



Co-ordination network for lignin—standardisation, production and applications adapted to market requirements (EUROLIGNIN)

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Abstract

Lignin is one of the most abundant renewable raw materials available on earth. Despite its unique characteristics as a natural product with multiple chemical and biophysical functionalities, it is largely under-exploited because of its image as low quality and low added value material. Also a complete lack of any organised professional co-ordination and communication tools explicitly dedicated to lignin market promotion is one of the major drawbacks for the further development of commercial applications for lignin. As remedy, the thematic multi-partner network called EUROLIGNIN has been started in August 2002 till July 2005 with financial support of the European Commission.

The major goal of this project is accelerated introduction of sustainable, high-value, lignin-based raw materials derived from leftovers in pulp and paper, and biomass processes to industry and consumers. This will be accomplished by compilation of fundamental information packages on existing and future lignin production and utilisation to create defined actions in research projects and technology activities that very precisely and with direct economic implications show the way to increased use of lignin. EUROLIGNIN consists of 26 participants including lignin producers, research centres, universities and lignin end users from 16 European countries resulting in a well-balanced consortium.

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1. Introduction

Lignin is one of the most abundant natural raw materials available on earth, second to cellulose if mass is considered, even first if solar energy storage is the criteria. Until now only about 2% of the lignins available in the pulp and paper industry is

commercially used comprising of about 1,000,000 tons/year lignosulphonates originating from sulphite pulping (Gargulak and Lebo, 2000) and less than 100,000 tons/year of kraft lignins produced in the kraft process. The existing markets are either very low value products (lignosulphonates mainly in dispersing and binding applications) or limited to very narrow market segments (high-quality dispersants from chemically modified kraft lignin). The possible development in these fields is limited to very low growth rates.

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Table 1
Participants in the EUROLIGNIN thematic network

Partner No.	Organisation	Country	Type
1	Agrotechnology & Food Innovations (A & F)	NL	Research institute
2	The International Lignin Institute (ILI)	CH	Institute
3	Granit SA	CH	Producer
4	Royal Institute of Technology (KTH)	S	Research institute
5	Institut National de la Recherche Agronomique (INRA)	F	Research institute
6	University of Basilica	I	University
7	Institut Francais du Textile et de l'Habillement (IFTH)	F	Research institute
8	Scottish Crop Research Institute (SCRI)	UK	Research institute
9	University of Lille	F	University
10	Adiagene SA	F	End user
11	Novozymes	DK	Supplier enzymes/Research
12	Oy Keskuslaboratorio (KCL)	FIN	Research institute
13	National Laboratory for Engineering and Industrial Technology (INETI)	P	Research institute
14	Technical University of Iasi (PPI)	RO	University
15	KIRAM AB	S	Producer
16	Transfurans Chemicals BVBA	B	End user
17	VTT Chemical Technology	FIN	Research institute
18	University of Lausanne	CH	University
19	Rhodia Acetow GMBH	D	Producer
20	University of Barcelona	E	University
21	Royal Veterinary and Agricultural University	DK	University
22	Mirteto	I	End user
23	Latvian State Institute of Wood Chemistry (LSIWC)	LV	Research institute
24	National Technical University of Athens	EL	University
25	Bakelite AG	D	End user
26	La Rochette Venizel SA	F	Producer

On the other hand, the potential for lignin production in the existing pulp and paper industry is more than 50 million tons/year without counting other possible biomass utilisations also included in this project. Based on already existing technical knowledge and on the technical characteristics that are already achieved with lignin products, this amount could be efficiently used to replace fossil resources. The major drawbacks to reach that goal are the low-purity standards of existing commercial lignins and the fact that most of this potential lignin is used for energy production and therefore not available for commercialisation.

Nevertheless, there exist several new driving forces that indicate that there could soon be a great improvement of this situation:

- Kraft pulp mills (95% of the world production) have increasingly experiencing bottleneck problems in their recovery boiler: the installed capacity becomes too small after increase of capacity in the fibre lines

(direct contacts through participants 1, 2, 3, 15; see Table 1). Debottlenecking of recovery boilers by partial lignin precipitation is a new strategy already contemplated by some pulp mills.

- New processes as patented by participant 3 (Abächerli and Doppenberg, 1998) allow the production of very pure soda lignins in sulphur-free and existing pulp mills at low cost that are based on agricultural plants (like straw, flax, sorgho, kenaf, miscanthus, bagasse). These lignins could not be efficiently separated by prior art technologies.
- New pulping processes might soon allow production of sulphur-free lignins also based on wood (participants 15 and 19). The process of participant 15 is further developed in a European project called NovaCell QLRT-2001-01482.
- New techniques for modification and increased sensitivity of the methods for analytical follow-up of the modifications allow new approaches to create lignin adapted to the need of the users.

- New biomass utilisations like ethanol production by steam explosion need further by-product valorisation of the lignin to become economically viable (participants 4, 6, 24).
- The market demand for natural and sustainable products is steadily increasing, as well as in traditional high-volume bulk applications of lignin, as in more particularly health-related fields like food and feed, cosmetics and pharmaceuticals and hygienic prevention. In these fields, the existing solutions are not satisfying and need other more natural approaches. Examples are the enormous problems in the European food chain: BSE or viral and bacterial infections. Toxic bactericides in end consumer products like cosmetics, textiles or used in industry for the production of paper, tanning and fish.

The resulting new global turnover that can be created in the short term (within 10 years) by lignin raw material sales is estimated at 2 billion Euros. For Europe, this means that including the multiplication effect by multiple sales at different distribution levels, the additional sales of lignin products can reach a similar amount of at least 2 billion Euros. To this, additional jobs and new sales have to be added by induced effects in adjacent fields: engineering and equipment, marketing, consultancy, research, etc. In particular, the better use of agricultural products in pulp or other biomass industries can induce significant multiplication effects (recoverable lignin is only about one-fifth of the other biomass products). New production facilities for non-food crop processing for fibres or ethanol should become economically feasible thanks to lignin co-products.

In addition, there are many small non-wood pulping mills mainly in South America and in Asia, which are confronted with overwhelming pollution problems. This will generate opportunities for European companies to export its most recent technologies. The resulting products can be imported to Europe at low cost creating high value added products by European companies for the European market.

The proof that such new approaches are commercially viable has been given already by the creation of a first industrial production unit in France for soda flax lignins (a direct result of FAIR contract CT 98-3521 including participants 1 and 3) and by the

use of lignins as an anti-bacterial agent in paper industry (participant 22). Europe therefore has a chance to take a leader position in these new markets via these key technologies in this field that have been developed by European companies and research institutes.

1.1. Lignin research state-of-the-art

Lignin research comes out of the tradition of organic chemistry. The applied R&D has primarily been driven by the needs for knowledge in relation to pulping and bleaching. Lignin recovery and utilisation research has been highly empirical and raw material-based rather than consumer-oriented. The 300 million dollar lignin business today is dominated by products from sulphite-pulping liquors, originally based on the need to solve a pollution problem. It is now a chemical business associated to the pulp mill. The products are primarily directed to the process industry, but increasingly higher value functional products are produced, particularly from kraft lignin. Technical service is more important and the research has to be multidisciplinary. Little of this research is done at the pulp and paper branch institutes and, in general, the academic groups do not have the critical mass or the interdisciplinary resources to address complex applications or new markets. The lignin business is faced with a high cost of R&D and has to carefully select which markets to serve. There are presently several new fields of lignin application that are too complex and competitive to be developed by a single partner and need synergistic effort to prove their viability for uses in fields involving for example bioactivity and biochemistry: anti-bacterial, anti-oxidant, animal feed and enzymes.

To make the goal of lignin value added products scientifically, as well as economically viable, the new stakeholders need the following:

- basic detailed information and specific data about existing lignin know-how;
- state-of-the-art expertise and knowledge;
- specific and achievable aims.

Apart from new lignin applications, uses of lignin in traditional fields like materials (polymers, adhesives) and speciality chemicals (dispersants, concrete additives, emulsifiers, binders) can be diversified according

to established needs for more natural products. The main difficulties in the lignin field are:

- The needs of the users are very specific, lignin market is not a commodity market.
- The available sources are not sufficient to make industrial decision makers feel comfortable to choose this raw material with regard to quality, quantity or supply sources.
- Lignin has the image of a low-quality, low-price waste product.

For all these points, a common action approach is proposed in this thematic network, which can contribute to make new stakeholders feel more comfortable and to support them in their projects.

1.2. Lignin analysis

As well as in traditional applications for kraft and sulphite lignins, the need to properly characterise and classify the new lignins to eliminate the three difficulties highlighted above and promote new lignins for potential uses is clear. At the production plant level there are quality and process control issues to explore. At the product development level, proper analysis will facilitate the definition of specifications for commercial purposes, allow the reliable monitoring of physical and chemical modifications and will promote the understanding of the relationship between properties and performance.

In an effort to assess how lignin analysis was practised in labs around the world, the National Renewable Energy Laboratories of the US (formerly known as SERI) spearheaded a round robin in the early 1990s (Milne et al., 1992). In this the participants were free to select the types of analysis and protocols used for the analysis of various lignins. This important effort underscored the need for standard methods, but unfortunately the work did not have a proper follow-up.

The need for developing standard methods, even for simple things like “dry matter” or “ash content” which presently do not exist, is obvious. If new lignins should be marketed at a larger level or existing lignins dedicated to new applications, appropriate standardisation principles are commercially essential for product specifications in the commercial contracts. Such agreement on methods can only be reached by a joint effort including lignin producers, lignin laboratories

and lignin users as conceived in the EUROLIGNIN concept.

EUROLIGNIN is the first thematic network that links the interests of industry (lignin production and lignin utilisation) and of research entities (development of fundamental knowledge and new methods). EUROLIGNIN will integrate the vision on lignin utilisation of these different stakeholders in one common strategy with clearly defined priorities and preferential tools.

Contrary to other efforts in the lignin field, EUROLIGNIN will focus on lignin applications, the need for promoting new lignin applications and the definition of new, promising projects. The combined effort of the development of analytical norms in direct contact with the needs of lignin applications and the presence of industrial companies is another innovative aspect of the EUROLIGNIN network.

2. The EUROLIGNIN thematic network

It is now essential to concentrate on the momentum and to increase the critical mass of the existing achievements. In the lignin field there is a pronounced need to co-ordinate the different players in the field, in order to increase the efficiency of their individual actions. The main problem for introducing new lignins at larger scales is not technical or economical feasibility, but it is the complete lack of any organised professional co-ordination and communication tools explicitly dedicated to lignin market promotion. The absence of reliable norms for lignin characterisation that would allow industry to rely on defined lignin qualities from multiple sources and the co-ordinated identification of the research needs for new markets is cared by the EUROLIGNIN project. Lack of efficient communication tools in public relations, lack of information and support, for start-up for new lignin projects, and the absence of comprehensive information packages are important drivers for establishing a network.

The common goal of introducing new raw material to industries and consumers needs a strong joint effort. The psychological barriers from industrial habits and practices based on other non-renewable materials or from marketing efforts by other competing non-renewable materials are important. Action is now

needed making a strong case for lignin whenever existing successes do allow it and whenever avenues and targets identified by a scientifically competent group, such as the EUROLIGNIN network, show important chances to use lignin for the benefit of quality of life of all.

The EUROLIGNIN thematic network addresses the beginning of this global lignin effort, since the scientific representation is significantly experienced, the industry is well represented and modern communication tools, such as the internet, with relatively little effort to reach a large public is used. Dissemination is guaranteed by the position of partner 2 (ILI) as an independent professional association. Given the popularity of the topic (sustainable development) it will be more important to prepare a coherent and well-organised base of knowledge and information packages rather than to invest largely into pure communication activities. Once such organised information is available, the existing information tools (press, radio, TV and electronic communication) will contribute without any doubt to their popularisation.

The goal of EUROLIGNIN is to concentrate on the preparation of fundamental information packages and to create concrete actions in research projects and technology transfer activities that very precisely, and with direct economic implications, show the way to increased use of lignin. The increased use of lignin, especially within high value-added applications, will be stimulated by initiation and co-ordination of international activities within the field of applied lignin research.

3. Aims and objectives of EUROLIGNIN thematic network

Globally there are dozens of laboratories within industry and agricultural or forest research institutes that are working on the development of lignin applications. In addition, there is a significant global demand in industry for renewable and more natural raw materials. Many of these companies are doing their own research on lignin and require more detailed information, experimental data and new processes that can improve the industrial feasibility of their work. Other companies are initiating activities in the lignin field and need both technical and economic information on

lignin regarding sources, properties of different lignin types and expected prices. This will allow their management to decide positively on future R&D activities within the lignin field. The aim of this thematic network is to improve and increase the information flow between the three types of stakeholders (lignin producers, development laboratories and lignin users) in order to facilitate the commercial success rate for existing projects and increase the creation rate of new projects.

The objectives of EUROLIGNIN are summarised hereafter.

3.1. Scientific and technological objectives

- Identify existing and future technologies and methodologies that allow the production of optimised lignin products.
- Identify existing and future uses of lignin.
- Evaluate potential and key success factors for an increase of existing lignin uses and creation of new lignin markets.
- Identify potential for market increase in specific high-tech and high added value fields; for instance, for the needs of European industry in replacement of more hazardous materials having specific characteristic like anti-microbial and anti-oxidant properties.
- Assess the potential of specific new methods for lignin modification and on-line quality control by modification.
- Assess the state-of-art and the future needs for analytical methods used for characterisation of lignins.
- Identify promising technologies for reaching the users' goals, including production, transformation and utilisation of lignin.
- Define the R&D needs for increasing production of tailor-designed lignins and their uses in industry.
- Provide tools for facilitating the start-up of new lignin R&D projects.
- Create new projects using lignin as raw material and in the field of lignin characterisation.

3.2. Environmental objectives

- Expand and facilitate the economical use of the waste products from wood, pulp and paper industry

as well as from other potential biomass-based industries such as bio-ethanol production plants.

- Promote the uses of a renewable material by making tools available for potential end users and lignin producers to launch new developments.
- Stimulate the replacement of synthetic and/or mineral oil-based materials, which have a negative influence on the compatibility with living organisms and which has a negative environmental impact, by lignin. Such applications include biocides and biostabilisers in textiles, cosmetics and animal feed (hygienic prevention in food chain) and health prevention by action of lignin as a polyphenolic compound.

3.3. Social and economic objectives

- To create new markets for lignin-based natural material with high added value by using a natural waste and recycling product.
- To promote the use of sustainable and natural materials in sectors that are subjected to increasing legal restrictions like textiles, biocides and cosmetics.
- To promote the sustainable development in pulp and paper sector and make this sector more environmental-friendly.
- Stimulate the interest of end users in lignin products by making available a specific network, including public reports facilitating the creation of new research projects.
- Make available a platform for contact with potential lignin users.
- Make available reports on existing production and markets of lignin based raw materials.
- Make available reports on market potential and growth rates in different lignin applications.
- To increase the benefits to the R&D organisations, consultancies, product and technology suppliers in the lignin field, by the development of new technologies and business opportunities for the valorisation of lignin products in its respective application field.

4. Consortium

All members of EUROLIGNIN have great experience related to lignin uses and the methodological problem linked to the specific area in which they are

active. In the consortium there are producers, who are interested in the increase of marketable lignin quantities as well as introduction of new commercially possible lignin uses, technology companies interested in finding markets for lignin by-products of their process, potential new users of lignin in specific market niches and private and public research institutions having special expertise in methods and techniques for lignin analysis or lignin application. The different approaches of the members of the thematic network will enrich the knowledge of the consortium and will help to reach the proposed project objectives.

The EUROLIGNIN thematic network consists of 26 participants including seven R&D companies, 10 universities, four lignin producers and five lignin end users from 16 European Countries. The partners are listed in [Table 1](#) and on the Cordis web site of the European Commission ([Cordis, 2002](#)).

5. Project organisation

The thematic network entitled EUROLIGNIN “Co-ordination network for lignin—standardisation, production and applications adapted to market requirements” has been started on 1 August 2002 and will be concluded on 31 July 2005.

EUROLIGNIN’s organisation is based in four areas within which all the tasks will be developed. The four areas called technology, market, analytical methods and project promotion ([Fig. 1](#)). [Fig. 1](#) shows the interaction between the different areas and exchange of information by the thematic network established. Besides the five areas, different potential markets were defined:

- Materials including wood adhesives, paper additives, phenolic resins, polyolefins and epoxies;
- Biocides and biostabilisers;
- Animal feed;
- Health prevention;
- Crops cultivation.

[Fig. 2](#) shows the structure of the work plan which is divided into six work packages (WP) where the four areas work simultaneously which guarantees the achievement of the proposed objectives. WP1 (analysis phase) is an activity required for accurate co-ordination of the future activities and contributions

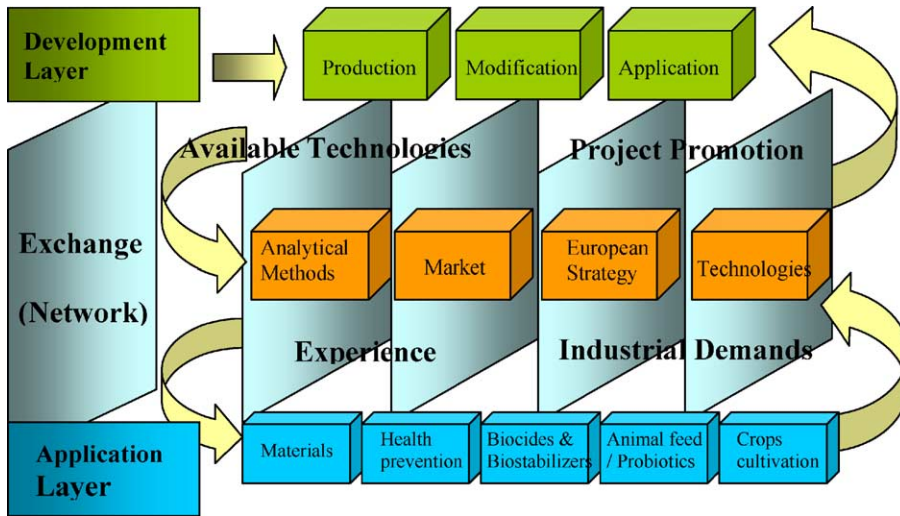


Fig. 1. Information exchange and links within EUROLIGNIN thematic network.

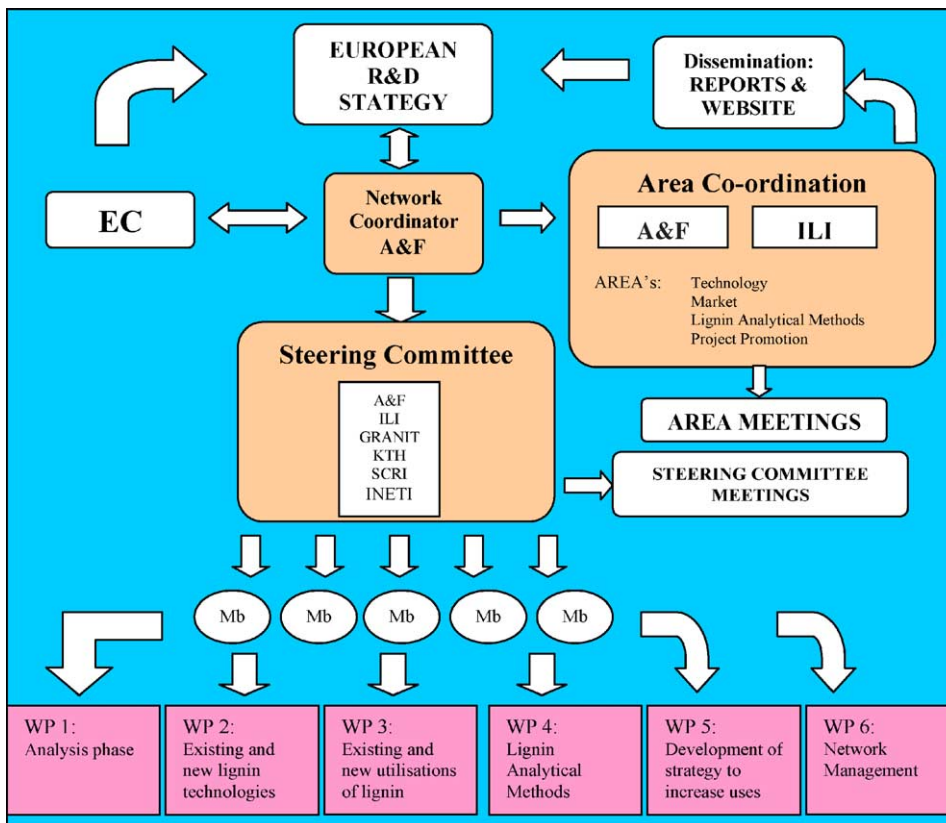


Fig. 2. Project structure of EUROLIGNIN thematic network.

of such a large number of partners. In WP2 (existing and new technologies for lignin production) the aspects of lignin production will be analysed to identify the lignin qualities potentially available or already available on the market, and to collect a maximum of information with regard to the processes used in their production. Also the analytical methods and already available data will be collected. Based on this information, WP3 (existing and new utilisations of lignin) will be dedicated to the identification of markets and of developments needed linked to them, including the need for analytical methods. With the data of analytical methods existing in WP2 and WP3, in WP4 (analytical methods for lignin) the best analytical protocols that are as general as possible with regard to different lignin types will be formulated and tested in three subsequent round robins. Each round will improve the results by adjusting the protocol according to the problems encountered at the previous round. Needs for more analytical method development will be formulated. With the development needs resulting from WP2, WP3 and WP4, WP5 will focus on the formulation of an overall globally consistent strategy on how to increase lignin markets and how to stimulate new development projects in the lignin field. All the information and conclusions of the thematic network's activities as well as the recommended strategy will be summarised in a final document disseminated through different communication systems including the internet. R&D European proposals will be defined and their realisation started including new participants that join the project group during the duration of the thematic network. WP6 will be dedicated to the network management.

EUROLIGNIN's management structure is based on area co-ordinators and a steering committee given in Fig. 2 where the different kind of members are represented (research organisations, consultants, suppliers and producers). Regular meetings of the steering committee and area co-ordinators guarantee the flow of information and communication within the network. The link of EUROLIGNIN with EC is the network co-ordinator A & F.

5.1. *The International Lignin Institute*

The issue of lignin use has been raised since the beginning of the 1990s in a context that seemed to

have important economic implications for new low-pollution pulping technologies. The International Lignin Institute (ILI) founded in 1991 is an association of about 50 members including scientists and companies interested in the development of lignin applications. It has the goal to facilitate research and exchange, but not realising these activities by itself. It is a platform for exchange, a marketplace and a matchmaker. Its goals are dedicated to applied lignin research and financial arrangements around new projects. The organisational frame is well established, including plenary forums, specific workshops, project creation, proceedings, newsletters and an internet page. More information can be found on the web site of ILI (ILI, 2003).

Dissemination of EUROLIGNIN information, results and conclusions will be performed by ILI via its web site. Companies which are interested to join the EUROLIGNIN network are invited to contact ILI.

6. Deliverables from the EUROLIGNIN thematic network

A successful EUROLIGNIN project will result in the following deliverables:

- A database of existing and new lignin production and lignin utilisation figures. This will be made available in the network and will include classification and amounts of lignins made throughout Europe with the potential of the 16 participating countries in the thematic network. The known practices currently used for production and utilisation will be documented on a European basis.
- The thematic network activities will help the European industries with special emphasis on SMEs by formulating a strategy and recommendations on how to best promote lignin markets.
- Project proposals resulting from a co-ordinated evaluation of the R&D needs will be available to the European industries.
- Dissemination of EUROLIGNIN information, results and conclusions at the International Lignin Institute and EC web sites.
- Compilation of analytical protocols including statistical performance parameters.

- Report on the results of round robins organised for extensive characterisation of selected lignins.
- Make available well-characterised lignin samples that will be used as reference materials for calibration purposes.
- Annual progress reports, mid-term review report and final report of EUROLIGNIN.
- Public report and brochure for the public dissemination network conclusion and proposals.
- Organisation of a European Seminar in 27–29 April 2005 in Barcelona, Spain entitled “Lignin production and utilisation in the European Union” where conclusions of EUROLIGNIN thematic network and new European R&D proposals in the three area’s will be presented and discussed with the participants. This forum will be opened for other organisations to present R&D proposals on lignin production and lignin utilisation (ILI, 2003).
- Summary description of initiated new projects created with thanks to the EUROLIGNIN activities.

The achievement of EUROLIGNIN’s objectives will have a direct impact in increasing employment within the lignin-producing and lignin-utilising sectors. Production industries will be able to introduce new production lines within existing production processes which should require more employees. Wholesalers and distribution organisations will be able to create value added through the commercial distribution chain with new or more health compatible products. Technology and equipment suppliers will be able to develop new equipment to fulfil the requirements of lignin-producing and lignin-utilising companies. All these new lignin-related activities will demand a longer work force in Europe.

Universities and research institutes will be involved in new R&D projects for lignin production and lignin

utilisation. The development of these projects will demand more researchers working in this field.

In summary, the proposed promotion of lignin-related materials and research and development in the lignin field could lead to a turnover in Europe of at least 2 billion Euros, which with the add-ons of induced effects in adjacent fields, could be contemplated as one of the most important materials of the next 10 years.

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