Telecommunication and postal services in DK, private cons.	4.6E + 04 ± 37%	0.9	33
Retirement homes, day-care etc. in DK, public consumption	4.6E + 04 ± 30%	0.9	34
Recreational services in DK, private consumption	4.3E + 04 ± 22%	0.8	35

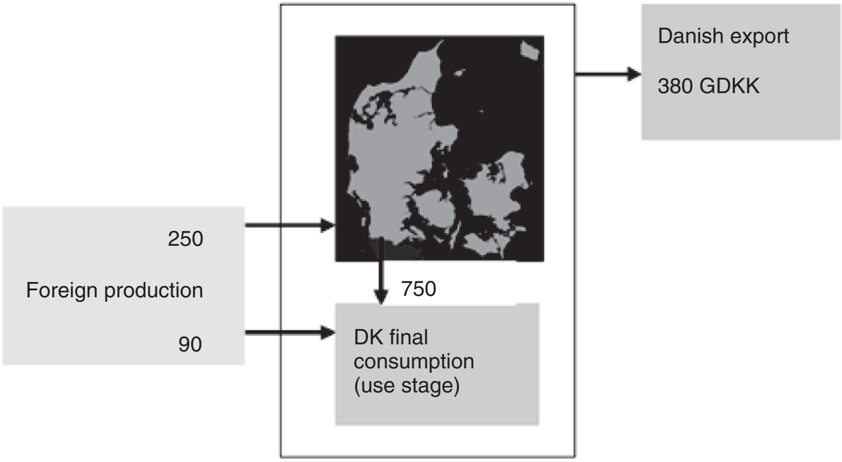

Fig. 20.2 The Flows of Products Related to Danish Production and Consumption, in Monetary Terms. Data Based on the National Accounting Matrices for Year 1999. Danish Consumption Amounted to 840 GDKK (Without Product-Related Taxes). Out of this 90 GDKK Were Products Imported Directly for Final Consumption, While 750 GDKK was from Danish Production. Danish Production also had an Import Totaling 250 GDKK (Without Re-export), but also an Export at a Value of 380 GDKK

with relatively large uncertainty. The main source of uncertainty is the aggregation level of data for the industries.

Danish exports are responsible for approximately half of the environmental impacts caused by Danish industry (see Fig. 20.1), in spite of this export contributing only half as much economic value as the Danes' own consumption (see Fig. 20.2). Thus, the export is relatively environmentally intensive. In other words, both imported products and products produced for export in general cause more environmental impact than products produced in Denmark for the Danish market. Especially noticeable is the export of meat and ship transport.

Figures similar to Figs. 20.1 and 20.2 can be made for each single product group and each single impact category, thus providing information on how environmental impacts are related to the import and export of that commodity. This could be useful e.g. when discussing how emission quota can best be designed and administered at the national level.

As it may be seen from Table 20.2, high environmental impact intensity is often linked to primary products, i.e. un-processed bulk products like fish, agricultural products directly from the farm, basic metals and plastics etc. Not presented in Table 20.2, but in the detailed project report (Weidema et al. 2004), low impact intensity is primarily linked to products with a relatively high proportion of labor, which does not contribute with environmental impact. This is also the explanation behind public consumption having much smaller environmental impact intensity than private consumption. Depending on the impact category, one DKK used by public authorities has an environmental impact between 13% and 64% of that of one DKK used by a private Dane.

Comparison with Results of Previous Similar Studies

In general, our results confirm those of the previous studies mentioned in the section "Background." However, the different perspectives and especially aggregation levels used by the different studies make exact comparisons difficult. For example, we regard electricity and heating as products to be ranked, while Hansen (1995) ranks the *energy carriers* including their use phase and Nemry et al. (2002) rank the *electrical appliances* including their use phase. Similarly, Nemry et al. (2002) point to packaging as an important product group, while packaging is not included as a product group on its own in our study, but contributes to explaining our high ranking of wholesale trade.

Other differences between studies may be explained by differences in the environmental indicators used. For example, Hansen (1995) apply the indicator "resource use", which implies that products that are destroyed or dissipated during use, such as detergents, newspaper, beer and furniture, receives a high ranking. Our study focus less on resource use and therefore such products appear less important in our prioritization.

Differences between countries in terms of the structural composition of industries are the reason for other differences in results. For example, Swedish pulp and paper industry has high impact intensity, while the corresponding Danish industry has a completely different product composition (more finished products), explaining its lower impact intensity.

Differences in scope may also explain some differences between studies. For example, tourist expenditures and car driving (private fuel use) do not appear in the Swedish ranking, since these product groups were not included in the Swedish data. Similarly, Nemry et al. (2002) do not include food products in their ranking.

It is interesting to note that dwellings and transport appear as important product areas in all studies, in spite of completely different methodological approaches (IO-analysis and bottom-up process analysis). This points to these two product areas as being of such size that they are likely to appear in any priority list, despite differences in methodology and data basis to derive these lists.

Implications for Policy

The relative importance of imports and exports illustrated by Figs. 20.1 and 20.2 naturally leads to a recommendation that the Danish product-oriented policy must include – and even focus on – both foreign producers and foreign markets. The importance of the supply perspective to identify important exported products, and the consumption perspective to capture important imported products, has already been mentioned.

Also in other ways, it appears that the different perspectives supplement each other. In Table 20.4, the policy relevance of the different perspectives is summarized.

Table 20.4 Policy Relevance of the Three Perspectives Depending on the Applied Ranking Principle

System delimitation: Ranking principle:	Supply perspective	Consumption perspective	Process perspective
Total impacts (impact intensity * production volume)	Suggests what product groups to target with policy elements that: • Address the producing industries directly • Create markets for environmentally improved products • Address the export markets	Suggests what product groups to target with policy elements that: • Address the level of consumption • Address consumer choices and behavior • Create labelling initiatives that include imported products • Address public consumption	Suggests which processes to target with policy elements that address process optimizations directly
Impact intensity alone	Suggests what product groups to target with policy elements that • Seek to substitute low priced, high-impact material inputs or techniques with high-quality, low impact labor/ service inputs, materials or techniques	Suggests what product groups to target with policy elements that: • Seek better correspondence between product price and environmental impact • Address consumer choices and behavior, taking into account substitutions as a result of price differences (re-bound effects)	Suggests which processes to target with policy elements that • Address process eco-efficiency (better correspondence between net value added and environmental impact)

While the supply perspective leads to a focus on industries' options for producing the same product in alternative ways, reducing impacts and/or reducing inputs (costs), the consumption perspective leads to a focus on options for substituting between products fulfilling the same need – or even substituting between needs. The process perspective supplements this by focussing attention on those processes where improvements would contribute significantly to many product groups.

The additional ranking according to impact intensity highlights important aspects of sustainable consumption, namely:

- That as long as the total consumption in monetary terms remains the same, reducing the level of consumption of one specific product may not have a positive impact on the environment – a change will only happen when substituting with products with a lower impact intensity.
- That overall environmental impact is best reduced by a strategy that combines impact reduction with measures that can increase the sales price, either by increasing the labor/service content and/or quality of the products, or through environmental product taxes that internalize the environmental impacts into the product prices.

Products with low environmental impact intensity are particularly services, e.g. bookkeeping and auditing, insurance, social security, financial and legal services, education and research, kindergartens and crèches, home and day care services and retirement homes. It is obvious that the products with high environmental impact intensities, such as food and transport, cannot be directly substituted by these low impact intensity services, since they do not fulfill the same needs. However, the information on impact intensities can be used to point out the products for which it would be highly desirable to search for satisfactory substitutes, which may go beyond the mere substitution of products with identical properties. For example, the general consumer welfare would not necessarily be affected by a non-compensated reduction in the amount of (high-impact-intensity) meat consumed. This could point to possible, desirable changes in the general consumption pattern.

Applying impact intensity alone as a ranking principle in the process perspective is equivalent to ranking according to process eco-efficiency (impact per net value added). As can be seen in Table 20.2, we have not applied this principle, since for prioritization of product groups we find it more relevant to look at product eco-efficiency (impact per product price), particularly when the use stage is included, as in the consumption perspective. However, this does not mean that process eco-efficiency may not be relevant in a product-related context as, for example, demonstrated by the application of the E2-vector by Goedkoop et al. (1998), identifying eco-efficiency based options for substituting processes within a product life cycle.

Conclusion

It has been demonstrated that available data and methods are sufficient to identify, within the Danish economy, the most important product groups from the perspective of environmental policy.

The system delimitation and the ranking principles have decisive influence on the results, as well as on the policy implications, which leads to the recommendation to apply several complementary system delimitations, notably both a supply and a consumption perspective, and a ranking according to both impact intensity and total impact. By combining these perspectives and principles, it is possible to gain an in-depth understanding of the policy options.

The most important cause of uncertainty in the results stems from the rather high data aggregation level. Thus, the most important improvement on the study results would be achieved by a further disaggregation of the 138 industries and 98 consumption groups applied in this study using hybrid techniques.

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Appendix: Mathematical Expression of the Three Perspectives Applied

Based on the data for environmental exchanges (emissions, etc.), the magnitude of environmental impacts can be calculated using life cycle impact assessment methodology (e.g. Hauschild and Wenzel 1998). Let b_{ij} denote the amount of environmental exchange i by the process or industry producing product j. Let c_{ki} denote the characterization factor for the contribution of an environmental emission i to the impact category k, and n_k and w_k respectively the normalization reference (in this study the total impact for Danish production and consumption) and the weighting factor (=1, in this study), for impact category k. Then the weighted total direct environmental impact m of product j is calculated by

$$m_j = \sum_k \left(w_k \frac{\sum_i c_{ki} b_{ij}}{n_k} \right) \tag{20.1}$$

which in matrix notation becomes,

$$\mathbf{m} = \mathbf{w}\hat{\mathbf{n}}^{-1}\mathbf{C}\mathbf{B} \tag{20.2}$$

The *supply perspective* takes the environmental intervention generated *by the Danish industries and their upstream imports* to satisfy the *Danish final demands and exports*. Let $\mathbf{B}^{\mathrm{Dk}}$ denote the environmental intervention per unit monetary production by process (industry) matrix for the industries in Denmark and $\mathbf{B}^{\mathrm{RoW}}$ the same for the rest of the world. Similarly, let $\mathbf{A}^{\mathrm{Dk}}$ and $\mathbf{A}^{\mathrm{RoW}}$ denote direct requirement coefficients matrices for Denmark and the rest of the world, respectively. Let $\mathbf{T}^{\mathrm{DR}}$ and $\mathbf{T}^{\mathrm{RD}}$ denote domestic (Danish) industry by foreign (rest of the world) industry and foreign industry by domestic industry matrix, respectively, both showing the international trade flows between the domestic and foreign industries. I.e., $\mathbf{T}^{\mathrm{DR}}$ shows inter-industry exports from Denmark to the rest of the world and $\mathbf{T}^{\mathrm{RD}}$ does that of the opposite direction. The amount of environmental impacts caused by Danish production processes throughout both domestic and foreign supply-chain is calculated by

$$\mathbf{m}^{*} = \mathbf{w}\hat{\mathbf{n}}^{-1}\mathbf{C}\left[\mathbf{B}^{\mathrm{Dk}}\ \mathbf{B}^{\mathrm{RoW}}\right]\left[\mathbf{I} - \begin{pmatrix} \mathbf{A}^{\mathrm{Dk}} & \mathbf{T}^{\mathrm{DR}} \\ \mathbf{T}^{\mathrm{RD}} & \mathbf{A}^{\mathrm{RoW}} \end{pmatrix}\right]^{-1}\begin{bmatrix} \mathrm{diag}(\mathbf{y}^{\mathrm{DDK}} + \mathbf{y}^{\mathrm{EDK}}) \\ \mathbf{0} \end{bmatrix} \tag{20.3}$$

Where $\mathbf{y}^{\mathrm{DDK}}$ and $\mathbf{y}^{\mathrm{EDK}}$ denote the total final consumption of domestically produced products by Danish households and exports, respectively, and diag($\mathbf{x}$) generates a diagonal matrix out of the vector $\mathbf{x}$.

The *consumption perspective* covers the environmental interventions generated from the *domestic and foreign production processes* to satisfy the *Danish domestic final consumption* on both domestically produced and directly imported products and the environmental emission *directly generated by Danish households*. Let $\mathbf{Y}^{\mathrm{DDK}}$ denote the product by consumption category matrix for domestically produced products consumed by Danish final consumers and $\mathbf{Y}^{\mathrm{IDK}}$ that for the imports directly consumed by Danish final consumers. Let $\mathbf{E}^{\mathrm{Dk}}$ be the environmental intervention by consumption activity matrix for the direct emissions generated directly by final consumption activities in Denmark. Overall, the environmental impacts per consumption activity including direct emissions from the final consumers and considering the entire supply-chain throughout both the domestic and the foreign supply-chain is calculated by

$$\mathbf{m}^{**} = \mathbf{w}\hat{\mathbf{n}}^{-1}\mathbf{C}\left\{\left[\mathbf{B}^{\mathrm{Dk}}\ \mathbf{B}^{\mathrm{RoW}}\right]\left[\mathbf{I} - \begin{pmatrix} \mathbf{A}^{\mathrm{Dk}} & \mathbf{T}^{\mathrm{DR}} \\ \mathbf{T}^{\mathrm{RD}} & \mathbf{A}^{\mathrm{RoW}} \end{pmatrix}\right]^{-1}\begin{bmatrix} \mathbf{Y}^{\mathrm{DDK}} \\ \mathbf{Y}^{\mathrm{IDK}} \end{bmatrix} + \left[\mathbf{E}^{\mathrm{Dk}}\ \mathbf{0}\right]\right\} \tag{20.4}$$

The process perspective covers the environmental interventions generated by domestic and foreign production processes and Danish households to satisfy both Danish consumption on domestically produced and directly imported products as well as Danish exports. More importantly, now the total amount of environmental interventions generated is not attributed to the end products, but is attributed on-site to the production or final use processes that generate the environmental intervention. This is calculated by

$$\mathbf{m}^{***} = \mathrm{diag}\left(\mathbf{w}\hat{\mathbf{n}}^{-1}\mathbf{C}\left[\mathbf{B}^{\mathrm{Dk}}\ \mathbf{B}^{\mathrm{RoW}}\ \mathbf{E}^{\mathrm{Dk}}\right]\right)\left[\mathbf{I} - \begin{pmatrix} \mathbf{A}^{\mathrm{Dk}} & \mathbf{T}^{\mathrm{DR}} & \mathbf{0} \\ \mathbf{T}^{\mathrm{RD}} & \mathbf{A}^{\mathrm{RoW}} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} \end{pmatrix}\right]^{-1}\begin{bmatrix} \mathbf{y}^{\mathrm{DDK}} + \mathbf{y}^{\mathrm{EDK}} \\ \mathbf{y}^{\mathrm{IDK}} \\ \mathbf{I} \end{bmatrix} \tag{20.5}$$