Drying of wood chips with surplus heat from TWO hydroelectric plants in Norway

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Abstract:
We studied drying of wood chips by surplus heat from two hydroelectric plants in the western part of Norway. The wood was chipped and loaded into the dryer; a tractor-trailer and a container were used. The dryers had perforated floors where warm air from the plants was funnelled into the dryer, using an electric fan of 4 kW. Four separate trials were conducted in September and October 2009. The drying capacity of the trailer and the container was roughly 11.5 m3 and 29 m3 loose respectively. The effective height at which drying took place was 1.2 m and 1.9 m.
The average temperatures of the air channelled into the dryers was 15–18 °C in the trailer and 24–26 °C in the container. The fan was operated for 139 hours (twice) for the trailer and 121.5 and 67.5 hour periods for the container. The fan used 556 kWh (twice), 486 kWh and 270 kWh of electricity respectively. The chips located at the bottom dried first, and chips located above dried later. The water content in the chip was measured to 66.1 to 52.1% (wet base) before and 9.6 to 6.9% (wet base) after drying. The amount of water removed from the container was approximately 28 kg per hour and 22 kg per hour from the trailer. For the container, drying cost roughly 9 Euro per MWh; the cost of the trailer was nearly twice as much. This indicates that the drying volume should be as high as possible. Drying determines net calorific value and hence market value of wood chip.

Keywords: Biomass, wood chip, wood fuel, drying, surplus heat.

1 Introduction

The use of wood chips as fuel in the production of energy is increasing. Wood chips are currently used as fuel in many heat and power plants and small chip boilers normally require dry wood chips. Wood chips can be dried in a dryer. Removal of water in a drying process is energy intensive and for that reason costly. Energy in the form of heat is available in many hydroelectric power plants. In this text, we explain how it is possible to dry the chip with waste heat from two hydroelectric power plants in Norway.

With the warm air it is conceivable to dry the chip, regardless of outside air temperature and relative humidity. The ambient air drying ability deteriorates during the autumn because of falling temperatures and generally increasing relative humidity. By increasing the temperature of ambient air the air's drying capacity increases significantly. Drying takes place by air with a high temperature transfer heat to the material, the heat evaporates the moisture and water vapor is carried away by the airflow in the dryer. It is common to use a fan to blow air through a dryer.

Drying fans are divided into two main types; centrifugal and axial fans. The pressure drop at the injection of air in a dryer will vary with a variety of physical properties. In a study of drying of wood chips with atmospheric air by (Kristensen, Kofman and Jensen 2003) indicated that drying fans with high counter pressure capability are not required for wood chip. This is mainly due to that the chip consists of larger particles and the counter pressure in the chip layer is small compared to the drying of e.g. agriculture crops.

The Norwegian Forest and Landscape institute conducted a drying experiment in Sel in Gudbrandsdalen in the summer of 1988. The experiment was based on additional air from the roof, heated by the sun. The results showed that solar heating provides better drying effects than an ordinary drying with ambient air (Grønlien, Fæste and Tengesdal 1991). In the drying experiment the drying time was five days and the collector system increased the temperature of the drying air by 5 °C. At the end of the trial the mean water content in the chip was 13.4% (wet base).

Energy in the form of heat is available from process industry, incinerators and power plants. In electric power plants mechanical energy is transformed into electrical energy. The efficiency of the generator is up to 98-99% (Novakovic, 2000). This means that in a hydropower plant 1-2% of the energy produced is heat. It is reasonable to dry energy wood at the storage site using natural forces such as solar and wind energy. However, the weather or climate can limit the drying of energy wood outdoors. The objective of this study was to find out if excess heat from electric power plants can be used for drying of wood chips and in seasons that are normally not very favorable for drying in atmospheric air. In addition it was also interesting to calculate the energy used and gained by drying the chip as well as the costs in euro per MWh.

2 Material and Methods

The fieldwork for this study took place at Kleive and Viksdalen in Norway. We dried wood chips in the immediate vicinity of two small hydropower stations as shown in Figure 1. Installed capacity was 2.2 MW and 1 MW respectively. The four drying experiments took place in late September and October. The dryers had perforated floors of steel with 3 mm holes. The heat from the power plant was distributed in the space below the steel plate.

The container was a standard GMM hook container with movable roof cover, and a side door for connecting the air duct. After rebuilding the container it was 6.0 m long, 2.4 m wide and 1.92 m high. The total volume was then 27.65 m^3. The tractor trailer was an Orkel TT 100 with scrollable canvas with ridge. After the rebuilding the trailer was 4.0 m long, 2.4 m wide and 1.2 m high. The total volume was 11.52 m^3.

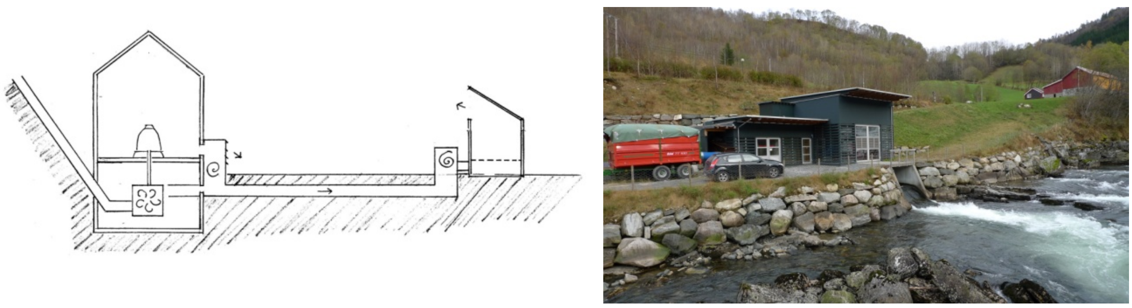

Figure 1: The hydroelectric power plants and the container (left) and trailer (right).

The radial fan, a Kongskilde HVL 55, had a power output of 4 kW. The fan should in accordance with the manufacturer provide large air flow and fan performance varies minimally by changes in pressure from various materials. The fan should be suitable for bed drying up to 5-6 meters.

2.1 Measurements

In order to weigh the chip loads the trailer and the container where placed on the weighing platforms of the type WWSE10T. The drying air temperature, relative humidity and the ambient temperature where registered every half hour. Moisture content samples were taken from the chip before and after drying. Electricity used by the electric fan was measured.

3 Results and discussions

3.1 Temperature and relative humidity

The air temperature at the top and bottom of the dryer and the ambient temperature are shown in Figure 2. The energy in the drying air is used to evaporate the water and the temperature drops. When the moisture content is low the temperature rises. The temperature rises first at the bottom of the chip load, and later at the top of the stack. The drying zone moves in other words, through the chip layer in the dryer. The dotted red line shows the ambient air temperature.

Measurements at the end of the drying process showed that the temperature and relative humidity in the dryer was about the same as in the drying channel. The explanation is probably that there is little water to evaporate. To control this, one sensor was placed in the drying channel. The temperature in the channel was approximately the same as in the chip layer. This can be seen before and after the drop in the red line in Figure 2.

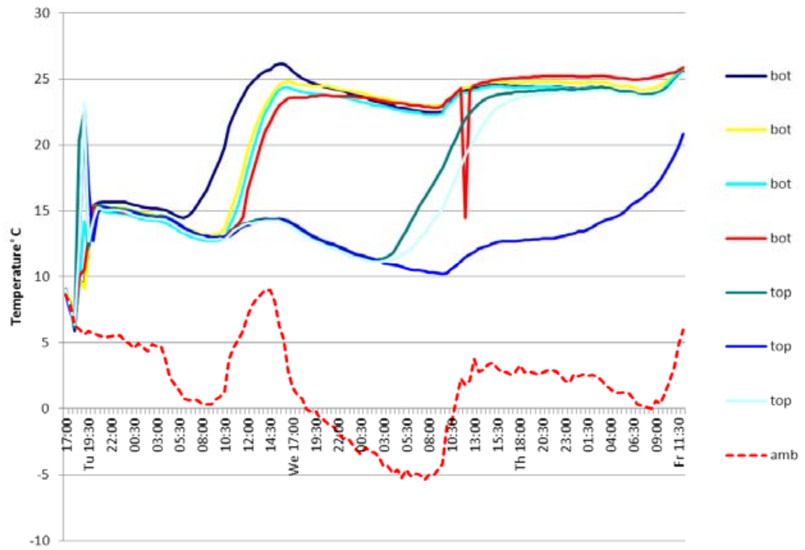

Figure 2: The air temperature at the bottom and top of the container and outside the container.

The figures in Table 1 shows that the air from the power plant contributed to an increase of the temperature of the air and the temperature was higher in Istad power station (container) than in Vallestad power station (trailer). The mean average values in Table 1 are based on collected records every half an hour.

Table 1: Mean values for air temperature and relative humidity

	Temperature		Relative humidity	
Site	Dryer (°C)	Outside (°C)	Dryer (%)	Outside (%)
Container	26.0	11.0	26.3	87.6
	24.4	1.8	23.7	90.7
Trailer	14.9	5.9	43.8	95.8
	18.5	8.4	29.9	64.3

3.2 Energy consumption and energy costs

The consumption of electricity for the radial fan was measured and the effect was 4 kW, which means maximum effect. The electricity costs were set to 5 euro cents per kWh. Energy costs varied according to fan hours i.e. drying time (Table 2).

Table 2: Effect fan, fan hours, energy used, energy prices and costs.

Site	Effect fan (kW)	Fan hours (h)	Energy used (kWh)	Energy price (¢ per kWh)	Costs (€)
Container	4	121.5	486	5	24.3
	4	67.5	270	5	13.5
Trailer	4	139	556	5	27.8
	4	139	556	5	27.8

3.3 Weight and moisture content

Three samples for the moisture content (wet base) were collected from the chip before and after drying. After drying, one sample was collected from the bottom, middle and top layer and they were collected near the rim of the container and trailer. The container and trailer were placed on load cells and the weights were recorded continuously over time (Table 3). The amount of water lost from the container was approximately 28 kg per hour and from the trailer 22 kg per hour.

Table 3: Chip weight and measured moisture content before and after drying.

	Before drying		After drying	
Site	Chip weight (kg)	Moisture content (%)	Chip weight (kg)	Moisture content (%)
Container	7485	52,7	4010	-
	7045	52,3	4935	6,9
Trailer	5300	66,1	2185	9,6
	5165	61,0	2165	8,7

3.4 Net calorific value before and after drying

We calculated the net calorific value of the chip load before and after drying. Typical values for net calorific value of solid biomass fuels are 19.1 MJ/kg or 5.3 kWh/kg of dry mass (EN 14961-1:2010). The net calorific value as received (the moist biofuels) can be calculated from the net calorific value of the dry basis (EN 14961-1:2010). The moisture samples were taken in front of the container. It is unlikely that wood chips in the middle of the container were as dry as shown in table 3. We therefore used an estimated value of 11% moisture content in the calculation of calorific value for the wood chip in the container. Calculated mean net calorific value before and after drying and the difference are shown in Table 4.

Table 4: Mean net calorific value before and after drying

	Before drying	After drying	Increase
Site	Calorific value (MWh)	Calorific value (MWh)	Calorific value (MWh)
Container	15.9	18.4	2.5
Trailer	7.7	10.2	2.5

3.5 The costs of drying wood chip

The hourly rate for transport and handling is set to 77 € per hour. The tractor driver used approximately 2 hours for transport and handling. The drying costs in euro per MWh of the trailer were almost twice as much as the container. This indicates that the drying volume must be as high as possible. As shown in Table 5, the drying costs can be a considerable cost factor in the supply chain. Total costs do not include investment costs for the dryer.

Table 5: Mean costs and calorific value of drying wood chip

Site	Energy costs (€)	Transport costs (€)	Calorific value (MWh)	Costs (€ per MWh)
Container	24.3	153	18.4	9.6
Trailer	27.8	153	10.2	17.7

4 Conclusion

This study concludes that heat from hydroelectric power plants can be used for drying of wood chips and in seasons that are normally not very favorable for drying in atmospheric air. It took less time to dry the wood chips with warm air than with ambient air. According to (Gigler et al. 2000) drying times varied from 21 to 100 days with ambient drying air. This study showed that one can dry a container and a tractor trailer with wood chips in approximately 6 days and it was possible to dry the wood chips down to about 10% water content.

A tractor trailer and a container can easily be converted to a dryer for wood chips. Other buildings, with waste heat can probably also be used as a heating source for drying of wood chips. The cost of drying must be considered in a supply chain for wood chips. Dried wood chips can be stored without loss of dry matter. It is possible to blend dried wood chips with moister wood chips. Drying determines net calorific value and hence market value of wood chip.

5 References

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