Advanced Torrefaction Technology

A customized option for sustainable energy production and a more profitable alternative for bioenergy end-users

Bioendev

The energy carrier of the future
What is torrefaction?

• An advanced technology which provides a sustainable, green renewable energy source utilizing biomass and reducing carbon emissions.

• A thermochemical process in which various types of biomass is heated to 250-350°C in a low-oxygen environment.

• This changes the elements of the biomass, resulting in a refined product with new characteristics:
  » Increased energy density of pellets > Significant cost savings during transport and handling
  » Hydrophobicity > Open transportation and storage
  » Decreased biological degradation > Enables longer storage time
  » Brittleness > Easier to grind to fine powder resulting in high powder energy density
  » Spherical particles > Improved feeding characteristics in powder feeding systems
  » Increased energy density of powder > Up to 50% higher thermal input power compared to traditional powder from pellets (depending on boiler and equipment)

• In comparison with other renewable alternatives like wind and solar energy, torrefied biomass does not suffer from the problem of irregular availability. Torrefied biomass enables renewable energy no matter environmental effects and through the whole year of energy demand.

• Torrefied biomass can further be used for co-firing with coal, in CHP plants and for industrial applications such as steel and cement production. Torrefied material is also better than non-pre-treated biomass for production of liquid biofuels in gasification processes.

The torrefaction process

<table>
<thead>
<tr>
<th>Biomass</th>
<th>Torrefaction</th>
<th>Densification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptance of various feedstock’s which are processed and pre dried to about 10% moisture content before entering the torrefaction.</td>
<td>Proven technology carried out under controlled atmospheric conditions and in the absence of oxygen. The final product remaining is a solid, dry, blackened material.</td>
<td>Torrefied materials can be transported economically due to their high energy density. Compaction through briquetting or pelletizing is suitable for long hauls via open rail car and ocean vessel.</td>
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</tbody>
</table>
Biomass feedstock

The biomass feedstock opportunity is large – Bioendev’s torrefaction technology enables processing various kinds of biomasses:

- Woody biomass
- Forrest residuals
- Saw mill residuals (e.g. saw, dust, chips, bark)
- Straw, grass
- Peat
- Others (Nut shells, olive stones, husks etc.)

Torrefaction advantages and value

<table>
<thead>
<tr>
<th></th>
<th>White pellet</th>
<th>Black pellet</th>
<th>Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat value (MJ/kg)</td>
<td>17 - 18</td>
<td>20 - 24</td>
<td>23 - 28</td>
</tr>
<tr>
<td>Bulk density (kg/m³)</td>
<td>620 - 670</td>
<td>650 - 850</td>
<td>800 - 850</td>
</tr>
<tr>
<td>Energy density (GJ/m³)</td>
<td>10,5 - 12</td>
<td>15 - 18,7</td>
<td>18,4 - 23,8</td>
</tr>
<tr>
<td>Moisture content (%)</td>
<td>7 - 10</td>
<td>1 - 5</td>
<td>10 - 50</td>
</tr>
</tbody>
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The torrefied material improves many material aspects in relation to conventional white pellet, such as increased hydrophobicity which results in possible onsite storage advantage, shipping in open trucks or boats, higher density which results in lower transportation costs and more. It is also a possible replacement for coal in existing coal plants because of its related characteristics.

White pellet

- Bulky volumes
- Moist
- Difficult to grind
- Difficult to feed
- Low energy density
- Inhomogenous
- Risk for bio contamination

Torrefied biomass

- Higher density
- Dry and hydrophobic
- Tenous and grindable
- Spherical particles
- Higher energy density
- Homogenous
- No bio contamination

Comments

» 15% higher density
» Enables outdoor storage
» 70-90% less electricity needed
» Feedable in coal plants
» 40% higher energy density
» Terminal storage possible
» Longer storage times

The biomass can be adjusted depending on the degree of torrefaction
Bioendev was founded in 2007 and has since then developed an unique torrefaction technology. A long-lasting research around torrefaction and gasification at Umeå University in Sweden has resulted in a strong patent portfolio consisting of seven active patents internationally, focusing on process control. Over the years, Bioendev has kept developing an energy-cost-efficient and reliable torrefaction technology for maximum yield and product quality. Bioendev did during 2016 commission the largest torrefaction facility in Scandinavia, out Industrial Demonstration Unit (IDU), with a capacity of 16 000 tons/year in order to prove our torrefaction technology in commercial scale. The produced black pellets is now available for large industry production tests in Scandinavia and internationally and we have now reached a position where the technic is commercially viable for large industry production.

Our strategic purpose is to deliver the market’s most cost-effective torrefaction facilities together with EPC-partners either through Greenfield projects or Retrofits of existing white pellets facilities. The organization especially consists of a creative team of Energy engineers, Doctors and scientists in Energy technology which have been part of the development of the torrefaction technology since the start.

<table>
<thead>
<tr>
<th>Lab</th>
<th>Pilot 1.0</th>
<th>Pilot 2.0</th>
<th>IDU</th>
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</thead>
<tbody>
<tr>
<td>1 kg/h</td>
<td>20 kg/h</td>
<td>150 kg/h</td>
<td>2 ton/h</td>
</tr>
<tr>
<td>2005</td>
<td>2008</td>
<td>2013</td>
<td>2015</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20 ton/h</td>
</tr>
</tbody>
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Commercial torrefaction plant
Bioendev torrefaction solutions

The unique torrefaction process (i.e. the “heart”) has the following key advantages:

- Easily adapted to existing processes for retrofit depending on configuration
  - Configuration 1 – Full Integration Retrofit (FIR) need:
    - Dried biomass to <10% moisture content (the lower the better)
    - Access of new gas burner to existing combustion chamber for combustion of the residual torrefaction gas mixture
    - Access to existing mill and compaction unit
  - Configuration 2 – Semi Integration Retrofit (SIR) need:
    - Dried biomass to <10% moisture content (the lower the better)
    - Access to heat sink for new boiler
    - Access to existing mill and compaction unit

- Robust and reliable directly heated transport screw torrefaction reactor

- Compact, direct and/or indirectly cooled product cooling and moisturizing screw

- Air tight design trough plug screws at biomass in- and outlet

- Very good process control which facilitates a homogeneous product with high product yield trough:
  - Control of residence time
    - Transport screw reactor
  - Control of torrefaction temperature
    - IR-thermometer at biomass outlet
  - Control of thermal runoff
    - Process cooling
  - Quenching of torrefaction reaction
    - Rapid and controlled product cooling

- High process efficiency with minimum heat losses

- High mass yields (i.e. low gas yields) without consumption of auxiliary fuel during steady-state torrefaction (except for startup) through ceramic lined combustion chamber in combination with extreme combustion air pre-heating

- Low wear due to few moving parts in contact with the torrefaction gas (2-3 slowly rotating screw shafts)

- No circulation fans in contact with difficult environments

- Minimized tar problems in pipes and ducts subjected to torrefaction gas, through electrical heat tracing

- Minimum amount of process residues (no continuous flow)

- Patented process

- Functional safety according to:
  - 94/9/EC: Equipment for potentially explosive atmospheres (ATEX)
  - SS-EN 746-2:2010: Industrial thermo-processing equipment – Part 2: Safety requirements for combustion and fuel handling systems
What we offer

Bioendev are experts in the processing of biomass through torrefaction. We offer:

- Retrofits of existing white pellet plants together with EPC partners
- Turnkey torrefaction plants for commercial production
- Industrial demonstrations of cost efficient torrefaction techniques at our Industrial Demonstration Unit
- Large test batches of Black Pellets from our Industrial Demonstration Unit
- A Pilot plant in operation for R&D projects in torrefaction and gasification

Bioendev are now looking for:

- Retrofit projects of white pellet industrial production units
- Commercial Green field projects
- Customers of Black Pellets
- Project partners and financial partners
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