Willow as Fuel

Methods and Techniques for 50 kW-2 MW Heating Boilers

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Willow as Fuel

This brochure describes the characteristics of short rotation coppice (SRC) willow as a fuel and presents methods for drying harvested willow and for burning the fuel in small-scale heating boilers (small businesses, schools, farms, local heating centres etc.). The chemical properties of willow and its estimated slagging and fouling tendencies are described. Tried and tested drying methods, suitable combustion techniques, operating strategies and some commercially available boiler types are presented.

Contents

Use of willow

Willow (Latin name Salix) is a fast-growing fuel crop that is produced in coppice plantations on arable land. Like many other arable crops, willow requires maintenance and fertilisation in order to produce good yields. A willow plantation is ready for harvesting every three to five years. The most common harvesting system today is direct chip harvesting.

The main area of application for willow is currently biomass production for energy purposes. Examples of other uses of willow plantations are for hunting and game, nature conservation and production of snow rods. Willow can be used in both small-scale boilers (local heating, farm plants) and large-scale heating plants. The main use at present is as a fuel mix with other biomass fuels in large-scale power or heating plants that use moist fuels.

In recent years there has been increasing interest in using willow in small boilers that require drier biomass fuels. Today there are alternative harvesting systems based on removing intact stems, with or without a bundling function. There are also harvesting machines for making round bales. The latest technology on the Swedish market is harvesting in the form of billets. These new harvesting techniques permit greater use of drier willow, which is more suitable for small combustion plants, e.g. big bale boilers for direct use of willow bales.

Drying of willow harvested by direct chip harvesting is also carried out in some areas. This is an interesting area of development since this harvest system gives a very homogeneous chip (particle size distribution) quality, which is preferential in most small-scale chip boilers which can suffer from poor quality fuel problems (for more on tested drying methods, see page 10).

Fuel properties of willow

When supplying willow chips, it is important to check the requirements set by the heating plant on incoming fuels and on the quality of the willow chips. A large boiler is often more flexible as regards particle size of chips and moisture content, while the requirement for low moisture content and uniform material generally increases with decreasing boiler size.

The fuel properties of willow are relatively similar to those of wood fuel from forests. The major difference is that willow is a fast-growing type of tree that is harvested regularly, which means that a willow plantation consists of slender trees that contain a relatively high proportion of bark. A higher proportion of bark increases the content of ash-forming elements and nutrients such as nitrogen. From a fuel perspective, harvesting of larger willow stems is therefore preferable.

As can be seen in table 1, willow has a similar content of nitrogen (N), sulphur (S) and chlorine (Cl) and of ash-forming elements such as potassium (K) and calcium (Ca) as forest residues. A characteristic of willow is its low content of silicon (Si). However, willow has a higher content of cadmium (Cd) than forestry wood fuel because willow has a high capacity for uptake of cadmium. Willow has a high energy content (5.1 MWh/ton dry matter (DM)) per unit weight, but a lower energy value per unit volume than wood chips, which means that the fuel store needs to be refilled somewhat more often and the feed to the boiler often needs to be adjusted if it has previously been used for wood chips.

Table 1. Fuel data (mean value) for willow compared with wood fuel and forest residues

% of dry matter	Fresh newly harvested willow	Wood fuel (stem wood)*	Forest residues*1
Ash content	1,2-1,7	0,5-1	1,3-4,7
Carbon, C	50	50	50
Hydrogen, H	6	6	6
Oxygen, O	44	44	41
Sulphur, S	0,02-0,03	0,01	0,04
Nitrogen, N	0,2-0,4	0,06	0,4
Chlorine, Cl	<0,01	<0,01	0,01
Silicon, Si	0,007-0,012	0,07	0,3
Potassium, K	0,15-0,18	0,05	0,20
Calcium, Ca	0,3-0,5	0,10	0,5
Magnesium, Mg	0,038	0,01	
Sodium, Na	0,004	0,001	
Aluminium, Al	0,003	0,002	
Phosphorus, P	0,09	0,005	0,05
Net calorific heating value, MJ/kg DM	18,4	19,2	19,2

**Taken from 'Bränslehandboken'. 1Tree tops and branches.*

Fuel properties of willow

Moisture content

The moisture content of willow is usually around 50% at harvest. However, it can vary from 45 to 55 % depending on cultivar, growing location, age and time of harvesting (Figure 1). The moisture content is one of the most important quality parameters for use of willow in small boilers. In order to achieve good combustion in small grate boilers, the moisture content should lie around 30% or lower, which means that the willow must be dried.

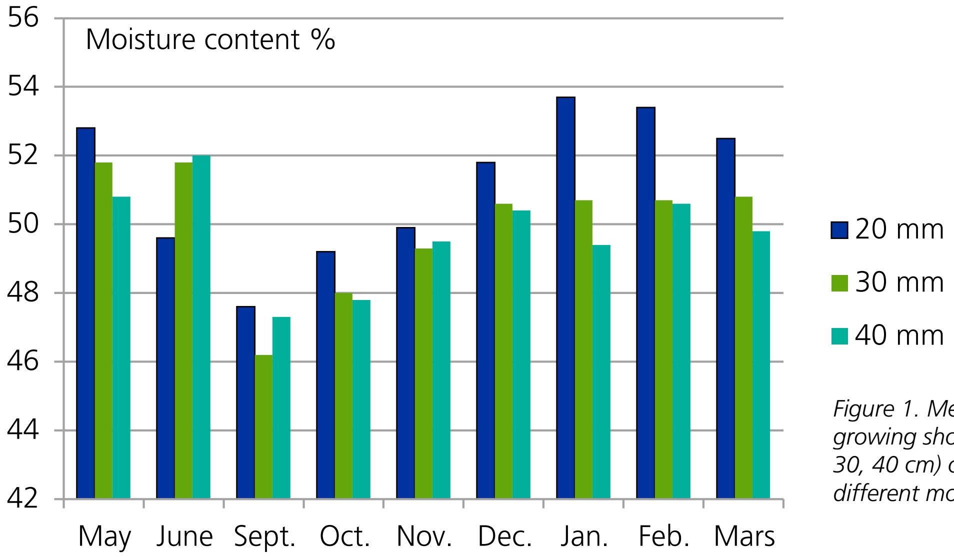

Figure 1. Measured water content in growing shoots of differing diameter (20, 30, 40 cm) of the willow cultivar Tordis in different months of the year.

Ash content

In all biofuels, in addition to the combustible material there is an inorganic residue that cannot be combusted, i.e. the ash. The ash content is defined as the proportion of ash, expressed as a percentage of dry matter in the fuel. The natural ash content consists of non-combustible substances, in particular potassium (K), calcium (Ca), magnesium (Mg) and silicon (Si), that the plant has taken up during its growth. The ash content in newly harvested willow from a four-year-old willow shoot is between 1.2 and 1.7 %. The ash content can vary slightly depending on cultivar, age (proportion of wood and bark), growing site and time of harvesting. If the willow is contaminated by sand and soil during handling, storage or transport, the ash content can easily double, to around 4%. A higher ash content due to contaminants lowers the heating value and increases the risk of problems of slagging in the boiler during combustion (see the section 'Slagging tendency of willow'). In order for willow to maintain good quality, it should be handled carefully, as it is relatively brittle and easily broken. When willow chips are stored at the field edge, it is important to leave the last chips on the surface to prevent soil from contaminating the material. A certain increase in the ash content can also occur during storage due to loss of dry matter (see the section 'Storage and its effects on fuel quality').

Heating value

Irrespective of whether the fuel is supplied to a customer or used in an on-farm boiler, it is good to know the heating value of the fuel. In a combustion context, the net calorific heating value is always mentioned. In order to calculate the net calorific heating value of a fuel batch, it is necessary to know the net calorific heating value of the dry matter and the moisture content of the fuel. To determine the heating value of the dry matter, a fuel sample must be submitted to a fuel laboratory for analysis. With data on the heating value of the dry matter and the moisture content, the equation below can be used to calculate the heating value of a fuel batch. For willow, the heating value of the dry matter in newly harvested material is on average around 18.4 MJ/kg DM, which is equivalent to 5.1 MWh/ton DM.

$$h = H \times D/100 - (2.45 \times (100-D)/100) \text{ (MJ/kg)}$$

where:

h = net calorific heating value on delivery (MJ/kg)
H = net calorific heating value in dry matter (MJ/kg DM)
DM = dry matter content (%) of the sample
2.45 = heat of vaporisation of water

Examples of values		
DM	h	
(%)	(MJ/kg)	(MWh/ton)
50	7.98	2.21
70	12.15	3.37
80	14.23	3.94

Slagging tendency of willow

Depending on the composition of a fuel, during combustion the ash can form a full or partial melt (slag), which becomes a hard material on cooling. This material can cause problems in the first instance for the ash removal system, which is often designed to handle relatively loose ash. In addition, the melt can have a corrosive effect on the fabric of the boiler (ceramic or metal).

Elements which are important in determining whether a fuel will form a slag are mainly potassium, silicon and phosphorus, while calcium and magnesium reduce the problem. It is mainly how these elements react with each other that determines the slagging risk. During slagging, phosphate- and silicate-rich deposits are formed (the term silicate refers to compounds containing silicon, oxygen and potassium). Phosphorus or silicon can be present either in the form of more reactive material from the organic matrix of plants and/or from pollutants such as sand particles. The melted ash formed during combustion of biofuel can consist of either a salt melt (e.g. a mixture of melted K2SO4, KCl, K2CO3) and/or an oxide melt (i.e. a mixture of various oxides, phosphates and silicates). Salt melts have low viscosity and are not very sticky, while oxide melts are highly viscous and more sticky. In a combustion context, it is mainly the oxide melts that give rise to slagging problems.

Newly harvested willow has a relatively low content of natural silicon and phosphorus and thus a low tendency for slagging. One way to determine the slagging tendency of a fuel is to use model calculations. Figure 2 shows the amount of oxide melt formed by three different types of fresh willow samples. As can be seen from the diagram, willow has a very low estimated tendency for slagging, i.e. the amount of melt formed is very low, less than 1 gram per kg dry combusted fuel sample. This estimated low slagging tendency is due to the low silicon and relatively low phosphorus content in the willow samples. Figure 2 also shows the amount of oxide melt formed by some other typical biofuels, which is high for the straw sample, moderate for the reed canary grass and low for the bark.

If a fuel is contaminated with sand/soil, the slagging tendency increases, as shown in Figure 3. The figure shows an example of where willow chips were stored in a small stack and were contaminated which gave rise to a large difference in estimated slagging tendency/amount of melt formed between contaminated willow and the other samples. This is primarily because of the significantly higher proportion of silicon, which together with potassium forms a potassium-rich silicate. To avoid problems with slagging, it is very important to prevent contamination of the fuel.

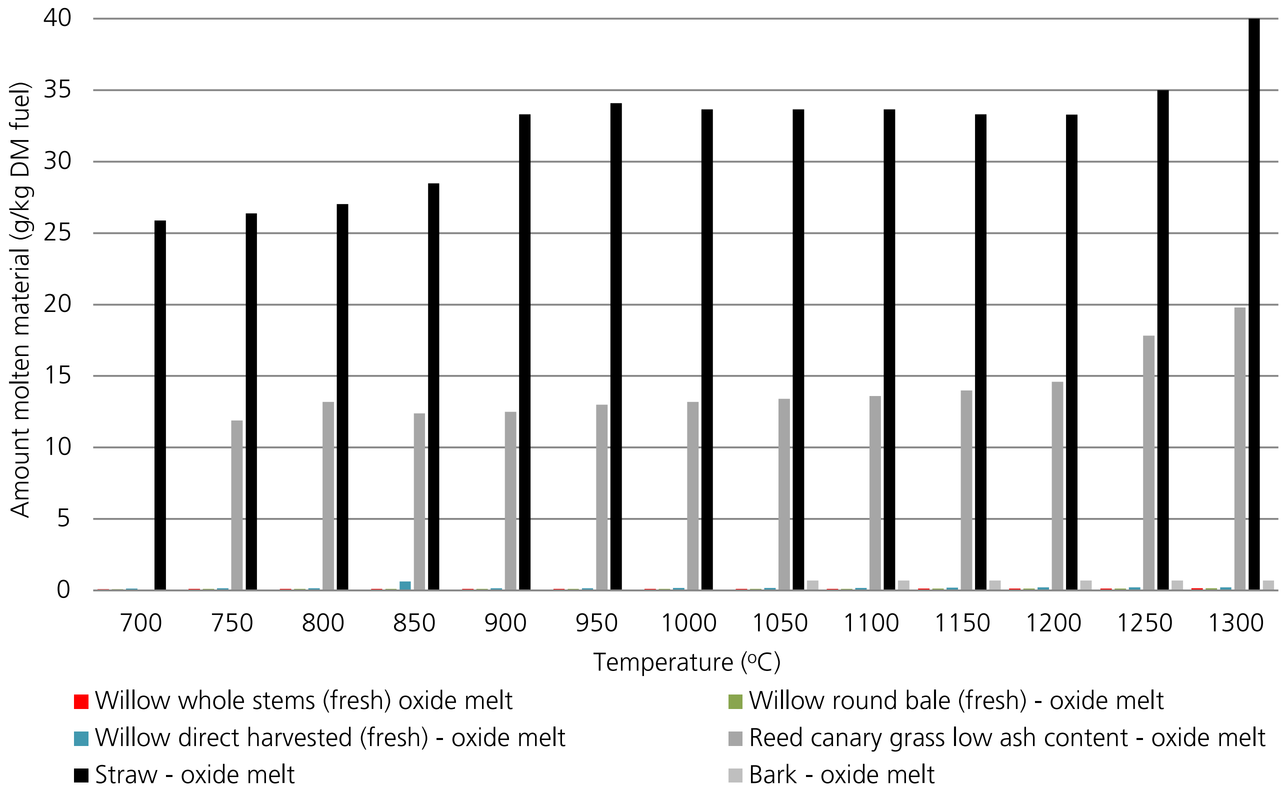

Figure 2. Estimated amount of oxide melt formed on combustion of three different fresh willow samples and of other typical biofuels.

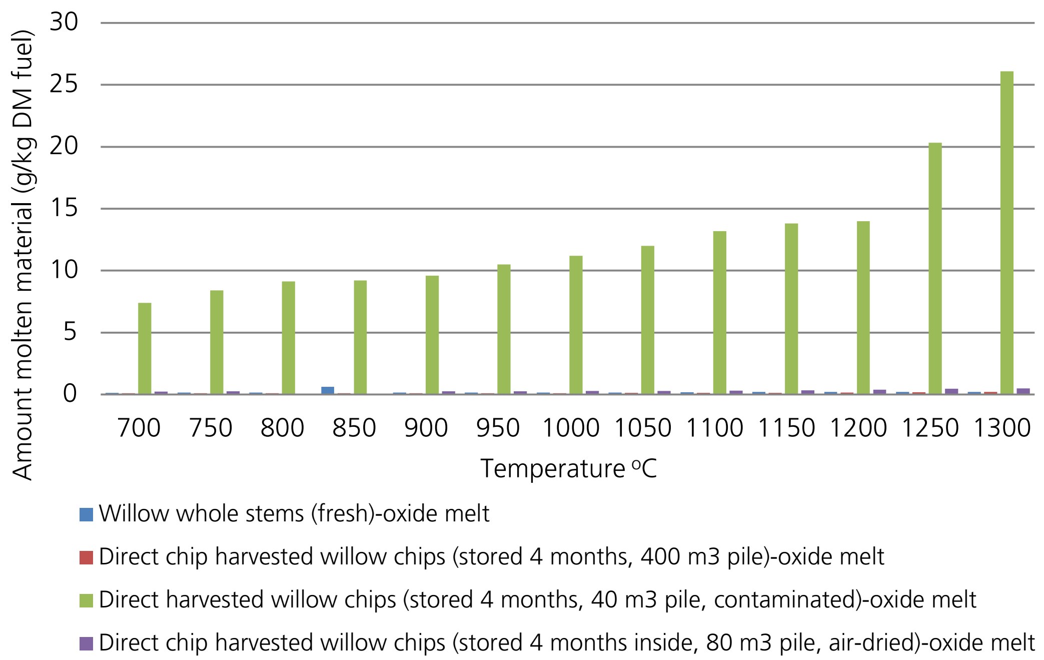

Figure 3. Estimated amount of oxide melt formed on combustion of fresh whole willow stems and of by sand/soil) or indoors.direct-chip harvested willow stored in a large stack (400 m 3), a small stack (40 m3, contaminated

Deposit tendency of willow

During combustion, in addition to accumulation of grate ash, some fly ash is formed. Fly ash is the fraction transported with the exhaust gas and is therefore found in deposits on surfaces further on within the boiler and as particulate emissions. Fly ash consists of both coarse particles (>1 µm), which mainly consist of trapped fragments of grate ash, and fine particles (<1 µm), which are formed through condensation of volatilised ash components. The proportion of fine particles increases along the exhaust channel as the temperature declines. The foulings formed by deposited fly ash can be detrimental in the form of decreased effectiveness of heat transfer surfaces unless these are cleaned regularly.

The deposit formed on the cooled heat transfer parts of a boiler consists of a mixture of deposited particles and condensed vapours of ash-forming elements. The composition of the deposit depends primarily on the composition of the fuel. If it contains a large amount of alkaline chlorides (as a result of high chlorine content in the fuel), the deposit can result in rapidly accelerating corrosion.

The tendency for deposition can be estimated by calculating the amount of potassium that goes to the gas phase and forms fine potassium-rich particles (when potassium in the gas phase condenses in upper parts of the combustion chamber/entrance to the convection section). As can be seen from Figure 4, the majority of the potassium present in willow is lost to the gas phase at temperatures above 900 oC (according to model calculations), i.e. the temperature is relevant for grate boilers. This means that a large proportion of the potassium in the gas phase, often more than 90%, is present as KOH(g), i.e. the proportion of KCl(g) is low. The sulphatisation ratio (calculated as 2S/Cl) for willow is 4 or higher. It is known from experience that a sulphatisation ratio as high as this mitigates the risk of high temperature corrosion in the superheater of a steam boiler. In practice, this means that willow forms relatively high levels of fly ash during combustion, which may mean that the smoke pipes needs to be cleaned slightly more often than when used for stem wood chips. However, the ash is not corrosive or sticky.

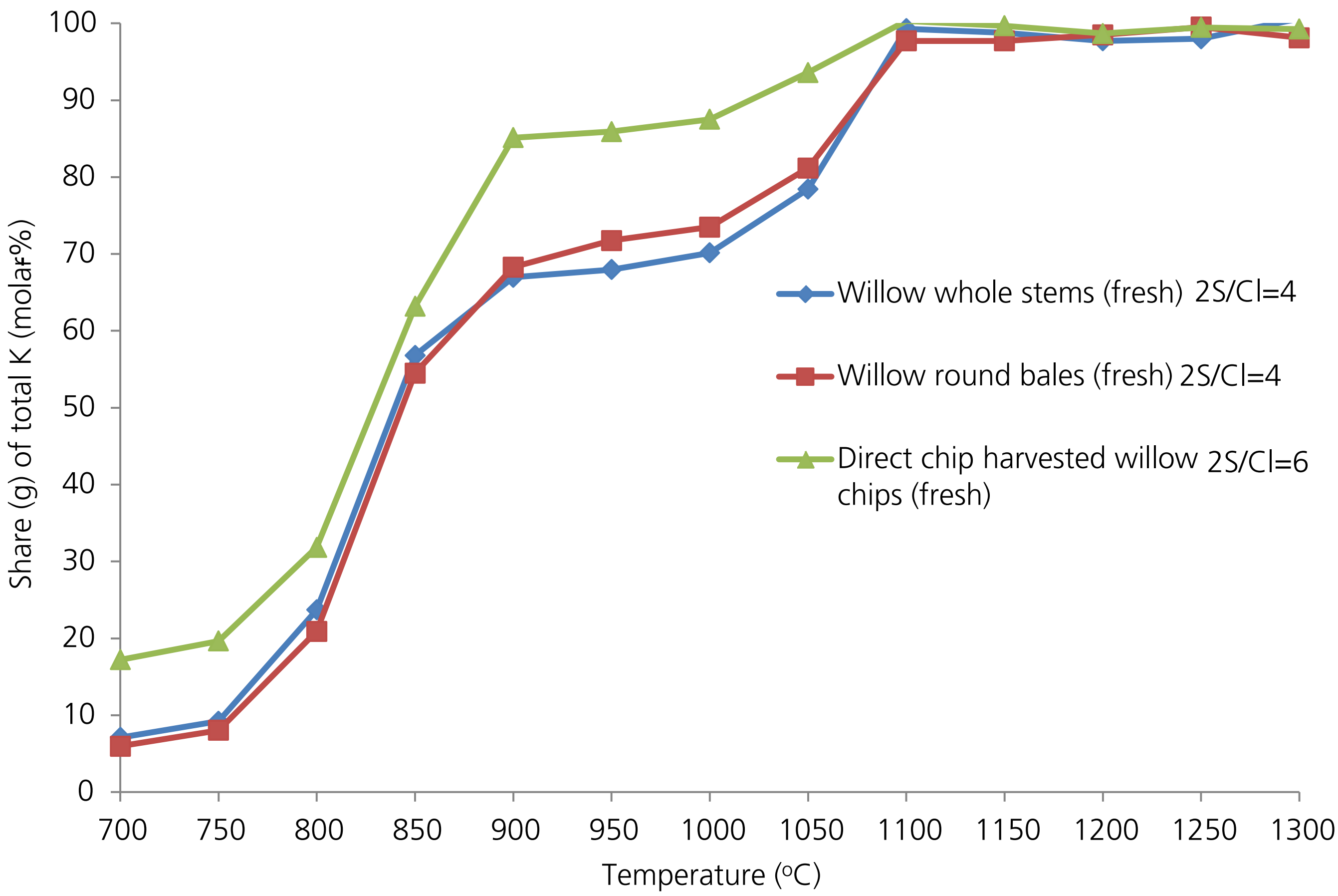

Figure 4. Estimated proportion of the potassium in the fuel that is lost to the gas phase at increasing temperature for different fresh willow samples.

Physical properties

When using willow chips in small-scale boilers, the fraction size is very important. Long sticks and overlarge pieces can cause blockages in the fuel feed augers to the boiler (Figure 5), while low bulk density of the chips can hamper the capacity of the boiler to achieve full and efficient output, since not enough fuel enters the chamber. Willow chips from direct-chip harvesting have the advantage of being very homogeneous, with no long fragments (Figure 6), which makes them suitable for use in smaller boilers. However, the chips have to be dried before being used in smaller boilers or if any duration of chip storage is planned.

Figure 5. Blockage in the fuel feed owing to long fragments in the chips.

Figure 6. Willow chips from direct chip harvesting have uniform and homogeneous quality.

Whole stem harvesting and round bale harvesting of willow produces a material that has the advantage of being suitable for storing outdoors in stacks that allow natural drying. The disadvantage is that extra operations are needed for these materials in the form of handling and chipping if the boiler uses chips, which increases the costs. For chipping, it is important to use a chipper that can handle thin stems, as these can otherwise pass through the chipper and leave long fragments in the chips. The chips also tend to be relatively light and fluffy, which can result in them overflowing the feed screws if these have small dimensions.

Before willow can be used as a fuel in small boilers, it has to be dried to a moisture content of 30% or less. There are different methods available for drying biofuel, the most common is to let the fuel dry in its natural form and then chip the material and store it under cover. When the fuel is allowed to dry out in its natural form, this decreases the breakdown of woody material caused by microorganisms and chemical oxidation processes. In principle, storage of organic material always results in some loss of substances, which is equivalent to loss of dry matter. Since chipped material has a relatively large surface area compared with the natural material, the decomposition rate and thus the loss of dry matter are greater for chips than for the material in its natural form. Table 2 shows the decrease in moisture content in willow stored as whole stems and as bales between March and September. As can be seen, the moisture content of the willow decreased to 22% within five-six months. For willow in bales there was a certain loss of energy during the storage period, as reflected by the slightly lower net calorific heating value compared with whole stems. The elevated ash content is the result of natural variations in the material (samples with more bark have a higher ash content), contamination by sand/soil and loss of dry matter. Storage of whole stems had no effect on the net calorific heating value and the variation in ash content was due to natural variations.

Table 2. Decrease in moisture content of willow stored in bales and as whole stems stored in piles

Month	Willow bales			Willow whole stems			
	Moisture content %	Net calorific heating value, MJ/kg DM	Ash content, % DM	Moisture content, %	Net calorific heating value, MJ/kg DM		Ash content, % DM
March	47*	18.30	1.2				
April	25	18.26	1.4	46	18.36	1.3	
May	16	18.23	1.6	39	18.23	1.7	
June	14	18.16	1.4	32	18.51	1.4	
July	-	-	-	28	18.40	1.5	
August	22	18.07	1.6	26	18.39	1.2	
Sept.	-	-	-	22	18.48	1.6	

**Moisture content at harvesting.*

Direct-chip harvested willow needs to be stored in stacks or in sheds. Practical experience shows that late spring harvesting (March-April) is preferable if the willow chips are dried in the stack. In the spring, the drying effect is often better and the air humidity is lower. If the stack is to be stored outdoors, it should be at least a few hundred cubic metres so that the volume of the moist outer layer is not too great in relation to stack size. To achieve a good drying effect, experience shows that the stack should be high and pointed to allow rainwater to run off down the sides. The smaller the storage stack, the more sensitive it is to the weather.

The loss of dry matter is greatest during the first weeks of storage of willow chips in stacks, but after a month or so the rate of loss declines. The loss of dry matter is also strongly influenced by particle size, the moisture content of the fuel at stacking, stack size and the impact of weather. Storage tests on willow chips have shown that the dry matter losses can be 10% or more when the material is stored over the summer months. If the fuel is going to be used in small boilers, the chips should be moved under cover in July-August, since otherwise the material may be re-moistened by high air humidity and rainfall in the autumn. For best results, the stack should be stored openly under cover (pad silo) directly after harvest, especially when handling small volumes.

Figure 7. Storage of willow bales.

During the summer, cold air drying can also be an option. However, there is a risk of the air creating good conditions for microfungi (moulds) before the chips are sufficiently dry to restrict microbial growth. Previous research and experience show that systems where air is forced out through the stack are preferable.

Figure 8. Willow stored in different stacks.

Table 3 shows the decrease in moisture content in willow stored in a large stack outdoors and in a stack indoors with cold air drying between April and August. As can be seen, the moisture content in the willow stored outdoors decreased from 50% to 30% in three months. As with willow in bales (see Table 2), there was some loss of energy from the outdoor stacks during the storage period, as indicated by the slightly lower heating value. The elevated ash content in the stacks is the result of natural variation in the material (samples with more bark have a higher ash content), contamination by sand/soil and loss of dry matter (at least 10 %). Cold air drying decreased the moisture content of the material to 20% in three months, but also resulted in some loss of dry matter. In that case there was also strong microbial growth in the centre of the stack (Figure 9).

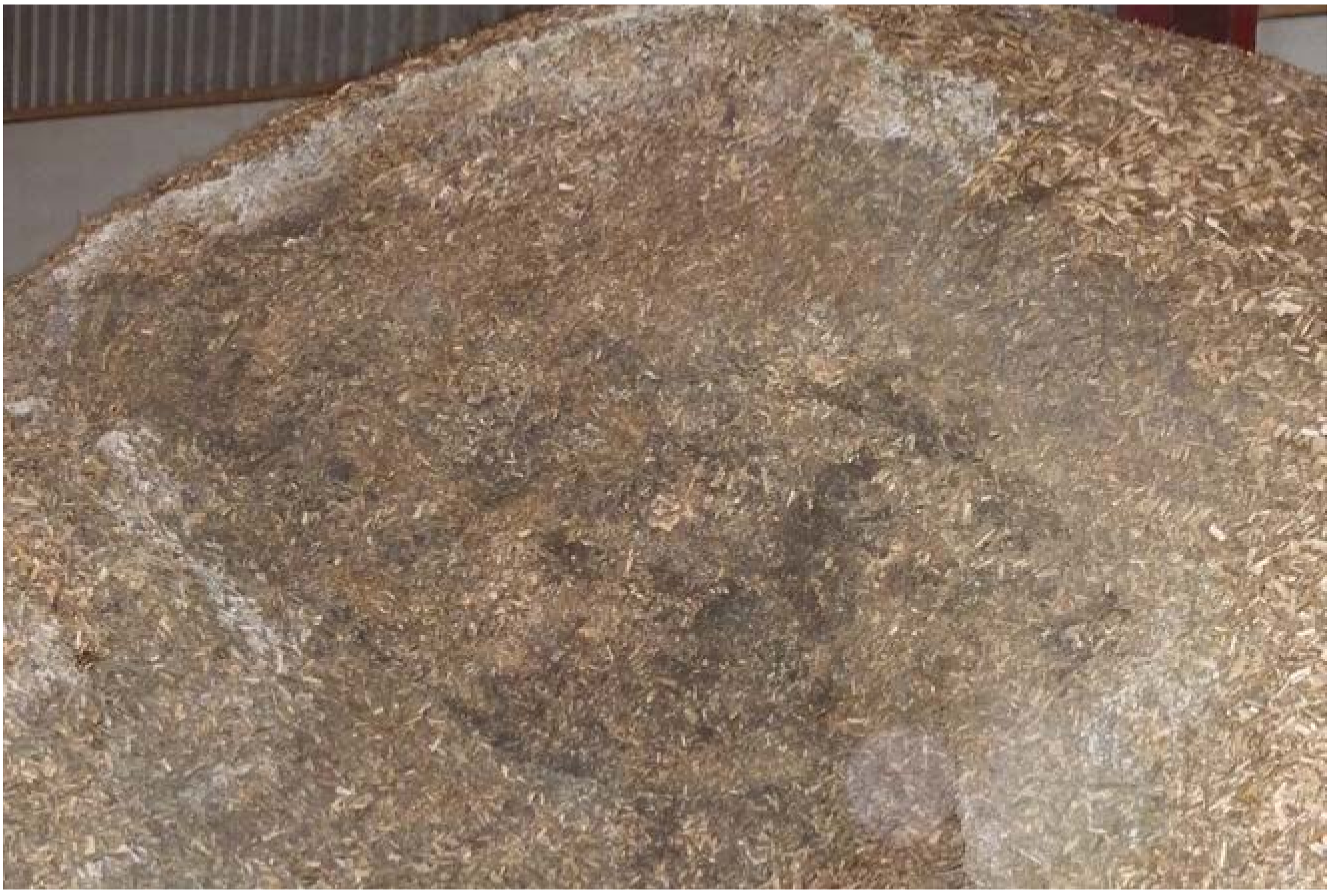

Figure 9. Microfungi in the centre of the indoor stack with cold air drying.

Table 3. Decrease in moisture content during storage of willow in a large stack outdoors and in a cold air-dried stack indoors

Month	Stack, stored outdoors 400 m³			Stack, cold air-dried 80 m³		
	Moisture content, %	Ash content, % DM	Net calorific heating value, MJ/kg DM	Moisture content, %	Ash content, % DM	Net calorific heating value, MJ/kg DM
March						
April	51[1]	1.7	18.44	51[1]	1.7	18.44
May	43	1.9	18.30	35	1.5	18.35
June	39	2.2	18.20	27	2.1	18.36
July	30	1.8	18.30	20	2.3	18.27
August	33[2]	2.2	18.15	24	1.9	18.28

[1]*Moisture content at harvesting .*
[2]*After a period of rain.*

Willow chips in small-scale boilers

The main area of use of willow today is as a fuel mix with other biomass fuels in large-scale heating or power plants that use moist fuels. The reason for this is that the most commonly used harvesting system is direct chip harvesting, which produces chips with high moisture content. When using chips in a small boiler (50 kW-2000 kW), the moisture content should be 30% or lower. When using willow in small boilers, it is important that the material meets the requirements set by the heating plant and for which it is designed. Problems arising in small chip-burning plants are often related to fuel quality. However, different boilers are more or less flexible to variations in fuel quality. A rule of thumb is that the smaller the combustion plant, the less flexible it is to variations in fuel quality.

Grate boilers 0.50-2 MW

A feature shared by all chip-burning boilers from 50 kW is that they all use continuous fuel feeding, while the combustion and the system design can vary, as can the degree of automation. The combustion technique used in the 50 kW-2 MW range is mainly a grate boiler. The grate in a chip-burning boiler can be either fixed or moving. For the latter, the movement can be forward, vibrating or rotating. There are also models that use a moving fuel/ash scraper on a fixed grate. The orientation of the fuel bed in relation to the air flow can also vary, e.g. co-flow, cross flow or anti-flow. The most common type today is a sloped moving grate with a cross flow of air, i.e. the fuel moves from the feed inlet to the ash outlet, while the primary air flows up through the fuel bed from the bottom of the grate. The primary air is often supplied through holes in the grate bars or through the channels between the bars. Secondary air is supplied later to achieve complete combustion of combustible gases and particles. Irrespective of boiler type, it is important to maintain a high temperature in the combustion chamber, good turbulence and a sufficient oxygen supply, and to ensure that the residence time in the hot zone is sufficiently long to allow the fuel to be completely combusted.

Advances have been made in small chip-burning boilers in recent years, and in particular with control functions. For example, control of fuel feeding has been improved through introducing more adjustable parameters, which gives a more regular infeed. The O2-regulation has also been improved to give greater sensitivity. Moreover, small boilers with automatic soot cleaning are becoming more common.

In addition to the boiler, it is important to have appropriate, suitably dimensioned systems for fuel feeding and ash removal. For example, if a more ash-rich fuel is used, a larger ash hopper should be fitted.

Willow chips in farm boilers

A number of farms with small-scale chip boilers have already tested willow chips or are using willow chips today. Three case studies are described below of farms in Sweden with three different types of grate boilers on which combustion tests and emissions measurements were carried out with willow chips in 2013/2014.
In the tests, the boilers were fired with 100% willow chips. During the trials, the boiler owner was responsible for setting the operating parameters and adapting the equipment to the fuel quality. SP Technical Research Institute of Sweden was responsible for the measurements, analyses and monitoring of operations.

Annex Farm, Trelleborg

Annex farm near Trelleborg is a conventional arable farm with a 3-4 hectare willow plantation. The farm has a 90 kW ETA Hack boiler installed in 2010 which heats the house and the farm buildings and is connected to the grain dryer. During winter 2013-2014, willow chips from the farm's own plantation were used as fuel in the chip-burning boiler. After harvesting, the willow chips were stored at the field edge from April to August in order to lower their moisture content. After a long dry period, the chips were transferred to an indoor store in August, which resulted in some mixing and further drying. The moisture content of the chips during winter was below 25%. The willow worked very well in the boiler largely due to the homogeneity of the willow chips with no branches or fragments that could cause problems with feeding.

ETA Hack

ETA Hack is a boiler designed primarily for combustion of chips and pellets and is manufactured in sizes from 20 to 200 kW. The fuel is added to the boiler with the help of a screw onto a tilting grate. The combustion chamber has ceramic lining and allows separate control of primary and secondary air with the aid of a lambda probe. During combustion of dry fuel, exhaust gas circulation is used to limit the temperature in the chamber so that slagging is prevented.

Willow chips in farm boilers

At predetermined intervals determined by the fuel type and the power requirement, the grate is tilted by 90° so that the ash formed falls down into a channel under the combustion chamber. A transport screw in the channel below carries this ash to a small ash box. The convection part, which has vertical tubes, is fitted with an automatic cleaning system that uses 'vibulators' and a screw carried the debris to the ash box. This screw is driven by the same motor as the screw for removing grate ash. The grate is cleaned by allowing the boiler to burn down and tilting the grate so that the ash falls out. The boiler then starts up again automatically. The ash box into which the two transport screws deliver the ash is positioned on the front of the boiler so that it is easy to empty.

ETA Hack, 90 kW.

Chip store, Annex Farm

Hans Schmidt, SP, emissions measurements

Combustion test with willow chips

During the study period, no stoppages occurred. The measurements showed that combustion was stable. The boiler coped with particles in the flue gas of below 150 mg/Nm³ (10% O2) without cyclone cleaning and NOx levels at 390 mg/nm³ (10 % O2).

Sövdeborg Castle

Sövdeborg Castle near Sjöbo is heated with a 120 kW Veto chip-burning boiler installed in 2011. The fuel consists mainly of chips from the farm's deciduous forest. The boiler is located in a small outhouse connected to the castle by a culvert.

Veto chip-burning boiler

Veto is a Finnish boiler that is fitted with separate burner heads installed in the chamber. With the Veto boiler, it is possible to burn different fuels, such as wood, peat and energy crops, chipped to appropriate size. The burners are either air- or water-cooled, with a fixed or moving grate. The moving grate stabilises the effect and decreases slagging on the burner head. It is possible to change the grate and moving parts. Veto boilers are available in a number of different versions from 20 to 990 kW. A moving grate is fitted on boilers from 120 kW up.

The ash is removed with two cross-running automatic ash screws. All parameters, such as feeding, grate, ash screw and air distribution, can be controlled independently of each other. Horizontal tubes and automatic cleaning are available as optional extras for the boiler. There are a number of farm plants in use in Sweden.

Vetopanna Sövdeborg

Sövdeborg Castle

Combustion test with willow chips

During the study period, no stoppages occurred. The measurements showed that combustion was stable. The boiler coped with particles in the flue gas of below 250 mg/Nm³ (10% O2) without cyclone cleaning and NOx emissions below 340 mg/nm³ (10 % O2).

Combustion of willow, Veto boiler

Karlaby Nygård, Tommarp

Karlaby Nygård near Tommarp in Skåne is a conventional arable farm with a turkey production unit. The farm has a 100 kW Reka boiler installed in 2004 which heats the house and farm buildings. The fuel used consists of two parts straw/cereal trash and one part dry chips. In order to handle different fuels the boiler has two fuel feed systems, a line with a straw shredder and a fuel hatch for chips.

Reka (HKRST)

Reka (HKRST) is a Danish multi-fuel boiler with moving grate that can incinerate fuel with a maximum moisture content of 30%. Models from 20 kW to 3500 kW are available. The boiler element has one of the world's smallest inbuilt moving stair grates. This means that ash-rich fuel can be combusted even in the smallest model. The chamber is relatively spacious and lined with a fireproof material on the top and sides. Primary air is supplied from below and secondary air through pipes on the sides . The ash is removed with an automatic ash screw. All parameters such as feeding, grate, ash screw and air distribution can be controlled independently of each other. Vertical tubes and automatic soot removal are available as options for the boiler. The boiler can use all kinds of fuels such as briquettes, chips or bales that are broken up before being fed into the boiler. From 100 kW up, the boiler can be complemented with a pretreatment/dosing section and a straw hack. There are currently a number of these boilers in use in Sweden that use chopped straw, horse manure or other wastes from agriculture.

Combustion test with willow chips

During the study period, no stoppages occurred. The measurements showed that combustion was stable. The conclusion was that the Reka boiler The boiler coped with particles in the flue gas of below 150 mg/Nm³ (10% O2) without cyclone cleaning and NOx emissions below 390 mg/nm³, 10 % O2.

Combustion of willow chips in a Reka boiler

Recommendations

The following points are important for success when using willow as a fuel:

- When using willow in small-scale boilers, the fuel must be dried to a moisture content of 30% or lower before use.
- Late spring harvesting (April) is best if the willow chips are dried in stacks. In the spring the drying effect is often better and the air humidity is lower.
- If the stack is stored outdoors, it should be at least a few hundred cubic metres in size to prevent the volume of the moist outer layer being too large in relation to stack size. To get a good drying effect, the stack should be high and pointed to allow rain to run down the sides.
- For best results, the stack should be stored openly under cover (pad silo) directly after harvest, especially when handling small volumes.
- When using home-grown willow, the fuel should be handled with care. Additional handling increases the risk of contamination by soil/sand particles and breaks up the fuel. The last layer of chips should be left on the ground.
- A fuel analysis should be performed on the willow material before use in order to check the moisture content, ash content and heating value. The ash content provides is indicative of how well the material has been handled. The ash content should be below 2.5%.
- A boiler with a moving grate that can cope with the slightly higher ash content and slag formed when contaminated chips enter the boiler should be chosen. Boilers with underfed hearths should be avoided.
- A boiler with an automatic tube cleaning function is a good choice, since more frequent cleaning is required when using willow chips compared with wood chips. However, even with automatic cleaning, manual cleaning is required occasionally. Automatic cleaning with pressurised air can therefore be preferable to mechanical cleaning. Vertical boiler tubes are also preferable.
- Willow chips have a lower energy value per unit volume than wood chips, so it is best not to stay too close to the limit when choosing boiler size, to achieve full efficiency. . Fuel density also affects the settings of the feed screws.
- Screws and feed systems should be dimensioned so that they can cope with a certain proportion of long fragments that can be created when chipping e.g. bales or whole shoots. However, long fragments are not a problem when direct-chipped willow is used.

More information

Short Rotation Coppice Willow- Best Practice Guidelines. AFBI/Teagasc 2015.
www.teagasc.ie/publications/2011/314/Short_Rotation_Coppice_Best_Practice_Guidelines.pdf

or

www.afbini.gov.uk/willowbestpractice.pdf

Rokwood : Energy crops in Europe - Best practice in SRP biomass from Germany, Ireland, Poland, Spain, Sweden & UK . This publication includes several case studies of self supply using short rotation coppice (SRC) willow.
www.rokwood.eu/public-library/best-practice-booklet/send/27-best-practice-booklet/45-best-practice-booklet.html

For readers in the UK:

The UK Government's Renewable Heat Incentive (RHI) requires participants to present an emissions certificate for their chosen boiler and fuel. In order to comply with the scheme a boiler must demonstrate laboratory emission levels of 30 g/GJ particulates (approximately 60 mg/nm³, 10 % O2) and 150g/GJ nitrogen oxides NOx (300 mg/nm³, 10 % O2). Based in the data from these Swedish experiments it is possible that a gas cleaning system for particulates will be required. Also, the NOx emissions may exceed this threshold depending on the nitrogen level in the willow fuel. However, the measured values presented here are based on field measurements whilst achieving compliance under the RHI is based on the boilers performance in laboratory conditions.

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It is available for download at: www.rokwood.eu

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