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Product Choice in Wood Industries with Growing Demand for Forest Resources: Some Aspects of Growth in the Frames Given by the Wish for Sustainability in Sweden and Fennoscandia 1850-2000

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The manufacture of wood products from the Nordic or more accurately the Fennoscandian forests has increased very much in quantity and value during the circa 150 years when industrialization has been at work here. During the same time period the felling of wooden raw materials from the forests has increased, too, but not as much by far. From the very beginning the forest industries, together with crafts-oriented production mainly for local markets, demanded only a small part of all the wood which was felled. Thus these early manufacturers achieved a favoured market position and could grab the best of the most valuable trees and tree species.

In this paper I will discuss how this extreme growth of industrial felling has been made possible while the estimated total natural growth of the timber forests has increased at a much slower rate. I will use "the Swedish case" as my example, even though it is my purpose to embrace the whole of Fennoscandia. In my presentation I will relate to three roughly appropriate phases of development and three progress paths. In the very beginning, local production for local markets dominated as far as timber and also fuel wood are considered. Swedish copper and iron production and Norwegian ship-building do not change this picture very much, even though their final products were traded at vast distances. The first phase of the industrial era was brought about by traders taking advantage of timber available in more or less unspoiled forests at some distance from previous exploitation centres, and also of less valued timber tree species, mostly Norwegian spruce. This development had started in the 1830s and 1840s, and a little earlier in Norway, but we can just as well begin our analyses one or two decades later. The second phase, beginning at about 1900 and continuing through the century, was characterized by the introduction of new products, through which much of the remaining resources in the already exploited forests could be used for industrial production, mainly pulp, paper and board. The third phase began some decades into the 20th century and gained momentum in the 1950s when what stem wood which had been used for fuel became available for the forest industries as it was substituted for by cheaper and more suitable alternative fuel raw materials, such as pit coal or oil.

It should be pointed out that the annual increment of the timber stock is estimated to have increased rather much during this time period, even though there are no reliable estimates available until the 1920s or 1930s. According to what we know the increase in volume growth in Sweden was estimated to fifty per cent from the 1920s to the 1990s, with a remarkable set-back in the 1960s and 1970s. However, this increase in the growth rate is a biological measure and does not relate exactly to the amount of mature trees or stems in the forests, and it is not feasible to add this factor to my analysis at the moment. I will only point to the importance of changing practices in adjacent industries, mainly agriculture and especially the cessation of

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cattle grazing. Much the same has resulted from the ditching and road building in the forest areas, and also to seed and pot reforestation and other practices which have changed the Fennoscandian forest landscape profoundly. The purpose of this work, which accelerated in the period after WW II, has been both to increase the increment rates and to save labour.

Applied economic theory would certainly have contributed to more exact knowledge and closer analysis than presented here. But both lack of sources and the required amassing of data make the task to find information suitable for good testing a little nasty. Rather, it is my purpose to sketch an interesting and intriguing research area. I think that even so it has some wider applications for our understanding of the development and organization of exploiting industries in relation to their exploited resources, especially in the case of potentially sustainable ones.

Another limitation should be mentioned before we start. In recent years the contest between forest and "timber land" – or timber plantation – has been intensified by the demand on forests for living qualities, tourism and biological and ethical qualities which also in turn have become economic realities. In this paper, I will keep strictly to the trees of the forests and leave out all other considerations of their natural and social aspects. Growth is thus measured as the growth of stem volumes, irrespective of their environmental or natural context. This is what matters in relation to the forest production industries in this theoretical approach. Similar approaches have of course been focused on by some schools and practices of forest education and research, while others have looked for a wider foundation in environmental thought.

The Product Paths of the Fennoscandian Forests

History tells us that the Fennoscandian countries together with the whole Baltic Sea region have served as a resource base for the economically most advanced regions in Western Europe for many centuries. In turn, fish, furs, tar, timber and cereals have been shipped to Spain, the Netherlands, France and England. All these resources are derived from the land, and, if properly managed, they obviously will have all the characteristics attributed to sustainability. The only exhaustible trade items of importance from this area (except for agricultural and fish products) have been copper and iron, but as especially iron production in the old days required large quantities of charcoal it depended heavily upon the locally available forest resources.

It would be an understatement to say that the core countries of Western Europe influenced the land use and policies in this North-Western fringe region. Whatever the true meaning ascribed to the concepts of industrial revolution and industrialism as well as their timing, the influences from the advanced centre have become much more powerful from that time on. Focusing upon the forestry sector we may summarize as follows: In the sign of Industrialism, the forests of Fennoscandia have been totally transformed by the creation of native industries during the last two centuries.

What kind of transformation? What have the timber trees in our forests been used for? The reply is ready for us in the well-known product cycles consisting of timber, tar, charcoal, potash, paper pulp, chemical applications thereof – e g rayon, spirit - and paper. To these we should add the very beginning: fuel wood. As mentioned above, they are all made from the stem of the trees, in a few cases with the addition of large branches and roots. I will keep to this restriction and leave out all other aspects of forests and trees. It is worth noticing that trees in these countries and in the whole boreal region do grow with one single stem which by far makes the largest part of the wood mass of the whole tree.

Abstracting the Underlying Structures behind the Development Paths

From a different angle we find that wood has been used for the production of energy, construction, chemical applications and paper. Energy and often also chemical products rely on burning and destroy the biological (botanical/morphlogical) structure of the wood, whereas construction and paper products are based on the original structural properties of the wood. As an approximation I have chosen to relate the structural element of the wood to its cellulose content and use the word *fibre* and *fibre content* for it.[2]

In some attempts to make forecasts, especially in the fields of economic development and resource availability, focus has been on the identification of underlying structures of the resources. When, and if, such structures were found, they could be used for analyses and predictions of future development from historical trends. There have been many, more or less imaginative, attempts to identify such chains, and rather often they have been applied to long time sequences. They have found their way to analyses of long waves of economic activities, and they fit well with the attempts to identify basic innovations as the driving force of economic development. Telling examples which show how abstractions fetched from certain physical qualities can be brought together with historical observation can be found in analyses of energy production and future demand for energy. There is, for example, the suggestion that the quality of energy products can be associated with their molecular hydrogen content, which is combined with the suggestion that this physical observation can be used for a description of a (historical and/or future) development path of energy production. From these assumptions and observations we might arrive at an underlying structure which can be associated with the consecutive steps of technological developments in the energy sector, at least as far as fuels proper have been involved.

This example has been taken from an IIASA-study of energy production, where the energy was ranked according to its quality for the final user on a scale which starts from the bottom with firewood and peat, goes through petroleum products like oil and gas and ends at the top with electricity generated by water or nuclear power stations. As far as we deal with fuels proper, the ranking from the hydrogen content seems appropriate. We observe that the suggested quality ranking corresponded rather nicely to the historical chronological order in which the technology has been put to full scale use. A further step on the efficiency scale has usually been sought in a combination of qualitatively new and research intensive technology and large scale production units.

In this example the cause of new technological break-throughs has been sought in a rapidly increasing demand for energy which would have been impossible to satisfy with the old raw materials even with a much improved utilization technology. Instead, the demand for energy continually has moved to new raw materials, causing large development costs and investments, especially in the latter half of the 20th century. As the supply of energy is fundamental for the economy, this development – and “development path” – has been accepted. Thus the adjustment to the rapidly increasing demand for energy has been made

[2] Both cellulose and hemi-cellulose should be regarded as fibre. They build the structure of the original wood as well as they do in pulp and paper, but in some cases such as in chemical products and in certain paper qualities the hemi-cellulose has been removed. For this reason it may be correct to define some of the economic and technological development paths which has been chosen by the forest industry by its effort to produce pure cellulose.

through innovations which have helped the industry to increase and broaden its supply of raw material and at the same time its use efficiency.

The common denominator of these energy approaches and mine is the attempt to find some basic factors of change which are embedded in the raw material used or in the qualities of the products in order to analyse the course of innovations of the two industries. There is, however, an important difference in that the forest sector is defined from its resource base, which is homogenous and renewable and has got rather similar growth and quality conditions, at least within countries in the boreal zone like Sweden and its neighbours. The common denominator used here is quantitative and reads *cubic meter solid measure under bark.* In the energy sector, inputs vary but if not homogenous the products can nevertheless be measured in a common measure in addition to money, namely TWh. On the other hand, the products of the forest industries differ considerably and have many end uses.

The issue at bay here is, to put it simply, where does all the wood base of the timber, pulp and paper industries in our Nordic countries come from? We have found that changing and stem-volume-oriented forestry practices may have contributed somewhat. The answer which I suggest is, that products which make use of the fibre qualities have been promoted at the expense of products which exploit other aspects of the wood resource. For a moment, let us look at the applications as described above. Fuel energy and the mere chemical products require fire, and in their production the fibre qualities will be destroyed. Building materials such as planks and boards consist of the raw wood in its natural shape, i e they use the properties of the fibre structure in full. However, there are large losses at the mills when the timber is cut for its final uses, so that in these processes the waste approaches fifty per cent, approximately. Thus even with stem wood lots of waste will be produced, and each development phase will handle it in its own way – just dumping it, or burning or chipping it. Finally, paper pulp is a substance which has been developed and prepared for paper making in such a way that the fibres of the cellulose and often also the hemicellulose will form the carrying elements of the paper sheet. The plasticity of the pulp has given it an advantage over the structurally inflexible sawn wood. Thus the pulping of the wood is directed towards the fibre qualities and carries over from 2/5 to all of the wood content into the final products. The rest of the stem volume will become waste. Coniferous wood consists of approximately 45 per cent cellulose, 25 hemicellulose and 30 lignin.

In the following I will give some preliminary information about the development path of the timber and pulp and paper industries in order to sketch their growth trends. It should be said that even here there are blind alleys along the development paths chosen, and it is our aim to suggest some explanations why they have turned out this way.

Finland, Norway and Sweden
Some aspects of the Fennoscandian development

The three countries under observation have rather similar forest conditions. Finland and Sweden have about the same forest areas available for forestry, as estimated in the year 2000, and Norway had some 30 per cent of that. The total was 48,5 million hectare. The felling totalled 132 million cubic meter standing volume under bark, and the net annual increment was estimated to 179,9 million.

Table 1 A. Production of sawn wood and wood pulp in Finland, Norway and Sweden 1875-2004 (per cent and total production)

Year	Sawn wood (per cent or 1000 cu.m)				Wood pulp (per cent or 1000 ton)			
	Finland	Norway	Sweden	cu.m	Finland	Norway	Sweden	Ton
1875-79	19	27	54	5780	22	43	35	23
1900-04	26	16	58	10390	14	52	34	368
1925-30	42	10	48	12130	21	38	41	1066
1950-55	39	16	45	12031	34	28	38	1888
1975-80	36	11	53	19385	39	18	43	4700
2000-04	41	9	50	32616	49	14	37	6589

Table 1 B. Production of chemical pulp and paper in Finland, Norway and Sweden 1875-2004 (per cent and total production)

Year	Cellulose pulp (per cent or 1000 ton)				Paper (per cent or 1000 ton)			
	Finland	Norway	Sweden	ton	Finland	Norway	Sweden	Ton
1890-94	8	21	71	70	20	29	51	70
1900-04	6	37	57	327	21	27	52	219
1925-30	21	20	59	2174	22	30	48	1166
1950-55	29	12	59	4110	27	21	52	2300
1975-80	34	6	60	10843	46	13	41	10405
2000-04	47	3	50	16306	50	8	42	26340

Sources: Central Bureau of Statistics in Finland. Norway and Sweden, and FAO (in print and on internet)

Evidently the Fennoscandian forest resources have been sufficient for a very large quantitative industrial growth in Finland and Sweden and a lesser but still large growth in Norway. The proximity to the markets in Western Europe guaranteed large and increasing demand for forest products, and it proved to be rather easy to transfer new technologies into the Nordic periphery and also to develop them further. The forest companies soon developed into a powerful interest group with large economic power in the "world" market of those days. They were pretty much safe for foreign competition in the timber markets, and when foreign intruders invaded local markets, they most often stayed local with their production. These foreigners had the same interest in the market for goods, and maybe they had a little more difficult position in the wood markets as compared to native companies. The generally adapted strategy was growth, growth in order to keep a favourable market position, and this was important both in the product and the timber markets.

When the international competition increased, especially in the market for sawn wood, the firms turned to broadening their output from the forests by paper pulp. There was a rather sophisticated interplay between the various groups of forest owners and the mill owners. In some areas such as in most of Norway, and in southern Finland and Sweden, the largest parts of the forest land was owned privately by small farmers. In parts of Finland and in northern Sweden forest companies were very influential, and in central Sweden the ironworks dominated. With this perspective in mind it is not surprising that the road into new product paths took various directions, but the result was to integrate Fennoscandian forest management with the demand for pulp wood and paper production.

Product choice with ”given” resources

Below I will present some aspects of this development in Sweden. In figure 1 which is a cumulative graph we can follow the rapid growth of industrial felling at the expense of fuel and household wood within the frame of the total fellings. The big change between these two categories came in the 1940s and 1950s. In the earlier periods charcoal wood together with export was rather large (See Chc+Hh+X!) and larger than pulp wood until the 1920s.

Figure 1. Gross felling in Sweden by assortments 1850-2004 (cumulative graph). Millions cu.m solid volume under bark

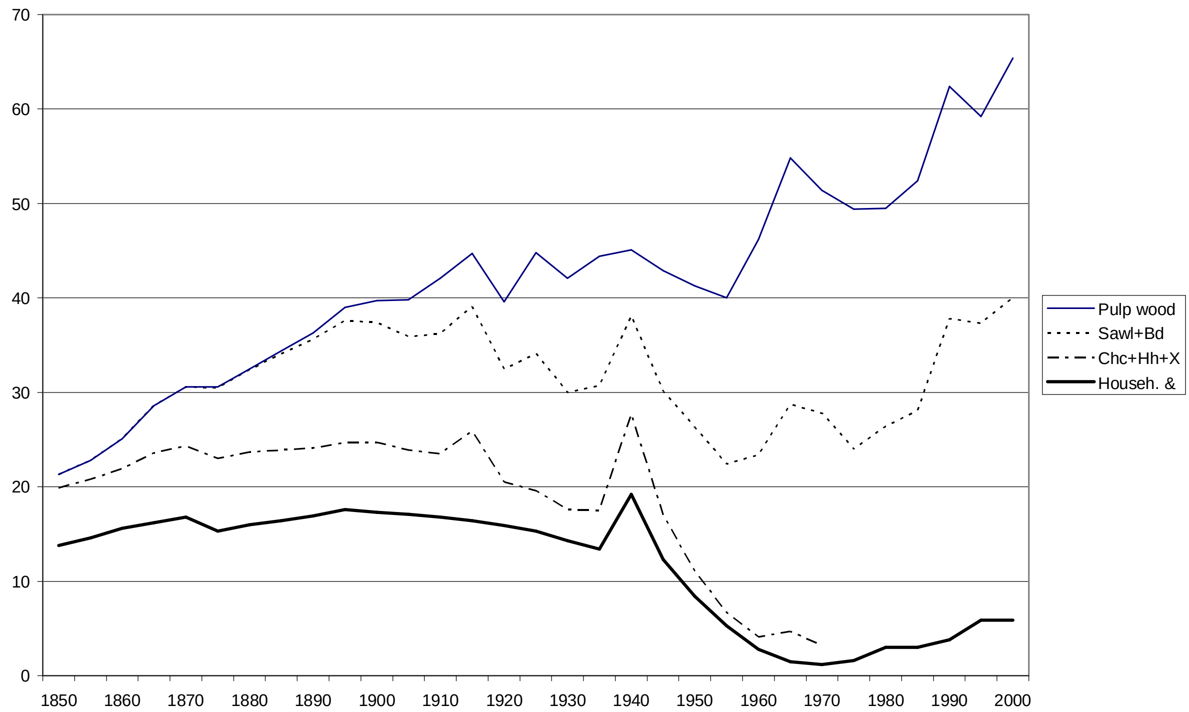


Table 2. Swedish timber production, distributed on its main assortments, 1851-1980. Per cent and total quantity in million cubic metres within bark.

Yearly average fellings and foreign trade in Sweden. Percentage of total fellings and M solid cu.m

Year	Yearly average fellings for – (million sol. cu.m) Charcoal wood	Saw logs	Pulp wood	Fuel & household	Sum	Export + Import -	Total consumption Million cu.m	Growth in the period
1851-75	16	14	0	68	98	- 2	25,2	44 %
1876-00	13	30	1	53	97	- 3	33,4	27 %
1901-25	9	30	12	47	98	- 2	40,3	0 %
1926-50	4	25	26	41	99	- 1	43,3	- 4 %
1951-75	1	41	46	10	98	- 2	45,0	24 %
1976-00	0	49	44	7	100	+ 7	58,7	24 %
2000-04	0	52	38	10	100	+ 8	70,4	..

Source: Arpi 1959 p 206 together with SOS Statistical yearbook of Forestry.

NB 1. Growth has been measured as the change from the first to the last of the five year periods within the twenty-five years interval.

Table3. Swedish timber production, distributed on its main assortements, 1851-2005. Per cent and total quantity in million cubic meters within bark.

Year	Yearly average fellings million sol. cu.m Charcoal wood	Saw logs	Pulp wood	Fuel & household	Sum	Export - Import +	Total consumption Million cu.m	Growth in the period
1851-75	4,2	3,6	0	17,4	25,7	- 0,5	25,2	44 %
1876-00	4,4	10,1	0,5	18,4	34,6	- 0,9	33,4	27 %
1901-25	3,5	12,4	5,0	19,4	41,2	- 0,9	40,3	0 %
1926-50	1,7	12,4	11,3	17,9	43,6	- 0,3	43,3	- 4 %
1951-75	0,3	19,1	21,0	4,6	46,1	- 1,1	45,0	24 %
1976-00	0	27,2	23,9	4,0	55,1	+ 3,6	58,7	24 %
2000-04	0	34,1	24,9	6,4	65,4	+ 5,0	70,4	..

Source: Arpi 1959 p 206 together with SOS Statistical yearbook of Forestry.

NB 1. Growth has been measured as the change from the first to the last of the five year periods within the twenty-five years interval.
NB 2. The only sudden change during a rather short period occurred during WW II (1941-45), when the fellings deviated from the average of the 25-years-period in the following way (M cu.m): Saw logs – 2,3, Pulp – 4,3, Charcoal wood + 0,4, Household/Fuel + 4,3 and Industrial fuel + 3,1. Totally the increase was not more than 1,2 M cu.m abouve the mean of the 25-year period. As regards WW I, the statistics of fellings, especially of household and fuel wood are rather incomplete, so it is difficult to estimate deviations from the trends.

II. Roundwood estimations according to final use

In the following we distinguish between three areas of consumption: charcoal, fibre goods and fuel. The term *fibre goods* is somewhat arbitrarily defined as commercially sawn timber, paper pulp, and boards of various kinds, while sawn lumber for subsistence has been placed in the group of fuels. This can easily be motivated by its small volume, but more principally it is important to estimate and delimit the subsistence use from all the industrial uses of the fibre material. The term *fuel* stands here for of all fire wood cut for heating in homes and industries plus all waste from the wood industries, and for practical data-estimating purposes it includes also the timber sawn for subsistence purposes. Among *waste* we recognize sawdust, edges &, black liquors from the pulp mills &. As already mentioned the black liquors are estimated as the quantities of wood from which they have been produced. Also we distinguish between the real and the potential fuel consumption. The real consumption is the one reported in the statistics, and when we add our estimations of the waste from the mills we get the potential fuel wood substance available.

When we use this new classification we get another picture of the historical wood consumption. The consumption for what we call fibre uses decreases, and the availability of our potential fuel wood increases. The impression of decreasing importance of wood as a fuel source which we were left with in the first estimations is obviously misleading. According to the new estimations they may have increased by ca 12 % from 1851-75 to 1951-75, as measured in absolute quantities.

This observation must be qualified in two ways. The first one applies to the changing methods of energy production from wood. In the 1850s and onwards almost all energy in this country was produced by fire wood for direct heating and by charcoal wood. Of the latter, about two thirds were used for heating the hearths and furnaces at the iron works and about one third was required for the chemical reduction process (reduction of the oxygen content in the iron ore). One hundred years later, from the 1950s and onwards, most of the energy from wood was produced from industrial waste, mainly pulp mill black liquors. The cutting of fire wood decreased rapidly. The second qualification applies to the years from the 1870s to the 1950s. During this long period there were very few uses for the surplus quantities which are indicated by the difference between potential and actual (real) fuel in my calculations. Thus this amount can be regarded as an estimate of the industrial wood waste of the time. In sulphite mills fuel production started in the 1940s whereas almost all sulphate black liquors were burnt in order to regain the processing chemicals already soon after 1900.

The waste question of the industry can be seen as a surplus problem which occurred when the production was centralized to mill sites at export or inland transport centres. This is especially true of the early export saw mills. As long as the timber was sawn or hewn by local peasants & forest owners the waste could easily be taken care of as fire wood, or it was left as what we may term biological residue in the forests. Quite contrary there were few and insufficient uses for all waste produced at the industrial mill sites, so it had to be disposed of somewhere in their neighbourhood. Thus this early lumber industry produced an increasing amount of waste. By the way we should perhaps consider the fact that this waste could have had some economic value if it had been used for fuel or as biological residue. The technology of the time did not permit this being so.

Figure 2. Final use of wood in Sweden 1850–2004 (five-year periods)
Estimated as of millions cu.m solid volume under bark.

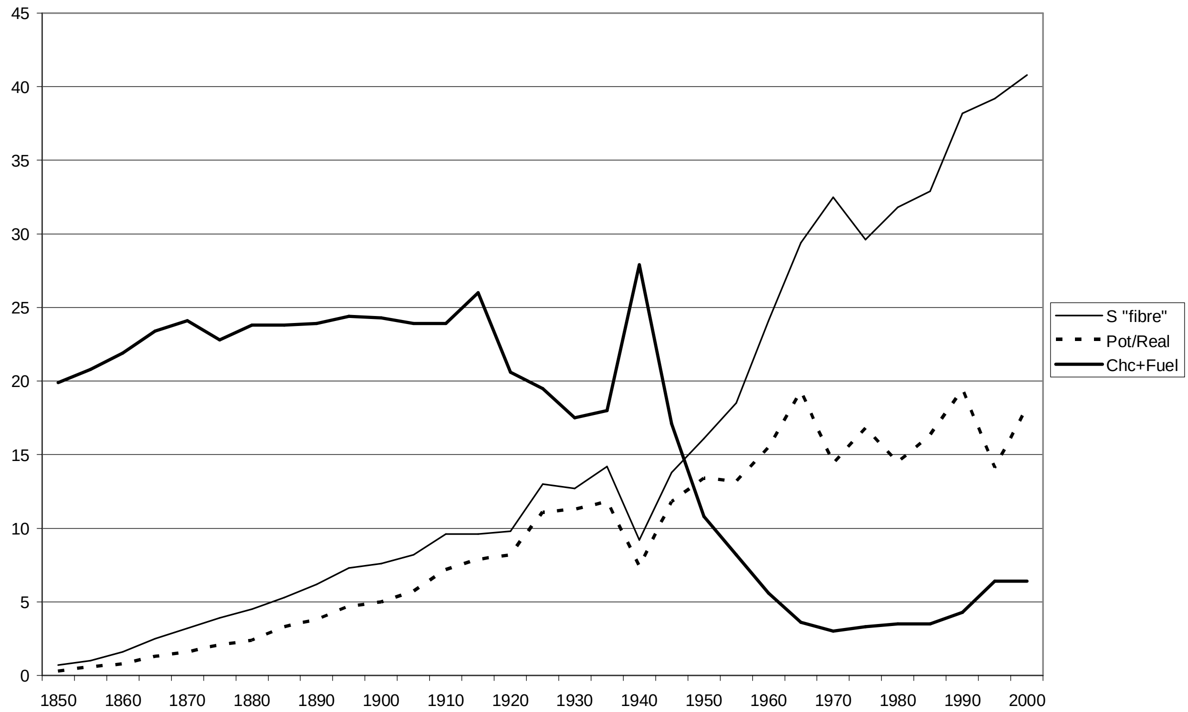


Figure 3.. Final use of wood in Sweden 1850–2004 (five-year periods):
Fuel wood (solid line) & Industrial wood (dotted line, estimated as” fibre” by subtracting waste from felling).
Estimated as of millions cu.m solid volume under bark.

In the early days of exploitation the demand for nothing but lumber from the mills meant that large amounts of wood residues were left as waste on the felling sites, mainly crowns and damaged timber. As time passed the combined residuals from felling and mill sites grew into very large stocks of waste available for innovative technicians and entrepreneurs. The introduction of pulp production made possible a much more efficient care-taking of the fibre content of the waste both in the forest and at the mills, and later on the waste liquors of the pulp mills were used for energy production. The amassing of waste in this sense indicates that the market to a large degree was approached from the supply side. Quite a few Swedish firms had forests of their own and were eager to get the most out of them.

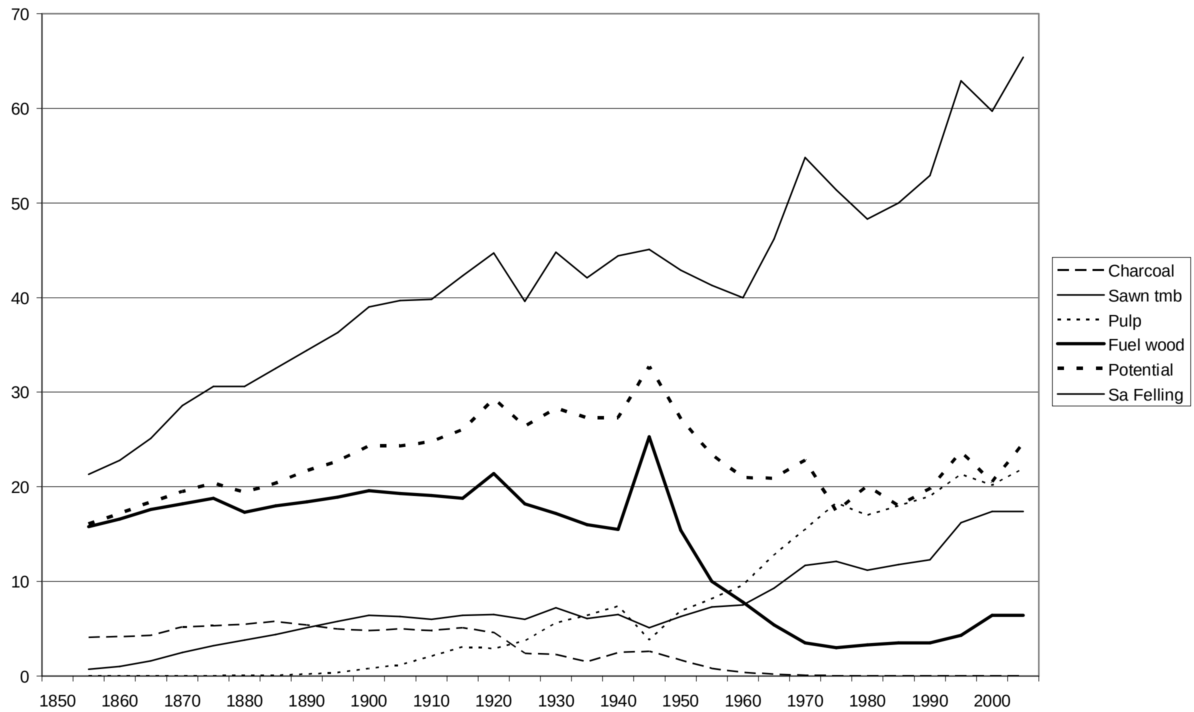
Since the 1970s waste paper has become a new fibre raw material for the pulp mills and it is also used as fuel in district heating stations. As this recycling of fibres can be repeated five to ten times, we cannot estimate the prime wood fibre content in pulp products in the same way as I have suggested here. In this sense my suggested way of estimations is confined to a certain time period and technology. However, the collection of waste here creates a new opportunity for qualitative changes in the paper production and for an increase in scale of production in large consumption areas. It may also be noted that in some way we have returned to the practise of the traditional rag paper industry to collect its raw material which had its heyday during the first half of the 19th century. At that time the state was even more deeply involved in the organization of the collection than it is now. But no environmental issues were involved as far as I know of.

Some notes on innovative waste use and its impact on production and forestry

Let us now take a short look at the waste versus fibre and fuel contest in Swedish forest industrial history. According to my estimations, waste from the Swedish forest industry was accumulating in a few periods, especially in the 1870s and the 1950s. In the decades before the 1870s, the saw mills were mechanized and concentrated to sites near the main transport routes, be it the sea, rivers and canals or railroads, and whereas the sawn and planed goods was brought away, the saw dust and wood residues were disposed of in the neighbourhood. Some of them were burnt in the steam engine of the mill, others were used to fill out lumber yards and wharfs, but most of it remained useless and (almost) worthless. With continuing concentration and as time passed, the issue became more and more important, and suggestions were made for new applications, mainly for paper pulp or charcoal. For both purposes new timber would be preferable, but with the rising prices from the end of the 1860s plans to use waste wood in new iron works located near the lumber mills were suggested. In some cases, e. g. in the Sundsvall district, there was already some traditions from old iron works, but the plans were drawn up by sawmill owners. As far as I know, however, they were never realized. One reason for the failures was in fact that the quality of the heating produced by fire wood was deficient. This problem was accentuated by the introduction of new technology some of which had been constructed for coal and coke, and in the following decades we often find mill owners and workers complaining together over the very big problems to produce e. g. sulphate pulp using waste-wood for fuel. The customers complained, too!

From the forest owner's angle pulp production aimed at a more efficient use of the forests themselves, and especially remains such as the tops of the trees were now brought to the industrial sites. However, the efficiency of the mills in producing pulp was very low - 7 - 9 cubic meters within bark for each ton of sulphite pulp was not unusual - and so ***even more*** waste was produced and deposited near the mills. It took rather many years until the pulp mills were able to use residues from the sawmills, and there were two reasons for the delay: First that the quality of the fibres of this wood was inferior, and secondly that there was some competition from fuel uses.

Figure4. Total felling in Sweden 1850 -2004, redistributed according to their final uses. Estimated as of millions cu.m solid volume under bark



Bleaching processes were introduced in the 1920s and 1930s. These innovations made possible the use of lower quality wood, e g with some bark or twigs, but while bleaching removed bark and twigs from the fibre pulp these simply became part of the waste water or black liquors. As a result more wood was taken from the forests - somewhat less valuable than before - but that is all it is to these innovations from our point of view.

Especially in the post-1945 period the demand for timber resulted among other things in new processes for birchwood pulping. In the turmoil of the market of the beginning 1950s, birch wood prices were up both because of an increasing international demand and because of rising energy prices. As birch had been the preferred firewood, its withdrawal from the fire wood market was a first "victory" or gain for the fibre trend in Sweden. It was speeded up by the fall of oil prices relative to other goods in the 1950s, and oil was an ideal substitute for firewood, efficient and easily handled and well suited for small scale units. Thus in this period wood fibres were higher paid for than wood energy. The price wave from the Korean war in the first years of the 1950s reached almost every acre of the Swedish forests. At the mills, experiments were made and new plants were constructed which produced cleaner and cleaner fibre products. One thing had been the viscose pulp of the interwar years which continued to be produced as raw material for artificial silk products in the 1950s and 1960s. It was the cleanest cellulose fibre quality with very little contamination from other wood substances. But this meant that it met other competitors in the market than did paper pulp, such as cotton viscose or petroleum-based textiles, and here it did not succeed but stagnated on the world market at a not neglectable level.

Another step taken in the 1950s was to introduce very strong pulp for sack paper and kraft liner. They were marketed with qualities such as strength and light weight and competed successfully in the European market with waste paper packaging qualities which were produced in "Continental Europe". Certainly it also contributed to the rapid spread of the modern distribution systems. This was the time when the waste production of the pulp mills, and the difference between real and potential fuel output from the forest sector was at its highest.

Now we had reached the super growth and construction years of the 1960s. They have been known for the applications of already established trends and innovations to new mills. The production of pulp increased almost 50 per cent and the integrated bulk paper production doubled at Swedish mills. With this increase economies of scale made it profitable to take care of the waste liquors and burn them in heating and power stations producing for the very large energy consumption in the pulp and paper mills. The recovering of chemicals contributed to the economic result; in the sulphate process it had started to be developed already in the 1920s as its chemicals were expensive enough to carry the cost of retrieval themselves. In addition to these motivations we find that in the 1970s the scale of the emissions of the mills had become so large that regulations concerning the environment were introduced which demanded large reductions. As a result of this total process, practically all of the wood content was taken care of, partly as fibre and partly as fuel. At some mills, especially those with integrated pulp and paper mills, almost the whole timber was used in the process, even including the bark as fuel.

From the 1980s the trend turned from paper made purely from strong fibre pulp and other paper qualities made from chemical pulp to mechanical and semi-chemical pulp and similar qualities. These latter pulps yielded a higher percentage of the wood content than the former, and for the first time in forest history it seems possible to use the whole tree, or rather the whole timber, in pulp production. This is in some way an overstatement, as many of the small wood pulp mills in the 19^{th} century were using similar technologies and tried to retrieve all wood, but they lost much of it in the grinding processes. These new pulp qualities were used for production of printing paper and news-print, and they made it possible to increase the output volumes from the forests without an increase in felling. However, also the felling increased, and as birch pulp was well suited for printing paper it came in demand again.

In this period the demand for packaging paper, including corrugated board, led the pulp producers to integrate into paper and board production, and thus they started to economize on their high-quality pulp. In the first stage they had competed successfully with their light and strong pulp and paper, and now when they had established a market position, they took a new path and tried to defend market shares by volume growth.

Concluding remarks

The big issues raised in the introduction still wait for answers. The few numbers and short notices which have been brought forth indicate that it will be valuable to continue speculation and research on these subjects. They point to theories of market behaviour and product and branch life cycles as useful research tools. The suggestion of underlying structures, such as "fibre content" and "fibre quality", as guides to historical exploration and explanation and as prognosis instrument needs more qualification, and often people in practical positions are sceptical. They may prefer more earthy considerations. However, it seems clear that the issues of waste and sustainability will help to our understanding of forest industrial practises and development.

Appendix 1

Figure 5. Gross felling in Sweden by assortments 1850-2004 (semi-logarithmic scale). Millions cu.m solid volume under bark

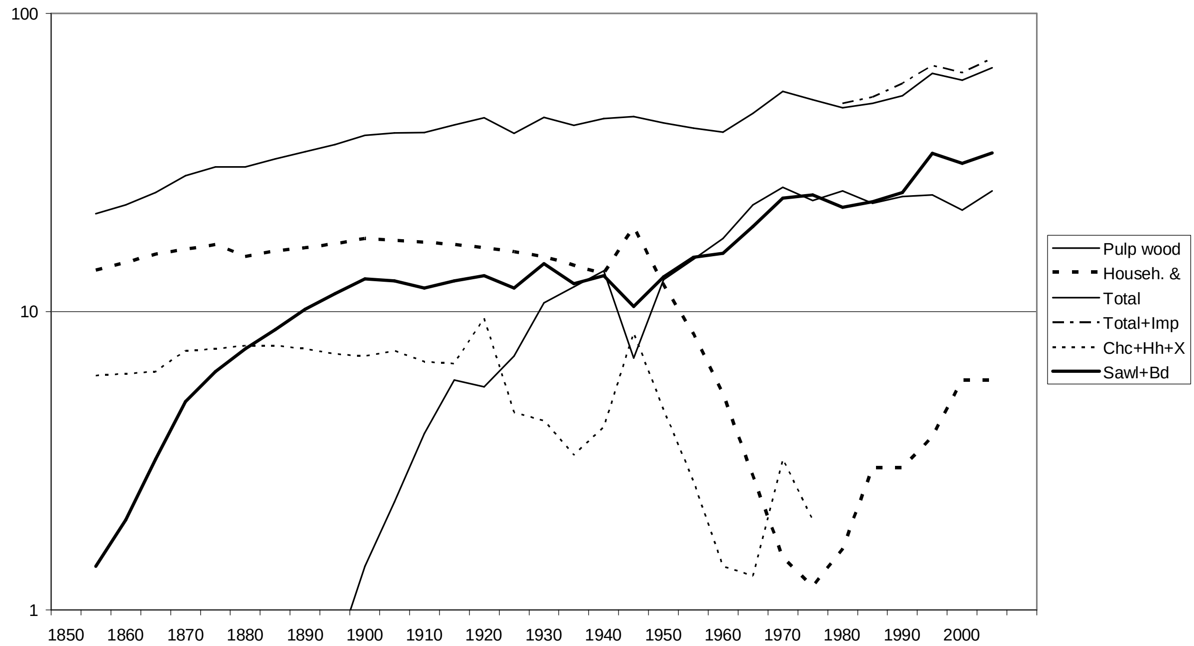


Figure 6. Final use of wood in Sweden 1850–2004 (five-year periods)
Estimated as of millions cu.m solid volume under bark

Appendix 2
Calculation methods and sources

Wood from Swedish tree species usually consists of somewhat less than half its weight of cellulose.

Substance	Pine & Spruce	Birch
Cellulose	45 %	40 %
Hemicellulose	25 %	40 %
Lignin	30 %	20 %

Included here are also some ashes and extract substances, which make for two or three per cent.

The cellulose molecules can be said to be the carrying elements of the wood. They look like spirals and are kept together by the lignin, which in its turn is the glue of the wood construction. The third large constituent, the hemicellulose, may be regarded as the filling but has some properties similar to cellulose proper.. In chemical pulping processes the lignin and much of the hemicellulose is removed. On the whole, however, the number of fibres or cellulose molecules remains the same, and if you permit the metaphor, the wood pulping process is similar to a slimming cure where the identity of the slimmed cellulose molecules endures but elements not needed for the intended purpose will be lost. It should be noted that the chemical composition of the cellulose pulp on the one hand and the wood remains from the chemical pulping process which are used for fuel (the black liquor) on the other are different. Thus one cannot exchange one for the other.

When we look upon the degree of utilization of the wood we find that it is used fully for building material and wood fuel. For chemical purposes some of the constituents are isolated. In pulp processing the wood sometimes is used fully, for instance for mechanical pulp, and sometimes with part or most of the lignin and hemicellulose removed, for example for unbleached and bleached chemical pulp. An extreme in this direction is the viscose pulp which should consist of almost pure cellulose fibre. In function, handling and research it has much in common with chemical technology.

In modern statistical series there is rather good information about the final use of the wood input in the forest and energy industries. Historically we have to make reconstructions, and these are based on very airy estimations of the primary wood uses. What we have got is some information about the industrial assortments and quite a few brave estimations of the fuel and building assortments which go back to the 1850s. First, I have accepted the estimations for Sweden made by Arpi in the 1950s of the wood assortments. Then, in order to estimate the final use I have made some very broad generalizations about the product and waste content in the production processes. Finally I have applied these output estimations to Arpis figures. The result is kind of an output table, showing where the wood input ended up after it had went through the production process. What I call the end use here is only half-way in the product cycle, as forest industries only take the task to prepare the material for further processing before it will before it will reach the final consumers. The measure I have chosen is the *quantity* of wood, in solid cubic metres without bark. This quantity is observed at the beginning of the processes. This means that waste from saw mills as well as black liquors from pulp mills have been estimated from the quantity of wood which is required to produce them. Take as an example the waste from saw mills: 50 % of the raw timber logs becomes sawn timber and the rest is wasted. This log waste goes, nowadays, to pulp mills where if chemical processing is chosen about half of it becomes pulp and the remainder stays with the black liquor which will be used for fuel. Thus out of the saw-log today we will roughly get 50 % sawn timber, 25 % cellulose fibre and 25 % fuel.

The main sources for this paper have been the series published by the Central Bureaus of Statistics in Sweden, Norway and Finland and FAO publications, mainly a Historical record published in the 1960s and the web-series from the year 1961-2004. Before the 1930s or maybe even the 1950s the official series of wood consumption and felled timber relies heavily on estimations based on industrial production data, and the estimates of timber stands and annual increment have been very much disputed decades after they were first introduced on a national scale in the 1920s (in Sweden).