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Keskusteluaiheita - Discussion papers

No. 699

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RESEARCH AND DEVELOPMENT IN EU FOREST CLUSTER

ISSN 0781-6847

10.01.2000

Hyvärinen, Jari, **Research and Development in EU Forest Cluster**, Helsinki: ETLA, Elinkeinoelämän Tutkimuslaitos, The Research Institute of the Finnish Economy, 2000, 37 p. (Keskusteluaiheita, Discussion Papers, ISSN; No. 699).

ABSTRACT: The EU forest cluster is a broad user of the new technology. The pulp and paper industry is strongly connected with machinery, electronics, information technology, and these industries together compose a strong technology- and skill-intensive part in the cluster. The EU forest cluster has exploited synergies of scale with logistics (harvesters, transporting) and in raw wood materials (forestry, silviculture). Consult companies in co-operation with universities, research centres as well as with machinery and information companies constitute a competitive "know-how mass" in the European forest cluster. Degrees related to forest cluster can be studied at 150 departments in at least 100 universities around Europe.

European printing companies are mainly SME's and their connections with research centres as well as with the paper and board producers are essential. In the packaging industry, the food industry, liquid packaging, housewares and personal care are primary products. The packaging industry R&D focuses on the packaging technology in the environmental and other ecological and hygienic issues throughout the entire production chain.

KEY WORDS: R&D, EU, forest cluster, R&D policy

Hyvärinen, Jari, **Tutkimus ja tuotekehitys EU:n metsäklusterissa**, Helsinki: ETLA, Elinkeinoelämän Tutkimuslaitos, The Research Institute of the Finnish Economy, 2000, 37 s. (Keskusteluaiheita, Discussion Papers, ISSN; No. 699).

TIIVISTELMÄ: EU:n metsäklusteri on laajasti eri alojen teknologiaa hyödyntävä kokonaisuus. Sellu ja paperiteollisuuteen liittyvä metalliteollisuus, elektroniikka ja informaatioteknologia muodostavat vahvan teknologian osaamiskeskittymän. Euroopan metsäklusteri on hyödyntänyt synergiaetuja logistiikan tutkimuksessa (harvesterit, kuljetukset) ja puuraaka-aineissa (metsänhoito, metsätalous). Konsulttiyritykset yhdessä yliopistojen ja korkeakoulujen, tutkimuslaitosten sekä konepaja- ja informaatioteknologiayritysten kanssa muodostavat kilpailukykyisen "tietomassan" metsäklusterissa. Metsäklusteriin kuuluvia opintoja voi suorittaa 100 yliopistossa ja korkeakoulussa ja 150 näiden osastossa.

Euroopan painoteollisuus on PK-teollisuutta, jossa yhteydet tutkimuslaitoksiin sekä paperin ja kartongin tuottajiin ovat ensisijaisen tärkeitä laadun varmistamiseksi. Euroopan pakkausteollisuudessa ensisijaisia paperin ja kartongin käyttäjiä ovat elintarviketeollisuus, nestepakkaukset, kotitaloustavarat ja henkilökohtainen hygienia. Pakkausteollisuuden T&K-kohteet liittyvät ympäristöön ja ekologiaan sekä hygieniatuotteiden kehittämiseen.

AVAINSANAT: T&K, EU, metsäklusteri, teknologiapolitiikka

EXECUTIVE SUMMARY

In the EU forest cluster, the pulp and paper sector is one of the key industries. The main related and supporting industries are pulp and paper machinery, the forest chemical industry, electrical machinery, automation and control equipment and some special machinery such as harvesting and transportation equipment. Furthermore, efficient solutions in environment and energy R&D are significant for the cluster. As mechanical paper grades are especially energy intensive, the new innovations brought by energy R&D are crucial. Even if the pulp process creates energy, this is insufficient to meet all the energy needs in the pulp and paper industry.

The European forest industry has maintained its competitive advantage in global competition and created a broad range of new products. The pulp and paper industry is a relatively innovative sector in terms of new technology transfer and also as an end-user. Taking the broader cluster perspective, pulp and paper technology is based on a comparatively large number of sciences, which are harnessed in the search for new R&D solutions. In the mechanical forest industries, such as the panel board industry, R&D is more focused on solving specific bottlenecks rather than mastering complete processes.

Degrees in subjects related to the forest cluster can be studied in 100 universities at more than 150 departments around Europe. The knowledge of consultancy firms in co-operation with universities and research institutes, engineering and information technology companies and pulp and paper enterprises have composed a global competitive advantage for the European forest cluster.

The estimated R&D expenditure shares of turnover in the EU forest cluster industries are as follows: R&D expenditure of the wood and furniture industry is 0.7 % and the pulp and paper industry around 1 per cent of turnover. Pulp and paper machinery spends approximately 4 per cent, forest industry related electrical machinery 4-5 per cent and forest industry chemicals 5 per cent of their turnover on R&D expenditure.

The European printing industry covers thousands of printing and publishing houses (SME's). R&D projects are frequently carried out in co-operation with the research centres and paper manufacturers. The packaging industry is a significant client for the European paper and board industry, since it purchases on average 35-40 per cent of total European paper and board production. The main user country in Europe is Germany, which consumes approximately one third of all European paper and board packaging by value. In Europe, the main packaging sectors by end-use are food (46 %), beverages (24 %), household products (18 %), and personal care (12 %). The R&D targets in packaging industry are environment, ecology and hygienic products.

YHTEENVETO

EU:n metsäklusteri on laajasti eri alojen teknologiaa hyödyntävä kokonaisuus. Paperiteollisuuteen liittyvä metalliteollisuus, elektroniikka ja informaatioteknologia muodostavat klusterissa vahvan teknologian osaamiskeskittymän. Euroopan metsäklusteri on hyödyntänyt synergiaetuja logistiikan tutkimuksessa (harvesterit, kuljetukset) ja puuraaka-aineissa (metsänhoito, metsätalous). Konsulttiyritykset yhdessä yliopistojen ja korkeakoulujen sekä konepaja- ja informaatioteknologiayritysten kanssa muodostavat kilpailukykyisen "tietomassan" metsäklusterissa.

Euroopan metsäklusteri on pystynyt ylläpitämään kilpailuetuja globaalissa kilpailussa ja luonut laajasti uusia tuotteita. Sellu- ja paperiteollisuus on suhteellisen innovatiivinen ala kun otetaan huomioon teknologian siirto ja sen rooli loppukäyttäjänä. Tarkastelemalla klusteria laajasti sellu- ja paperiteollisuus hyödyntää monipuolisesti eri tieteenaloja, joiden avulla pyritään löytämään uusia T&K-ratkaisuja. Mekaanisessa metsäteollisuudessa kuten levyteollisuudessa tutkimus ja tuotekehitys ovat enemmän keskittyneet ratkaisemaan pullonkauloja.

T&K-panostuksen osuudet liikevaihdosta ovat mekaanisessa metsäteollisuudessa ja huonekaluteollisuudessa 0,7 %, sellu- ja paperiteollisuudessa 1 %. Sellu- ja paperikoneita valmistavassa teollisuudessa T&K-panostuksen osuus on 4 %, metsäteollisuuteen liittyvässä elektronisten komponenttien valmistuksessa 4-5 % ja metsäteollisuuden kemikaaleissa 5 %.

Metsäklusteriin kuuluvia opintoja voi suorittaa noin 100 yliopistossa ja korkeakoulussa ja 150 näiden osastoissa. Suomessa on eniten metsäalan tutkijoita verrattuna maan koko tutkijamäärään. Suurimmat tutkimuslaitokset henkilömäärällä mitattuna ovat KCL Suomessa, STFI Ruotsissa ja CTP Ranskassa.

Euroopan painoteollisuus on PK-teollisuutta, jossa yhteydet tutkimuslaitoksiin ja paperin tuottajiin ovat ensisijaisen tärkeitä laadun varmistamiseksi. Euroopan pakkausteollisuudessa paperia ja kartonkia käytetään elintarviketeollisuuteen yleensä ja sen nestepakkauksiin (46 %), kotitaloustavaroihin (18 %), henkilökohtaiseen hygieniaan (12 %). Pakkausteollisuuden T&K-kohteet liittyvät ympäristöön ja ekologiaan sekä hygieniatuotteiden kehittämiseen.

Contents

R&D in EU Forest Cluster

Jari Hyvärinen[1]

1. Introduction

As noted in cluster studies or other industrial organisation literature, industries do not act alone in the international competitive environment. They have links with customers and raw material producers as well as other related and supporting industries. Through this process, clusters create or attain their competitive advantage in the world markets. The main statistical or Porterian method of exploring industrial clusters is to compare the market shares in the OECD trade level.[2] The product's world market share is compared to the OECD average market share calculations. If the product's market share is higher than this average, a international competitive advantage is created in the core industry or somewhere in the cluster.

The European forest industry, especially in the Nordic Countries, has taken a leading role as regards the fastest growing paper grades, such as mechanical coated and uncoated printing and writing papers. These are used mainly in magazines, catalogues, books, advertising material and various kinds of office papers. In the 1990's, consumption has increased most rapidly in coated papers, consumption of coated mechanical paper increasing 4 per cent and coated woodfree 5 per cent, respectively. Consumption of newsprint has increased 2.5 per cent. In the Nordic countries some newsprint machines have been converted for producing other printing papers, and newsprint production has moved closer to the consumers. Also, in the light of FAO's consumption estimates for 2010, the consumption of printing and writing grades will achieve 4.5 per cent yearly growth.

In spite of increasingly widespread discussion of globalisation, the main markets of the European forest companies are in Europe - Germany, Italy, the UK and France. Outside Europe, in North America and Asia there were likewise crucial markets, but these are at a different stage. In North America (as well as in Europe) it has been noted that the markets are at a mature phase, where every new innovation step requires extremely "hard work". The situation in Asia is somehow disparate. Comparing pulp and paper engineering, the

[1] I wish to express my gratitude to Colin Hazley, Markku Lammi, Pirkko Molkentin-Matilainen, Pertti Laine and Petri Rouvinen who helped me during the project. I also appreciate comments received from Forest Cluster Project supervisor group.
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[2] Rouvinen (1993)

chemical industry, energy solutions, logistics in pulp and paper mills, paper grades or ,for example, education and the research infrastructure in general, the Asian continent is a mystery as far as "innovation and technology" are concerned. While the pulp and paper markets are expected to grow most in Asia in the future, the technology of logistics and transportation of forest goods as well as information technology, and environment and energy R&D will become more important in future decades. Another, but smaller R&D target is near. As the EU enlarges, the Central European countries are likewise expected to become important markets. Therefore, technology transfer and direct foreign investment will grow, and this will increase the importance of R&D in the European forest cluster.

One of the most crucial issues is that the pulp and paper industry is conceived by the public as a low technology industry. Comparing R&D expenditure with that of other industries, for example with electrical engineering or the chemical industry, the gap is considerable. This behaviour is better understood if the problem is approached through the cluster framework. This is because a kind of R&D allocation between forest cluster firms is implemented in such a way that R&D expenditures accrues more to other firms than to pulp and paper. The whole logistics chain "from log to printed paper" improvements have largely evolved through better logistics effectiveness. This development is mainly happening in the pulp and paper firms, but the technology of harvesting and transportation ais based on R&D in engineering works, and the automotive and information technology industries. Perhaps the strongest supporting industry is, therefore, mechanical engineering, where investments in R&D are noteworthy and considerable improvements have been made in pulp and paper machine technology.

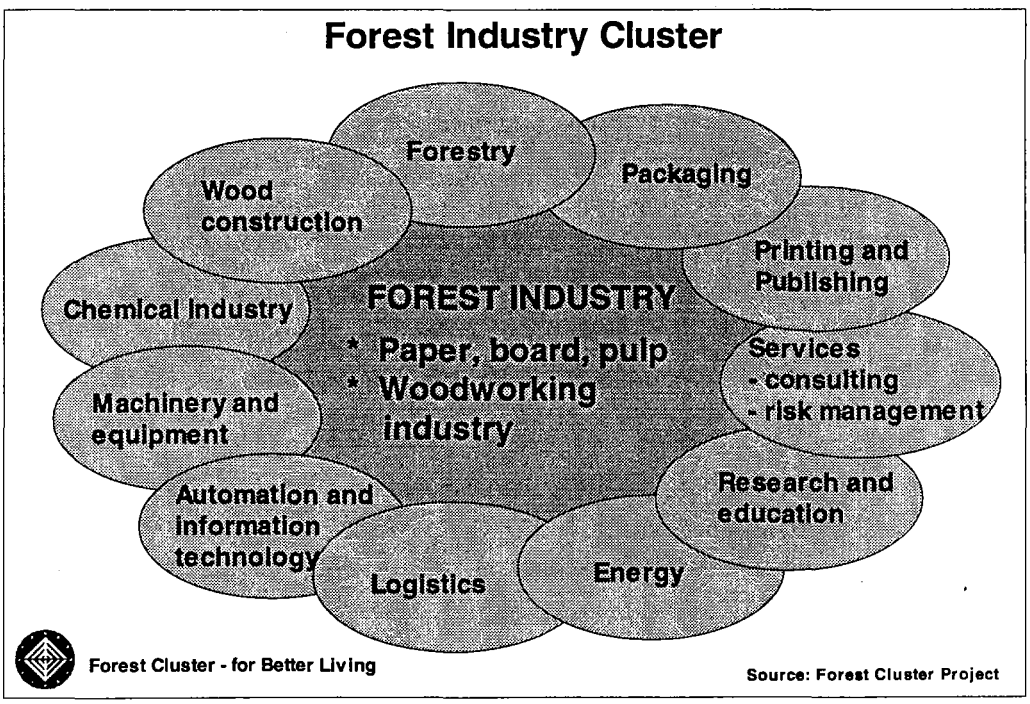
Another high R&D intensive industry is paper chemicals, which are developed in co-operation between the chemical industry and the pulp and paper industry. As the manufacture of mechanical paper grades especially are energy intensive, the new innovations brought by energy R&D are crucial. Even if the pulp process creates energy, this is insufficient to meet all the energy needs of the pulp and paper industry. Further, taking account of user-producer links, the different paper grades will be accommodated by technology in thousands of printing houses which are extended all over the Europe.

This paper discusses several areas of R&D: *i)* Competitive advantage of the European forest cluster in R&D; *ii)* Role and importance of R&D in the Forest Cluster; *iii)* Share of Forest Cluster Technology Inputs. The method of this paper is more from the pulp and paper than other parts of the cluster.

2. What is the EU Forest Cluster?

The industry's competitive advantages can be analysed by clustering sectors, which are in co-operation with the forest industry. The vast bulk of the capital goods are purchased when the industry launches investment programmes - such as paper machines, recovery boilers, grinders, refiners, forest machines and many other kinds of machinery and equipment. These items play a significant role in the mechanical engineering industry's output. The inputs of companies in other sectors, such as chemicals manufacturers, service producers and the contributions of research institutes and universities have likewise helped to make the European forest cluster the integrated and competitive entity that it is today. Furthermore, consulting firms have increasingly enhanced the cluster's competitive advantage. The effectiveness of this entity is further strengthened by such features as its advanced technology in the field of energy in general, and especially in electricity generation, automation and information technology as well as logistics.

Figure 1.



According to estimates, EU forest cluster sales are on average EUR 400 billion and the cluster employs around 4,2 million people. The EU forest cluster is both research and technology intensive and environmentally sound, based as it is on sustainable forestry, recycling, and the function of forests as carbon sinks., Advanced technology is therefore used throughout the chain. Employ-

ees in EU forest cluster can reach the highest level of expertise and enjoy challenging job opportunities.

Table 1.

Comparison of EU Industries

bill. EUR in current prices 1995

	Production	Employment (thousands)	Extra-EU exports	Production av. growth 1985-1994
Chemicals	357,7	1599	66,6	2,8
Pulp, paper and paperboard	49,4	183	8,2	2,7
Wood processing	54,2	482	3,5	3,7
Printing and publishing	89,6	818	4,7	1,3
Mineral oil refining	137	101	7,6	3,6
Metal products	216,1	2133	17,8	2,2
Machinery and equipment	329,7	2394	91,5	0,7
Electronic engineering	211,7	1377	51,5	4,9
Electrical machinery	117	1128	26,6	3,5
EU forest cluster	399	4200	20,5	-

Sources: Panorama of EU Industry 1997, EU Forest Cluster Project database, OECD, ETLA

3. Competitive Advantage of Paper, Board and Pulp Grades

3.1 Paper Grades in Nutshell

The pulp and paper industry has a broad range of products and there is a large gap in terms of quality and technology-intensinevess between newsprint and woodfree papers depending on the end-use. Papers can be classified by raw materials or the end-use and the combination of these as graphics papers (newsprint, printing and writing), packaging materials (packaging paper, paper for liquid containers and for construction), household and sanitary papers, and special papers. There is also a large scale of different paper products which are converted into paper products or are used in manufacturing other products. These are packaging products (containers, bags, wrappings), household and hygienic paper goods (cotton tissue, nursing, baby care, feminine hygiene, kitchen towels, toilet paper), stationary and office supplies (envelopes, labels, printing and copy paper, fax paper) and miscellaneous (tubes, wallpaper, metallised paper).

The main technology-intensive grades are coated woodfree papers, and almost at the same level are some mechanical grades such as medium weigh coated (MWC) and light weight coated (LWC). There is a broad choice of papers for various press technologies between MWC/LWC and traditional newspaper. LWC is a high quality grade which is used for top magazines and needs a high percentage of valuable kraft pulp in the furnish. super calendered (SC) paper can replace MWC and LWC in some publications where printing quality is not of overriding importance. Although SC papers can be printed using the heatset offset process, there are certain problems with water sensitivity, dot gain and dusting or milking. Recent entrants to the range of value added mechanical papers include surface treated newsprint and machine finished coated (MFC) papers, machine finished pigmented (MFP) papers and film coated offset (FCO) papers.[3]

Machine finished coated (MFC) papers were developed in Finland in the 1980's in order to allow value-added grades to be made on narrow newsprint machines. All MFC installations use short dwell blade coaters. MFC has found its own markets and does not compete directly with LWC. MFC has higher brightness and provides excellent contrast between paper gloss and print gloss compared with LWC. Machine finished pigmented (MFP) is used as substitute for LWC and is made by coating the sheet with a gate roll coater before running the web through a standard machine calender. An innovation in press technology in the mid-1980's was the introduction of the metering size press as a device to overcome the speed limitations of conventional size presses on uncoated woodfree machines. The metering size printing provides a contour-type coating with excellent fiber coverage. This press has enabled the development of new film coated offset (FCO) paper, which is more like LWC than MFC, and has become an alternative to LWC.[4]

The pulp and paper industry is often characterised by a low level of technology creation, making less direct use of R&D compared to other industries such as electronics or biotechnology. Taking a broader view, the situation is not so straightforward. In terms of new technology transfer and as an end-user, the pulp and paper industry is a relatively innovative sector, being a strong investor in new technology and adapting it from related and supporting industries.

[3] PPI (1998)
[4] PPI (1998)

Figure 2.

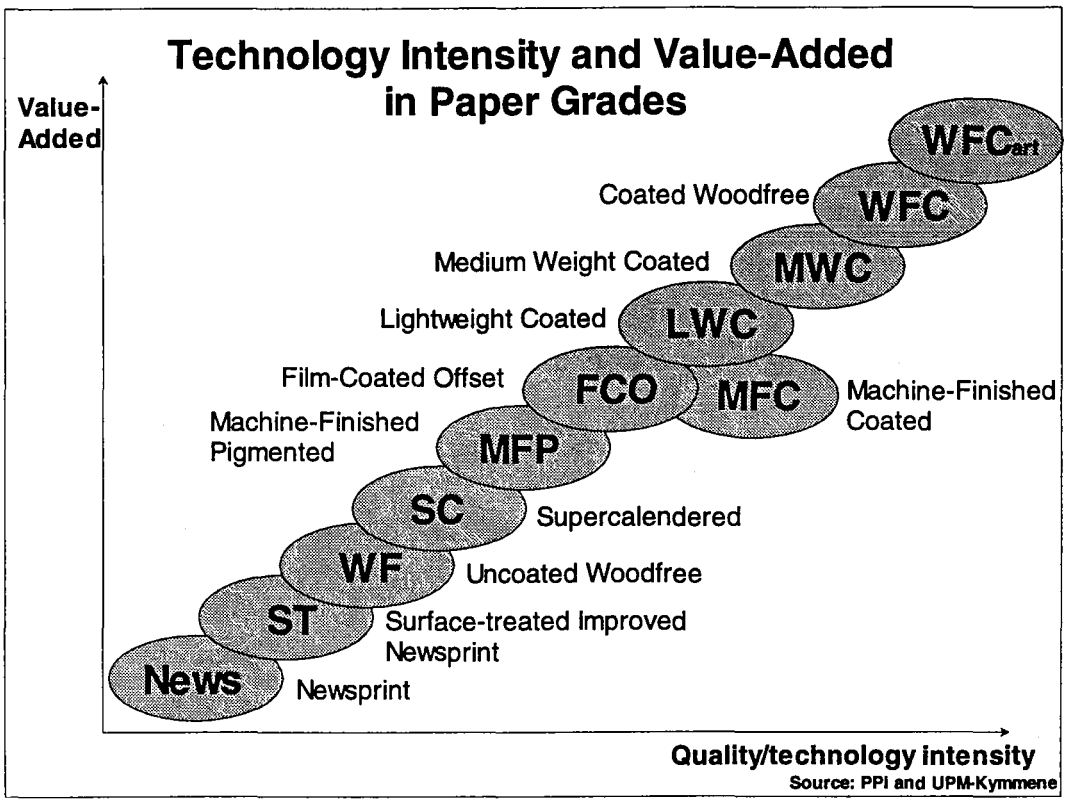


Table 2.

New Grades	Furnish	Surfacing Appl.	Finishing
Surface Treated Newsprint	Chemical pulp, mechanical pulp, deinked old newspaper	Metering size press, gate roll size press	Machine calender, soft nip calender
Machine Finished Offset pigmented (MFP) Papers	Chemical pulp, mechanical pulp, deinked old newspaper	Metering size press, gate roll size press	Soft nip calender, supercalender
Machine Finished Coated (MFC) Papers	Chemical pulp, mechanical pulp	On-machine, short-dwell blade coater	Soft nip calender (gloss 20-25 %, 2.0-2.5 mu PPS-10)
Film Coated Offset (FCO) Papers	Chemical pulp, mechanical pulp	Metering size press	Soft nip calender (gloss 50-55 %, 1.5-1.7 mu PPS-10)

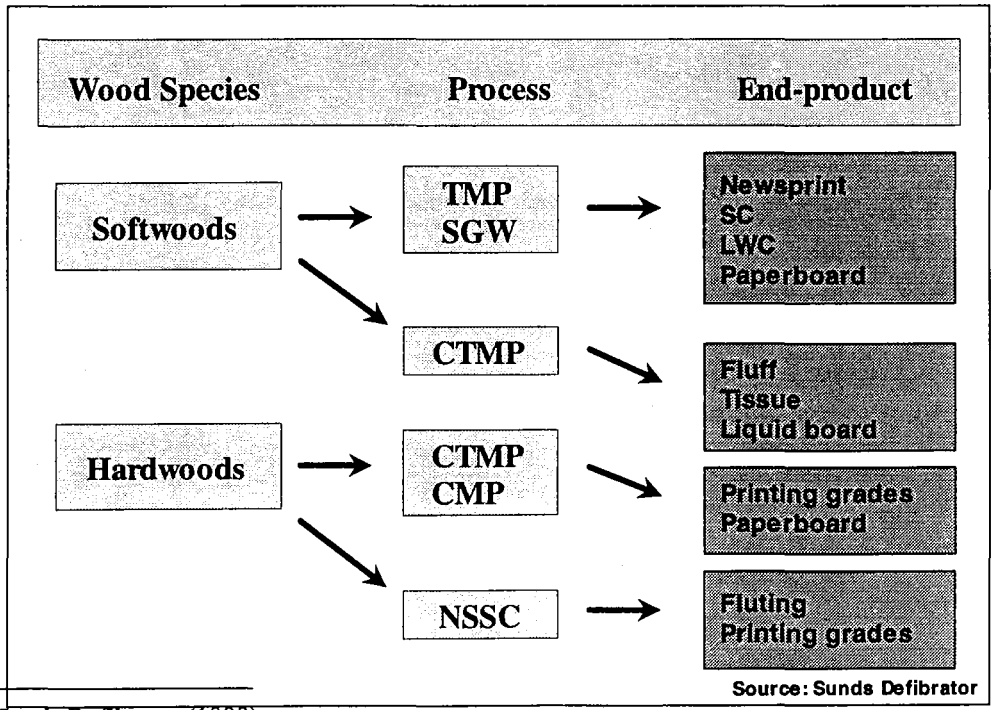
Source: PPI 1999

3.2 Pulp and Paper Technology Characteristics

In pulping, the basic technology has conceived decades ago (groundwood mechanical, soda, sulphite, semichemical, kraft, and thermomechanical). Nevertheless, there has been a revolution in paper making process technology. In the 1950-60's, the main technological strides in addition to integrated mechanisation of production processes were new instrumentation techniques and process indicators. Automation and computerisation of process control systems and the installation of new large-scale machines took place in 1970's.

After the main innovations, the technology has improved expeditiously in both chemical and mechanical pulping processes. According to Sunds Defibrator, the needs of reducing energy and protect environment are main guidelines with customer needs and different raw materials and end products. The R&D of chemical pulping includes the wide range of various technologies such as cooking, de-knotting, screening, brown stock washing, oxygen and ozone delignification and bleaching. Recycled fiber is one significant way to balance the raw material resources. This technology include R&D processes as repulping, de-trashing, pre-screening, de-inking, washing, fine screening, fractionation, de-watering, dispersing, bleaching, post-refining and pulp quality monitoring.[5]

Figure 3. Selection of mechanical pulping process by raw material and end-product



[5] Sunds Defibrator (1999)

The different wood species and the end-products are the key cases when the mechanical pulping process is selected. Mechanical pulping include technology and equipment for complete refiner-based fiber lines and from wood handling to pulp baling.[6]

According to Levlin (1997), the main R&D efforts in pulp and paper[7] industry are concentrated on:

- higher value products
- cost-effective and environmentally acceptable production, including efficient and sustainable use of raw materials and innovative technologies
- an increase in the knowledge base, where R&D as well as education levels have a primer role.

3.3 Mechanical Forest Industry Technology Characteristics

Panelboard industry has used the main R&D resources in the mechanical forest industry. The whole panelboard production process is through chipping and screening to sawing and storage. Main panelboard processes are such as Medium Density Fiberboard (MDF), Particleboard (PD), Oriented Strandboard (OSB) and Wet Hardboard (WHB).[8] As the natural resources are scarce the R&D innovations are concerned to find new solutions to economize environment and lower energy-intensive processes in different types of forests.

3.4 Other technology advantages

Since then new technology has increasingly made it possible to build larger and faster paper machines. More R&D time has also been devoted to new integrated production control systems and overall planning of production as the mill integrates, and converting and co-operative business operations. In particular, the revolution in control systems and logistics has brought about favourable changes in the forest cluster. New information technology has made it possible, for instance, to optimise the sales-to-delivery-cycle with respect to costs, flexibility, quality and process documentation[9]. Information technology such as CAD/CAM and CIM are exploited in the design and manufacturing of

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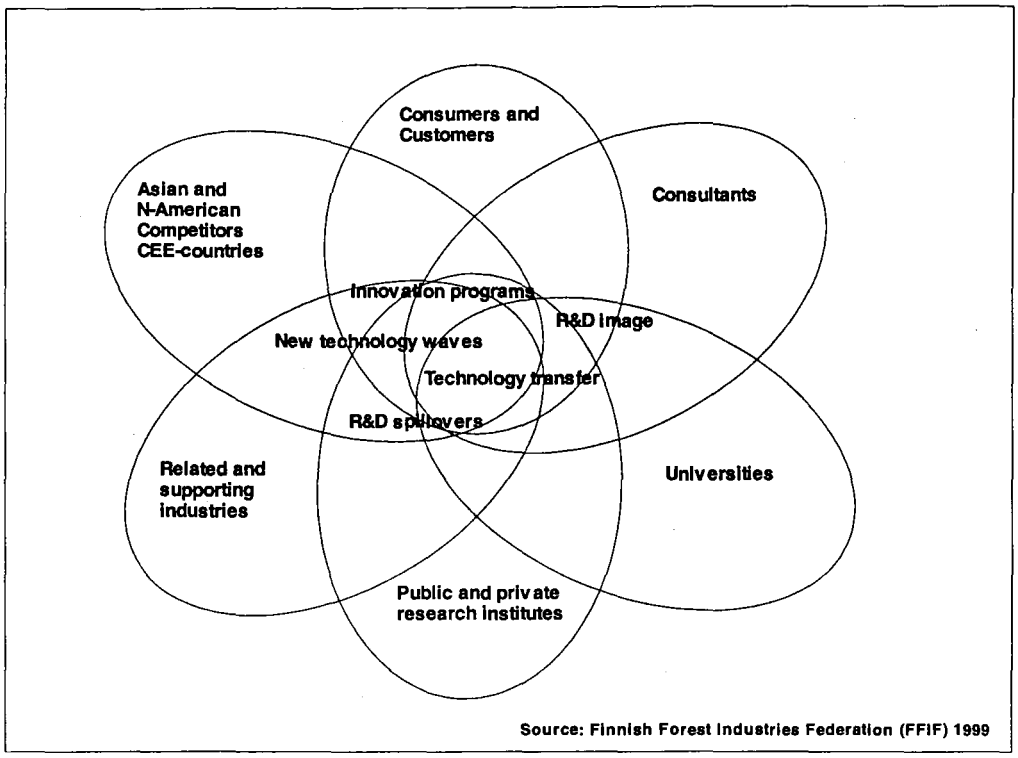
[6] See Sund Defibrator (1999) for more specific description of mechanical pulp process
[7] See chapter 4.4.1. R&D in Machinery
[8] Sunds Defibrator (1999)
[9] Lefflner (1993)

paper products. With these systems available the sector's productivity has improved rapidly[10].

While chemistry, machinery, electronic and information technology can be seen as the main related and supporting industries in the European forest cluster, also other industries such as the life sciences has become more involved. Thus e.g. biotechnology and environmental technology are used to increase the impact of sustainable health and to improve the environment of production processes. The life sciences are also involved in research on sustainable wood fibre producing crops. Biotechnology research is developing a natural fibre with a reduced lignin content for more efficient pulping[11]. Taking this broader cluster perspective, pulp and paper technology is based on a comparatively large number of sciences, which are harnessed to find new R&D solutions. For example, a recently published Yale study is supports the view that pulp and paper ranks in third place after semiconductors and measuring and controlling devices with respect to the number of technologies in use[12]. Thus, pulp and paper industry is classified neither as a high nor as a low-tech industry, but considered as a broad-technology industry[13].

[10] Bourque (1987), See also Autio et al. (1997)
[11] CEPI (1995)
[12] Klevorick et al. (1995)
[13] Lindström (1996)

4. R&D Actors In European Forest Cluster

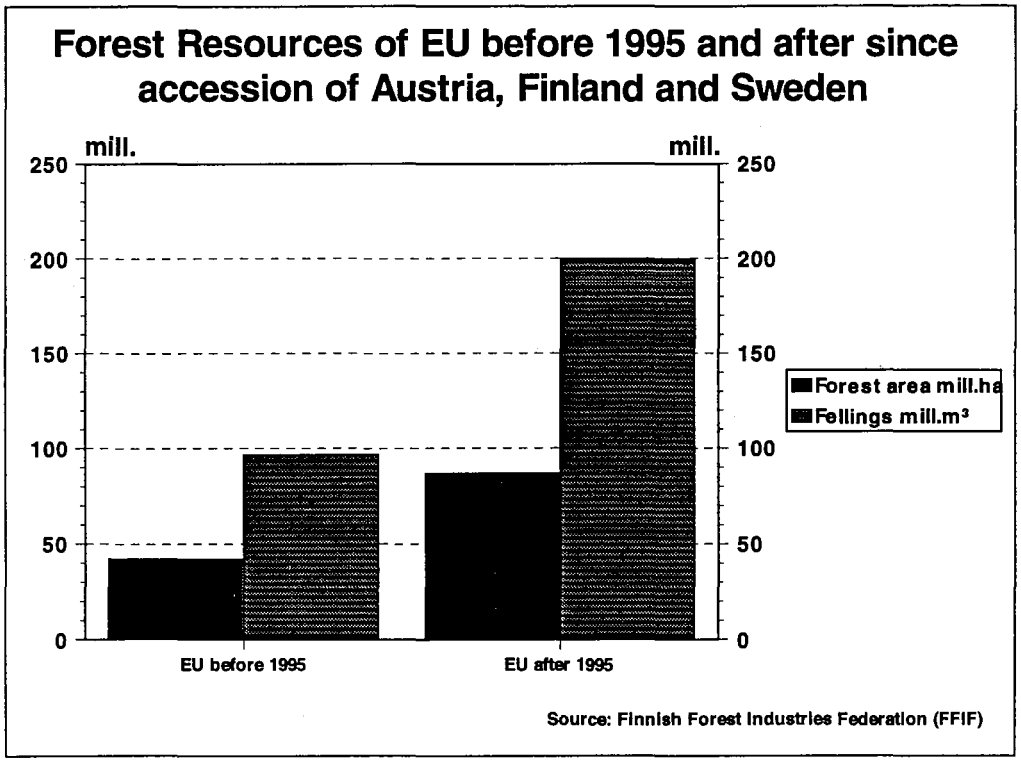


4.1 R&D in Forestry

European forests are located mainly in the Nordic countries. After 1995, when Finland, Sweden and Austria joined the European Union, the forest industry became a net exporter, whereas earlier it had primarily served internal markets. The accession of the three new members increased the forest area from 42 to 87 million ha, whilst annual felling rose from 97 to 200 million m^3. In Figure 5, researchers in forestry are compared to the total number of researchers in the country giving degree of forest-centredness, while the proportion is highest in Finland and Sweden. Table 3 shows the European forestry research organisations. The leading research countries measured by the number of researchers are France, Germany, Finland and Sweden. Comparing the type of research organisations in Europe on average, 40 % of forest research is done at universities, 49 % in public research organisations, and 9 % in private research organisations.[14]

[14] Hellström and Palo 1995

Figure 4.



Box 1. FIBRE – Research Programme 1997 – 2002

Fibre is the Finnish biodiversity programme, which concentrates the themes such as the role of key species and diversity in the functioning of eco-systems, landscape ecology, species identification and systematics, and applied research on e.g. forest management and agricultural practices. The project finances directly about 90 scientists both at Ph.D. and postdoctoral levels and another 200 scientists in various projects. The mission of the project is to produce interdisciplinary and innovative research on biological diversity, with the application of the results as the central goal.

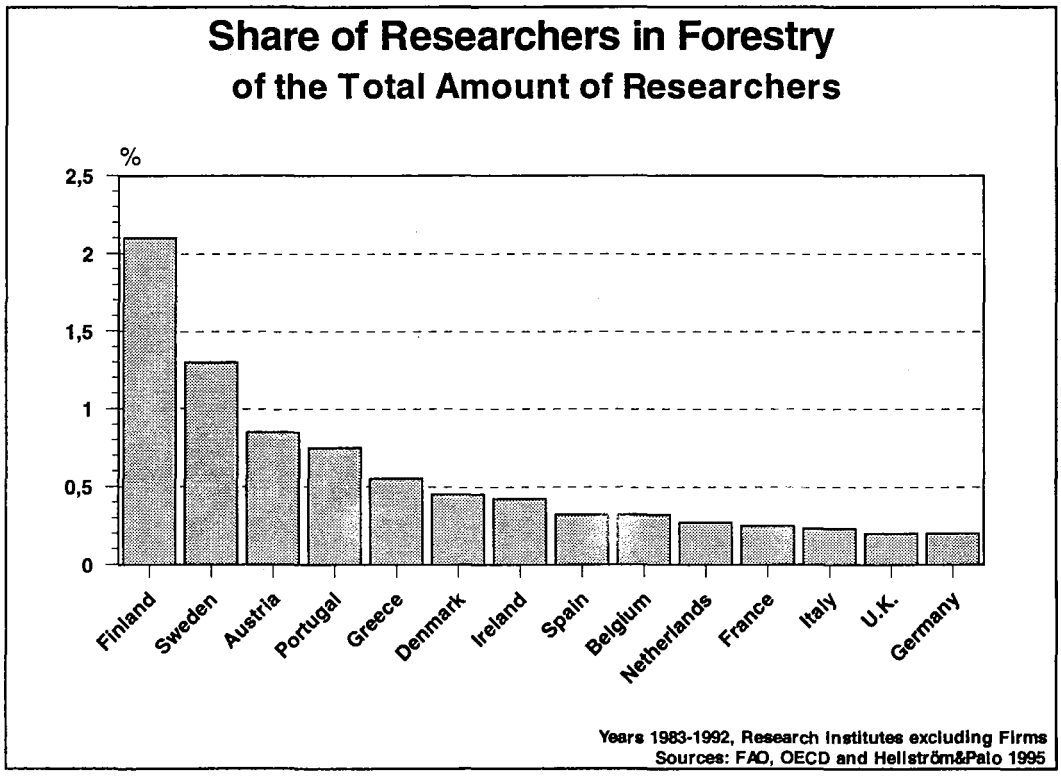
Source: FIBRE publications

Table 3. EU Research Organisations in Forestry

Country	Universities %	Public Research Institutes %	Private Research Institutes %	Other %	Researchers
France	24	70	6	0	709
Germany	39	40	5	16	675
Sweden	58	0	42	0	655
Finland	20	53	27	0	537
U.K.	33	52	15	0	468
Italy	38	61	1	0	308
Spain	64	17	4	15	198
Netherlands	39	52	4	5	186
Austria	31	46	23	0	183
Belgium	58	21	3	18	112
Denmark	36	50	14	0	102
Portugal	0	73	27	0	92
Greece	16	84	0	0	51
Ireland	16	84	0	0	51
Total	40*	51*	9*	-	4327

*Weighted average, Sources: FAO 1986 and 1993, Hellström and Palo 1995

Figure 5.



4.2 R&D in harvesting and transportation

Only some decades ago harvesting and forwarding were an area of high employment in the forest industry. It employed large numbers of forest workers, farming tractors and even horses. The main devices used were the saw, winch, axe and billhook. Today after extensive mechanisation of forest operations forest machinery have replaced the manual work. To take the extereme development as example forest workers no longer walk in the forests, but mechanical walking forest machine are being tested.

Nowadays harvesting and forwarding tractors contain a great deal of technology and highly-trained drivers are needed. The principal manufacturers are Timberjack and Ponsse from Finland, and Partek in Finland and produced in Sweden. In forest operations basically two different technologies are used. In the cut-to-lenght method logs are pre-cut to specified lenght lenghts and the logs are sorted for different use already in the forest. In the other method, full-tree method, logs are after delimbing transported in full lenght to the mill where they are sorted. Timberjack is the world's leading designer, manufacturer and distributor of forest machines. The company produces a wide selection of machines for harvesting - including attachments - terrain transportation, log handling and hauling.[15] The Ponsse Group designs, manufactures and markets forest machines and their principal components for cut-to-length harvesting, as well as information technology related to logging.[16] Partek's Valmet forest machines are also based on this cut-to-length method.[17]

Timberjack is a subdivision of Metso Corporation and supplies a comprehensive line of harvesters for cut-to-length applications, as well as feller-bunchers for full-tree harvesting. The product line includes specially designed machines for all timber harvesting operations, whatever the terrain or harvesting conditions. Forwarders and skidders are designed to transport harvested timber from the forest to the roadside.[18] Ponsse also has information technology products for timber transportation. This product group applies computers for timber trucks and other vehicles and weight indicator systems for loader cranes of trucks.[19]

New harvester technology involves extensive R&D, and these machines can perform many operations. The harvester machine fells, delimbs, cross-cuts, measures and piles the logs at the felling site. The logs are then transported

[15] Timberjack (1998), sold to Deere and Co. in December, 1999.
[16] Ponsse (1998)
[17] Partek (1998)
[18] Timberjack (1998)
[19] Ponsse (1998)

from the forest by forwarders. A high-tech control system optimises cross-cutting and classifies the timber according to customer needs. The forwarder picks up the cut-to-length harvested logs and transports them from the forest to the roadside. The machines are equipped with efficient loaders for loading and unloading logs. Timberjack has designed for forwarders a Total Machine Control system (TMC®), which controls all machine functions, including the hydrostatic drive and the loader. Feller-bunchers fell and bunch timber, which is then transported by skidders to a landing or roadside for delimbing. They feature fully enclosed forestry undercarriages, powerful boom sets, advanced hydraulic and cooling systems, and easy service access. The product line includes both conventional swing models and no-tail swing tilt-table machines for steep slope applications. In full-tree harvesting, skidders are used to transport the felled trees to a landing or roadside for delimbing. [20]

New information technology used in harvesters includes Ponsse Opti's advanced harvester data system that measures trees to the nearest millimeter, predicts the taper of each trunk, calculates a mathematical model of it and divides trees into the optimum number of logs before cutting it. This system is based on a normal PC using the Windows operating system, and it enables data transmission and map applications during logging. A GPS system and maps of the stand marked for cutting make it possible for the operator to see on a large colour screen the location of his machine, the borders of the stand marked for cutting, as well as any nature preservation areas. Satellite locationing and map programmes provide information on the location of the vehicle and the target spot in real time.[21]

Partek's Forest Machines include harvesters such as felling machines, forwarders and harvesting heads. The production includes also cranes for forest machines and timber trucks. Partek's production is based on the cut-to-length method, in which it is possible to do both thinning and final felling while at the same time operating with consideration for the environment. The cut-to-length method has become increasingly widespread throughout the world during the 1990s mainly because of the combined effect of the machines' efficiency and their positive attributes in relation to the environment compared with other methods. [22]

These companies work in close co-operation with customers such as pulp and paper companies, and also with drivers who have the most important knowledge, that is how the technology works in the real situation.

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[20] Timberjack (1998)
[21] Ponsse (1998)
[22] Partek (1998)

4.3 Related Industries

4.3.1 R&D in the Printing Industry

The European printing industry covers thousands of printing and publishing houses. The R&D projects are frequently carried out in co-operation with the research centres and paper manufacturers. The main issues and requirements of printing and writing papers include good appearance, formation and availability in varying shades of whiteness and colours; thickness, bulk, stiffness and handling strength and sheetfed printing properties; freedom from curl, stability in conditions of humidity and temperature variations; texture and suitability for use with a wide range of inks and printing technologies.[23]

4.3.2 R&D in Packaging Industry

The experience of many decades has shown that the leading packaging materials are paper and paperboard. The proportion of these materials used for packaging in Europe by volume is illustrated by the fact that paper and board consumption was 27 million tonnes, making up 40 per cent of total packaging materials consumed in 1995. The packaging industry is therefore a significant client for the European paper and board industry, since it purchases on average 35-40 per cent of total European paper and board production. The main user country in Europe is Germany, which consumes approximately one third of all European paper and board packaging by value. In Europe, the main packaging sectors by end-use are food (46 %), beverages (24 %), household products (18 %), and personal care (12 %). The ten biggest European packaging supply companies represented about 5 per cent of the world's total packaging expenditure in 1995.[24] Packaging industry R&D focuses on improve packaging technology in environmental and other ecological and hygienic issues throughout the entire production chain.[25]

4.4 Supplier Industries

4.4.1 R&D in Machinery

The challenges and pressures faced by the European forest cluster with respect to new innovations, spillovers and technology transfer will come from various sources. The main factors involved are competition and customer needs, but

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[23] PIRA 1998, The Future of Pulp and Paper to 2007

[24] Goddard (1997)

[25] See more for example in Packaging and the environment (1992), PIRA; Global Packaging Trends (1993), PIRA.

new innovations from other sectors which create substitutes for paper will also present challenges. Active links with related and supporting industries, consultants and research institutes and universities will help to face competition. There are immediate industrial links with machinery for example Ahlström Machinery and Valmet[26] and Rauma from Finland, Beloit from the U.S. and the Swiss-German Voith Sulzer group. These enterprises are especially technology and research-intensive, with typical R&D investments ranging up to 2-4 per cent of production.[27] As an investment needs a heavy input of capital and takes 2-3 years to complete, co-operation and service are carried out in close co-operation with the customer. The development of new technology applications is crucial to Valmet's operations. New technology also helps to resolve runnability questions, and paper machines and coaters are constantly being developed to run at ever higher speeds, while producing paper of even higher quality. In this, Valmet is assisted by high-speed runnability simulators and pilot facilities.[28] Important research themes have included the development of more efficient and environmentally rational production methods and machine configurations, press technology, paper finishing, pulp drying, board machine R&D, higher product quality and greater productivity in pulp, and paper and board machinery.[29] Further, Ahlström Machinery offers systems and processes that are used in chemical fiberlines, chemical processing and recovery, wastewater and sludge treatment as well as in the processing of recycled fiber systems and the preparation of paper machine stock.[30]

4.4.2 R&D in Chemicals

Another significant member of the cluster is the chemical industry, which spends about 3-4 per cent of production on R&D[31]. Chemicals are used environment-efficiently in pulp and paper making itself, in coating and recycling and in converting. The principal chemical producers include Raisio Chemicals and Metsä Specialty Chemicals in Finland, EKA Chemicals in Sweden, BASF in Germany and other smaller companies. The most significant group of paper chemicals is fillers and coating pigments, such as clay, calcium carbonate and talc. These improve brightness, opacity and printability.[32]

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[26] Rauma and Valmet announced a merger plan on 17th November 1998. The new company resulting from the merger will be called Metso corporation and it will be operative under this name as from July 1. 1999. The company will have through its technological coverage an unique capability for turn-key deliveries.

[27] OECD (1995)

[28] Valmet (1998)

[29] Valmet (1998), Voith Sulzer (1998)

[30] Ahlström (1997)

[31] OECD (1995)

[32] Nurmi et al. (1998)

Many of these companies have their own research centres and they co-operate with customers to create new innovations for the pulp and paper industry. For example, Raisio Chemicals has the Paper Technology Center (PTC) for wet-end and recycling chemicals, offering various services and consulting for their customers. Raisio Chemicals' Coating Technology Center (CTC) is also a modern, efficient paper coating test centre, where it is possible to test new coating colour and chemicals rapidly and reliably.[33] Valmet Paper Machinery has a commitment to equip the CTC with the latest coating machine technology.[34] At the same time the need to reduce both the amounts of circulation water and effluent streams is revolutionising the approach to circulation water treatment and the design of chemicals.[35] The development of the pulping and bleaching processes shows how important suppliers are as regard advances in core pulp and paper technology.[36]

5. Science & Education and Consulting

5.1 Universities and R&D Organisations

The critical factors in the European forest cluster now and in the future will be human resources, education and R&D. Employees in R&D are, at least in Nordic countries, highly-educated and the competitive advantages to the cluster come from skills and know-how from personnel. Table 4 compiled at the Lappeenranta University of Technology shows that education and research in the cluster are broadly represented in European Union universities. The cluster as a whole includes various specialised sources of advanced knowledge in universities, private and public research institutes and corporate R&D departments. Degrees relating to the forest cluster can be studied in at least 97 universities and 151 departments around Europe. Technology engineering degrees cover for example forest products, wood technology, automation and process, information technology, biochemistry, industrial management, and the environment as well as chemical and mechanical engineering. University degrees can be taken in biology and other natural sciences, bioenergy, forestry, forest genetics and plan physiology, forest ecology, silviculture and environmental issues etc. There is also a different type of specialised degree, which connects pulp and paper studies with marketing and management. Other degrees such as those in economics, social sciences and education also fulfil needs in compa-

[33] Raisio Chemicals (1998)
[34] Raisio Chemicals (1998)
[35] Nurmi et al. (1998)
[36] Autio et al. (1997)

nies. Some universities provide also corporate specific management education for the forest cluster corporations through their separate management education units.

Table 4. Research Organisations and University Departments in the European Forest Cluster

	Number of Universities	Number of Departments	Number of Research Organisations
Austria	5	15	10
Belgium	5	5	3
Finland	10	26	11
Greece	1	2	1
Denmark	1	1	4
France	5	4	13
Germany	8	10	21
Ireland	6	16	5
Italy	8	12	18
Luxembourg	-	-	1
Netherlands	4	5	12
Portugal	4	4	7
Spain	7	9	8
Sweden	19	28	8
U. K.	14	14	14
TOTAL	97	151	136

Source: Lappeenranta University of Technology (LTKK) 1999

Research institutions play a major role in pulp and paper R&D. Often these research organisations and projects funded by companies or other funds. Some of these institutes are funded by the government, conducting a wide range of basic research. The tasks vary widely, but their main role is in projects such as reducing water and air pollution, improving energy efficiency or promoting better use of wood supplies and waste paper. Almost all-European countries have research institutes concentrating on pulp and paper research. Table 5 shows the ten largest R&D organisations in Europe. The largest organisations measured in man-years are KCL in Finland, STFI in Sweden and CTP in France.[37] PIRA in the UK is also significant, even though it remains outside the "top ten" table. KCL, STFI and CTP are funded by the companies, VTT and PPRI are government-funded and EFPG, TU LUDZ, TU Dresden and KHT are based on the university research.

[37] Eriksson (1997)

Table 5. Ten largest R&D organisations in the Pulp and Paper In dustry

Man years, %	total	scientists	technicians	research students
1. KCL, Finland	223	44	52	4
2. STFI, Sweden	182	50	38	12
3. CTP, France	115	32	62	6
4. PTS, Germany	91	60	34	6
5. VTT, Finland	75	61	31	8
6. PPRI, Poland	70	56	43	1
7. EFPG, France	69	20	28	52
8. TU LUDZ, Poland	65	55	37	8
9. TU Dresden, Germany	49	41	33	26
10. KTH, Sweden	46	28	7	65

Source: Eriksson (1997)

Comparing man-years used in different R&D areas of these organisations, pulp and paper products take up a significant proportion of the resources. More than 520 man-years were spent on pulp production and almost 300 man-years on paper products in 1995-1996.

After the main themes of research, fibrous raw material (over 260 man-years), paper product properties (almost 250 man-years) and paper finishing have also been among the main focuses of R&D. The main research areas have included effluent and other environmental issues, energy conservation, control technology and the production and development of chemicals from wood. The major research themes are listed in table 6.[38]

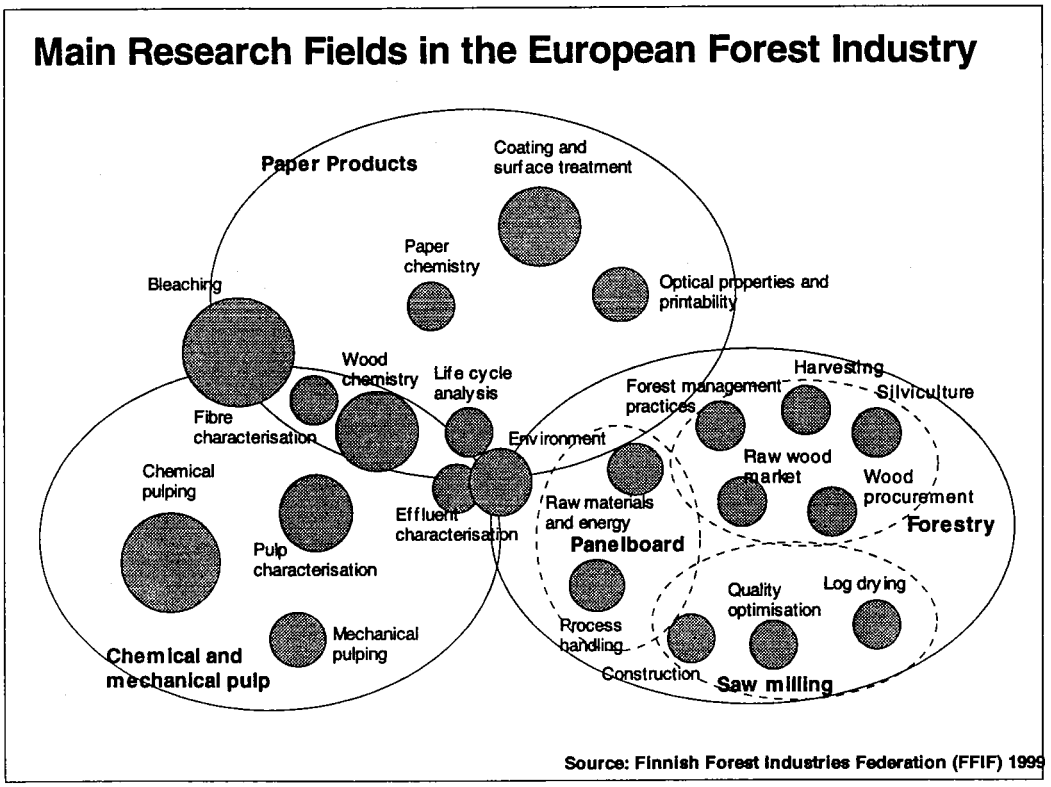
Table 6. Major Research Themes

Rank	Theme	Man-years
1.	Bleaching	126
2.	Chemical pulping	103
3.	Coating and surface treatment	88
4.	Wood chemistry	87
5.	Optical properties and printability	87
6.	Pulp characterisation	68
7.	Mechanical pulping	61
8.	Fibre characterisation	60
9.	Paper chemistry	59
10.	Effluent characterisation	53

Source: Eriksson (1997)

[38] Eriksson (1997)

Figure 6.



5.2 Consulting

Consulting services have recently begun to play an increasingly crusial role in the pulp and paper industry. An investment project needs a considerable amount of capital and takes 2-3 years, depending on the scale of plan. Consultants have various tasks to offer from business analysis and engineering services to R&D solutions for innovation and production process bottlenecks. Typical consulting activities are such as optimisation of logistics, production scheduling or cutting of paper, the engineering of custom-made conversion machinery, or the design of packaging.[39] In forestry consulting the main areas are services concerning sustainable development of natural resources.

The knowledge of consultant enterprises co-operating with universities and research institutes, engineering and information technology companies and with pulp and paper enterprises constitutes one of thecompetitive advantages to the European forest cluster.

[39] Autio et al. (1997)

6. R&D Industry Expenditures in European Forest Cluster

6.1 R&D Expenditures by Cluster Industry

The level of R&D expenditure is a significant indicator of innovation activity. The core cluster includes the wood, pulp and paper industries. Because pulp and paper is a highly capital-intensive sector, the comparison with other industries gives rather moderate results for the core cluster, where R&D expenditure in relation to production is between 0.5-0.7 per cent and in relation to value added about 0.8-1 per cent.[40] Moreover, the pulp and paper industry in Finland has, for example, funded research activities performed outside the firms themselves to an amount that has been about one-fourth of the industry's "in-house" research expenditures.[41]

Figure 7.

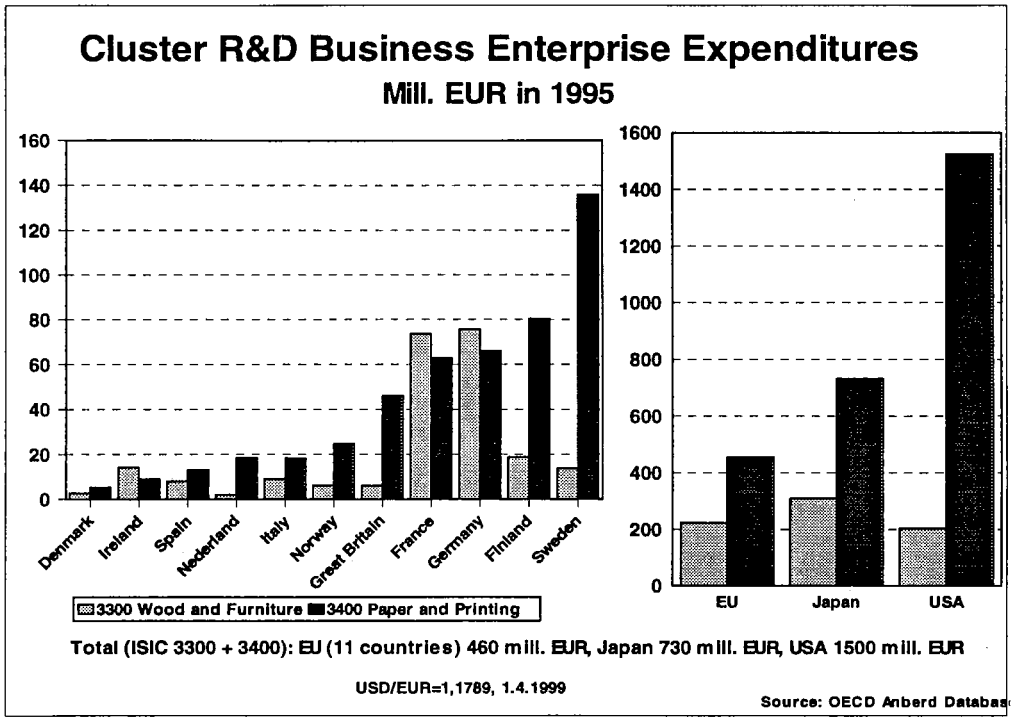
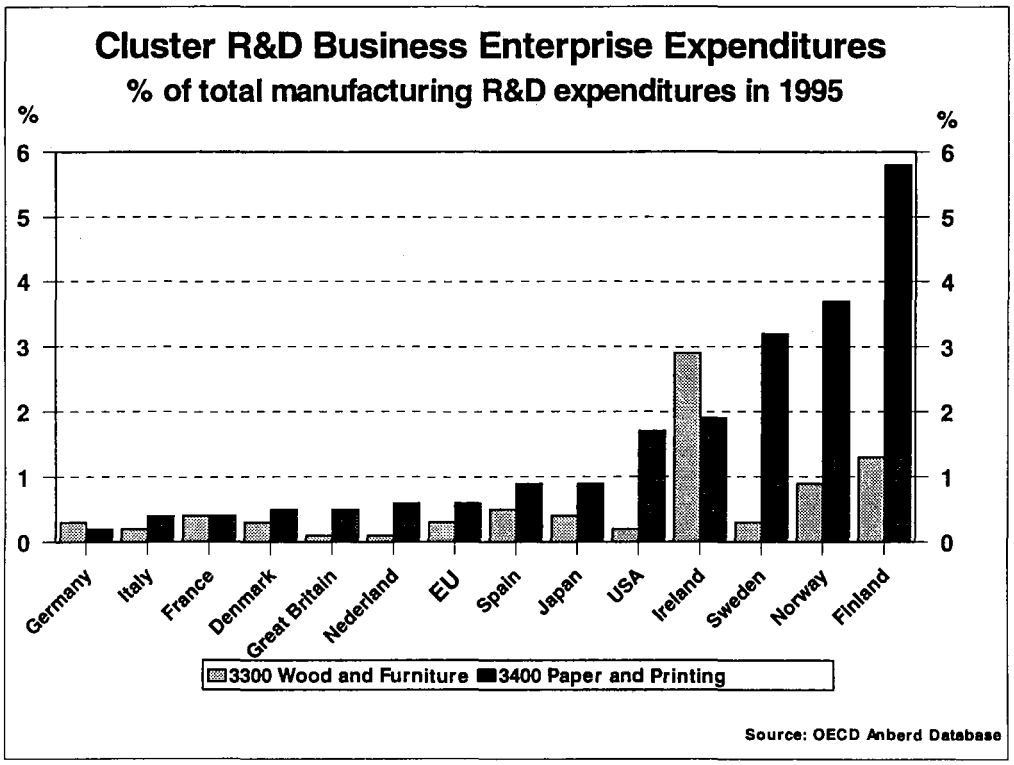


Figure 7 compares enterprise expenditure by country in wood and furniture sector and in the paper and printing industry. Finnish and Swedish companies have been the most active in investing in R&D in the European Union. Depending the definions of OECD Anberd database, the comparing the EU, Ja-

[40] Furniture and printing are included
[41] Vuori and Vuorinen (1993)

pan and the USA gives the surprising results. According the database, the US firms spent enormous 1500 mill. EUR on paper and printing R&D and European firms almost 500 mill. EUR. In figure 8, forest core cluster R&D expenditures are related to each country's total manufacturing R&D expenditure. The percentages are highest in the Nordic countries (Finland, Sweden, Norway). This result is anticipated as pulp and paper is a vital industry in these countries.

Figure 8.



The non-electronic machinery, motor vehicles, scientific instruments, industrial chemicals and electrical machinery industries are close to the forest cluster and R&D related to production is between 3-9 per cent (OECD (1995)). The chemical industry and machinery industries are investing almost 30 per cent of the total business R&D expenditures in the EU. When R&D is related to the industry's value added (figure 9), the largest groups are instruments and industrial chemicals. Figure 10 gives an estimate of R&D shares in the forest cluster. In some special industries or corporations as in automation or pulp and paper machinery these numbers are even higher. Anberd data and annual reports are used as background information.

Figure 9.

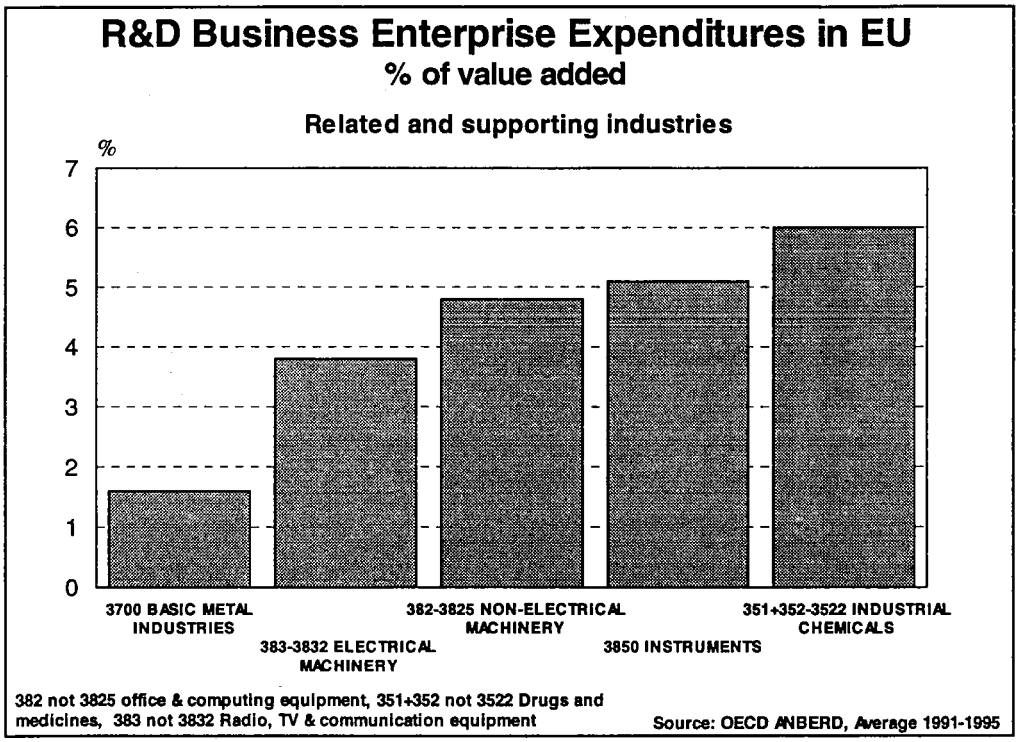
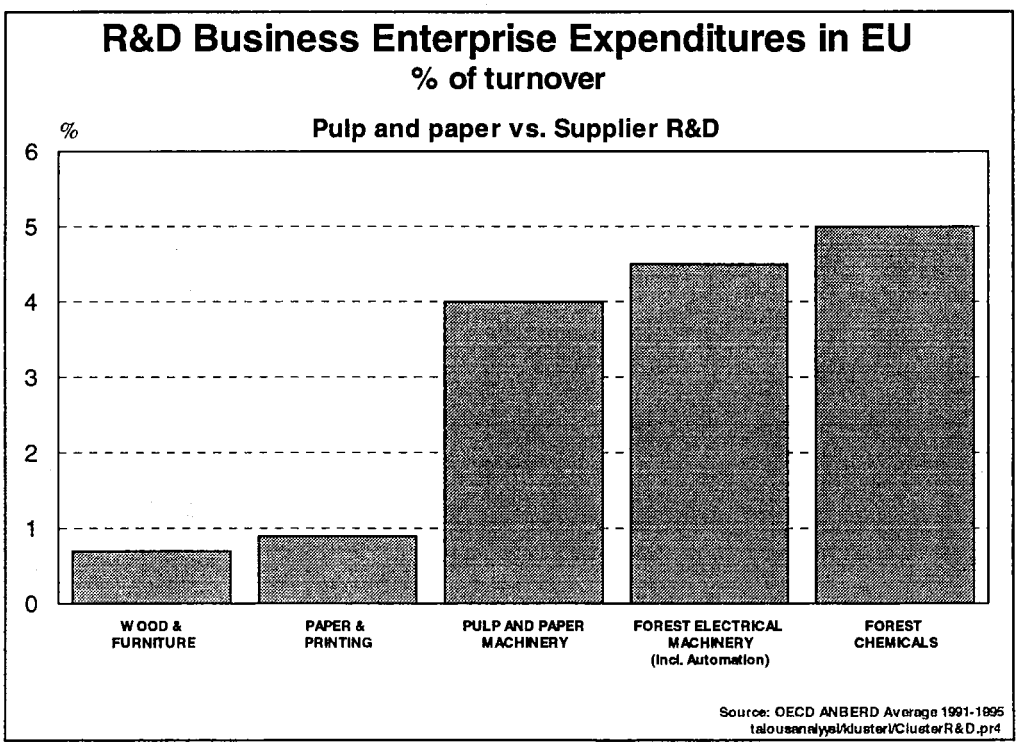


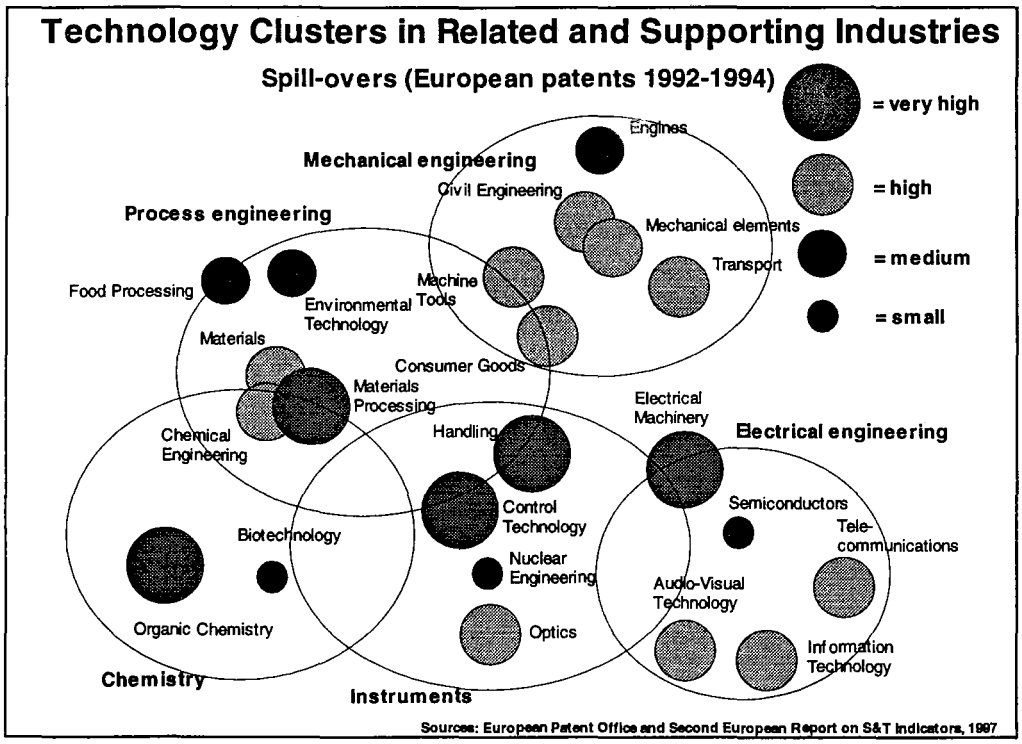
Figure 10.



6.2 Patent Information

Innovation activity is often measured with patents or spill-overs. The clustering between industries can be through several institutions such as universities, research institutes and consultant services. According to a study carried out on the basis of European Patent Office data in 1992-1994, the number of patents is very high in materials processing, organic chemistry, handling and control technology, and in electrical machinery. Some synergies can be found, for example, between materials, chemical engineering and materials processing. Machine tools and consumer goods take advantage of mechanical engineering and process engineering. Instruments and process engineering have synergies with handling and control technology, and electrical machinery is close to both electrical engineering and instruments. The pulp and paper industry has connections with transport, mechanical elements, environmental technology, consumer goods, materials processing and chemical engineering, control technology, electrical engineering and information technology, among others.

Figure 11.



7. Visibility of the Forest Cluster in EU R&D Policy

One of the main co-operation instances between the European Commission and the European forest industry is the Confederation of European Paper Industries (CEPI). According to CEPI's Activity Report 1998, the main research field is "The Fifth Framework Programme for Research (1998-2002)". Much of the CEPI Research Group's focus has been on preparing this Fifth Programme and the Specific Programmes through which it will be implemented. CEPI's activities with its forest cluster partners, including private forest owners (CEPF) and the woodworking industries (CEI-Bois) as well printing and allied industries (INTERGRAF), have focused on ensuring that the interests of the wood and paper chains are sufficiently represented in the Fifth Framework Programme.[42]

7.1 Industrial and Technology Policy in the EU - Some Evidence

The EU industrial policy is aimed at harmonising the actions of its member states. The joint aim is to promote structural reform of European industry and to improve its international competitiveness.

In the course of 1999, the Commission will submit a formal report (Communication on the Competitiveness of the EU Forest-Based and Related Industries) on the state of the European forest product sector's competitiveness to a council comprising representatives of member states and to the European Parliament. The Commission's intention is to analyse key factors in the sector's competitiveness and issue recommendations for measures to be taken by both the Union and member states. When the Council and the Parliament have made their formal replies to the report, the Commission and the member states will start implementation of the recommended measures.

At the industrial branch level, the role of industrial policy is to guarantee an environment, where dynamic enterprises can survive and prosper, and economic institutions are dedicated to thinking strategically about the economy.[43], Industrial policy must also aim to enhance market flexibility, reduce barriers to mobility, and stimulate adaptability within large corporate bureaucracies.[44] Therefore, a key issue in industrial policy is how the government can influence the activities of businesses in the most flexible way. The possible task of in-

[42] CEPI Activity Report (1998)
[43] Cowling (1990)
[44] Geroski and Jacquemin (1985)

dustrial policy is to ensure that the elements determining competitiveness create a favourable environment for the development of competitive industries, industrial networks and competitive clusters.

Another relatively important point of view is that it is a task of industrial policy is to set up the needen research institutions which the market is not able to support on their own. Since market mechanisms would not allocate sufficient resources for R&D in the long run, it makes sense to allow the public sector a certain role in this area. However, while firms have their own research departments, the main goal is to make co-operation between public-financed and business-financed institutions as flexible as possible.

Comparing general technology policies it can be noted that the specialisation of innovation systems differs across countries. There are considerable differences in their ability to respond to change and to exploit the potential of new technologies.[45] In the United Kingdom, the major target is to exploit scientific innovations in science-based industries immediately. In Denmark and Finland, the task is in some respect different, since the main task is to increase the knowledge content of resource-based clusters of industries. In France there is a trend towards redefining the traditional missions of innovation and technology policy, directing them away defence. The technology policy in Sweden, the Netherlands and Germany is basing on the major companies i.e. on the effort to cope with the consequences of the internationalisation of R&D strategies in these companies.

National innovation systems are increasingly multinational, and the networks between nations are growing through globalisation. During the ongoing "new global" consolidation process, mergers and acquistions are expanding company sizes and pushing production and ownership from a national to a multinational level. Productivity growth has increased in countries such as in Denmark and Netherlands which exploit the technology enbodied in imported capital and intermediary goods. This process has rapidly increased the number of international technology alliances and foreign patents and licences. Ireland is an example of a "catch-up economy", where the effect of the absorption of international technology, whether low-or high tech, has had a favourable impact on productivity and economic growth. In locating the technology centre, the position of company's headquarters is important at least in France, Germany and Italy, where it is typical that innovation activity is placed near the company's headquarters. The internationalisation of R&D for firms emphasises in countries such as in Belgium, Finland, the Netherlands and Sweden.

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[45] OECD (1998)

7.2 Research and development in the European Union

The European Union's research and development activities are based on five-year framework programmes, each of which contains 10-20 separate programmes. Sector-specific research programmes have been phased out over the years and have given way to more general interdisciplinary ones.

The Fourth Framework Programme, which is now nearing completion and has a budget of 13.1 billion EUR, has enabled the forest products sector to participate in at least six different programmes. The most important from the forest industry perspective have been the agriculture and fisheries programme, FAIR, and the industrial and materials technologies programme, Brite-Euram. Also of importance have been the environmental and energy programmes and the standardisation and information technology research programmes.

In the work of the Fifth Framework Programme, to begin in 1999 and to continue until 2003, The Commission has allocated a budget of EUR 13.7 billion for the Programme. Furthermore, the Commission has approved 1.26 billion EUR for Euratom, the nuclear energy research programme. The Programme is more "problem-based" and less "technology-based" than previous Framework Programmes.[46]

The Fifth Framework Programme covers four themes: Theme 1 is called "Quality of Life and Management of Living Resources". The area of sustainable agriculture, fishing and forestry includes as a priority area of sustainable and multipurpose utilisation of forest resources and integrated forestry in the wood chain. In general, the research of the entire forest cluster research is comprised in Theme 1. Theme 2 – "User Friendly Information Society" accepts research projects, which are concentrated on the electronic media and paper. Theme 3 – "Competitive and Sustainable Growth" the innovative products and processes contains items such as clean eco-efficient processes and promotion of the use of renewable resources. Theme 4 is called "Energy, Environment and Sustainable Development", and therefore includes research cases such as renewable energy resources, biodiversity and climate change, as well as water management.[47] In general, in the Fifth Framework Programme, socio-economic and environmental issues are emphasised and integrated into all the themes.

[46] Molkentin-Matilainen (1998)
[47] Molkentin-Matilainen (1998)

8. Conclusions

As a result of broad European forest cluster R&D, the European forest industry has kept its competitive advantage in global competition and created a broad range of new products. In new technology transfer and as an end-user, the pulp and paper industry is a relatively innovative sector, being a strong user of new technology, making competitive advantage with the related and supporting industries. The European forest cluster has exploited synergies of scale with effective logistics (harvesting, transportation) in production and advantages in raw materials (forestry etc.) and other effective related and supporting industries such as paper machinery and chemical industry. While chemistry, machinery, electronics and information technology can be seen as the main related and supporting industries in the European forest cluster technology, industries such as the life sciences have become increasingly essential. The life sciences are also used for research on sustainable wood fibre producing crops, for example, biotechnology research is developing natural fibre with reduced lignin content for more efficient pulping. Taking this broader cluster perspective, pulp and paper technology is based on a comparatively large number of sciences, which are harnessed to find new R&D solutions. Thus, the pulp and paper industry can with good reason be classified as a broad-technology industry.

While Asia is expected to be the focus of the highest growth rate in the pulp and paper markets in the future, the technology of logistics and transportation of forest goods as well as information technology, environmental and energy R&D will also gain increasing importance in future decades. As the EU enlarges, the Central European countries are likewise expected to become important markets. This means that technology transfer and direct foreign investment will likewise grow, and this will increase the importance of R&D in the European forest cluster.

Finding efficient solutions in energy R&D is a matter of great importance for the cluster. As mechanical paper grades in particular are energy-intensive, the new innovations in energy R&D are crucial. Even though the pulp process creates energy, this is insufficient to fulfil all the energy needs of the pulp and paper industry.

The forest cluster as a whole includes various specialised sources of advanced knowledge in universities, private and public research institutes and corporate R&D departments. Degrees relating to the forest cluster can be studied in at least 97 universities and 151 departments around Europe. The knowledge of these universities and public research institutes, research units in engineering

and information technology companies and pulp and paper enterprises constitute a globally competitive advantage for the European forest cluster. In the European forest cluster, R&D personnel is highly educated and the competitive advantages in the cluster derive from the skills and know-how of personnel and students.

The chemical and machinery industries account for almost 30 per cent of the total European Union business R&D expenditure. When R&D costs is seen in relation to the industry's value added, the largest groups are instruments and industrial chemicals. Pulp and paper machinery industry accounted for approximately 9-10 per cent of R&D expenditure related to value added in Finland. The chemical industry spends about 3-4 per cent of production on R&D. The share accounted for by R&D of the turnover in the forest cluster industries is also estimated. R&D expenditures of wood and furniture were 0.7 as well as in pulp and paper around 1 per cent of the turnover. This result is satisfactory, although in the related and supporting industries the result is more encouraging. The pulp and paper machinery consumed approximately 4 per cent, forest electrical machinery 4-5 per cent and forest chemicals 5 per cent of turnover. Chemicals are used environmental-efficiently in pulp and paper making itself, in coating and recycling and in converting. Many of these chemical companies have their own research centres and they co-operate with customers to create new innovations for pulp and paper companies.

Innovation activity is often measured by patents or spillovers. New innovations are crucial in environmental issues, finding products for paper and following global economic changes, while greatest challenges for R&D in the European forest cluster are increasing global competition, the mature European markets, expanding synergies with other industries (metal industry, chemical industry, information technology), environmental questions, and cost-reduction in energy and transportation.

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