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Improved energy efficiency in sawmill drying system

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HIGHLIGHTS

- A heating system at a sawmill was investigated and improved.
- Different impacts of external technologies at the energy usage were explored.
- The heat and electricity consumption was analysed separate between technologies type.
- The result point out a significant decrease of the biomass consumptions.

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ABSTRACT

The worldwide use of biomass has increased drastically during the last decade. At Swedish sawmills about half of the entering timber becomes lumber, with the remainder considered as by-product (biomass). A significant part of this biomass is used for internal heat production, mainly for forced drying of lumber in drying kilns. Large heat losses in kilns arise due to difficulties in recovering evaporative heat in moist air at low temperatures. This paper addresses the impact of available state-of-the-art technologies of heat recycling on the most common drying schemes used in Swedish sawmills. Simulations of different technologies were performed on an hourly basis to compare the heat and electricity demand with the different technologies. This was executed for a total sawmill and finally to the national level to assess the potential effects upon energy efficiency and biomass consumption. Since some techniques produce a surplus of heat the comparison has to include the whole sawmill. The impact on a national level shows the potential of the different investigated techniques. The results show that if air heat exchangers were introduced across all sawmills in Sweden, the heat demand would decrease by 0.3 TWh/year. The mechanical heat pump technology would decrease the heat demand by 5.6 TWh/year and would also produce a surplus for external heat sinks, though electricity demand would increase by 1 TWh/year. The open absorption system decreases the heat demand by 3.4 TWh/year on a national level, though at the same time there is a moderate increase in electricity demand of 0.05 TWh/year. Introducing actual energy prices in Sweden gives an annual profit (investment cost excluded) on national level for the open absorption system of almost 580 million SEK. For the mechanical heat pump technology the profit is 204 million SEK and for the traditional heat exchanger the profit is significant lower. It has been found that a widespread implementation of available energy recovery technologies across Swedish sawmills would result in substantial savings of biomass for other purposes in the society.

1. Introduction

A sawmill produces lumbers from the entering timber with the help of the sawmill processes; timber handling, barking, sawing, sorting, drying, package and in some cases a grinding process is necessary. In these processes a lot of biomass is produced as by-products from the lumber production. About one tenth of the incoming timber is used for the internal supply of heat. The sawn lumber needs to be dried to a desired end moisture content to prevent cracks, shrinking and mould issues. The supplied heat is mainly used for the drying process, which is a large energy and time intensive process. The drying process is done in a facility called drying kiln; dry outside air is heated and circulated through the lumber packages to carry away the moisture in the lumber. The additional part of the produced biomass is nowadays sold.

When producing lumber the lead time and wood quality are prioritized before the energy consumption. The reason for the high thermal energy requirement in the drying processes is that the evaporation heat is normally difficult to recover usefully, due to the low temperature. Heat recycling in the kilns is quite uncommon. In some few cases the heat is recovered with air/air heat

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Nomenclature

$\dot{m}$	Mass flow [kg/s]
x	Absolute moisture content [kg water/kg dry air]
P	Pressure [kPa]
h	Enthalpy [kJ/kg]
ϕ	Relative humidity [% RH]
u	Lumber moisture content [kg water/kg lumber]
V	Volume [m^3]
ρ	Density [kg/m^3]
T	Temperature [°C]
r	Latent heat [kJ/kg]
Cp	Specific heat [kJ/kg K]
M	Molar mass [g/mol]
$\dot{Q}$	Heat [kJ/s]
$\dot{q}$	Specific heat [kWh/kg]
L	Mixing rate

Subscripts

1	out door, point 1
2	before the heating battery, point 2
3	middle of lumber package, point 3
3d	before lumber package, point 3b
4	after lumber package, point 4
t	time t = 0
$t-1$	time t = −1
i	initially
n	interval number
w	water
v	vapor
dry	dry
wet	wet
tot	total
sat	saturated conditions
evap	evaporated
diff	difference
wood	wood
air	air

exchanger [1]. The research devoted to increased energy efficiency when drying of lumber has been low prioritized in the past decades, due to the large supply and the historical low prices of biomass. Different software has been developed during the last decades to ensure correct kiln air conditions in order to attain adequate lumber quality [2–4]. Several experiments were made to evaluate the different variables' effect on the energy efficiency when drying lumber for different drying conditions. [5–12]. That method is very time consuming and costly, especially if each drying condition needs to be tested for each type of recycling technology. It has been found that the heat consumption is possible to decrease by about 60% if available state-of-the art technologies are used in the drying kiln [1,5,9–10,13].

The main objectives of this work are to compare different technologies for increased energy efficiency hour by hour based on certain drying schemes. The focus is on wood types, lumber dimensions and kiln types that are most commonly used in Sweden according to earlier work [1,5,14]. To ensure high lumber quality the drying, scheme is constructed with the help of a simulation program called Torksim [15,16]. Torksim was developed by the Technical Research Institute of Sweden. It is regularly used by sawmills to predict the drying scheme, to obtain a specific lumber end moisture content with a secured lumber quality and lead time, for the specific drying conditions.

2. Background

2.1. Swedish sawmills

In sawmills today only 47 wt% [1,14] of the entering timber becomes lumber. Except for timber the production processes needs electricity and heat to fulfill their purposes. The heat is often supplied by the sawmills own biomass fired furnace; otherwise the heat is purchased from nearby industries. The heat and electricity demand for each process is shown in Table 1. The main part of the energy used by the sawmill is heat and the drying process uses the majority part of it, while additional heat is used for local heating. About 12 wt% [2] of the entering timber is used to supply the sawmill with heat.

The drying process is necessary to prevent unwanted mold, cracks and lumber modifications. A lumber drying process is a struggle among sufficient quality, low lead time and low energy usage. The quality and the lead time are always prioritized before the use of energy. To decrease the lead time forced drying technique is applied (in drying facilities called drying kilns), which gives rise to the high use of heat. The most common type of dryer is the progressive and batch kiln. The main difference between these kiln types is that the air state inside the batch kiln changes over time corresponding to the planned drying scheme. Compared with the progressive kilns, with several air zones of different air state, were the lumber package changes zones when travelling through the kiln. This gives rise to different energy uses and lead times, which is advantageous for different types of drying conditions.

Table 1
Usage of heat and electricity between the lumber production processes [5,6,8,18].

	Electricity [kWh/m^3lumber]	Heat [kWh/m^3lumber]	Temperature [°C]
Barking	4	–	–
Sawing	23	10	30
Sorting	2	5	30
Drying	31	299	75
Dry handling	4	5	30
Grinding	13	5	30
Office		15	30
Total	77	339	

Conventional drying technique uses outdoor air as moisture transport medium of evaporated water from the lumber. The moisture in the air has a lower partial pressure compared to the air close to the lumber. The equilibrium principle forces a moisture transport from the lumber into the air close to the lumber and further to the circulation air in the surroundings, which results in a drying effect. The bound and free water between and inside the wooden cells will be transported towards the surface. A large difference in partial pressure will cause a faster moisture transport; if this is done too fast an ununiformed distribution of the water can result in cracks and large lumber deformation, i.e. an unwanted low quality of the lumber (the amount of stored bound water compared to the amount of free water makes the structure more sensitive to these forces in the fiber structure). On the other hand a low difference in partial pressure will lead to unwanted slow drying. However, before the circulation air becomes saturated it needs