Economic torrefied pellets from herbaceous biomass.

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01
CENER OVERVIEW
RESEARCH AREAS

- Wind Energy
- Photovoltaic Solar Energy
- Solar Thermal Energy
- Biomass
- Energy in Buildings
- Grid Integration of Renewable Energy
CENER MAIN FIGURES

100 M€
2002-2013 Infrastructure Investments

> 500
Customers around the World / 5 Continents

19 M€
2015 Annual Budget

200
Staff Employed

11 M€
2015 Annual Budget

1000
Customers around the World / 5 Continents
SERVICES

- Development of Technology through R&D Projects
- Testing Components Services & Support for Certification
- Training & Capacity Building
- Technical Assistance & Feasability Studies
- Services & Support for Certification
- Renewable Energies Know How
- Development of Technology through R&D Projects
BIOMASS DEPARTMENT MAIN BUSINESS LINES
SUPPORTING THE WHOLE INDUSTRY CHAIN AND INSTITUTIONS

L1 – SOLID BIOFUELS

- Torrefaction Processes Development
- Pelletizing Processes Development
- Gasification Processes Development
- Solid Biofuels Characterization

L2 – BIOPROCESSES

- Development, upscaling and validation of biochemical processes
- Development of new processes for the production of bio-based products and biofuels

L3 – SUSTAINABILITY

- Ad-hoc sustainability services
L1 – SOLID BIOFUELS
MAIN RESEARCH ACTIVITIES

1. Additives development for biomass pelletization
2. Pellets development from not conventional feedstock
3. Biomass torrefaction process development and validation
4. Biomass gasification processes development and validation

Pre-commercial scale demonstration facilities TRL6-7
CAPACITIES AND EXPERIENCE IN TORREFACTION
MAIN MILESTONES

- **2006-2007**: Feasibility study biomass torrefaction for cofiring applications
- **2007-2008**: Evaluation and selection of technologies. Laboratory and bench scale testing.
- **2010**: Modification in the pilot plant. Transfer of the pilot plant from Noain to BIO2C in Aoiz.
- **2011**: Beech woodchips torrefaction. First pelletization tests.
- **2012-2015**: SECTOR FP7 EU project ([www.sector.eu](http://www.sector.eu)): CENER is leading partner of herbaceous biomass torrefaction activities.
- **2012**: Torrefaction and pelletization of beech and pine. Torrefaction reactor model development 1.0.
- **2014-2015**: Torrefaction and pelletization of eucalyptus, paulownia, olive tree pruning and cereal straw pellets. Torrefaction reactor model development 2.0.
- **2015-2018**: Optimization and improvement of torrefied biomass pelletization.
- **2018-2022**: CLARA H2020 EU project Development of new technology to upgrade herbaceous biomass into high quality pellets:
TORREFACTION PILOT PLANT

- **Torrefaction pilot plant** with a production capacity of **150 - 350 kg/h** based on a internally rotating shaft indirectly heated reactor using thermal oil (250-300°C):
  - Very flexible regarding raw material particle size distribution (0,25-40 mm) and bulk density (50-500 kg/m³) including **herbageous biomass** like straw.
  - Excellent mixing and agitation minimizing internal temperature gradients, **easy temperature control**, being able to cope with feedstock with exothermal heat of reaction, producing a extremely homogeneous product.

- **Raw materials tested**:
  - Beech woodchip
  - Pine woodchips
  - Loose chopped straw
  - Poplar woodchips
  - Eucalyptus woodchips
  - Paulownia woodchips
  - Olive tree pruning woodchips
  - Cereal straw pellets
  - Compost
  - Forest residue woodchips
PELLETIZATION PILOT PLANT

- **Pelletizing pilot plant** with a production capacity of 200-400 kg/h:
  - Hammer mill: screen size 2-12 mm
  - Mixer with 1 m³: moisture content adjustment and additive feeding
  - Mill press of **30 kW**:
    - Ad Hoc die designs: pellets diameter, compression ratio, number of holes, etc...
### TORREFIED BIOMASS PELLETIZATION

**EXAMPLE OF TORREFIED BIOMASS PELLETS PROPERTIES**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Beech</th>
<th>Pine</th>
<th>Straw</th>
<th>Poplar</th>
<th>Eucalyptus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torrefaction degree</td>
<td>% dry basis</td>
<td>13-22</td>
<td>14-23</td>
<td>13-22</td>
<td>14-23</td>
</tr>
<tr>
<td><strong>Bulk density</strong></td>
<td>kg/m³ (ar)</td>
<td>620-710</td>
<td>660-680</td>
<td>620-710</td>
<td>660-680</td>
</tr>
<tr>
<td>Durability</td>
<td>%</td>
<td>92.6-98.2</td>
<td>96.4-97.1</td>
<td>92.6-98.2</td>
<td>96.4-97.1</td>
</tr>
<tr>
<td>fines</td>
<td>%</td>
<td>0.05-0.6</td>
<td>0.06-0.09</td>
<td>0.05-0.6</td>
<td>0.06-0.09</td>
</tr>
<tr>
<td>Moisture</td>
<td>% (ar)</td>
<td>5.1-8.3</td>
<td>7.0-7.7</td>
<td>5.1-8.3</td>
<td>7.0-7.7</td>
</tr>
<tr>
<td>C</td>
<td>% (daf)</td>
<td>50.5-51.5</td>
<td>53.3-55.5</td>
<td>50.5-51.5</td>
<td>53.3-55.5</td>
</tr>
<tr>
<td>H</td>
<td>% (daf)</td>
<td>~6.2</td>
<td>6.0-6.1</td>
<td>~6.2</td>
<td>6.0-6.1</td>
</tr>
<tr>
<td>N</td>
<td>% (daf)</td>
<td>0.58-0.77</td>
<td>0.12-0.16</td>
<td>0.58-0.77</td>
<td>0.12-0.16</td>
</tr>
<tr>
<td>Ash</td>
<td>% (db)</td>
<td>4.8-6.0</td>
<td>1.6</td>
<td>4.8-6.0</td>
<td>1.6</td>
</tr>
<tr>
<td>Volatile</td>
<td>% (db)</td>
<td>73.6-74.8</td>
<td>73.1-77.0</td>
<td>73.6-74.8</td>
<td>73.1-77.0</td>
</tr>
</tbody>
</table>
ECONOMIC TORREFIED PELLETS FROM HERBACEOUS BIOMASS
WHY IS HERBACEOUS BIOMASS INTERESTING?

✓ Herbaceous biomass has a very **high potential** world wide similar to wood
✓ Low **moisture content**
✓ **High reactivity** in torrefaction process
✓ **Lower price** than wood

✓ On the other hand herbaceous biomass is a **challenging fuel** for torrefaction and combustion:
  ✓ Very low bulk density
  ✓ Poor flowability
  ✓ Exothermal heat of reaction
  ✓ Potential self-heating behaviour
  ✓ Challenging pelletization behaviour
  ✓ Challenging ash melting behaviour
CENER TORREFACCTION PROCESS CONCEPT

<table>
<thead>
<tr>
<th>WET BIOMASS</th>
<th>DRY BIOMASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indirectly heated reactor using thermal fluid at temperatures between 240 and 300°C</td>
<td>No drying is required</td>
</tr>
<tr>
<td>The combustible vapors are burned to heat up the thermal fluid.</td>
<td></td>
</tr>
<tr>
<td>Previous biomass drying down to 5-15% moisture content</td>
<td>Flue gases from the boiler are used air preheater.</td>
</tr>
<tr>
<td>Flue gases from the boiler are used in the drier.</td>
<td></td>
</tr>
<tr>
<td>Additional fuel could be necessary, mainly for drying, depending on biomass moisture content and target torrefaction degree</td>
<td>No additional fuel is necessary</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Particle size reduction below 8-40 mm depending on the feedstock</td>
<td></td>
</tr>
</tbody>
</table>
In order to close the energy balance, required torrefaction degree and thermal efficiency depends on straw moisture content. Efficiency is higher than the case of wet woody biomass.
CHLORINE VOLATILIZATION

Torrefaction is a dechlorinating process for herbaceous biomass, releasing 10-50% of chlorine in the torrefaction gas.
## TORREFIED STRAW PELLETS QUALITY

Torrefied straw pellet characterization

<table>
<thead>
<tr>
<th>Analysis Description</th>
<th>Min</th>
<th>Max</th>
<th>Standard Method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Proximate Analysis</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total moisture (% a.r.b.)</td>
<td>7,1</td>
<td>8,6</td>
<td>UNE EN ISO 18134-2:2015</td>
</tr>
<tr>
<td>Ash (% d.b.) (1)</td>
<td>4,4</td>
<td>8,0</td>
<td>UNE EN ISO18122:2016.</td>
</tr>
<tr>
<td>Volatile matter (% db.)</td>
<td>66,5</td>
<td>74,8</td>
<td>UNE EN ISO 18123:2016</td>
</tr>
<tr>
<td>CV Net MJ/kg db</td>
<td>18,5</td>
<td>20,4</td>
<td>UNE-EN-14918:2011</td>
</tr>
<tr>
<td><strong>Ultimate Analysis (1)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chlorine (% d.b.)</td>
<td>0,057</td>
<td>0,20</td>
<td>UNE-EN- ISO 16994:2015</td>
</tr>
<tr>
<td>Sulphur (% d.b.)</td>
<td>0,038</td>
<td>0,085</td>
<td>UNE-EN- ISO 16994:2015</td>
</tr>
<tr>
<td>Nitrogen (% d.a.f.)</td>
<td>0,52</td>
<td>0,80</td>
<td>UNE-EN- ISO 16948:2015</td>
</tr>
<tr>
<td><strong>Physical Properties</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tamped Bulk Density (kg/m³)</td>
<td>700</td>
<td>730</td>
<td>UNE-EN ISO 17828:2016</td>
</tr>
<tr>
<td>Fines Content through 3.15mm round hold sieve (%)</td>
<td>0,02</td>
<td>0,16</td>
<td>UNE-EN ISO 17827-2:2016</td>
</tr>
<tr>
<td>Mechanical Durability</td>
<td>96,2</td>
<td>98,2</td>
<td>UNE-EN ISO 17831-1:2016</td>
</tr>
</tbody>
</table>

(1) Dependent on raw material composition
CENER’S APPROACH WITH HERBACEOUS BIOMASS

In order to solve challenges and reduce whole value chain production cost:

- **optimized raw material pre-treatment**
  - Facilitates raw material handling
  - Increases torrefaction reactor capacity
  - Improves pelletization behaviour

- Reduce production cost up to 20%
REACTOR THROUGHPUT OPTIMIZATION.

With optimized pretreatment, torrefaction production rate was increased by 55% at the same torrefaction temperature compared with base case.

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Torr. Temp. (°C)</th>
<th>Torr. Material photo</th>
<th>AWL (%)</th>
<th>Production (kg/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>260</td>
<td></td>
<td>16.0</td>
<td>217</td>
</tr>
<tr>
<td></td>
<td>260</td>
<td></td>
<td>14.8</td>
<td>336</td>
</tr>
</tbody>
</table>

Due to the much higher straw reactivity, the production rate was significantly higher than the production rate for all the woody biomass feedstock tested in the same pilot plant (for example 20% higher than pine using a lower temperature in the case of straw).
PRESS MILL PRODUCTIVITY

![Graph showing productivity of different materials](image-url)
OPTIMIZED PRODUCTION COST OF TORREFIED STRAW PELLETS

Levelized pellet cost
• 133 €/t
• 24 €/MWh

Framework conditions:
• Production capacity 80,000 tpy
• Biomass cost 12 €/MWh

• 20% production cost reduction (excluding raw material cost)
CONCLUSIONS
AND
NEXT STEPS
CONCLUSIONS

✓ Herbaceous biomass has a very high potential world wide similar to wood and low price in many areas

✓ Chlorine content is reduced in the torrefied product.

✓ High quality torrefied herbaceous biomass pellets can be produced

✓ Thermal efficiency of torrefaction process is significatively higher for dry biomass compared with wet wood.

✓ With optimized pretreatment, production rate was increased by 55% at the same torrefaction temperature. Achieved production rate is significantly higher than all the woody biomass tested in the same pilot plant

✓ In this way production cost could be reduced up to 20%

HERBACEOUS BIOMASS IS A CHALENGING FUEL BUT PROCESS COULD BE OPTIMIZED TO ACHIEVE HIGH PLANT THROUPUT AND PRODUCT QUALITY AT LOW COST
NEXT STEPS


✓ CENER leader of workpackage WP2 Development of a Concept for Pre-treatment of Straw

✓ Development of a herbaceous biomass pre-treatment technology to:
  ✓ reduce chlorine and other impurities (N, S, K,...) content,
  ✓ increase ash sintering temperature and
  ✓ Increase energy density,

✓ Supply of feedstock for gasification tests
✓ Production cost assessment
✓ Environmental assessment via life cycle analysis
MUCHAS GRACIAS.