Energias Renováveis (Biomassa)

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LAETA - Laboratório Associado de Energia, Transportes e Aeronáutica

Research units:
• IDMEC/IST
• INEGI/UP
• ADAI/UC
• AEROG/UBI

Thematic research lines:
• Energy
• Transports technology
• Aeronautics and space
• Advanced manufacturing
• Advanced materials
• Biomechanics
• Engineering design
• Engineering systems
• Forest fires

In 2013
• 253 PhD researchers
• 284 PhD students
• 25 projects (FP7)
• 1.1 MEuro/year
• 320 papers ISI/year
Current areas of research on biomass

- Co-combustion of coal with biomass, with emphasis on difficult biomass fuels
  (3 PhDs: Rita Silva, Pedro Ferreira, Miriam Rabaçal)

- Formation of fine particulate matter in biomass combustion
  (1 PhD: Ulisses Fernandes)

- Torrefaction of biomass (particle fragmentation)
  (1 PhD: Francisco Costa)

- Polygeneration district heating and cooling systems based on renewable resources, including RDF from MSW
  (1 PhD: Natalia Kabalina)

- Destruction of the tar present in syngas by combustion in porous media
  (1 Pos-Doc: Cláudia Casaca; 1 MSc: Tiago Brito)

- Biomass gasification and pyrolysis
  (1 Pos-Doc: Ana Filipa Ferreira; 1 PhD: Ricardo Gouveia; 1 MSc: Ana Ferreiro)

- Energy valorization of crude glycerin (combustion, co-combustion, steam reforming,...)
  (2 MScs: Pedro Queirós, Pedro Barata)
Experimental facilities and instrumentation
Slagging and fouling can reduce the heat transfer in heat exchangers.

Co-combustion: biomass fuels present high percentages of inorganic matter; high levels of alkali metals can produce sulphates and chlorides (KCl, NaCl, Na$_2$SO$_4$, K$_2$SO$_4$); ashes with low melting point; high levels of Cl (corrosion)
Co-combustion of coal with biomass (2)
Co-combustion of coal with biomass (3)

- Coal + sawdust co-firing
- High content of Si and Al
  $\text{SiO}_2$ e $\text{Al}_2\text{O}_3$ have high melting temperatures

- Coal + olive stones co-firing
- High content of K
  $\text{K}_2\text{O}$ and $\text{K}_2\text{SO}_4$ have low melting temperatures
- High content of S
  Formation of sulfates
Formation of fine particulate matter in biomass combustion (1)

Simplified illustration of the particulate formation mechanisms during fixed-bed combustion of a solid biomass

Coarse particles
- Residual fly ash

Fine particles
- Fly ash (Cl, S, K, Na, Zn), Soot

Mechanisms:
- Agglomeration
- Char burning
- Char release
- Nucleation
- Inorganic vapour
- Coagulation & condensation
- Coagulation & surface growth
- Oxidation
- Soot formation
- Devolatilisation: CO, CO₂, H₂, H₂O, CH₄, tar

Fuel bed: C, O, H, S, Cl, Si, Al, Ca, Fe, K, Mg, Mn, Na, P, Ti, Zn, ...
Formation of fine particulate matter in biomass combustion (2)
Formation of fine particulate matter in biomass combustion (3)
Torrefaction of biomass (1)
Torrefaction of biomass (2)

<table>
<thead>
<tr>
<th>Parâmetro</th>
<th>Casca de pinheiro</th>
<th>Bagaço de azeitona</th>
<th>Carvão</th>
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<tr>
<td></td>
<td>Original</td>
<td>Torrado</td>
<td>Original</td>
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<tr>
<td>Matéria volátil</td>
<td>58,9</td>
<td>69,4</td>
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<td>Carbono fixo</td>
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<td>Humidade</td>
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<td>Análise imediata (wt%, as received)</td>
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<tr>
<td>Carbono</td>
<td>47,8</td>
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<td>Hidrogénio</td>
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<tr>
<td>Oxigénio</td>
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<td>Análise elementar (wt%, da)</td>
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<tr>
<td>Poder calorífico superior (MJ/kg)</td>
<td>18,82</td>
<td>23,52</td>
<td>17,54</td>
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</tbody>
</table>
Polygeneration district heating and cooling systems based on renewable resources

- biomass
- fossil fuel*
- solar, geothermal energy
- *back-up fuel

Technology

Value-added product

Heat

Cooling

Electricity

Consumer

Distribution system

Consumer

Consumer

Consumer
Destruction of the tar present in syngas by combustion in porous media
Biomass pyrolysis
Energy valorization of crude glycerin

Co-combustion of crude glycerin

NG + H₂

NG + H₂ + glycerin
Energy valorization of crude glycerin

Steam gasification of crude glycerin in a packed bed reactor

Glycerin + water

Water out

Nitrogen

Water in

Packed bed

Electrical furnace

LHV (MJ/m³)

70 wt.%

0 1 2 3 4 5 6

W/G

900 °C
800 °C
700 °C

H₂
CO
CH₄
CO₂

Gas composition (mol%)

0 10 20 30 40 50 60 70 80 90 100

0 0.5 1 1.5 2 2.5 3

Flow rate (g/min)
Some challenges

- Co-combustion of coal with biomass, with emphasis on difficult biomass fuels
- Formation of fine particulate matter in biomass combustion
- Torrefaction of biomass (particle fragmentation)
- Gasification of RDF from MSW
- Integrated Energy Systems (biomass, solar, …)
International collaboration

- Imperial College London (Londres)
- Universidade Federal de Santa Catarina (Brasil)
- Universidade de Lund (Suécia)
- Universidade de Haifa (Israel)
- Universidade Zaragoza (Espanha)
- Universidade de Granada (Espanha)
- Universidade de Aachen (Alemanha)
- Universidade de Duisburg-Essen (Alemanha)
- Kungliga Tekniska Högskolan (Suécia)
Recent publications on biomass (ISI)