ENERGY AUDITS OF WOOD PROCESSING TECHNOLOGIES

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ABSTRACT:

Energy audit is a good tool to assess the impact of timber processing technologies on environment. The energy audit is based on LCA and LCI to identify energy requirements of the technology in question. Energy used in four principal areas, viz. (1) manufacture, assembly and haulage, (2) operations, (3) repair and maintenance, (4) disposal and/or recycling is quantified for each machine in all partial working processes on the basis of the machine's life cycle diagram. The used energy is converted to a production unit suitable for the given system. Provided that an energy audit is made for all applicable technologies at a specific stage of manufacture, it may represent an important instrument to support the process of decision-making. The commonly used economic valuation of technologies is affected by many factors and usually ends in the cost function of the given technology, the calculation of which however includes only purchasing and operating costs. In many a case, the environmental aspect cannot be expressed in money. Energy audit provides a comprehensive information on energies invested into the given technology. In the case that more technologies are to be considered with the same load on environment such as damage to forest stands, soil etc., the expression in numbers of the energy invested into the technology should be one of basic factors for the choice.

Keywords: energy audit, LCA, environmental aspect, wood processing

INTRODUCTION

The consumption of energies is continually growing on a global scale. Statistic data published in the United States of America (U.S.A.) speak of a continually growing energy consumption in the last 40 years (Anon., 2006). In 2003, the energy consumption in the U.S.A. reached a breathtaking cipher of 98.22×10^{15} BTU (British Thermal Unit, i.e. 103.6×10^{18} J); of that 40% was for the consumption of energy from crude oil products. The growing consumption of energies increases the pollution load on environment. This is why the choice of environment-friendly technology in any field of human activities, based on energy balance, is a rational way of the management of resources. Energy audit provides a comprehensive information about energy consumption. If there are more technologies to be considered, the energy audit may become a key indicator for the best possible selection.

BACKGROUND

LCA (Life Cycle Assessment is a method to assess potential impacts relating to a product or a service. It is also a method for the establishment of relevant inputs and outputs in the product use and for the interpretation of the product's impact on environment (Anon., 1997, 1998, 2000).

LCA is a method for the assessment of diverse human activities with a gross impact on environment. For example in Japan it was found out that an important environment-affecting factor is the railway network. Nagatomo et al. (1997) prepared a study of the Shinkanzen railway and further developed the LCA studies in the following years.

There are a number of authors engaged in the assessment of logging technologies with the use of LCA and LCI (Life Cycle Inventory) methods. LCI was for example used by Athanassiadis et al. (1999) to identify the consumption of fuels, oils and lubricants in harvester technologies in the conditions of Sweden. The collection of data is followed by the calculation of the average consumption of fuels, coolants and lubricants. Machines are classified in three categories: small, medium-sized and large – in harvesters by their engine output power and in forwarders by their payload capacity. The classification appears to be very useful which can be documented among other things also by essential differences in the consumption of working fluids. A good example may be fuel consumption in harvesters with values of 1220 litres per m³ (over the bark), 902 l.m³ and 878 l.m³ recorded in small, medium-sized and large machines. In another publication, Athanassiadis et al. (2000) focused on the volume of individual materials consumed by harvesters and forwarders during their life cycles providing figures on the consumption of steel and cast iron, aluminium, plastic materials, rubber and glass, accumulators and other materials. With respect to the use of LCA and LCI methodology Athanissiadis et al. (2002) also expressed in numbers harmful emissions and their load on environment.

Energy audit of harvester technologies was studied by Klvac et al. (2003) and energies consumed per a cubic meter over the bark were expressed in numbers for three basic areas – manufacture, operation, maintenance and repair.

The impact of technologies on environment by means of LCA was studied by many authors in order to express for example the emissions of harmful substances in exhaust gases and losses on fuels, coolants and lubricants.

Based on the data gathered during the product study a strategy was prepared for the reduction of energy use (Energy Reduction Strategy – ERS). Klvac et al. (2003) published an ERS for the harvester technology that made it possible to reduce the amount of used energy to reference unit (production unit) by 13%.

OBJECTIVES

The goal of this paper is to submit a procedure proposal for the assessment of all technologies for the processing of raw timber materials within their entire life cycle so that the methodology could be used for the assessment of individual members in the chain and results of the assessment could become one of criteria for the selection of a suitable and environment-friendly wood processing technology.

MATERIAL AND METHODS

Energy audit

The first step consists in a precise identification of the system and in the delineation of its boundaries. In the following step it is necessary to determine within the system its individual members for an easier assessment. Each member of the chain is to be assessed separately. Primary life cycle elements of individual members in the technological chain are illustrated in Fig. 2.

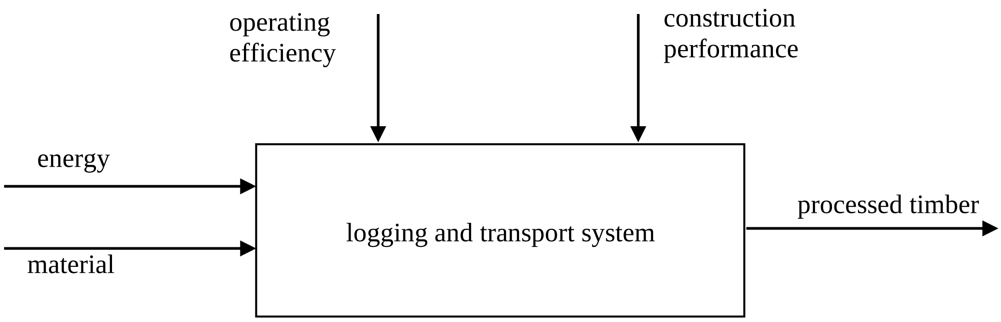

Fig. 1 : The scheme of logging and transport system

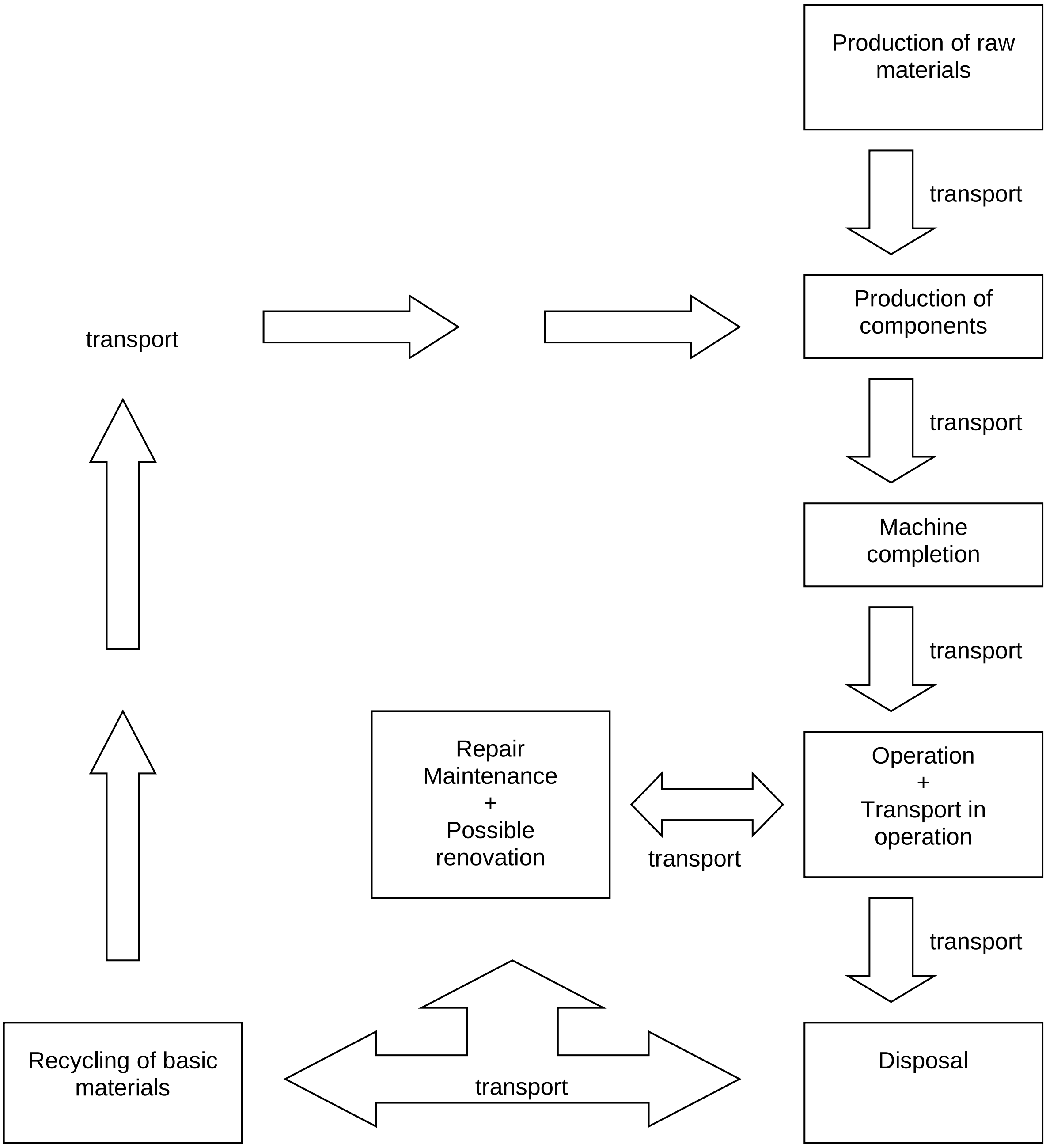

Fig. 2: The scheme of primary elements in the life cycle

The energy audit is proposed for implementation in four main fields:

Field 1 – Manufacture, assembling and transportation

Determination of primary energies used for the manufacture of raw materials. Division of materials into groups: metals, plastic materials, glass, rubber, pulp, paper, organic substances. Determination of the share of the respective materials in individual machine parts. Expression in numbers of energies used during the manufacture of the machine parts. Determination of transport distances and expression in numbers of energies consumed during the transport. Determination of total energy consumption – for the manufacture of materials, for the manufacture of machine parts, for the assembly and for the transportation.

An example may be the expression in numbers of energy used for the manufacture of a forwarder. Athanassiadis et al. (2002) studied forwarders and concluded that 66.4 MJ is required for the manufacture of each kilogram of machine mass. Based on a LCA study of harvester node and on the basis of productivity an amount of energy was calculated consumed in the manufacture of harvester node at 11.3 MJ loading each cubic meter of produced wood (Klvac et al., 2003).

Field 2 – Operation

Determination of the consumption of fuels, coolants and lubricants, and determination of energy consumption. In the working fluids it is the determination of fuel consumption, consumption of hydraulic oils, engine oils, gear oils, chain lubrication oils and other lubricants. In consumed energies it is the determination of energies consumed for the manufacture of fuels, coolants and lubricants and energy contained in these working fluids (Table 1 and Table 2). Determination of machine productivity and all data required to express in numbers the energy used per the defined reference unit (most frequently one m^3 over the bark or a metric ton).

Table 1: Energies used in the production of oils and energy contained in the oils ($MJ.l^{-1}$) (Väg et al., 2000)

Oil type	Energy content	Energy use in production	Total
Mineral	38.5	45	83.5
Vegetable	36.1	12	48.1
Synthetic	36.1	22	58.1

Table 2: Energies used in the production of fuels and energy contained in the fuels ($MJ.l^{-1}$) (Grägg, 1994; Altin et al., 2001; McDonnell, 1996)

Fuel type	Energy content	Energy use in production	Total
Mineral Diesel fuel	36.14	4.5	40.64
RME (Rapeseed Methyl Esther)	33.1	15.6	48.70
Mixture of 25% RME and 75% Diesel fuel	35.64	7.07	42.74

Field 3 – Maintenance and Repair

Identification of primary data required to express in numbers the used energy, i.e. working machine's age, productivity, weight of the machine, amount of transported and/or processed reference units. Determination of energy amount used for maintenance and repair including the calculation of energy used for transport. In the case that some machine parts have been renovated, the calculation will include only the energy invested into the renovation – not the energy used for a complete replacement of the machine part. In harvester technologies, the calculation can be based on a value of 66.4 $MJ.kg^{-1}$ presented by Athanassiadis (2002), additionally loaded with energy consumed in haulage.

Field 4 – Disposal, recycling

Determination of energy required for diassembly, recycling and/or disposal. Specification of transportation distances and energies consumed in haulage. In the case that some machine parts have been renovated, the calculation will include only the energy invested into the renovation. Classification of materials into groups – metals, plastic parts. glass, rubber, pulp, paper, organic substances, and establishment of the share of the respective materials in machine's component parts.

In the case of disposal/recycling there are three possible ways:

- dumping: the energy audit will include only energies used in haulage and dumping; high environmental load
- incineration: the energy balance will include energies used in haulage reduced by the energy released during the incineration of individual partial materials
- recycling: the energy balance will include energies used in haulage and recycling. In terms of energy use, recycling is less demanding than the production of raw materials, which brings energy savings. Thus, the recycling can decrease the energy balance at a stage of raw materials production.

RESULTS

Outputs from using the above described method are as follows:

- Quantification of total energy used per reference unit that is a sum of energies used in all four partial fields
- Proposal of a strategy for the reduction of energy use (ERS) on the basis of the obtained data, whose main purpose consists in the abatement of technology impact on environment
- Quantification of emissions and leakages of fuels, coolants and lubricants.

DISCUSSION AND CONCLUSION

The above described method of energy audit enables an assessment of individual members in the technological chain. Thanks to detailed data provided by LCA and LCI an ERS can be designed that would reduce the energy requirements of partial sections. Klvac et al. (2003) designed a harvester node ERS which makes it possible to reduce the energy demand by 13% to 104 $MJ.m^{-3}$ (over the bark) of raw timber within a space demarcated by the stump-roadside landing boundaries. The original study, however, did not include recycling which can positively affect the energy balance.

Based on the consumed energies and the impact of respective technological chain members on environment this method makes it furthermore possible to replace the technological member with another one with a better energy balance where technologically possible.

In the case that a choice is to be considered in Field 4 between recycling and disposal, the recycling appears to have a better energy balance and a lower environmental impact. Hitherto studies published by different authors indicate that as compared with the manufacture of new raw materials the energy savings of recycling amount to 97%, 95%, 74% and 25% in plastic machine parts, aluminium parts, steel and glass, respectively.

ACKNOWLEDGEMENTS

The paper was prepared within the framework of research project of the Ministry of Education of the Czech republic “Forest and wood. Support to a functionally integrated forest management.“, MSM 6215648902, Part 02/05/01.

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