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# The long term trade implications of changes in energy technology

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## **Abstract**

This paper examines the importance of changes in energy technology for long-term trade developments. The Danish manufacturing industry is considered as a case with emphasis on the consequences of changes in the Danish energy system in the years 1966-1992.

Energy technologies affect the competitive position of industries through their energy costs. Another important effect of the change in energy technologies is the competitive option for the industries producing the capital equipment of a specific energy technology. Here the consequences for the wind turbine manufactures and for the manufactures of pipes for district heating can be highlighted.

The paper presents an empirical investigation of the Danish industries with respect to the energy intensity and the relative production development of the energy intense industries relative to the average industry. The degree to which basic manufacturing industries and heavy industries have decreased their energy consumption by replacing elements of own production that have high energy content with imports is examined.

Energy demand changes that are related to change in trade patterns have implications for different issues as energy efficiency developments for industries, international comparisons of energy demand and the discussion of the relevance of different policy measures to reduce greenhouse gases.

## **1. Introduction**

Changes in energy technology have impacts on foreign trade. Three different aspects of change in technology can be highlighted.

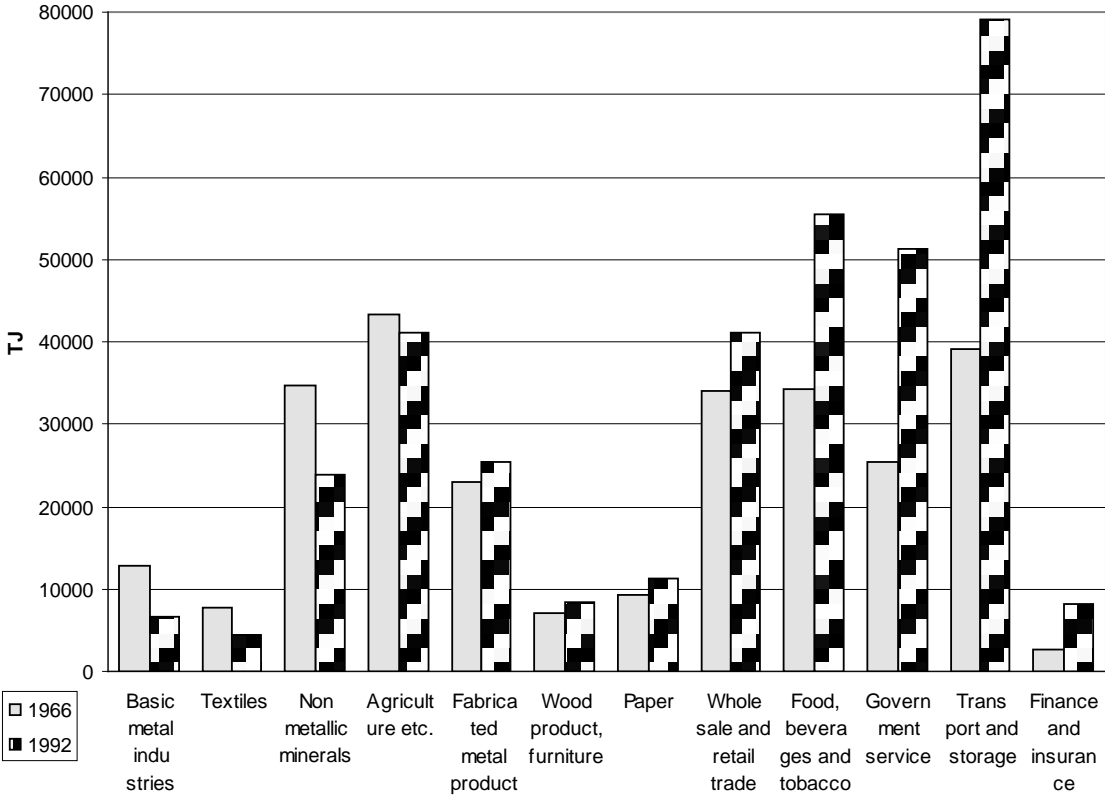
- Change in energy efficiency and technology has consequences for the competitive position of industries.
- New energy technologies creates export possibilities.
- Energy technology change and trade in energy commodities.

Denmark has very few energy intensive industries today. To some extent the development of energy technologies and energy policies for the implementation of new technologies have contributed to less energy intense industries in Denmark. It also seems that the relatively energy intensive industries have succeeded in energy efficiency improvements to some extent accomplished by changing their activities towards more R&D and consulting. Any expansion of the energy intense part of production have then been placed abroad. There are several other explanations of why the share of energy intense industries of Denmark have decreased. Energy intense industries will, for example, often be characterised by increasing returns to scale. With high energy cost

shares the international competitive position have been dependent on the ability to decrease energy costs and compete or to lose their market.

The relative importance of technological progress in energy technologies versus labour augmenting technological progress is not very clear. For the industries with low energy intensity it is possible that cost reductions to some extent have been achieved by investments aiming at reducing labour input but not reducing energy input. For the energy intensive industries it is possible that some have achieved cost reductions by changing energy technology or introducing conservation technologies. The degree to which this has taken place or if a failure to reduce energy intensity and costs has led to stagnation or decline in these industries will be examined in here.

The availability of cheap power resources of a non-transferable nature and located at remote places has led to a concentration of the very energy intensive industries at such locations. Denmark has no such resources and no new energy intensive industries have been located here.



**Figure 1 Energy input in Danish industries, 1966 and 1992**

The industries in Figure 1 are sorted by the relative change in energy demand from 1966 to 1992. In the service sector energy demand have increased quite substantially, while in some of the manufacturing industries and agriculture energy demand have fallen. Much of the explanation for this development must be that the service sectors share of total production have increased relative to the more primary industries, but there are at the same time changes in the energy intensity in the sectors where especially the manufacturing sectors have experienced a fall in energy intensity.

The change in energy technology and energy conservation technologies has created export opportunities for Danish industries. This has especially been the case for wind

turbines and district heating pipelines. With regard to conservation and cleaning technologies both the sector producing insulation materials and also production of de-sulphuring equipment have benefited. Also the service sectors of consulting on energy technology implementation and energy planning have raised considerable export earnings. Some of these export stories will be quantified below.

A very large impact on the balance of trade can be attributed to a change in trade with energy commodities. Much of this change has nothing to do with a change in energy technology, but to the extent that a change in fuels can be characterised as a change in technology especially the introduction of coal for power production and natural gas in particular have had large impacts on the balance of trade. Another issue is the trade in electricity, which is of growing importance with large annual fluctuations and increased transmission capacities. The dominating power production technology today of combined heat and power has also implications for the possibilities of trade in electricity.

**2. Production and export performance related to energy intensity and energy technology**

In the period from the mid sixties to the early nineties the energy technology used in production sectors as well as in energy conversion has changed drastically. The economy has become less energy intensive due to a change in the composition of final demand and a change in production structure along with a reduction in energy intensity for nearly all sectors.

Manufacturing industries are relatively less energy intensive compared to international levels. This is mainly a result of the very few energy intensive industries in Danish manufacturing. An interesting question is the performance of manufacturing industries with respect to production dependent on the energy intensity of their production. It is obvious that manufacturing as a whole have experienced slower demand growth than the overall economy due to a shift in consumption towards services. But it is not necessarily the case that the energy intensive industries should experience slower growth than the energy extensive industries.

Energy intensity classification 1992 TJ/mill DKK	Share of manufacturing production 1992	Average energy intensity TJ/mill. DKK	Change in production 1966-1992	Change in exports 1966-1992	Share of direct exports in production 1992
< 1	86.2%	0.41	+83%	+193%	50%
1 - 3	12.3%	1.67	+62%	+293%	40%
> 3	1.5%	6.71	-1%	+135%	49%
Total manufacturing	100.0%	0.66	+78%	+199%	49%

**Table 1 Change in production and exports dependent on energy intensity**

In the table 82 branches of manufacturing have been grouped according to their energy intensity in 1992. Especially the four very energy intensive branches: cement, structural clay products, paper and pulp, iron and steel works, have experienced a much less favourable development than the majority of manufacturing industries. Also the group that consist of 18 manufacturing industries with energy intensity between 1 and 3 TJ/mill. DKK have experienced slower growth than the average.

Energy intensity classification 1992 TJ/mill DKK	Share of liquid fuels 1966	Share of liquid fuels 1992	Share of electricity 1966	Share of electricity 1992	Share of natural gas 1992
< 1	52%	18%	33%	64%	6%
1 - 3	68%	27%	18%	42%	14%
> 3	66%	10%	15%	48%	11%
Total manufacturing	55%	19%	30%	61%	7%

**Table 2 Fuel technology change**

The very energy intensive industries have more substitution possibilities between fuels than the two other groups. This can be seen from Table 2 where the energy intensive industries reduces the share of liquid fuels much more drastically than the two other groups. It is also for the two most energy intensive group of industries that natural gas has been most widely introduced. For the manufacturing industries with low energy intensity the share of electricity is very high. This is a result of a limited number of processes where there are any alternative to electricity. It is only due to the inclusion of iron and steel works that the energy intensive industries have an electricity share of 48%. In iron and steel works the electricity share is as high as 83%.

Energy technology change can to some extent be represented by the change in fuel use. The general pattern for manufacturing is a reduction of liquid fuels and an increase in the share of electricity. The decline in the use of liquid fuels is general with one exception (book printing) also if all 82 branches of manufacturing is examined (Appendix A). This indicates that the reduction in energy intensity been partly accomplished by reducing the processes using liquid fuels, that means a move towards more sophisticated processing for all the manufacturing industries. To some extent the processes using liquid fuels have changed towards use of natural gas, in some instances coal (sugar factories and refineries), electricity in the case of steel works, and in some cases district heating.

Fuel technology change has been necessary compete internationally. If the large share of liquid fuels had persisted the production costs would have included a much larger energy dependency. In some cases industries that had less substitution options have been hit by international competition. This has been the case for: structural clay products, paper and pulp, manufacture of raw glass and basic plastic materials. For the last two industries the energy intensity have been reduced drastically which is a result of closing down some very energy intensive plants, and the structure within the industry changing totally towards production of different and new products. For both these industries the product change has been accompanied by success in export markets.

### **3. Trade patterns, cheap energy and taxation**

Denmark has a very energy extensive production structure today. The availability of cheap energy resources at other places has led to stagnation or decline for the very energy intensive industries that existed in Denmark in 1966.

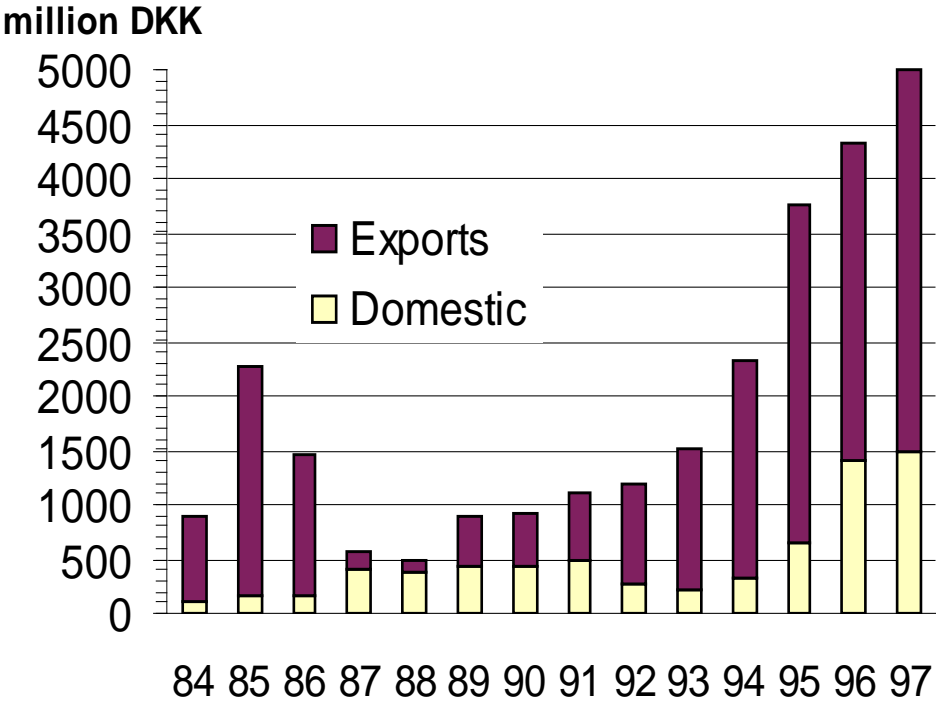
On the other hand the price on energy actually paid by the industries has been relatively competitive to the energy prices paid in other countries. Taxation on energy use has not been widespread and the competition-threatened industries have always been widely exempted from energy taxation. Electricity has been low priced relative to many other European countries. Compared to this the consumer has been very heavily taxed with respect to energy consumption.

The change towards reliance on electricity instead of liquid fuels has not it self contributed to changing trade patterns, but it is an indication that Danish manufacturing has increased labour productivity by increasing electricity based capital equipment. This has contributed to maintaining international competitiveness of Danish manufacturing.

Cheap energy is important when energy is a main input and hereby an important determinant for competitiveness. For the very few energy intensive industries in Denmark there has not been cheap energy available. Cheap energy available can be a result of either a subsidisation of energy or the existence of specific local resources e.g. hydropower or natural gas. In the Danish case the subsidisation of the energy intensive industries has not been through subsidising energy use, but has in a very limited number of cases been directed through other channels as capital support. In general industrial policy directed at conserving heavy industries in Denmark been not been especially emphasised.

**4. Export opportunities from new and renewable energy technologies**

New energy technologies introduced in Denmark have led to considerable contributions to export performance. This is the case for wind turbines, where Denmark has been a major actor in international markets. The market share is close to 50%.



Source: Danish Wind Turbine Manufacturers Association  
 1997: Estimate by the Danish Wind Turbine Manufacturers Association

**Figure 2 Turnover for Danish wind turbine manufacturers**

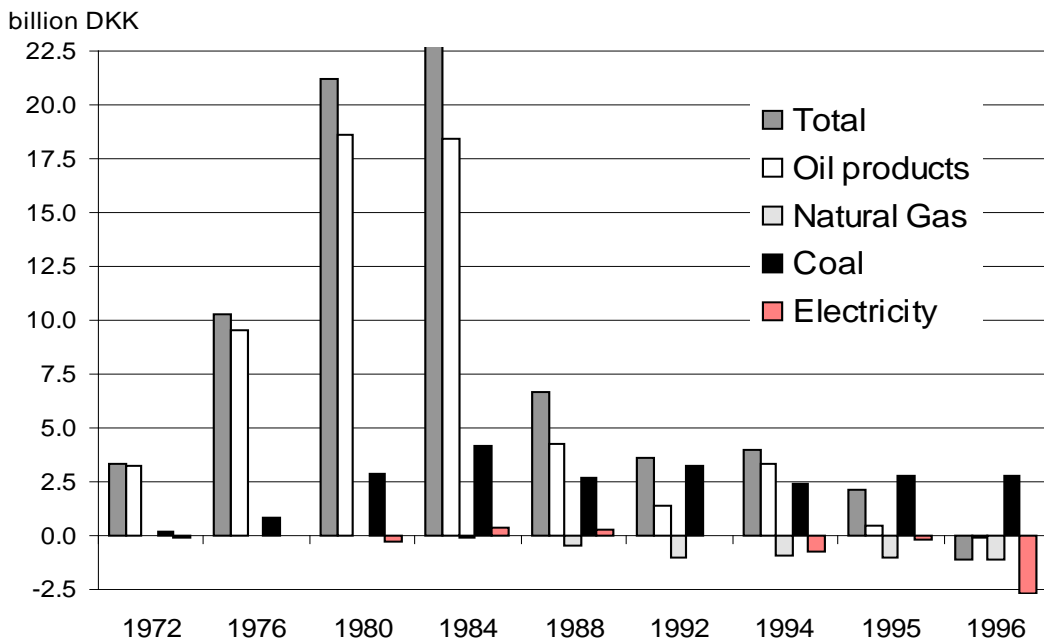
District heating systems especially pipelines have a long tradition in Denmark and this technology have been improved partly based on the public support of expanding district heating in Denmark. Denmark has one of the two largest manufactures of pre-insulated pipes in the world. The exports from the four largest producers in Denmark amount to 1.4 billion DKK in 1997. Exports of pumps, heating controls etc. from other producers related to district heating should be added to this figure.

Some export success has been recorded for cleaning technologies related to specific power producing technologies.

Consulting in the field of renewable energy is a positive contributor to service balances. This has been supported by the international reputation of the Danish case as a very “green” and environmental friendly policy. Also a very long tradition for detailed energy planning and especially the implementation of renewable energy has contributed to export opportunities for consulting firms and institutions. Some of the consulting activities have been tied to bilateral aid activities to developing countries or countries in transition. But also in the field of fully commercial projects the consultants have been successful.

### 5. Trade in energy commodities

Denmark has experienced major shifts in the trade with energy commodities. Originally nearly 100% reliant on foreign resources the Danish economy is today (1997) more than self-sufficient (125%) in oil products and even self-sufficient (101%) in total energy consumption.



Source: Danish Energy Agency

**Figure 3 Net import of energy commodities**

Oil products were the main source of the very large trade deficits in energy commodities until the mid- eighties. The shift from oil towards coal in the power sector and the reduction of liquid fuels in manufacturing industries contributed to a reduction of the import costs of oil products. The fall of oil prices in the mid-eighties also contributed to this reduction of oil import costs. Danish extraction activities increased very much from then and today the country is more than self reliant in oil products.

Natural gas has contributed to reduced imports of oil products and has to some and increasing extent been exported.

Electricity trade has traditionally been with Scandinavian countries and Germany. The size of trade has been determined by seasonal and climatic conditions. Recently the yearly change in trade flows has been very large and has caused production changes from +50% to -50%. This is partly technological dependent as investment in transmission capacities determines the possible sizes of daily transmissions. Also expansion of hydropower has created more scope for trade variation and especially the expansion of wind power in Denmark could benefit from the connection to hydropower resources.

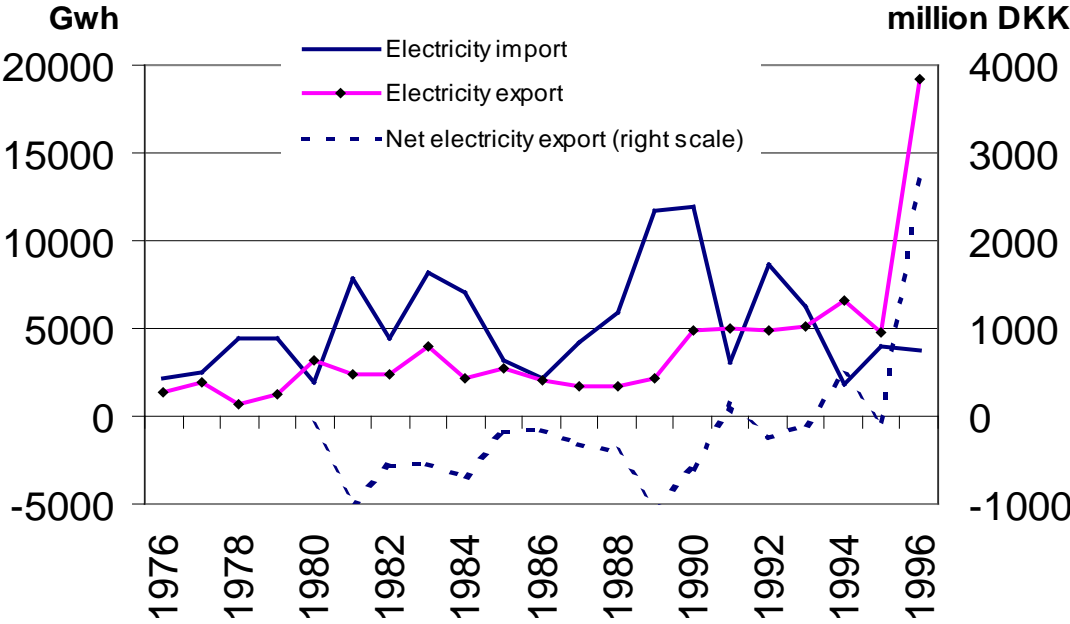


Figure 4 Trade in electricity

Trade in electricity has for many years resulted in a deficit both in physical terms and in fiscal terms. The size of the deficit has not been very big and has mainly been a result of the availability of periodically cheap hydropower from Norway and nuclear power from Sweden combined with a lack of competitors on the demand side. This trade pattern might change as the transmission capacities between Scandinavia and northern Europe is being expanded rapidly and the liberalisation of electricity markets increases the number of buyers. The surplus in electricity trade recorded in recent years (1991, 1994 and 1996) has been caused by lack of rain in Scandinavia and to some extent temporary unavailability of nuclear power plants.

The value of electricity trade has historically been very cheap imports and relatively high prices on exports. This picture will probably change towards a more equal price mainly due to an expected higher import price. The extreme case of 1996 with net exports of 2.7 billion DKK will not be the main picture in the future, but Danish producers will continue to benefit at times of low water resources in Scandinavia. This export revenue is of course matched by increased imports of coal and oil products that were also used for power production in the extreme year of 1996.

6. Concluding remarks



Energy technologies in a broader meaning has had an impact on trade patterns. This impact has been direct in the case of exporting energy technology equipment as wind turbines and district heating pipelines. The indirect effect through energy technology change and impact on competitiveness can be seen in the relative decline of the energy intensive industries of Denmark.

The relative energy intensive manufacturing industries of Denmark have experienced a stagnation of production and much slower export growth than the average of manufacturing. The number of industries with high energy intensity have also declined and hereby the production share of these four energy intensive industries are just 1.5% of total manufacturing production.

Exports of products that are related to new energy technologies have been rising fast. The examples of wind turbines and district heating pipes show that Danish producers have captured very large shares of the world market. Exports of just these two goods constitute more than 2% of total manufacturing exports.

In the field of trade with energy commodities the period from 1966 to 1992 includes major shifts in the fuel technology of the Danish economy. A shift from liquid fuels towards coal around 1980 resulted in a coal-based combined heat and power sector which is relatively robust to international competition in a rising market of electricity trade. The future trade in electricity could be off a substantial value as the recent figures suggest and the technological developments in this sector will have a large impact on trade in this commodity.

Altogether the issue of energy technology and trade developments seem to be related. The effect of the general competitive position from changing energy technologies will be rather limited as the Danish manufacturing industries have a very small share of energy in total production costs. Just as important are the export opportunities for the industries producing energy technology equipment for the world market.

### **Acknowledgements**

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<b>Appendix A: Data</b>	TJ/mill. DKK 1966	TJ/mill. DKK 1992	Production 1966 mill. DKK	Production 1992 mill. DKK	Electri- city 1966	Electri- city 1992	Liquid fuels 1966	Liquid fuels 1992	Natural gas 1992	Export 1966	Export 1992	Export share 1992
<b>Manufacturing industries</b>												
Magazine publishing	0.14	0.13	835	751	10%	70%	52%	11%	6%	0	0	0%
Other publishing	0.15	0.13	541	1289	10%	59%	53%	9%	5%	0	0	0%
Knitting mills	0.53	0.16	1259	1998	33%	68%	51%	8%	2%	352	1192	60%
Manufacture of jewellery, etc.	0.16	0.16	1249	376	24%	55%	40%	12%	1%	251	131	35%
Manufacture of wearing apparel	0.34	0.17	3678	3262	24%	52%	54%	18%	8%	409	1935	59%
Manufacture of footwear	0.40	0.19	865	829	25%	61%	55%	16%	14%	87	258	31%
Petroleum refineries	0.24	0.19	7800	13620	99%	99%	0%	0%	0%	1875	5986	44%
Slaughtering etc. of pigs and cattle	0.24	0.20	18638	29959	29%	67%	60%	23%	5%	10725	19541	65%
Manuf. of telecommunication equipment	0.81	0.22	896	5537	19%	70%	66%	9%	11%	311	3465	63%
Newspaper printing and publishing	0.23	0.23	3164	2933	38%	77%	20%	2%	1%	48	42	1%
Reproducing and composing services	0.42	0.23	285	1080	33%	78%	21%	3%	0%	10	87	8%
Professional and measuring equipment	0.21	0.23	734	4084	37%	70%	36%	9%	7%	436	3178	78%
Book and art publishing	0.31	0.24	808	573	11%	58%	61%	9%	5%	0	0	0%
Manuf. of made-up textile goods	0.30	0.28	316	1153	27%	57%	49%	19%	8%	41	428	37%
Other printing	1.03	0.29	321	1087	34%	69%	45%	3%	3%	7	185	17%
Manuf. of other electrics supplies	0.74	0.32	3536	5008	39%	64%	42%	19%	2%	770	1796	36%
Processing of fish	0.29	0.33	1267	5816	40%	71%	41%	18%	4%	921	4606	79%
Poultry killing, dressing, packing	0.94	0.33	575	2025	38%	76%	51%	16%	2%	375	1108	55%
Manuf. of toys, sporting goods, etc.	0.84	0.33	947	3147	18%	72%	66%	9%	2%	357	2154	68%
Manufacture of soap and cosmetics	0.73	0.33	759	1227	16%	53%	77%	30%	6%	112	612	50%
Manufacture of household machinery	0.44	0.35	561	2072	48%	63%	36%	28%	2%	163	1470	71%
Manuf. of chemical products n.e.c.	1.67	0.35	484	1032	13%	52%	81%	37%	0%	137	426	41%
Ship building and repairing	0.51	0.36	5466	6634	35%	73%	44%	18%	1%	2219	3865	58%
Manuf. of refrigerators, accessories	0.78	0.38	4400	12743	22%	64%	73%	19%	6%	1607	7296	57%
Tobacco manufactures	0.59	0.38	1049	977	30%	69%	53%	15%	13%	81	317	32%
Manuf. of metal cans and containers	0.94	0.40	955	1797	28%	64%	57%	9%	23%	61	512	29%
Manufacture of industrial machinery	0.52	0.40	2855	4855	32%	59%	54%	26%	4%	1775	3123	64%
Railroad and automobile equipment	0.57	0.41	2068	2546	22%	63%	55%	18%	7%	310	1255	49%
Dairies	0.64	0.42	10152	11868	22%	55%	72%	30%	7%	3787	4928	42%
Manuf. of structural metal products	1.23	0.43	1812	6719	21%	66%	59%	17%	6%	303	2404	36%
Bookbinding	0.20	0.44	318	433	34%	77%	25%	3%	2%	8	51	12%
Manuf. of electrical home appliances	0.78	0.45	308	411	29%	56%	61%	32%	7%	112	203	49%
Offset printing	0.43	0.47	833	2084	19%	42%	52%	4%	38%	51	274	13%
Manuf. of agricultural machinery	0.68	0.47	1373	1755	16%	50%	73%	27%	6%	615	1100	63%
Repair of machinery	0.87	0.50	2045	2430	12%	46%	66%	7%	4%	0	0	0%
Manuf. of paints and varnishes	0.54	0.50	905	1058	20%	59%	71%	18%	8%	185	439	41%
Chocolate and sugar confectionery	0.48	0.50	989	2129	48%	59%	40%	26%	5%	154	824	39%
Manuf. of paper containers, wallpaper	1.01	0.53	1892	4338	22%	63%	69%	14%	19%	194	1214	28%
Processing of fruits and vegetables	0.40	0.53	909	2064	21%	51%	63%	38%	9%	132	641	31%
Cake factories	1.10	0.53	506	1540	14%	58%	62%	31%	7%	127	890	58%
Book printing	0.36	0.54	2037	2158	27%	32%	42%	54%	2%	118	379	18%
Margarine manufacturing	0.73	0.55	589	683	25%	48%	66%	31%	15%	22	217	32%
Manuf. of wooden furniture, etc.	0.52	0.56	3231	6206	24%	52%	52%	8%	5%	736	4141	67%
Cordage, rope and twine industries	0.96	0.58	567	521	45%	73%	49%	6%	12%	156	267	51%
Manuf. of other fabricated metal products	0.95	0.60	3458	5862	27%	69%	62%	15%	7%	881	2079	35%
Ice cream manufacturing	1.33	0.60	204	976	47%	72%	31%	6%	0%	9	404	41%
Manufacture of metal furniture	1.05	0.62	344	1503	14%	55%	59%	23%	13%	69	627	42%
Manufacture of cycles, mopeds, etc.	1.40	0.63	341	591	16%	33%	72%	13%	49%	67	287	49%
Manufacture of drugs and medicines	0.79	0.66	789	5599	55%	54%	38%	38%	4%	483	4535	81%
Grain mill products	0.77	0.67	1069	1049	54%	85%	41%	4%	9%	73	278	26%
Manuf. of basic plastic materials	3.35	0.68	636	3991	25%	87%	7%	7%	4%	213	2166	54%

<b>Appendix A: Data</b> (continued)	TJ/mill. DKK	TJ/mill. DKK	Production 1966	Production 1992	Electri- city	Electri- city	Liquid fuels	Liquid fuels	Natural gas	Export 1966	Export 1992	Export share
	1966	1992	mill. DKK	mill. DKK	1966	1992	1966	1992	1992			1992
<b>Manufacturing industries</b>												
Manuf. of accumulators and batteries	0.65	0.76	312	141	38%	88%	49%	8%	0%	111	92	65%
Oil mills	1.75	0.78	1232	1849	8%	47%	90%	46%	7%	419	776	42%
Bread factories	0.78	0.78	740	907	16%	46%	68%	30%	6%	18	95	10%
Processed cheese, condensed milk	1.11	0.81	1429	2896	16%	37%	76%	40%	15%	1185	2013	70%
Manuf. of plastic products n.e.c.	0.83	0.85	1166	5042	61%	74%	34%	8%	15%	306	2203	44%
Manufacture of leather products	0.95	0.85	545	261	19%	47%	67%	37%	12%	74	107	41%
Manufacture of wood products, ex. furnit.	1.87	0.98	2892	5107	42%	29%	44%	10%	0%	587	2031	40%
Manufacture of food products	1.80	0.99	538	2518	48%	21%	45%	8%	37%	146	1338	53%
Manuf. of earthenware and pottery	2.42	1.10	517	235	15%	33%	46%	21%	4%	138	159	67%
Spinning, weaving etc. textiles	1.92	1.12	2278	2354	23%	56%	74%	25%	17%	410	1168	50%
Tyre and tube industries	2.24	1.13	140	234	7%	46%	79%	40%	0%	0	47	20%
Bakeries	0.88	1.20	2978	1561	12%	67%	66%	10%	6%	0	0	0%
Non-ferrous metal casting	1.37	1.23	210	376	15%	72%	78%	23%	3%	22	126	34%
Concrete products and stone cutting	0.68	1.29	2317	2706	29%	25%	46%	26%	32%	111	654	24%
Manuf. of rubber products n.e.c.	2.14	1.31	507	602	33%	55%	64%	23%	20%	146	410	68%
Fish meal manufacturing	2.41	1.32	480	2347	10%	36%	89%	21%	28%	275	1161	49%
Distilling and blending spirits	8.64	1.35	248	318	4%	25%	62%	32%	11%	52	114	36%
Breweries	1.52	1.39	2381	4598	9%	31%	81%	50%	9%	559	1110	24%
Manuf. of glass and glass products	12.28	1.63	500	839	9%	50%	88%	8%	39%	58	264	31%
Manuf. of basic industrial chemicals	2.45	1.71	768	4469	19%	62%	80%	26%	8%	480	3460	77%
Manuf. of fertilizers and pesticides	4.02	1.75	759	894	42%	65%	53%	18%	16%	70	328	37%
Sugar factories and refineries n.e.c.	2.10	2.20	922	2013	6%	7%	81%	27%	0%	126	844	42%
Manuf. of asphalt and roofing cater.	2.26	2.33	830	1261	17%	22%	76%	55%	21%	48	284	22%
Iron and steel casting	2.69	2.42	567	656	30%	85%	42%	6%	1%	72	246	38%
Non-metallic mineral products n.e.c.	5.67	2.55	883	1500	14%	38%	66%	7%	9%	207	706	47%
Manuf. of prepared animal feeds	2.92	2.61	714	2120	25%	35%	70%	21%	14%	204	615	29%
Iron and steel works	10.10	3.10	998	1383	8%	83%	84%	2%	14%	367	890	64%
Manuf. of pulp, paper, paperboard	5.60	5.30	838	941	22%	42%	71%	18%	9%	97	416	44%
Manuf. of structural clay products	6.78	6.50	907	410	16%	19%	67%	11%	18%	168	194	47%
Manuf. of cement, lime and plaster	16.74	14.20	871	856	13%	12%	41%	13%	1%	124	274	32%