



HAL
open science

The development of wood technology and technology developments in the wood industries—from history to future

Alfred Teischinger

► **To cite this version:**

Alfred Teischinger. The development of wood technology and technology developments in the wood industries—from history to future. *European Journal of Wood and Wood Products*, 2010, 68 (3), pp.281-287. 10.1007/s00107-010-0458-2 . hal-00608725

HAL Id: hal-00608725

<https://hal.science/hal-00608725>

Submitted on 14 Jul 2011

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

The development of wood technology and technology developments in the wood industries – from history to future

Alfred Teischinger

Institute of Wood Science and Technology, Department of Material Sciences and Process Engineering, University of Natural Resources and Applied Life Sciences, Vienna, (BOKU), Peter Jordan Straße 82, 1190 Vienna, Austria, and Competence Centre Wood K plus

alfred.teischinger@boku.ac.at,

This article is dedicated to Gerd Wegener on the occasion of his retirement as professor at the Technische Universität München.

Abstract

The term technology is frequently used in every-day communication and in the specific areas of producing goods and providing services. Technology comprises the science of knowledge and usage of tools and techniques or its systems, methods, organization and material products thereof. The meaning of the word technology itself as well as the specific meaning of the term wood technology has changed over the past centuries of industrialized production systems. The current paper analyses the development of wood technology over a period of about 300 years. Based on various COST actions and the European Forest-sector Technology Platform current topics of wood technology are addressed and a future outlook is given.

Zur Entwicklung der Technologie des Holzes und technologische Entwicklungen in der Holzwirtschaft – von der Vergangenheit zur Zukunft

Zusammenfassung

Im Alltag wird der Begriff Technologie häufig in einer sehr allgemeinen Bedeutung verwendet. Grundsätzlich umfasst der Begriff Technologie die Wissenschaft der Anwendung der Technik, wird aber häufig auch als Synonym für die eingesetzte Technik an sich verwendet. Der vorliegende Essay beleuchtet die Entwicklung des Begriffes Technologie sowie spezifisch die Technologie des Holzes, deren Entwicklung analysiert und diskutiert wird. Dabei werden die aktuellen technologischen Fragestellungen anhand der Themen verschiedener COST-Aktionen sowie der Europäischen „Forest-based Sector Technology Platform“ beleuchtet und ein Ausblick auf technologische Herausforderungen der Zukunft gegeben.

1 Roots of wood technology

In his „Forest Journey – The Role of Wood in the Development of Civilization“, Perlin (1991) asserted wood’s crucial place in the evolution of civilization, and he states wood as the unsung hero of the technological revolution that has brought us from a stone and bone culture to our present age. For many centuries the raw material wood served as society’s principal fuel besides the use as a building material, and it was the emergence of the fossil fuels which brought a decisive change in the supply of heat and fuel. Perlin also chronicles various scarcities of wood throughout the history of civilization which triggered major technological changes and advances.

Quite similar to Perlin’s chronicle Radkau (2007) puts a strong emphasis on the conflicts between the technological development and the rise of civilization, which resulted in deforestation due to an excessive use of wood. Many times throughout history, the scarcity of wood became a driver for resource efficient use of the material, innovations and new technologies, but efficiency gains and innovations have quite often been eaten up by so-called rebound and backfire effects as well (Krafft 2009).

The period of the Industrial Revolution with major changes in agriculture, manufacturing, mining and transport had a profound effect on the socioeconomic and cultural condition of the civilizations involved and marked a major turning point in human history. Besides the arts, humanities and the natural sciences at the

various established and new universities, technology as a separate discipline slowly emerged with the foundation of the first mining and mechanical schools such as the University of Technology in Ostrava (1716) and the École Polytechnique in Paris (1794).

Presumably it was Beckmann who first set the term “Technologie” in the year 1777 in his first edition of a technology handbook (cit. in Beckmann 1780, Fig. 1) and other technologists followed such as Karmarsch (1825) at the Institute of Polytechnique in Vienna with his book “Einleitung in die Lehren der Technologie” (introduction to technology). Later on as the head of the school of polytechnique in Hannover he dedicated a whole chapter to wood technology in his handbook of technology (Karmarsch 1851).



Fig. 1 Part of the front page of J. Beckmann’s instruction to “Technologie” (technology) from the year 1780 (courtesy library of the University of Vienna)

Abb. 1 Ausschnitt der Titelseite von J. Beckmanns „Anleitung zur Technologie“ aus dem Jahr 1780 (Bibliothek der Universität Wien)

In German and some other European languages, there is a difference between the terms “Technik” and “Technologie” that does not exist in English. As both terms are usually translated as “technology”, one has to bear in mind that the German term “Technologie” is not completely identical to the English term “technology”. Over the years the term “technology” has been further developed into the current meaning but still today dictionaries and scholars offer a variety of definitions. Most widely technology can be defined as the entities, both material and immaterial, created by the application of intellectual and physical efforts (sometimes referred to as techniques) in order to meet demands and create values (sometimes also threats) as discussed by Teischinger and Müller (2010). Technology is not usually an exclusive product of science but as a cultural activity, technology predates both science and engineering, each of which formalize some aspects of technological endeavor.

As there is a strong but not exclusive link between science and technology, many universities, institutes, handbooks and scientific journals establishing new knowledge contain in their title “technology” or the phrase “... science and technology ...”. For example the Massachusetts Institute of Technology (MIT) in USA with its mission statement: The mission of MIT is to advance knowledge and educate students in science, technology, and other areas of scholarship that will best serve the nation and the world in the 21st century (<http://web.mit.edu>). Also the International Academy of Wood Science refers to technology (“The

International Academy of Wood Science ... is a non-profit assembly of wood scientists, recognizing all fields of wood science with their associated technological domains) and its Journal “Wood Science and Technology” (<http://www.iaws-web.org/>) paves the way from science to technology.

2 The development of wood technology

The development of wood science – with some aspects of technology, too, is well documented in a compilation in the first volume of the journal Wood Science and Technology (Coté et al. 1967) and a series in Holz als Roh- und Werkstoff (now European Journal of Wood and Wood Products). A continuous update of a documentation of new knowledge in wood science – besides the many scientific wood science journals – is given by the Springer Series in Wood Science (ed. R. Wimmer) which also covers aspects of technology. Before the start of this series of wood science and parallel to it, books and collected works such as “Wood and Cellulose Science” (Stamm 1964) and “Wood – Chemistry, Ultrastructure, Reaction” by Fengel and Wegener (1983) – with many other wood science compilations and specialist literature referred to – built up a profound basis of wood science, followed by Hon and Shiraishi (1991) and Rowell (2005) focussing on wood chemistry and Niemz (1993) with the focus on wood physics. With the textbooks by Bodig and Jayne (1982) and Smith et al. (2003) wood material science and engineering mechanics is combined and a deep understanding of wood mechanics is provided.

Following the first documentations by Beckmann (1780) and Karmarsch (1851) - besides many other books which cannot be fully listed in this essay - the books by Kollmann (1936), Vorreiter (1949 and 1958) in German and the English versions Kollmann and Coté (1968) and Kollmann et al. (1975) as well as Haygreen and Bowyer (1982) became the very documentation of wood technology. Additionally many further technological aspects have been covered in a deeper or more specific way by various authors such as: wood machining by Koch (1964), the field of wood adhesives and technology of bonding by Pizzi (1983) and Marra (1992), wood-based materials by Maloney (1977), Deppe and Ernst (1977), Sellers (1985), Dunky and Niemz (2002) etc. With the “Primary Wood Processing” by Walker (1993) one example of the many books dealing with the first step of wood processing is given.

Yet also the reinvention of old technologies such as the wood modification process has to be mentioned and as this area is undergoing huge developments at present, driven in part by environmental concerns regarding the use of preservatives treated wood. Hill (2006) provides a new scientific basis for these “green” wood protection technologies.

Society’s concern over increasing fuel prices, green house gas emissions, and the associated global warming have created tremendous interest in the science and technologies that promise the sustainable production of materials, chemicals, and energy from domestic resources. These considerations unambiguously dictate the need for practically oriented scientific research and the book by Argyropoulos (2006) is just one example of a comparatively new compilation of the abundant research literature covering a wide range of the production of materials, chemicals and energy from forest biomass.

Predating a handbook which contains the many findings of the various research being done, much of the new knowledge is firstly presented at conferences and published in conference proceedings and scientific journals. With the growing

emphasis on wood research and the growing new knowledge in this field of research, more and more wood research journals have been founded in order to build up a wood science and technology literacy (Table 1):

Table 1: selection of international wood science and technology journals, sorted according to their year of foundation. Journals with a "*" are listed in the ISI web of science

Tabelle 1: Auswahl internationaler Zeitschriften auf dem Gebiet der Wissenschaft und Technologie des Holzes, gelistet nach dem jeweiligen Gründungsjahr. Zeitschriften mit einem "*" sind im ISI web of science gelistet

Journal title	Founding year	Homepage
* European Journal of Wood and Wood Products (before: Holz als Roh- und Werkstoff)	1938	http://www.springerlink.com/content/0018-3768?sortorder=asc&p_o=647
* Holzforschung	1947	http://www.reference-global.com/loi/hfsg
* Forest Product Journal	1951	http://www.forestprod.org/fpjover.html
* Wood Research	1955	http://www.vupc.sk/sdvu/index.htm
Journal of the Japan Wood Research Society	1955	http://www.jwrs.org/editor/index-e.html
Holztechnologie	1959/2005	http://www.holztechnologie.de/index.php?id=223
* IAWA Journal	1965	http://bio.kuleuven.be/sys/iawa/
* Cellulose Chemistry and Technology	1966	http://www.ear.ro/3brevist/rv45/rv45.htm
* Wood Science and Technology	1967	http://springerlink.metapress.com/content/102511/?sortorder=asc&p_o=205
* Wood and Fiber Science	1968	http://swst.metapress.com/content/120742/
* Canadian Journal of Forest Research	1971	http://pubs.nrc-cnrc.gc.ca/rp-ps/journalDetail.jsp?jcode=cjfr&lang=eng
* Journal of Wood Chemistry and Technology	1981	http://www.informaworld.com/smpp/title~content=t713597282
* Scandinavian Journal of Forest Research	1986	http://www.informaworld.com/smpp/title~content=t713711862~db=all
* Cellulose	1994	http://www.springer.com/chemistry/organic+chemistry/journal/10570
* Journal of Wood Science	1998	http://www.springerlink.com/content/1435-0211?sortorder=asc&p_o=49
Journal of Forest Products Business Research	2004	http://www.forestprod.org/jfpbr.html
* BioResources	2006	http://www.bioresourcesjournal.com/index.php/BioRes/index
Wood Material Science and Engineering	2006	http://www.informaworld.com/smpp/title~content=t741771155~db=all
International Wood Products Journal	2010	http://www.maney.co.uk/index.php/journals/iwp

It has to be emphasized that Table 1 only provides a selection of wood research journals in the core of the discipline, and it is not easy to set a clear line between forest related journals, pulp and paper technology and timber (civil) engineering journals. One can also observe that more and more wood technology related research work is published in journals related to general material and composites science, adhesives and polymer science, bioresource technology, chemical engineering and technology, drying technology etc. Is this a challenge to the established journals of the community of wood science and technology or can this also be seen as an emancipation of wood within the general material science and technology disciplines?

As a scientific discipline the further development of wood technology is strongly related to forest products research (a worldwide overview on wood research institutes is given by Ellefson et al. 2007) and academic education, which is covered by the subdivision 5.14.00 of IUFRO Division 5 “Forest Products” on a worldwide scale. There are many international and national networks in order to document and foster wood education programmes such as the Society of Wood Science and Technology (<http://www.swst.org/>). Observing the global changes and developments in society and technology and screening the various documentations on wood technology education programmes one can state that it is very important to redefine and strengthen the numerous programmes worldwide, to anticipate the future and to make wood technology the key technology of a renewables-based sector.

3 Current wood technology issues

In the last decades the key issues and driving forces of wood technology have changed significantly. Many – but by far not all - of the current issues of wood technology have been addressed by COST actions of the forest-related domain of COST (Forests, their Services and Products/FPS) as summarized in Table 2. In general, COST (<http://www.cost.esf.org>) is an intergovernmental framework for European Cooperation in Science and Technology, allowing the coordination of nationally-funded research on a European level.

The forest domain FPS has the mission to promote research along the whole forestry-wood-chain by providing a platform for the effective coordination of nationally funded research activities in the areas of forestry, wood technology and pulp & paper. Analyzing the various actions within FPS, it becomes evident that the domain has changed its focus in the last years: from a technology-focus to a more environmental-related focus.

Table 2: Wood technology-related COST-Actions within the COST domain “Forest, their Services and Products/FPS” from about 1994 up to now. From COST action E 14 onwards, the results and various activities of each action are well documented on the domain’s homepage (<http://w3.cost.esf.org/index.php?id=146>)

Tabelle 2: Auflistung von COST-Aktionen ab ca. 1994 mit Bezug zur Technologie des Holzes innerhalb des COST-Arbeitsgebietes "Forstwirtschaft, ihre Leistungen und Produkte". Ab der COST-Aktion 14 können die Resultate und Aktivitäten der einzelnen Aktionen im COST-Arbeitsgebiet "Forstwirtschaft, ihre Leistungen und Produkte" auf der Bereichs-Homepage abgerufen werden (<http://w3.cost.esf.org/index.php?id=146>)

Number of the COST action	Title of the action ¹⁾
E 2	Durability of wood
E 5	Fire safety of medium-rise timber frame residential building
E 8	Mechanical performance of wood and wood products
E 9	Life cycle assessment of forestry and forest products
E 10	Wood properties for industrial use
E 13	Wood adhesion and glued products
E 15	Advances in the drying of wood
E 18	High performance in wood coating
E 20	Wood fibre cell wall structure
E 22	Environmental optimisation of wood protection
E 24	Reliability of timber structures
E 29	Innovative timber & composite elements / components for buildings

E 31	Management of recovered wood
E 34	Bonding of timber
E 35	Fracture mechanics and micromechanics of wood and wood composites with regard to wood machining
E 37	Sustainability through new technologies for enhanced wood durability
E 40	Innovative utilisation and products of large dimensioned timber including the whole forest-wood-chain
E 41	Analytical tools with applications for wood and pulping chemistry
E 44	Wood processing strategy
E 49	Processes and performance of wood-based panels
E 53	Quality control for wood and wood products
FP 0602	Biotechnology for lignocellulose biorefineries
FP 0702	Net-acoustics for timber based lightweight buildings and elements
FP 0802	Experimental and computational micro-characterisation techniques in wood mechanics
FP 0901	Analytical techniques for biorefineries
FP 0904	Thermo-hydro-mechanical wood behaviour and processing

¹⁾ Besides the title, the names of the various working groups (WG) within an action give even a more detailed impression of the science and technology issues to be addressed e.g.: COST Action E53 – WG 1 scanning for wood properties, WG 2 moisture content and distortion, WG 3 strength, stiffness and appearance grading

It is the aim of science to build up new concepts, theories and methods in order to create knowledge by employing formal techniques. Technology, however, is the usage of knowledge and the techniques in pursuit of business and life in general. For entrepreneurs and corporations it is important to develop and choose the proper technology to become successful and competitive on the market, for government bodies and political decision makers it is important to support proper technologies in order to make a national economy successful. The latter includes the evaluation of technology impacts and hazards by means of technology foresight studies, which are becoming more and more important in the course of introducing new technologies.

Aiming for future technologies many approaches are to be made. Currently technology roadmapping is a frequently used tool in order to develop a plan that matches short-term and long-term goals with specific technology solutions to help meet those goals of a company, industrial cluster or a national economy (Garcia and Bray 1997). Besides corporations and wood industry clusters (e.g., Kirstof and von Geibler 2008), wood industry associations and governmental institutions have launched and supported several wood technology roadmaps addressing a specific forest products industry, value added wood products, nanotechnology in the forest products industries etc. in the USA, Canada and Europe as referred to by Teischinger and Tiefenthaler (2009).

In 2003, the Confédération Européenne des Industries du Bois (CEI-Bois) launched a process to establish a “Roadmap to 2010 for the European Woodworking Industries” with the main objective of producing an updated analysis on key factors and challenges affecting the European woodworking industries, identifying the opportunities for the sector, describing the ideal position and producing an action programme towards 2010 (www.roadmap2010.eu). This roadmap has become an important nucleus of strategic R&D activities within the European wood industries sector but is also an

important tool to convince political decision makers on the European level of the importance of the wood industries in Europe.

With the European Technology Platforms (ETPs) the European Union (EU) provided a framework for stakeholders, led by the industry, to define research and development priorities, timeframes and action plans on a number of strategically important issues where achieving Europe's future growth, competitiveness and sustainability objectives is dependent upon major research and technological advances in the medium to long term (<http://cordis.europa.eu/technology-platforms/>). ETPs are addressing technological challenges and play a key role in ensuring an adequate focus on research funding on European level (e.g. European Framework Programme) and national levels and foster public-private partnerships as well.

With the support from the European Commission, the European forest-based sector, represented by various confederations for the woodworking industries, forest owners and paper industries, launched a forest-based sector technology platform in 2004 (www.forestplatform.org). This platform is based on a vision document “innovative and sustainable use of forest resources – vision 2030” and a strategic research agenda for innovation, competitiveness and quality of life. In addition to this research agenda many European countries developed national research agendas. Reading the European and national research agendas one can analyze the various research topics addressed along five different value chains (VC) such as: VC forestry, VC wood products, VC pulp and paper products, VC specialities (incl. biorefinery) and VC bioenergy.

4 Future aspects of wood technology and final conclusions

Besides the various roadmaps and the research agenda of the Forest Technology Platform addressed above, the COST action E44 “A European Wood Processing Strategy” (van Acker and Fioravanti 2008), many papers and essays are envisioning the future of wood technology such as Wegener (1995), Sutton (2000), Youngs (2007), Winandy et al. (2008) etc. As a general conclusion one can state that the forest-based industry is essentially a mature industry which has to rejuvenate and innovative science and technology will be critical drivers for incremental improvements and breakthrough processes as well.

Challenges and a call for improved or new technologies can be identified along the whole wood supply and process chain:

- Wood supply – forest resources are being squeezed between growing needs (including fast growing demand for wood as an energy carrier) and environmental restrictions. This will open the raw material allocation to semi-natural forests, forest plantations, agroforestry and agricultural resources and new mobilization concepts for wood resources as discussed by Scarascia-Mugnozza and Pisanelli (2008). This new raw material spectrum, including the increasing use of recycled material, will have a huge impact on wood technology and material design as well.
- Timber in construction - Wood is a highly synthesized and optimized raw material from nature with load-bearing functions as one of its main functionalities. Using wood as timber in construction comes next to the natural features of wood, but man still can improve the mechanic performance of wood by proper grading and excluding natural pattern and inhomogeneities and building up engineered material structures. Material

and building components models and simulation will become a major tool in order to understand and improve the materials and components.

- Material engineering - Engineered wood composite materials and structures on all hierarchical levels (from nano- to macrostructures) are already a main field of technology research and will become even more important in order to make wood materials more competitive. A strong focus on resource- and ecoefficiency of materials, including raw materials from any renewable sources, will lead us to “Green Composites” as envisaged by Baillie (2004).
- Wood aesthetics - Morphology and chemical composition including the various extractives create an inimitable surface aesthetic appearance of wood, especially with the various hardwoods. Unfortunately the colour of wood is not UV-stable so is a main challenge to prevent fading and discoloration to a further successful and viable use of wood surfaces (veneer and solid wood) in indoor and outdoor application in competition with technical surface structures.
- Wood modification - Much emphasis has been put on wood modification in the last years in order to make it more durable and stable etc. Putting new functionalities (including multifunctionalities) into the wood or onto the wood surface will be necessary in order to create a new wood performance which pave the way to so-called smart materials.
- Fractionizing wood - Various mechanical disintegration and chemical decomposition processes are well established in order to break down and fractionize the raw material wood and to re-arrange and re-engineer it to glued components, wood-based panels, paper sheets etc., however, improved and completely new processes of disintegration have to be envisaged.
- Machining and processing - Primary and secondary wood processing has improved a lot in the last centuries (e.g. high capacity sawmills, continuous presses for wood based panels, high-performance wood machining), but new process technologies, manufacturing concepts (mass customization, tailoring of products etc.) have to be developed. Resource- and eco- efficient processes have to be envisaged in wood industries by means of improved and new process analytics as discussed by Kessler (2006) and production management systems which in turn are part of a concept of knowledge-based production.
- Wood refinery - Thermo-chemical processes, and increasingly, biotechnology are used to break down lignocellulosic feedstocks to their building blocks for the chemical and energy industry – the terms “integrated biomass technologies” and “wood biorefinery” became the key-words within the emergence of a new industrial sector of renewables-based technologies, which is outlined by Dewulf and van Langenhove (2006). Today we are in a labyrinth of different though ambitious approaches to unzipping lignocelluloses to their building blocks so that they can be used for further processes. Even though parts of that concept already exist, a sweeping economic breakthrough is still missing.
- Recycling – Even as the majority of wood products are considered as medium- und long-term products, an increased use of wood builds up a huge secondary feedstock to be used as a material and/or energy carrier. The material, industrial and building designs have to be matched to a future demolishing of used structures and the recovery of wood. Wood

technology becomes an important role in the concept of a cascading use of wood.

- Technology assessment - In the future, the development of new technologies has to be accompanied by technology assessment (such as described by Bröchler et al. 1999). As technological progress is pursued, a concept of the selection of the appropriate technology has to be implemented in order to minimize risks and environmental hazards but that still provides future well-being. An eco-driven material and technology selection – based on various indicators currently being under discussion – has to become a must in future productions.
- Technology education - Wood technology as an academic discipline has to be further developed (and discussed within the wood science and technology community) encompassed by rigorous academic curricula in order to provide a profound technology education to the students, which has to create the intellectual backbone of tomorrow's forest-based industries and a knowledge-based society as well.

This essay was meant to be a journey from the history to the present state of wood technology, including an outlook on the future. Because of the limitations in space not all aspects of wood technology have been covered. Yet it was a main intention of the current contribution of this special issue of the European Journal of Wood and Wood Products to discuss the link between wood science and technology so as to point out that scientists prepare the foundations of new knowledge and technologists have to pave the way of knowledge for the crafts and industries. It is their turn to meet the society's needs, to make the products desired and to solve problems. One can observe that the parties involved do not always steer in the same direction.

5 Literature

- Argyropoulos D (ed.) (2006) Materials, Chemical and Energy from Forest Biomass. ACS Symposium Series 954. American Chemical Society, Washington, DC
- Baillie C (ed.) (2004) Green composites: Polymer composites and the environment. Woodhead Publishing Limited, Cambridge
- Beckmann J (1780) Anleitung zur Technologie, oder zur Kenntnis der Handwerke, Fabriken und Manufakturen, vornehmlich derer, welche mit der Landwirtschaft, Polizei und Kameralwissenschaften in nächster Verbindung stehen. Göttingen, Verlag der Wittwe Bandenhoeck
- Bodig J, Jayne BA (1982) Mechanics of Wood and Wood Composites. Van Nostrand Reinhold, New York
- Bröchler S, Simonis G, Sundermann K (ed.) (1999) Handbuch der Technikfolgenabschätzung (Handbook of Technology Assessment). Band 1-3. Edition Sigma® Rainer Bohn Verlag, Berlin.
- Coté WA, Freudenberg K, Kisser J, Koch P, Kollmann FFP, Liese W, Marian JE, Stamm AJ, Thunell B, Winkelmann HG, Ylinen A (1967) The History of Wood Science. Wood Sci Technol 1 (3): 161 – 190
- Deppe HJ, Ernst K (1977) Taschenbuch der Spanplattentechnik. DRW-Verlag, Stuttgart
- Dewulf, J, van Langenhove H (ed.) (2006) Renewables-based technology. John Wiley Sons, Ltd, Chichester
- Dunky M, Niemi P (2002) Holzwerkstoffe und Leime: Technologien und Einflussfaktoren. Springer, Berlin
- Ellefson PV, Kilgore MA, Skog KE, Risbrudt CD (2007) Forest products research and development organizations. Organization, governance, and measures of performance in a worldwide setting. Forest Products Journal 57 (10): 6 – 13
- Fengel D, Wegener G (1983) Wood – Chemistry, Ultrastructure, Reactions. Walter de Gruyter, Berlin, New York
- Garcia ML, Bray OH (1997) Fundamentals of Technology Roadmapping. Strategic Development Department Sandia National Laboratories, Sand97-0665, Albuquerque, NM. doi: 10.2172/471364

- Haygreen JG, Bowyer JL (1982) Forest Products and Wood Science. IOWA State University Press/AMES, Iowa
- Hill C (2006) Wood modification. Chemical, thermal and other processes. John Wiley & Sons, Chichester, West Sussex, England
- Hon NS, Shiraishi N (1991) Wood and cellulosic chemistry. M. Dekker, University of Michigan, Michigan
- Karmarsch K (1825) Einleitung in die mechanischen Lehren der Technologie. Erster Band. Druck und Verlag J. B. Wallichausser, Wien
- Karmarsch K (1851): Handbuch der mechanischen Technologie. Hellwingsche Hofbuchhandlung, Hannover
- Kessler RW (ed.) (2006) Prozessanalytik. Wiley-VCH, Weinham
- Kirstof, K, von Geibler, J (ed.) (2008) Holzwende 2020. Zukunftsmärkte für das Bauen mit Holz. DRW Verlag. Karlsruhe
- Koch P (1964) Wood Machining Processes. The Ronald Press Company, New York
- Kollmann F (1936) Technologie des Holzes – Erster Band Julius Springer Verlag Berlin
- Kollmann FFP, Coté WA (1968) Principles of Wood Science and Technology, I Solid Wood. Springer Verlag, Berlin, Heidelberg, New York
- Kollmann FFP, Kuenzi EW., Stamm AJ. (1975) Principles of Wood Science and Technology, II, Wood Based Materials. Springer, Berlin, Heidelberg, New York
- Krafft U (2009) Effizienz und Innovation – Allheilmittel ohne Nebenwirkungen? Schweiz. Z. Forstwe. 160 (12): 371-374
- Maloney TM (1977) Modern particleboard & dry-process fibreboard manufacturing. Miller Freeman Publications, San Francisco
- Marra AA (1992) Technology of wood bonding. Principles and practice. Van Nostrand Reinhold. New York
- Niemz P (1993) Physik des Holzes und der Holzwerkstoff. DRW Verlag, Stuttgart
- Perlin J (1991) A forest journey. The role of wood in the development of civilization. Harvard University Press. Cambridge. Originally published by W.W. Norton, New York 1989
- Pizzi A (ed.) (1983) Wood Adhesives. Chemistry and Technology. Marcel Dekker, New York and Basel
- Radkau J (2007) Holz. Wie ein Naturstoff Geschichte schreibt. oekom Verlag 2007
- Rowell RM (ed.) (2005) Handbook of Wood Chemistry and Wood Composites. Taylor & Francis, Boca Raton
- Scarascia-Mugnozza G, Pisanelli A (2008) Multifunctional forestry, global change and the impact on mobilizing wood resources. In: Van Acker, J, Fioravanti, M (ed.) (2008) A European wood processing strategy: future resources matching products and innovations. COST action E44 final conference. Ghent University, p 1 - 9
- Sellers T (1985) Plywood and Adhesive Technology. Marcel Dekker, New York and Basel
- Smith J, Landis E, Gong M (2003) Fracture and Fatigue in Wood. Wiley, Chichester, West Sussex, England
- Stamm AJ (1964) Wood and Cellulose Science. The Ronald Press Company, New York
- Sutton WRJ (2000) Wood in the third millennium. Forest Products Journal 50 (1): 12 - 21
- Teischinger A, Tiefenthaler B (2009) Zukunftsideen für Forst – Holz – Papier. Ergebnisse zum Projekt „Technologie – Roadmap für Holz in Österreich“. LIGNOVISIONEN, Issue 23. University of Natural Resources and Applied Life Sciences (BOKU), Vienna
- Teischinger A, Müller U (2010) Vom Technologiebegriff zur Technologie des Holzes. Holztechnologie 51 (3): 30 – 32
- Van Acker J, Fioravanti M (ed.) (2008) A European wood processing strategy: future resources matching products and innovations. COST action E44 final conference. Ghent University
- Vorreiter L (1949) Holztechnologisches Handbuch – Bd. 2: System Holz-Wasser-Wärme, Holzrocknung, Dämpfen und Kochen, spanlose Holzverformung. Verlag Georg Fromme & Co, Wien
- Vorreiter L (1958) Holztechnologisches Handbuch – Bd. 1: Allgemeines, Holzkunde, Holzschutz und Holzvergütung. Verlag Georg Fromme & Co, Wien
- Walker JCF (1993) Primary Wood Processing. Principles and Practise. Chapman & Hall. London
- Wegener G (1995) Perspektiven der Holznutzung (Wood utilisation prospects), Forstw. Cbl. 114: 97 - 106
- Winandy JE, Rudie AW, Williams RS, Wegner TH (2008) A future Vision for optimally using wood and biomass. Forest Prod J 58 (6): 6 – 16
- Wimmer R (ed.) Springer Series in Wood Science. <http://www.springer.com/series/760>
- Youngs RL (2007) Meeting the challenge of change. Forest Prod J 57 (6): 6 - 13

Web accesses

International Academy of Wood Science. <http://www.iaws-web.org/>. Accessed 23 April 2010
Massachusetts Institute of Technology. <http://web.mit.edu>. Accessed 23 April 2010
Springer Series in Wood Science. <http://www.springer.com/series/760>. Accessed 23 April 2010
COST – Forests, their Products and Services Domain Committee
<http://w3.cost.esf.org/index.php?id=146>. Accessed 23 April 2010
European Technology Platforms (ETPs). <http://cordis.europa.eu/technology-platforms/>. Accessed 23 April 2010
COST – European Cooperation in Science and Technology. http://www.cost.esf.org/about_cost. Accessed 23 April 2010
Wood – CE Bois Roadmap 2010. www.roadmap2010.eu. Accessed 23 April 2010
Forest-Based Sector Technology Platform. www.forestplatform.org. Accessed 23 April 2010