The combustion of herbaceous biomass in low power boilers (10 to 500 kW)
Test results and recommendations for use
AILE (Association d’Initiatives Locales pour l’Énergie de l’Environnement – Association for Local Initiatives concerning Energy and the Environment) has been coordinating the Green Pellets project since 2009. The purpose of this 3-year experimental project is to identify the conditions for the development of procedures for agrofuels from herbaceous biomass which are environmentally-friendly. Combustion tests conducted in the laboratory and on pilot sites in the field have made it possible to understand the combustion performance and atmospheric emissions of various agrofuels. The practical information obtained is shown here:

5 points to be verified for the use of a herbaceous fuel

1. With the distributor, check the compatibility of the fuel with the boiler
The composition of a fuel can be estimated using the table on Page 4 or by analysis in a laboratory. Immediately set aside fuels with a composition that does not adhere to the requirements for the NF 444 Agrocombustible Qualité Haute Performance mark. Favour those adhering to the Obernberger recommendations**.

2. Perform the adjustments for the fuel feed
Bulk herbaceous fuels can be very voluminous, e.g. miscanthus chips are twice as voluminous as wood chips for the same energy.

3. Adjust the air factor
The air factor must be between 1.5 and 2.5 for good combustion. This parameter can be measured by a combustion analyser and the boiler settings can then be adjusted.

4. Adjust the de-ashing and the cleaning of the turbulators
Herbaceous biomass produces more ash than wood (up to 5% as opposed to 1 to 2% for wood). The settings must be appropriate. When the boiler is started with the new fuel, check for the possible formation of clinker and, if necessary, that it is correctly removed in the ash box (favour the use of boilers with removable grills in the firebox).

5. If possible check the carbon deposits during the run and change the maintenance programme if necessary

The Green Pellets project combustion tests

More than 20 herbaceous fuels produced and analysed
14 fuels tested in the laboratory under controlled combustion conditions
Tests in a multi-fuel boiler at two different loads for a period of two hours. Monitoring of emissions, output and ash production.

16 fuels tested in real conditions and compared with wood
Tests in 10 plants with power varying between 10 kW and 500 kW. Monitoring of emissions and output in two 1-hour trials, observation of the behaviour of the fuel and ash produced from one week to one month.
Herbaceous biomass: perform composition analyses

Why should fuel composition analyses be performed?

- To find out the calorific value of the fuel
- To compare the results with the existing standards
- To understand the risks of pollutant emissions
- To adapt the settings of the boiler and optimise combustion

The main analysis criteria

The NCV (Net Calorific Value) and humidity

The quantity of heat released by combustion of the biomass, known as the calorific value, depends mainly on the carbon content of the fuel, followed by the hydrogen content. Humidity also has a strong influence on calorific value as water evaporation requires additional energy.

<table>
<thead>
<tr>
<th>Humidity (%)</th>
<th>NCV (kJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>17 000</td>
</tr>
<tr>
<td>10</td>
<td>16 000</td>
</tr>
<tr>
<td>20</td>
<td>14 000</td>
</tr>
<tr>
<td>30</td>
<td>12 000</td>
</tr>
</tbody>
</table>

Nitrogen, sulphur and chlorine contents

The initial nitrogen, sulphur and chlorine contents in the fuel have an impact on the formation of nitrogen oxides, NOx, sulphur oxides, SOx, and hydrochloric acid, HCl. This may cause pollutant emissions and corrosion of the boiler.

Analysis of metal trace elements is recommended for some fuels (e.g. vine stocks and shoots)

- Mark relating to pellets of ligneous origin and those of herbaceous and/or fruit tree origin that are not chemically treated, based on the XP CEN/TS 14961 standard, managed by the FCBA (Technical Centre for Forests, Wood Products and Furniture) and certified by AFNOR (French Standards Association).

** Austrian who conducted research into biomass combustion.
The combustion of herbaceous biomass in low power boilers
Results of tests and recommendations for use

Analysis results for the composition of the agrofuels tested

The wood pellets and wood/miscanthus mixed pellets adhere to all the requirements of the Biocombustible Qualité Haute Performance mark.

Energy crops (hemp and switchgrass) are also compliant apart from their rather low energy value.

The residues of cereal crops contain too much chlorine and sulphur to be used in this form in low power boilers. When mixed in small quantities with wood they adhere to the mark requirements.

The vine stocks and shoots analysed adhere to the criteria for the chemical composition of this reference.

The residues from maintaining the land (heaths, reeds) contain too many minerals to be used in boilers, even though they grow in natural areas. They must be mixed with wood.

Which agrofuel is suitable in a low power boiler?

- If its composition does not adhere to the requirements of the NF Biocombustible Agro Qualité Haute Performance mark, it should be set aside immediately (significant risk of polluting and damaging the boiler).

- To limit the risks of atmospheric pollution and corrosion, it is preferable to adhere to the Obernberger recommendations.

- If its composition adheres to these recommendations, its use may be envisaged in a multi-fuel boiler, after the agreement of the manufacturer and taking the following setting recommendations into account.

---

### Summary of the results of the composition of herbaceous fuels (2011 analyses)

<table>
<thead>
<tr>
<th>Agrofuel</th>
<th>NCV (kJ/kg)</th>
<th>Humidity (%)</th>
<th>Ash at 550°C (%)</th>
<th>Nitrogen (%)</th>
<th>Total sulphur (mg/kg)</th>
<th>Total chlorine (mg/kg)</th>
<th>Ash-melting temperature (°C)</th>
<th>Cadmium (mg/kg)</th>
<th>Chromium (mg/kg)</th>
<th>Copper (mg/kg)</th>
<th>Zinc (mg/kg)</th>
<th>Mercury (mg/kg)</th>
<th>Arsenic (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coopédom wood pellets</td>
<td>16 876</td>
<td>8.7</td>
<td>0.9</td>
<td>0.30</td>
<td>227</td>
<td>107</td>
<td>1209</td>
<td>6.8</td>
<td>3.6</td>
<td>10.0</td>
<td>&lt; 0.08</td>
<td>&lt; 0.1</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Miscanthus pellets</td>
<td>16 012</td>
<td>10.6</td>
<td>3.4</td>
<td>0.20</td>
<td>152</td>
<td>657</td>
<td>740 (min)</td>
<td>4.3</td>
<td>3.5</td>
<td>12.0</td>
<td>&lt; 0.08</td>
<td>&lt; 0.1</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Hemp pellets</td>
<td>16 637</td>
<td>9.5</td>
<td>3.4</td>
<td>0.26</td>
<td>870</td>
<td>235</td>
<td>1182 (min)</td>
<td>1.8</td>
<td>2.5</td>
<td>4.4</td>
<td>0.004</td>
<td>0.1</td>
<td>x</td>
</tr>
<tr>
<td>Switchgrass pellets</td>
<td>15 568</td>
<td>10.9</td>
<td>3.7</td>
<td>0.33</td>
<td>610</td>
<td>305</td>
<td>1123 (min)</td>
<td>1.9</td>
<td>3.1</td>
<td>9.1</td>
<td>0.005</td>
<td>0.1</td>
<td>x</td>
</tr>
<tr>
<td>Wheat straw pellets</td>
<td>15 066</td>
<td>10.0</td>
<td>6.9</td>
<td>0.43</td>
<td>445</td>
<td>170</td>
<td>101 (min)</td>
<td>0.8</td>
<td>2.2</td>
<td>4.4</td>
<td>0.005</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Rape straw pellets</td>
<td>16 807</td>
<td>10.7</td>
<td>6.9</td>
<td>0.81</td>
<td>2000 (min)</td>
<td>1160 (min)</td>
<td>144 (min)</td>
<td>0.6</td>
<td>2.2</td>
<td>4.5</td>
<td>&lt; 0.1</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Wood pellets</td>
<td>15 246</td>
<td>11.3</td>
<td>6.1</td>
<td>0.45</td>
<td>1520 (min)</td>
<td>680</td>
<td>1280 (min)</td>
<td>1.6</td>
<td>2.7</td>
<td>7.4</td>
<td>0.001</td>
<td>0.1</td>
<td>x</td>
</tr>
<tr>
<td>Miscanthus pellets</td>
<td>14 783</td>
<td>8.0</td>
<td>14.6</td>
<td>0.43</td>
<td>427</td>
<td>420</td>
<td>1132 (min)</td>
<td>2.2</td>
<td>2.7</td>
<td>10.8</td>
<td>0.002</td>
<td>0.1</td>
<td>x</td>
</tr>
<tr>
<td>Hemp pellets</td>
<td>15 201</td>
<td>6.0</td>
<td>2.0</td>
<td>0.32</td>
<td>1013 (min)</td>
<td>1367 (min)</td>
<td>1412 (min)</td>
<td>1.2</td>
<td>0.14</td>
<td>9.1</td>
<td>&lt; 0.1</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Mixed miscanthus</td>
<td>11 000</td>
<td>22.1</td>
<td>2.5</td>
<td>0.55</td>
<td>1566 (min)</td>
<td>565</td>
<td>1380 (min)</td>
<td>0.8</td>
<td>2.3</td>
<td>7.6</td>
<td>&lt; 0.1</td>
<td>0.1</td>
<td>x</td>
</tr>
<tr>
<td>Bulk average 3 miscanthus</td>
<td>14 807</td>
<td>16.0</td>
<td>2.5</td>
<td>0.33</td>
<td>457 (min)</td>
<td>1300 (min)</td>
<td>1700 (min)</td>
<td>0.4</td>
<td>0.8</td>
<td>9.6</td>
<td>0.001</td>
<td>0.1</td>
<td>x</td>
</tr>
<tr>
<td>Bulk reeds</td>
<td>15 624</td>
<td>13.6</td>
<td>0.7</td>
<td>1.35</td>
<td>1933 (min)</td>
<td>967</td>
<td>1102 (min)</td>
<td>2.1</td>
<td>7.6</td>
<td>47.2</td>
<td>&lt; 0.2</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>15 134</td>
<td>20.4</td>
<td>2.4</td>
<td>0.30</td>
<td>242 (min)</td>
<td>1065 (min)</td>
<td>1565 (min)</td>
<td>0.05</td>
<td>0.4</td>
<td>47.3</td>
<td>&lt; 0.1</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Bulk average 3 miscanthus</td>
<td>14 807</td>
<td>16.0</td>
<td>2.5</td>
<td>0.33</td>
<td>457 (min)</td>
<td>1300 (min)</td>
<td>1700 (min)</td>
<td>0.4</td>
<td>0.8</td>
<td>9.6</td>
<td>0.001</td>
<td>0.1</td>
<td>x</td>
</tr>
</tbody>
</table>

Compliant with the mark: ✔️
Not compliant with the mark at more than 10%: ✗
Compliant with the mark at ±10%: +
Compliant with the mark (+ 10%), not adhering to the Obernberger recommendations: ✗
Compliant with the mark (+ 10%), and adhering to the Obernberger recommendations: ✔️

### Table notes:
- NCV: Net Calorific Value
- Humidity: (%)
- Ash at 550°C: (%)
- Nitrogen: (%)
- Total sulphur: (mg/kg)
- Total chlorine: (mg/kg)
- Ash-melting temperature: (°C)
- Cadmium: (mg/kg)
- Chromium: (mg/kg)
- Copper: (mg/kg)
- Zinc: (mg/kg)
- Mercury: (mg/kg)
- Arsenic: (mg/kg)

The table above provides a summary of the results of the composition analysis for various herbaceous fuels tested in 2011. The results are expressed for dry product and adhere to the Biocombustible Qualité Haute Performance mark and Obernberger recommendations.
Use a multi-fuel boiler

1. Refractory "Volcan" firebox
2. Primary air
3. Pre-heated secondary air
4. Combustion chamber
5. Regulation
6. Inspection trap
7. De-ashing auger
8. Dust removal from smoke
9. Turbulators
10. Smoke extractor
11. Lambda sensor
12. Smoke outlet
13. Removable de-ashing grill

3 good reasons for purchasing a multi-fuel boiler

If you intend to burn herbaceous biomass

1. **An appropriate firebox**
   Herbaceous biomass ash contains more minerals and starts to melt at between 800 and 1000°C, whereas wood ash remains powdery up to 1400°C. So manufacturers are designing multi-fuel fireboxes where the temperature remains lower, or which are fitted with moveable grills which can evacuate the clinker as soon as it is formed.

2. **Automatic de-ashing and cleaning are essential**
   Herbaceous biomass makes more ash than wood (up to 5 or even 10% as opposed to 1 to 2% for wood). The ash box is filled more quickly and the powdery ash clogs the boiler faster.

3. **Ceramic ducts are recommended**
   Herbaceous biomass contains more sulphur and chlorine than wood. These cause acids to form. A ceramic duct avoids corrosion of the equipment but does not prevent pollutant emissions.

The Agofire Hargassner boiler shown here has been purchased by AILE within the scope of the Green Pellets project combustion trials. The laboratory tests were performed using this boiler. There are other brands producing this type of boiler.
Adjusting a biomass boiler

The combustion equation

Biomass, which is mainly composed of carbon (black), hydrogen (white) and oxygen (red), burns in the presence of oxygen (O₂).

› Biomass contains minerals (Si, Ca, and Mg) in smaller quantities. These produce the ash.
› Biomass contains several thousandths of nitrogen (blue), sulphur (yellow) and chlorine (green).

The unburnt residues

CO

An example of a volatile organic compound, benzene

The combustion products are nitrogen (N₂), water (H₂O), carbon dioxide (CO₂) to which are added the unburnt residues and the products from the oxidation of secondary molecules (nitrogen, chlorine and sulphur).

Other combustion products

SO₂
HCl
NO
NO₂

Sulphur dioxide (SO₂) and hydrochloric acid (HCl) are products which are produced in proportion to the sulphur and chlorine contents of the fuel.
› Emissions of nitrogen oxides (NOₓ) are linked both to the adjustment conditions and the nitrogen content of the fuel.
› NOₓ and SO₂ are responsible for acid rain. HCl is corrosive and a precursor in the formation of dioxins.
› With clean healthy wood there is no SO₂, no HCl and very little NOₓ emitted.

› CO (carbon monoxide) and VOCs (volatile organic compounds) are signs of incomplete combustion and are toxic to humans.
› The formation of dust is above all linked to the quality of the combustion. This is a health risk factor, (respiratory problems, etc.).
Poor adjustment

If the combustion settings are not optimised, there is a risk that emissions of unburnt products and pollutants will be high.

- Black smoke
- Feed auger
- Primary air
- De-ashing auger
- Absence of unburnt products in the de-ashing auger

To optimise the adjustment of the boiler, the French 4Ts rule should be observed:

- Firebox Temperature between 650°C and 900°C (linked to settings)
- Residual oxygen content (Teneur) between 7 and 12% (linked to settings)
- Good Turbulence (linked to equipment design)
- Gas retention Time between 1.5 and 2 seconds (linked to equipment design and settings).

In practice, there are 5 stages in the adjustment of the boiler:

- Adjustment of the fuel feed depending on the power required
- Check where the flame is in the firebox, that the fuel is evenly distributed and that there are no unburnt products in the ash box
- Adjust the combustion visually by the supply of primary and secondary air (colour of the flame). Depending on the operating regime: 20 to 50% secondary air, the rest primary air
- Check that the air factor is between 1.5 and 2.5. Determine its optimum value at which the energy output is maximal and the CO emissions minimal (see graphs opposite)
- Check there are no unburnt products and clinker in the ash box (if necessary, adjust the operation of the moveable grills and the de-ashing system) and check carbon deposits regularly
- Carry out regular servicing

Good adjustment

- Smoke hardly visible
- Secondary air
- Feed auger
- Primary air

A well adjusted boiler and regular servicing makes it possible to:

- optimise the boiler output and therefore the fuel consumption
- reduce pollutant emissions
- preserve the equipment and extend its service life
Results of combustion trials: Bulk miscanthus

The fuel in pictures

Fuel composition

<table>
<thead>
<tr>
<th>Moisture content (%)</th>
<th>Bulk density (kg/m³)</th>
<th>Net Calorific Value (kJ/kg)</th>
<th>Results expressed for dry product</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nitrogen (%)</td>
</tr>
<tr>
<td>NF Agrogranulés (QHP) mark</td>
<td>&lt;11</td>
<td>&gt;650</td>
<td>&gt;15800</td>
</tr>
<tr>
<td>CIW wood (St Fulgent)</td>
<td>20.3</td>
<td>183</td>
<td>14 015</td>
</tr>
<tr>
<td>Wood pellets (CSTB)</td>
<td>8.7</td>
<td>620</td>
<td>16876</td>
</tr>
<tr>
<td>Bulk miscanthus (St Fulgent)</td>
<td>15.9</td>
<td>123</td>
<td>14 683</td>
</tr>
<tr>
<td>Bulk miscanthus (CSTB)</td>
<td>16.2</td>
<td>130</td>
<td>14848</td>
</tr>
</tbody>
</table>

ADVANTAGES OF BULK MISCANTHUS
› Low nitrogen and sulphur content
› Quite low ash content
› Dry from harvest (about 15% humidity)

DISADVANTAGES OF BULK MISCANTHUS
› Variable chlorine content
› Low ash-melting temperature, risk of forming clinker
› Very voluminous (twice the volume of wood chips)

Results of combustion tests:

CONDUCT OF THE TRIALS
› Good results in terms of atmospheric emissions
› Simple use of the fuel but emissions sometimes high in HCl [corrosion and pollution risks]
› Formation of clinker

RECOMMENDATIONS FOR USE
› Can be used in appropriate boilers with augers [moveable grills, ceramic ducts].
› Beware of clinker: check the ash box several hours after the boiler is started for the first time.
› Beware of carbon deposits: monitor them and carry out regular servicing.
› Avoid chlorinated inputs on the land and remain very vigilant about corrosion [ceramic ducts and good boiler adjustment recommended].

<table>
<thead>
<tr>
<th>NF EN 303-5 (1999) Class 3</th>
<th>Thresholds in mg/Nm³ at 10% O₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>P boiler</td>
<td>CO</td>
</tr>
<tr>
<td>0-50 kW</td>
<td>3000</td>
</tr>
<tr>
<td>50-150 kW</td>
<td>2500</td>
</tr>
<tr>
<td>150-300 kW</td>
<td>1200</td>
</tr>
</tbody>
</table>

Decree dated 23/07/1997 | Thresholds in mg/Nm³ at 17% O₂ |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>P boiler</td>
<td>NO, (in NO₂)</td>
</tr>
<tr>
<td>2 at 20 kW</td>
<td>500</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TA Luft*</th>
<th>Thresholds in mg/Nm³ at 17% O₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>P boiler</td>
<td>HCl</td>
</tr>
<tr>
<td>&gt; 100 kW</td>
<td>30</td>
</tr>
</tbody>
</table>

* TA Luft (German Technical Instructions on Air Quality Control)
Results of combustion trials: The mixed 20% rape straw – 80% wood pellet

The fuel in pictures

**Fuel composition**

<table>
<thead>
<tr>
<th>Moisture content (%)</th>
<th>Bulk density (kg/m³)</th>
<th>Net Calorific Value (kJ/kg)</th>
<th>Results expressed for dry product</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nitrogen (%)</td>
</tr>
<tr>
<td>NF Agrogranulés (QHP) mark</td>
<td>&lt;11</td>
<td>&gt;650</td>
<td>&gt;15 800</td>
</tr>
<tr>
<td>Wood pellets</td>
<td>8.7</td>
<td>620</td>
<td>14876</td>
</tr>
<tr>
<td>Rape/wood mixed pellets</td>
<td>6.6</td>
<td>710</td>
<td>17 200</td>
</tr>
</tbody>
</table>

**ADVANTAGES OF MIXED PELLETS**
- Significant density
- High NCV (due to low humidity levels)
- Homogeneous fuel moving easily in the feed augers

**DISADVANTAGES OF MIXED PELLETS**
- High chlorine and sulphur levels
- Too high a compaction rate

**Results of combustion tests:**

- **CONDUCT OF THE TRIALS**
  - Good results in terms of atmospheric emissions (higher than wood but lower than the references)
  - Quite high dust emissions
  - Quite high NOx emissions, even though < 550 mg/Nm³
  - Significant carbon deposit problem causing the boiler to be stopped during the trials (in the laboratory and in real conditions).

- **RECOMMENDATIONS FOR USE**
  - Not recommended in low power boilers
  - Possible to use this fuel in high power boilers with a smoke processing system, particularly for particles and even NOx.
Results of combustion trials: hemp pellets

The fuel in pictures

Fuel composition

<table>
<thead>
<tr>
<th>NF Agrogranules (QHP) mark</th>
<th>Moisture content (%)</th>
<th>Bulk density (kg/m³)</th>
<th>Net Calorific Value (kJ/kg)</th>
<th>Results expressed for dry product</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 11</td>
<td>&gt; 650</td>
<td>&gt; 15 800</td>
<td>Nitrogen (%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total sulphur (mg/kg)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total chlorine (mg/kg)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ash at 550°C (%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ash melting point (°C)</td>
</tr>
<tr>
<td>Wood chips*</td>
<td>20.4</td>
<td>247</td>
<td>14 305</td>
<td>&lt; 1.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt; 2 000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt; 5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt; 1 000</td>
</tr>
<tr>
<td>Wood pellets</td>
<td>8.7</td>
<td>620</td>
<td>16 876</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>650</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>260</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1182</td>
</tr>
<tr>
<td>Hemp pellets</td>
<td>9.5</td>
<td>545</td>
<td>15 617</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>870</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>150</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1182</td>
</tr>
</tbody>
</table>

*The physical characteristics of wood chips cannot be compared with the agripellets reference.

ADVANTAGES OF HEMP PELLETS

› Dry fuel
› Chlorine content comparable with that of wood
› Homogeneous fuel
› High ash-melting temperature.

DISADVANTAGES OF HEMP PELLETS

› NCV and density low for pellets (possibility of improving compaction)
› Higher ash content than for wood
› Higher sulphur content.

Results of combustion tests:

CONDUCT OF THE TRIALS

› Very good results in terms of emissions of unburnt residues and HCl (comparable to those of wood)
› Higher results for SO₂ and NOₓ than for wood, but lower than references
› Fuel is easy to use
› Slight clinker formation when fuel was changed.

RECOMMENDATIONS FOR USE

› Can be used in low power multi-fuel boilers with augers
› Adjust the boiler correctly.
Products from land maintenance: reeds and heath (used in a mixture with wood)

The fuel in pictures

Fuel composition

```
<table>
<thead>
<tr>
<th></th>
<th>Moisture content (%)</th>
<th>Bulk density (kg/m³)</th>
<th>Net Calorific Value (kJ/kg)</th>
<th>Results expressed for dry product</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Nitrogen (%)</td>
</tr>
<tr>
<td>NF Agrogranulés (QHP) mark</td>
<td>&lt; 11</td>
<td>&gt; 650</td>
<td>&gt; 15800</td>
<td>&lt; 1.5</td>
</tr>
<tr>
<td>Wood chips*</td>
<td>23.7</td>
<td>213</td>
<td>13 285</td>
<td>0.6</td>
</tr>
<tr>
<td>Wood pellets</td>
<td>8.7</td>
<td>620</td>
<td>16876</td>
<td>&lt; 0.3</td>
</tr>
<tr>
<td>40% reed mixture</td>
<td>17.3</td>
<td>154</td>
<td>14 621</td>
<td>0.9</td>
</tr>
<tr>
<td>25% heath mixture</td>
<td>22.9</td>
<td>160</td>
<td>13 747</td>
<td>0.8</td>
</tr>
</tbody>
</table>
```

ADVANTAGES

› Reed mixture: Advantageous NCV (dry product)
› Heath mixture: limited nitrogen, sulphur and chlorine contents

DISADVANTAGES

› Bulkiest fuels than wood chips and with a more irregular particle size distribution.
› Reed mixture: high ash, chlorine and sulphur levels. Lower the proportion of reeds in the mixture to reduce the chlorine and ash content and adhere to the recommended thresholds.
› Heath mixture: fuel feed difficulties in an auger system.

Results of combustion tests on reeds:

CONDUCT OF THE TRIALS

› Results for atmospheric emissions adhering to the emission thresholds applicable to low power boilers
› Quite high NOₓ and dust emissions for one of the trials
› Difficult to use the fuel in an auger feed system.

RECOMMENDATIONS FOR USE

› Can be used in boilers fitted with a belt feed system and smoke treatment system (dust)
› Analyse the reeds or the heath to adapt their rate of incorporation into the chips
› Carry out optimised adjustment and regular servicing.
TRIALS AT THE CSTB
(FRENCH BUILDING SCIENTIFIC AND TECHNICAL CENTRE)
Tests performed on 14 agrofuels compared with wood
2 trial runs

THE COMBUSTION COMMITTEE
Included ADEME, CETIAT, Coopédom, LERMAB and ARVALIS

THE 10 PILOT SITES WHICH TOOK PART IN THE TRIALS

Besné (44) :
Reed pellets,
20% rape straw,
40% miscanthus

Coopédom (35) :
Wood-miscanthus mixtures

Forges (49) :
Vine stocks and shoots

Plouaret (22) :
Miscanthus pellets

Pouzauges (85) :
Wood-miscanthus mixture

Retiers (35) :
Miscanthus and hemp pellets

Rostrenen (22) :
Wood-heath mixture

Saint Fulgent (85) :
Miscanthus

Talensac (35) :
Switchgrass pellets

Thorigné d’Anjou (49) :
Wheat straw pellets

The partners of the Green Pellets project:
Contact Aile
Tel. +33 (0)2.99.54.63.23
www.aile.asso.fr

The financial partners: