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Abstract of the Ph.D. thesis

**Handling and recycling of waste in wood  
industry**

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## ***1. Introduction, antecedent and importance of the research topic***

Regarding the waste management in the Hungarian wood industry, serious problems have come up recently caused by numerous conflicts. In the Hungarian society of wood industry it is an accepted fact that the incineration is not the best way for wood waste utilization because in many cases it can be considered as a by-product and may be recycled in several production processes as a secondary raw material. Therefore the distinguishing of waste and non-waste materials arising during the production process, and their utilization method should be decided from an economical and ecological point of view.

For a more efficient waste utilization and the environment load reduction, the European Union has launched several research and technological programmes known as COST (*CO*operation on Scientific and Technical Research). One of them is the COST E31 dedicated to the wood recycling (the closing conference was held on May 2-5, 2007). Twenty countries participated in this program. Hungary was represented by me and my colleagues. The members met regularly and the new research results were shared, the development of the individual countries on this field was introduced. There were two main teams in this action: one analyzed the European management of recycled wood, while the other engaged in the handling of the recycled wood (technical, economical and environmental aspects). Furthermore, the aim was to harmonize the definitions and the quality of the data too, which is important because of data comparison.

In their researches, the following wood wastes were emphasized:

- packing waste
- demolition wood
- wood waste from the building industry
- fractions of used wood from public, industrial and commercial activities.

Based on the common research activity, the most important utilization methods are (in hierarchical order):

- reuse
- recycling
- energy generation
- „disposal”

In Hungary, in many cases the conflict is between recycling and energy generation since the determination of the appropriate ratio can be difficult

(eg. wood chips should be used for particle board production or as energy source for heating systems?). It is clear that the third possibility, the disposal is the worst solution from the aspect of greenhouse effect. In this case, the wood is considered as waste or as compost material, possibly it is burned without using as an energy source – so it leaves the carbon CO<sub>2</sub>-cycle. It can not be used further on, and if it is handled as waste, significant amount of methane and other greenhouse gases will be released. Consequently, reduction of GHG-emission may be realized in this way – moreover valuable secondary raw material can be saved.

Recycling and energetic utilization have a big market, but there are restricting factors. For example, the utilization of timbers treated with dangerous chemicals is difficult because of the content of preservatives in them (copper, arsenic, chrome, etc.).

It is of primary importance that the carbon bounded in wood should be preserved as long as possible and released back to the atmosphere as the last possibility, from where the trees (perhaps the sea, polar ice caps etc.) can absorb it again.

The process is important not only from the viewpoint of environmental protection. From economic and social aspect, it can be stated that the cost of material collection and recycling is smaller than that of gathering and storage (eg. the timber dissolves in a waste yard it without providing energy but CO<sub>2</sub> releases in the same way). Naturally, recycling is economic for a company only if the derived secondary raw material is cheaper than the primary. In many cases this aspect helps to decide the question: recycling or burning?

The unsuitable regulation resulted in the burning of the raw material of plywood and particle board production. However, there were other deteriorative effects too:

- Hungary's dependency on foreign wood raw material has grown;
- The use of other materials have come to the front that are
  - not renewable
  - less recyclable
  - less energy-efficient
  - less efficient economically
- Growing stress for forestry companies that give the raw material for wood industry, hereby the biological diversification is jeopardized.

According to Van Riet (European Panel Federation's expert) examples of these effects can be found in several countries of EU. Wood industry companies that process the wood chips, sawdust etc. have got into trouble:

in many countries, like in Belgium, Germany, France, there is a raw material shortage, and for instance in Denmark several factories were closed.

Due to the problems described, the value chain of the wood should be taken into consideration. The right order that helps to exploit the carbon fixation capability of wood in the highest degree would be as follows:

**Wood products → reuse → recycling → energy source**

## 2. *Objects*

The primary aim of my comprehensive research was to gather information about wood waste arising sites and utilization possibilities as well as to describe their potential development directions. For this purpose, firstly I had to become familiar with the operative domestic and foreign legal regulation, most of which deal with the waste generally. Accordingly, my object is to determine which parts of the laws refer to the waste arising during the production and how do they influence the handling, utilization and disposal of wood waste.

In order to clarify the possibilities of wood waste utilization, it is necessary to differentiate waste and by-product since this classifying affects fundamentally the actions of utilization. Therefore, creating of an overall flowsheet may help to decide what should be considered as waste and what as by-product. Since there is no practical method for wood waste classifying in Hungary, its determination and development is crucial to obtain a clear picture of quantity and quality related questions of waste/by-product. In the same way, an important question that must be clarified is the danger of wood waste. In many cases, the first question should be if the wood waste is dangerous or not.

The problem in the present domestic wood industry is that even the experts are unable to decide where is the line of demarcation between energetic utilization and recycling. My aim was to clearly define this boundary emphasizing the “keeping alive as long as possible” approach of wood wastes/by-products beside the maintenance of the basic hierarchy of utilization/disposal. Evidently, for this purpose it is necessary to know the area of both parties including the possibilities of energetic utilization together with their advantages and drawbacks.

During my basic researches, a problem was found concerning wood-based packing waste, namely their minimum utilization ratio given by the EU is 15% contrary to paper for example where this ratio is 60%. My recommendation regarding the modification of the related directive is able to solve this problem.

It is necessary to discuss the problem of other type of wastes having different compound that arise during the wood process next to the wastes/by-products. Their complex waste utilization possibilities will be clarified through flowsheets that are easy to understand for specialist with the respect of legal aspects.

Although the title of my dissertation refers to wood wastes, for the sake of entirety, the question (circumstances of formation, possibilities of collection) of the so called “old wood” (“Altholz”), which is the collecting

noun for used wood products and wood-based packing wastes, will also be discussed in each part . Reuse of wood wastes as a raw material for particle board considered to be standard, naturally after the utilization of the by-product arising inside the factory. In this section of my research work I intended to explore the possibilities of the integration of materials, which turn from waste into by-product, into the particle board production process. It is my belief that the conscious handling of waste should be started right before its formation. The test aiming the rationalization of the raw material performed towards prevention using the SIMUL8 production simulation software is of primary importance.

### ***3. The applied research method***

Practical experiences obtained during R&D activities at different wood working companies as well as the acquiring of the related legal knowledge are important basics of my research work. During the exploration of the scientific literature special emphasize was put on the understanding of foreign countries' wood waste management, first of all those taking part in COST E 31 programme – especially Germany and Poland. In this manner I had the possibility to obtain practical experiences in foreign countries.

The aim of the specific preliminary studies was to explore the type and amount of waste arising in the Hungarian wood industry. At first, a questionnaire seemed to be suitable for this purpose, however I had to acknowledge that an exact survey could only be performed personally since the diversity in our wood industry is perceptible even in the company sector. Another reason is that the affected companies reluctantly gave an answer to questions related to utilization and disposal of waste. These data were enough for a basic survey designating the starting point for mapping of waste management in wood industry in case of the specific factories. On the other hand, I experienced that the companies gladly joined in a kind of consortial work though, because they could get an internal view of the research. Hereby it became clear what are the benefits for their own companies. For a more detailed and exact analysis, researches and surveys were done at several remarkable companies that determine the domestic wood industry. At the same time, this allowed me to participate in their waste management and as a result of my researches work out new possibilities of utilization. On the basis of my preliminary researches, it can be stated that most of the problems of the manufacturers in wood industry arising from the wood waste, thus my research focuses also on this material primarily. My aim in this field is to make well applicable the developed new methods of prevention and utilization for companies having similar problems.



#### ***4. Summary of the new scientific results***

Considering the ecological aspects of the sustainable development, final results of my research can be summarized in frame of the following scientific statements:

1. The difference between wood waste and by-product was determined to be able to decide the applicable utilization method. It was found that the wood waste turns into by-product during its life cycle by the starting of the handling and utilization processes.
  - a. According to my definition, *wood waste* refers to all object, material, material mass that arises during the production next to the product or during the deterioration of the product, which reuse and recycling is insolvable, and is direct or indirect danger to the environment.
  - b. All object, material, material mass considered as wood based by-product that arises during the production next to the product or during the deterioration of the product, which reuse and recycling can be solved, and is neither direct nor indirect danger to the environment.
  - c. In the course of wood based by-product process there are always such operations that have to be done for the further utilization. If these operations are integral part of the manufacturing process, the arising material can be regarded as by-product. However, if further recovery is necessary for the latter application, even if the utilization is sure, the material has to be considered as waste until the completion of the raw material recovery.
2. It was found that it is necessary to define the life cycle of a waste/by-product to decide its utilization method, . For this purpose, a new, universal model was introduced ( Flowsheet model for the life cycle of wood products, waste/by-products). Based on this model, a technically and economically valid decision can be ensured on every single utilization and disposal possibility.

3. It is suggested to create a legal and technical regulation on “wood waste utilization” that should include, beside the statements in thesis 1 and 4, the segregation of wood waste/by-product as follows:
  - a. Wood waste/by-product arising in the course processing
  - b. Deteriorated wood, “dead” wood (“Altholz”, RW-recovered wood)

It is necessary to separate wood wastes depending on the contamination rate (WW = wood-waste):

*WW I.:* Processed or deteriorated wood containing no or only slight pollution.

*WW II.:* Glued, painted, stained, lacquered wood, deteriorated wood product containing no halogenated organic components or wood preservatives.

*WW III.:* Wood wastes/by-products that do not belong to the previous two categories contain halogenated organic components but are not treated with wood preservatives.

*WW IV.:* Wood wastes/by-products treated with preservatives.

*WW V.:* Polluted wood waste with a PCB (polychlorine biphenyl) content higher than 50 mg/kg.

4. It was found that there is a conflict of interest between the present Hungarian wood industry and the wood power plants because of the common raw material basis. To dissolve this conflict, a flowsheet model was created entitled “Relationship between utilization and disposal possibilities and wood wastes”, which helps to select the rational utilization method of a given waste type. In case of wood wastes it is of capital importance to recycle the wood as much as possible or to produce new product in order to ensure the “closed-loop solar energy” and the CO<sub>2</sub> cycle, and it should be energetically utilize only in the last resort when there is no other solution due to the contamination of waste or the high recycling costs. For this purpose, a bill and a support system should be created which gradually supports the spread of energy plantations.

5. The 94/62 EC directive on packing waste modified in 2004 should be reviewed. This specifies an obligatory minimum utilization ratio of an average 60% of the packing wastes for Hungary in 2012(utilization as a raw material and energy source together). The expected minimum utilization rate of 15% for wood based packing wastes, which is a constant value since the directive is effective, should be increased with around 10% per year, so thus the value of 55-60% may be reached in 2012, which is a requirement in case of paper or glass for instance. According to my evaluation, the utilization rate of 60% means 100 000 tons of wood based packing waste per year which would significantly contribute to the raw material supply of particle board factories and the energy sector. This quantity equals to 30% of the raw material need of a factory producing 400 000 m<sup>3</sup> particle board per year.
6. Based on the wood industry practice and the related legal aspects, new, complex flowsheet models of main waste types and waste flows arising during the process next to the wood wastes/by-products were introduced. These flowsheets contain utilization possibilities, occasionally disposal opportunities thought to be environment friendly.  
The created flowsheets apply to the following waste types:
  - a. Wood preservatives, adhesives, coatings.
  - b. Non-wood based packing wastes.
  - c. Wastes arising during the maintenance and operation of machines and vehicles.
  - d. Rating of other wastes that may be hazardous.With the help of the created flowsheets, wood processing factories may easily find environment friendly solutions of utilization of certain waste types. On the other hand, the orientation among several waste related orders becomes easier, which will contribute to the development of a uniform, environmental conscious waste management.
7. Models were created for the recycling of wood wastes/by-products through particle-board production, for the integration of wood wastes into the production as well as for the utilization of other wood based and non-wood based wastes arising during the production. These models contributed to an environmental-friendlier waste management of the factories taking part in the research moreover the disclosed defects and failures were improved.

Through the models, waste management troubles of similar domestic or foreign companies primarily from the Eastern Europe region can be solved in EU-conform way.

8. A generally valid flowsheet model was created for wood wastes in the wood industry. This model ensures the economical storage and utilization possibilities of wood chips and saw dust. During the creation of the model, the continuous, constant formation of wood waste, its composition and on annual basis constantly changing demand of energy (heating and technologic thermal demand) were also considered.
9. A brand new method was introduced to reduce the quantity of arising wood waste/by-product using the traditional survey and analysis method as well as the SIMUL8 production simulation software. With this method, 10-15% yield increase can be reached effecting similar decrease of waste/by-product.
10. A new possibility was discovered for the utilization of wood dust containing certain coatings in the wood briquette production. If this contaminated dust is mixed to the pure wood saw dust up to a rate of 5 %, the consistency value of the briquette will not be influenced moreover the dangerous substance emission during firing changes only slightly and stays under the limit of the German DIN 51731 and the Austrian Ö-Norm M 7135 standards.

## **5. Publications and commissions related to the topic of the Ph.D. thesis**

### **Reviewed publications in foreign languages published in foreign scientific journal**

1. *G. Nemeth, T. Alpar, M. Varga*: General Waste Handling and Recycling in Particle Board Production. Management of Environmental Quality An International Journal Volume 15 Number 5, 2004., (pp. 509-520., ISBN 1-84544-006-4; ISSN 1477-7835)
2. *G. Nemeth, M. Varga, E. Csanady, Sz. Nemeth*: Aerodynamic investigation of head of vacuum apparatus of CNC processing machinery; Drevarsky Vyskum Wood Research Journal 51(2) 2006 (pp. 49-62, ISSN 1336-4561)

### **Reviewed publications in foreign languages published in Hungarian scientific journal**

3. *G. Nemeth, M. Varga*: Waste Management in the Wood Product Industry. Magyar Tudományos Akadémia Agrár Műszaki Bizottság idegennyelvű kiadványa Hungarian Agricultural Engineering. N 16/2003 (pp. 47-51, HU ISSN 0864-7410).
4. *G. Nemeth, M. Varga, E. Csanady, Sz. Nemeth*: Component analysis of particles of residues originating from CNC milling machines correlation with the milling parameters; Magyar Tudományos Akadémia Agrár Műszaki Bizottság idegennyelvű kiadványa Agricultural Engineering N 17/2004 (pp. 68-70, HU ISSN 0864-7410).

### **Reviewed publications in Hungarian languages published in Hungarian scientific journal**

5. *Németh G., Varga M.*: Modellek a faiparban keletkező hulladékok kezelésére és hasznosítására I., Faipar LII. Évf. 2004/3.: (pp. 7-12.) HU ISSN 0014-6897
6. *Németh G., Varga M.*: Modellek a faiparban keletkező hulladékok kezelésére és hasznosítására II. Faipar LII. Évf. 2004/4.: (pp. 24-28.) HU ISSN 0014-6897

### **Publications in Hungarian languages published in Hungarian scientific journal**

7. *Németh G., Varga M.*: Fafeldolgozási hulladék kezelése, felhasználhatósága I.; Magyar Asztalos és Faipar 2002. XII. évf. 6. sz. (pp. 127-129)

8. *Németh G., Varga M.*: Fafeldolgozási hulladék kezelése, felhasználhatósága II. Magyar Asztalos és Faipar 2002. XII. évf. 7. sz. (pp. 147-149)
9. *Németh G., Varga M.*: Fafeldolgozási hulladék kezelése, felhasználhatósága III. Magyar Asztalos és Faipar XII. évf. 9. sz. (pp. 151-153.)

### **Proceedings, presentations, posters in foreign language**

10. *G. Nemeth, M. Varga, E. Csanady, Sz. Nemeth*: Technological and Technical Correlation or Reduction of Dust Exposition of Wood Working Machinery at the Workplaces; 16<sup>th</sup> International Wood Machining Seminar; Matsue, Japan. 24-30. Aug. 2003. (poster, proceeding: pp. 732.) ISBN 4-9901767-0-7
11. *T. Alpar, G. Nemeth, M. Varga*: General Waste Handling and Recycling in Particle Board Production.; ICECFOP (International Conference on Environmentally-Compatible Forest Products), Fernando Pessoa University, Oporto, Portugal (2004, szeptember. 22-24) (presentation, proceeding: pp.255-268.) ISBN 972-8830-23-8
12. *G. Nemeth, M. Varga, E. Csanady, Sz. Nemeth*: Analysis of exhausted and remaining dust at workplaces applying CNC processing machinery; The 4<sup>th</sup> International Science Conference Chip and Chipless Woodworking Processes; Trieskové A Beztrieskové Obrábanie Dрева '04 Technical University in Zvolen, Szlovákia 14-16. Oct. 2004, ISBN 80-228-1385-0 (presentation, proceeding pp.263-273.)
13. *T. Alpar, G. Nemeth, M. Varga*: Global wate handling and reuse in particleboard production; Hardwood research and utilization in Europe, University of West Hungary, Hungary, September 6, 2005 (presentation, proceeding: pp. 103-112.)
14. *G. Nemeth, M. Varga*: Wood waste handling and recycling in Hungary; 2<sup>nd</sup> International Science Conference: Woodworking Techniques; Zalesina, September 11 – 15, 2007 (presentation, proceeding: pp. 331-338.) ISBN 953-6307-94-4
15. *G. Nemeth, M. Varga, Z. Kocsis*: Wood waste handling and recycling in Hungary; Problems of Wood Processing 1<sup>st</sup> Workshop Sopron, Hungary September 3, 2007 (presentation, proceeding: pp. 39-45.)
16. *G. Nemeth, M. Varga*.: Wood waste handling and recycling in Hungary; Möbeltage in Dresden, Internationale Fachtagung, Germany May 29-31, 2008 (digitális kivettítés, konferencia kiadvány: pp. 39-45.)

### **Proceedings, presentations, posters in Hungarian language**

17. *Németh G., Varga M.*: Hulladékgazdálkodás kérdései a faiparban; MTA Agrártudományok Osztálya, Agrár - Műszaki Bizottsága XXVII. Kutatási és fejlesztési tanácskozás, Gödöllő January 2003 (presentation, proceeding: pp. 19.) ISBN 963 611 390 4
18. *Németh G., Varga M.*: A faiparban keletkező hulladékok keletkezésének és újrahasznosításának modellezése MTA Agrártudományok Osztálya Agrár-műszaki Bizottsága, XXVIII. Kutatási és fejlesztési tanácskozás kiadványa, Gödöllő January 2004 (presentation, proceeding: pp. 27-28) ISBN 963 611 406 4
19. *Németh Gábor*: Hulladékgazdálkodási folyamatmodellek a faiparban; IV. Életciklus-elemzési (LCA) szakmai konferencia, Sopron September 11-12, 2008. (presentation, digital-proceeding)

### **Presentations given in Hungarian language**

20. *Németh G., Varga M.*: A hulladékgazdálkodás kérdései a faiparban. Légtécnika és környezetvédelem a faiparban című szakmai szimpózium. Nyugat-Magyarországi Egyetem, Rendező: Faipari Tudományos Egyesület; Sopron, 2002
21. *Németh G., Varga M.*: A faipari hulladékgazdálkodás energetikai vonatkozásai; Megújuló Energia Regionális Konferencia; InnoLignum Sopron, September 11, 2008.

### **Research collaborations**

22. *Varga Mihály (témavezető), Molnár Sándor, Németh Gábor*: A nemzeti erdővagyon minőségi fejlesztésének és bővítésének, valamint a fahasznosítás korszerűsítésének programja; Széchenyi Terv Nemzeti Kutatásfejlesztési Program, Erdő-Fa Kutatási program 7/4. alprogram: Fafeldolgozási hulladékok keletkezése, kezelése, felhasználhatósága. 2001-2004.
23. *Varga Mihály (témavezető), Németh Gábor*: „Keménylombos fafajok technológiai porának morfológiája és munkaegészségügyi összefüggései” témájú kutatás; OTKA-Kutatás. 2002-2005.
24. *Winkler András (témavezető), Alpár Tibor, Németh Gábor*: Hulladékgazdálkodás és környezetvédelem (RET 2.4 projekt, 2.4.1 Fahulladékgazdálkodás). 2005-2007.

## Research and development activities

25. *Gerencsér Kinga, Hargitai László, Németh Gábor, Spendel József, Schöberl Miklós*: Az Innovációs Központ biomassza fűtőművéhez kötődő faipari melléktermék hasznosítás logisztikai rendszere. Tanulmány, 2005. március; 40. oldal
26. *Németh Gábor, Varga Mihály, Magoss Endre*: Interfa Kft. hulladékgazdálkodásának feltérképezése, javaslattétel a korszerűbb hulladékkezelésre. Tanulmány, 2004. november; 72. oldal
27. *Németh Gábor, Varga Mihály, Németh Szabolcs*: Garzon Bútor hulladékgazdálkodásának elemzése, javaslattétel a korszerűbb hulladékkezelésre. Tanulmány, 2004. november; 51. oldal
28. *Németh Gábor, Varga Mihály, Magoss Endre*: Hungaropro Kft. jelenlegi hulladékkezelésének felülvizsgálata, valamint hulladékkezelésének lehetséges innovációja a hazai és az Európai Unió törvénykezésnek megfelelően. 1. rész: Nem faalapú hulladékok. Tanulmány, 2005. március; 40. oldal
29. *Németh Gábor, Varga Mihály, Kocsis Zoltán, Walter Autó Kft.*: A Walter Autó Kft. hulladékkezelésének lehetséges innovációja a hazai és az Európai Unió törvénykezéseknek megfelelően. Tanulmány, 2005. november; 47. oldal
30. *Németh Gábor, Varga Mihály*: Hungaropro Kft.: Faalapú hulladékok hasznosításának és innovatív fejlesztésének lehetőségei a Hungaropro Kft.-nél, különös tekintettel az energiaelőállításra. Tanulmány, 2006. március; 40. oldal
31. *Németh Gábor, Varga Mihály, Magoss Endre*: Az Interfa Kft.-nél keletkező fahulladék tárolásának és helyi hasznosításának lehetőségeiről. Tanulmány, 2005. november; 28. oldal
32. *Németh Gábor, Varga Mihály, Kocsis Zoltán*: A SWEDWOOD Sopron Bútor Kft.-nél keletkező lakkcsiszolatpor hasznosításának újszerű (innovatív) lehetőségéről. Tanulmány, 2006.; 18. oldal
33. *Németh Gábor, Varga Mihály, Csanády Etele, Kocsis Zoltán*: Tanulmány az INTERFA Kft. szanyi üzemének tömörfa alkatrészeinek újszerű vágásoptimalizálásának kidolgozása, különös tekintettel a CNC megmunkáló központokra, lap és tömörfa szabázzat gépeinek optimális igénybevételére. Tanulmány, 2007. december; 67. oldal



*Notes*