# First results of the SECTOR-project: Production of Solid Sustainable Energy Carriers from Biomass by Means of Torrefaction

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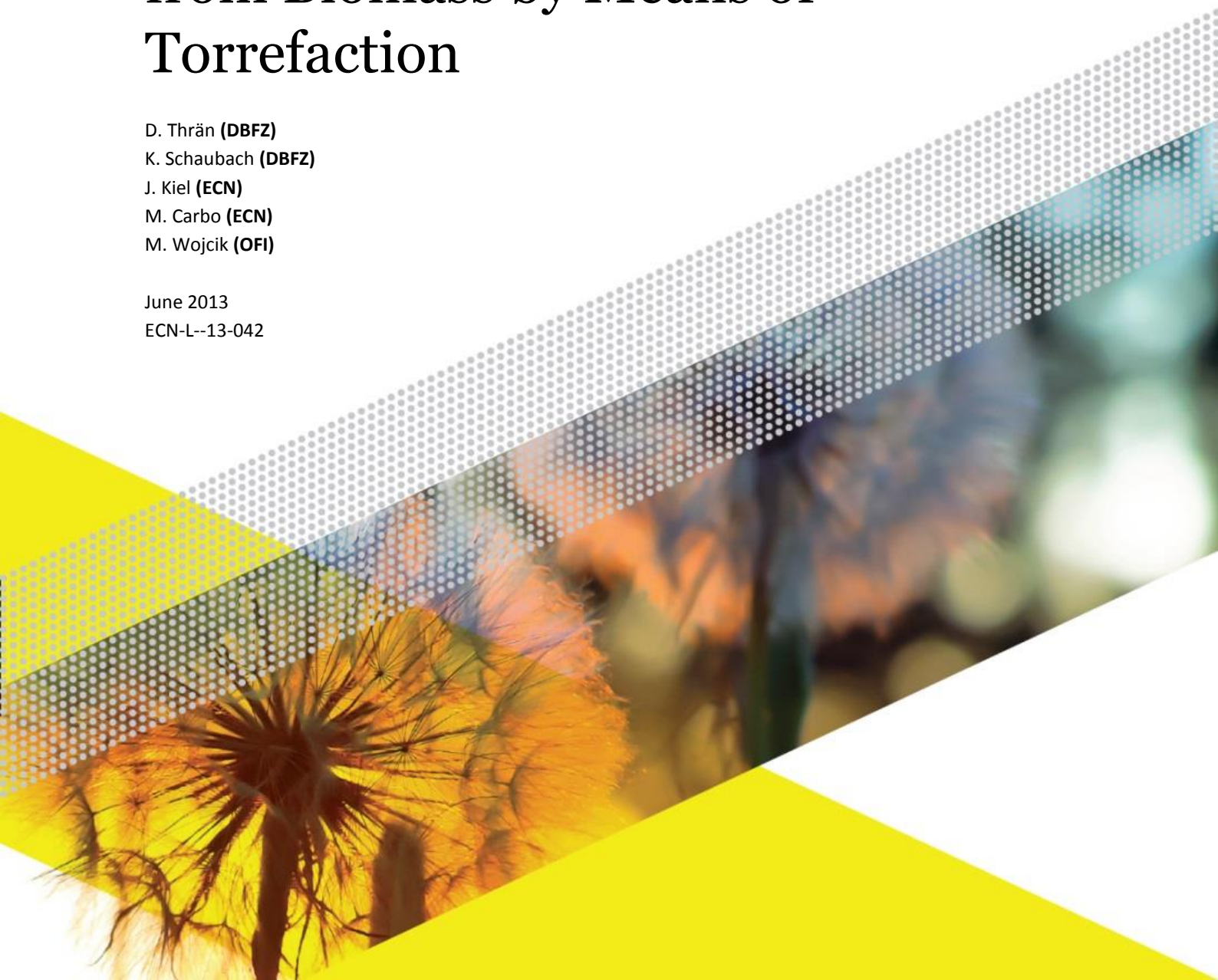

SECTOR

Production of Solid Sustainable Energy Carriers from Biomass by Means of TORrefaction

# First results of the SECTOR-project: Production of Solid Sustainable Energy Carriers from Biomass by Means of Torrefaction

A European R&D Project funded within the Seventh Framework Programme by the European Commission

**21st European Biomass Conference and Exhibition**
6th of June 2013

Daniela Thrän, Kay Schaubach, Jaap Kiel, Michiel Carbo, Magdalena Wojcik






The research leading to these results has received funding from the European Union Seventh Framework Programme FP7/2007-2013 under grant agreement n° 282826

# outline

- The SECTOR project
  - Consortium
  - Objectives
  - Structure
- First results
  - Market assessment of biomass feedstock
  - Torrefaction
  - Densification
  - Fuel specification and analysis
  - Value chains and sustainability
- Summary & Outlook

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# The SECTOR project

- Collaborative project: SECTOR
- Project start: 01.01.2012
- Duration: 42 months
- Total budget: 10 Mio. Euro
- Participants: 21 from 9 EU-countries
- Coordinator: DBFZ

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# a pan European consortium


Kick-off meeting at ECN
(14-15 February 2012)

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# SECTOR objectives

- **Support the market introduction** of torrefaction-based bioenergy carriers as a commodity renewable solid fuel
- **Further development of torrefaction**-based technologies (up to pilot-plant scale and beyond)
- **Development of specific production recipes**, validated through extensive lab-to-industrial-scale logistics and end-use performance testing
- Development and standardisation of dedicated **analysis and testing methods** for assessment of transport, storage, handling logistics and end-use performance
- Assessment of the role of torrefaction-based solid bioenergy carriers in the bioenergy **value chains** and their contribution to the development of the **bioenergy market in Europe**
- Full **sustainability assessment** of the major torrefaction-based biomass-to-end-use value chains
- **Dissemination** of project results to industry and into international forums (e.g. EIBI, EERA, CEN/ISO, IEA and sustainability round tables)

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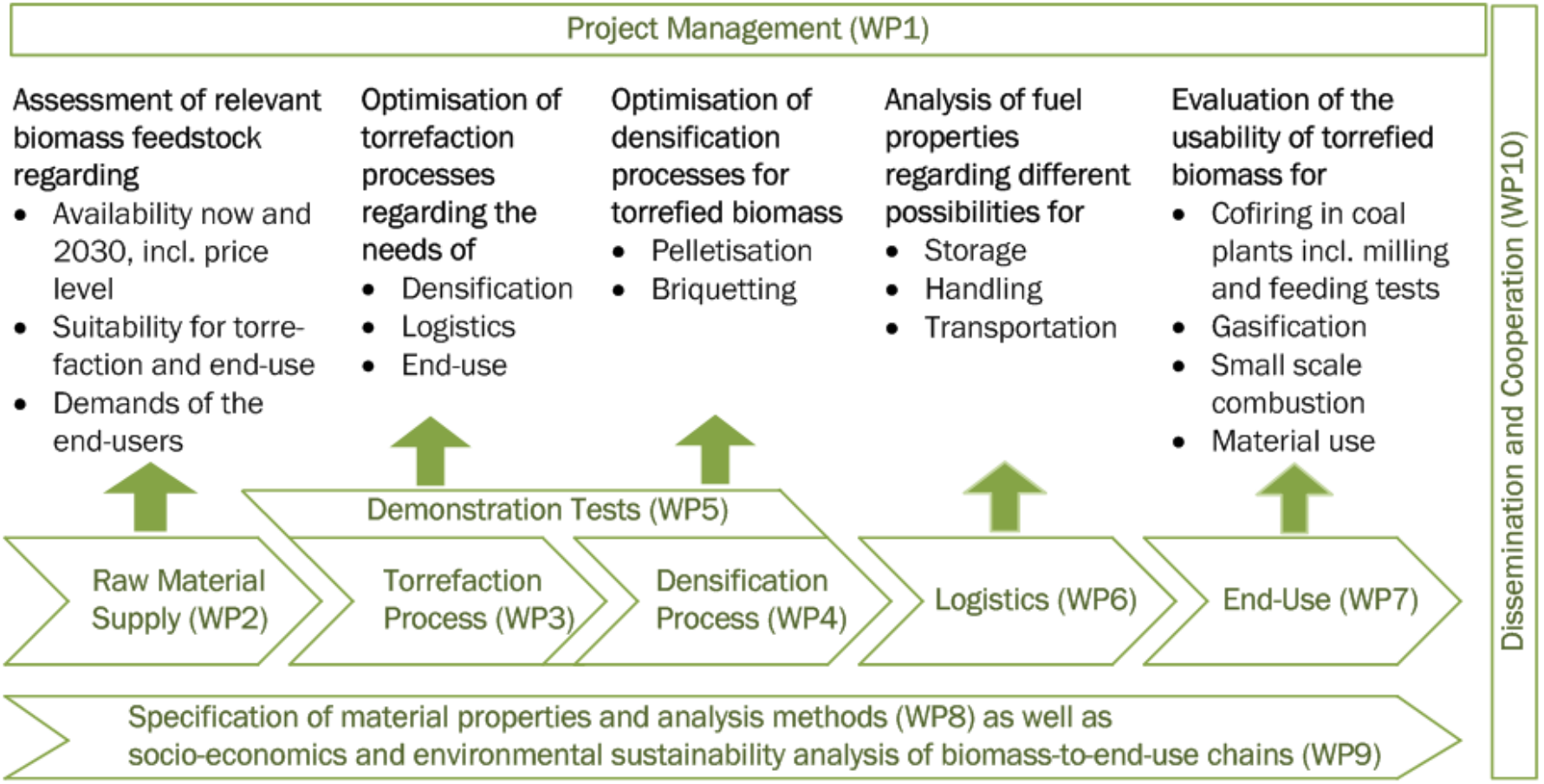
# project structure

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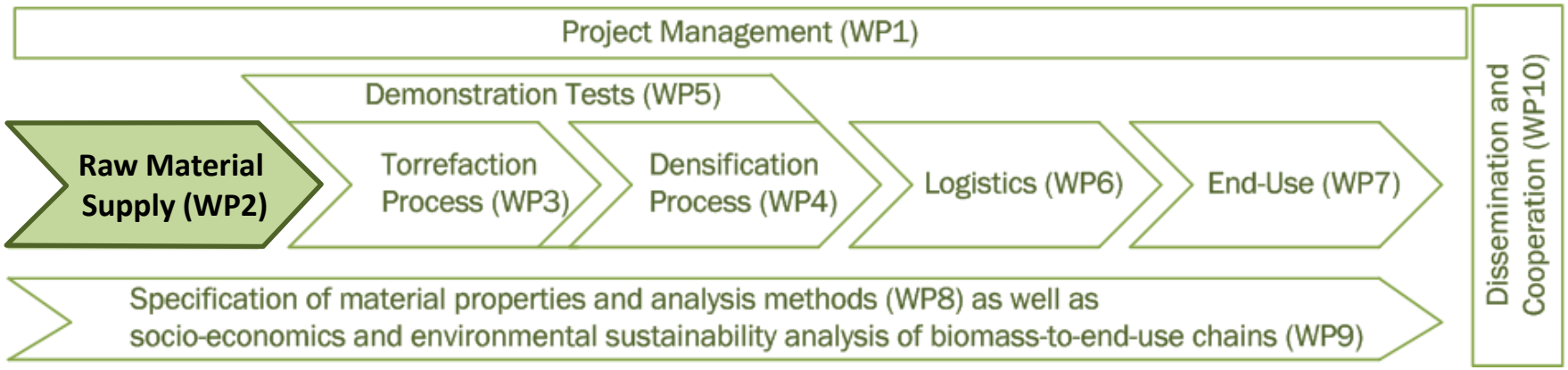


Production of Solid Sustainable Energy Carriers by Means of Torrefaction

# MARKET ASSESSMENT OF BIOMASS FEEDSTOCK (WP2)

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# Raw Material Supply (WP2) – Market Assessment of Biomass Feedstock

- Objective:
  - estimation of the supply potentials of different main feedstocks for torrefaction; independent of existing utilisation pathways
  - where are the largest and most interesting biomass potentials

- Methodology:
  - work was based on the existing studies of resources collected by project partners
  - potentials considered are techno-economical potentials
  - raw materials were divided into three sub-groups:
    - Wood based fuels
    - Agricultural residues
    - Energy crops

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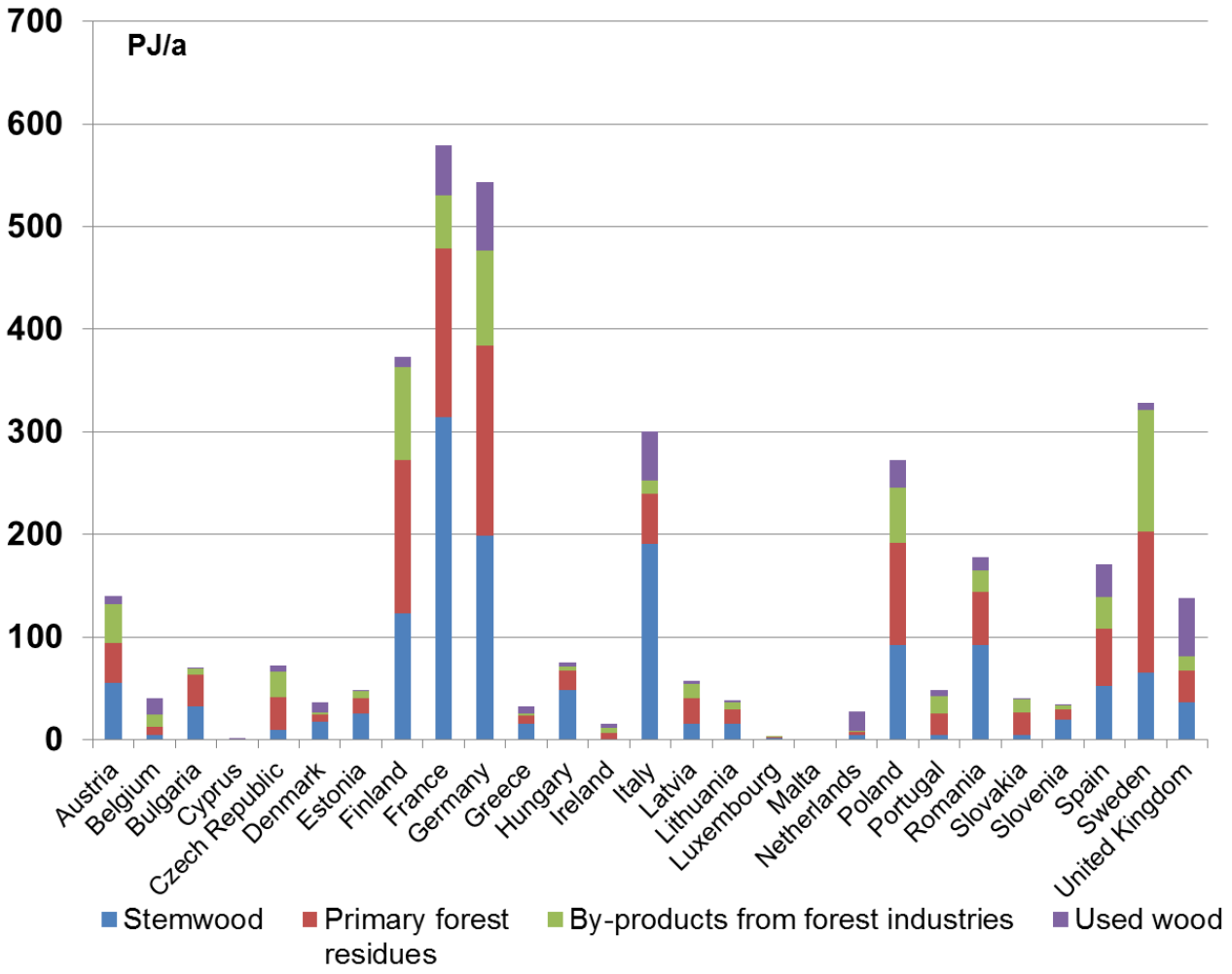
# Raw Material Supply (WP2) – Wood based fuels: energy potentials in EU-27

- The total wood energy potential is 3,700 PJ/a in EU-27.
- Largest forest energy potential: stem wood & forest residues
- Additionally promising raw materials:
  - straw
  - residues from palm oil production
  - bagasse

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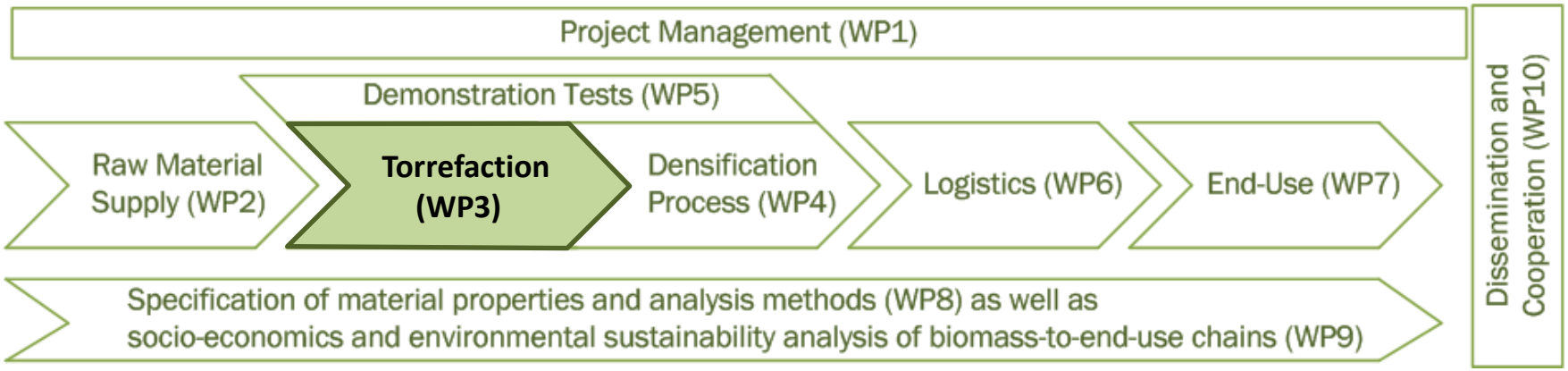


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# WP 3 – TORREFACTION

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# Torrefaction (WP3) - Mass yield comparison (ECN)

Objective:

- Compare mass-yields obtained during Thermo-Gravimetric Analysis (TGA), batch- and pilot-scale experiments for various feedstocks
- Use TGA and batch-scale experiments as predictive tool to determine extent of exothermic behaviour in pilot- and commercial-scale torrefaction plants
- Determine appropriate setpoints for torrefaction process, which allow adequate process control

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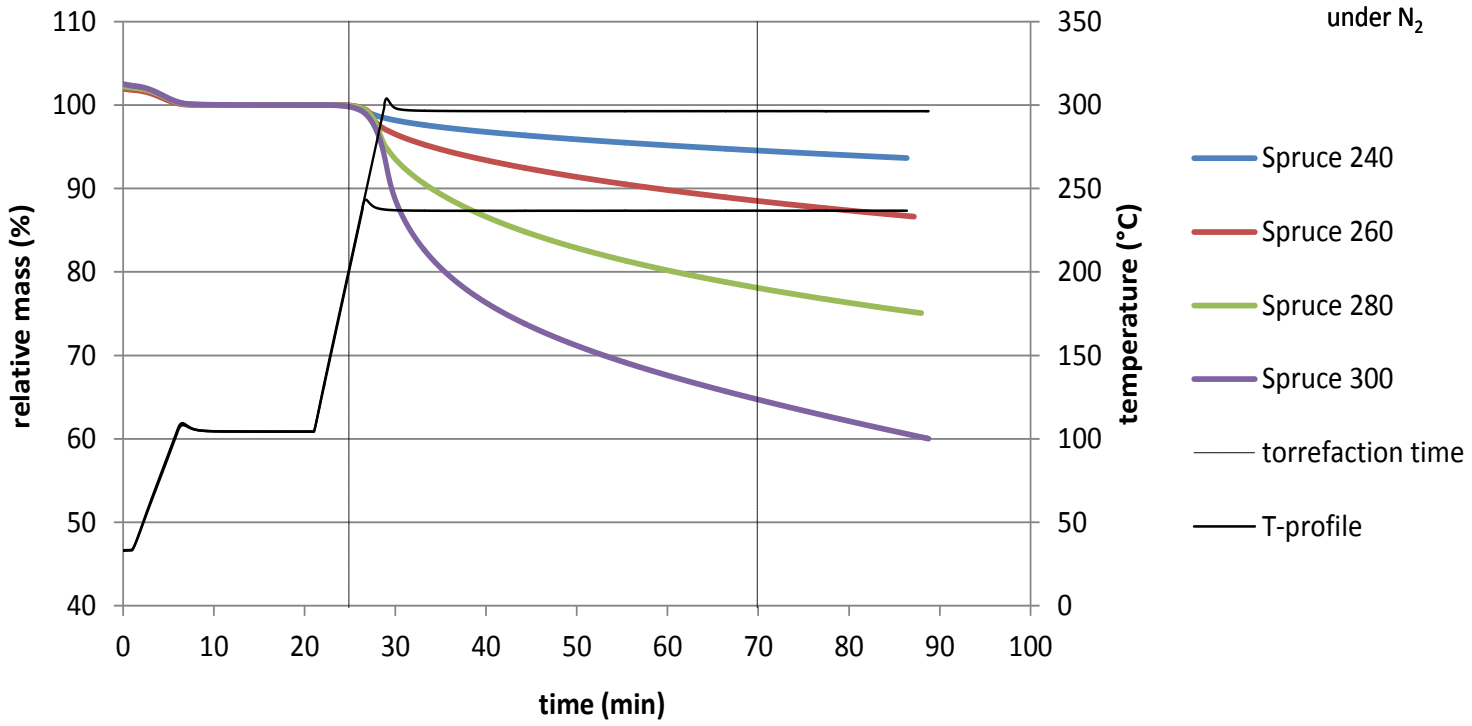
# Torrefaction (WP3) - Mass yield comparison (ECN)
# Thermogravimetric analysis (TGA)

- Example for Spruce
  - T-profiles shown are for the 240 and 300°C measurements
  - Torrefaction time is 45 min starting at 200°C

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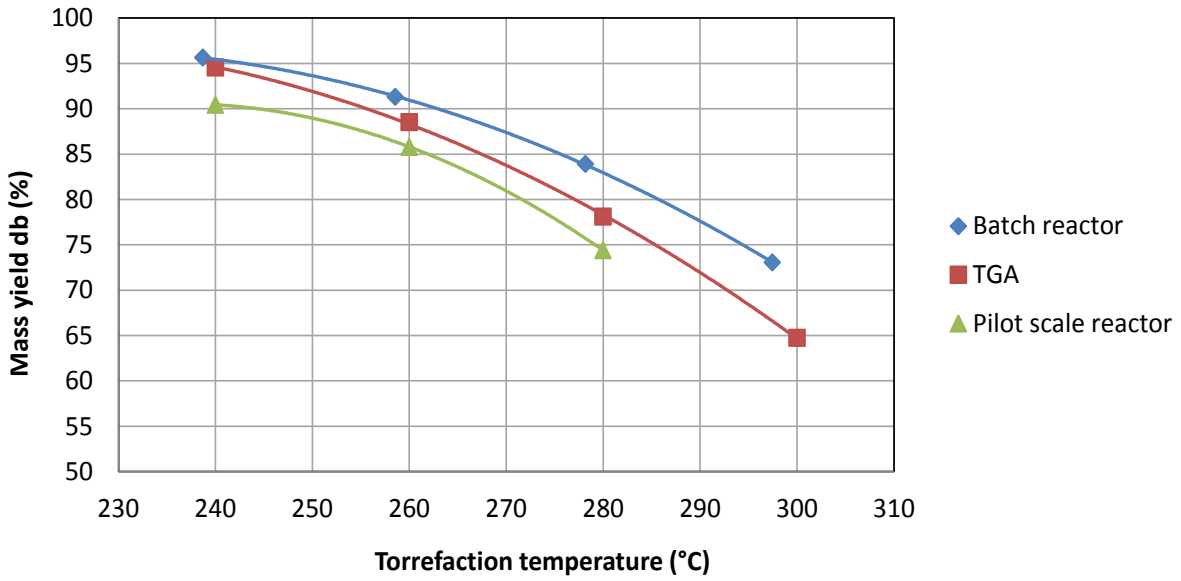
# Torrefaction (WP3) - Mass yield comparison (ECN)

- The mass yields were compared for:
  - TGA measurements (10-20 mg per batch)
  - Batch reactor torrefaction tests (3-5 kg per batch)
  - Pilot reactor torrefaction tests (50-100 kg per hour)

- Spruce

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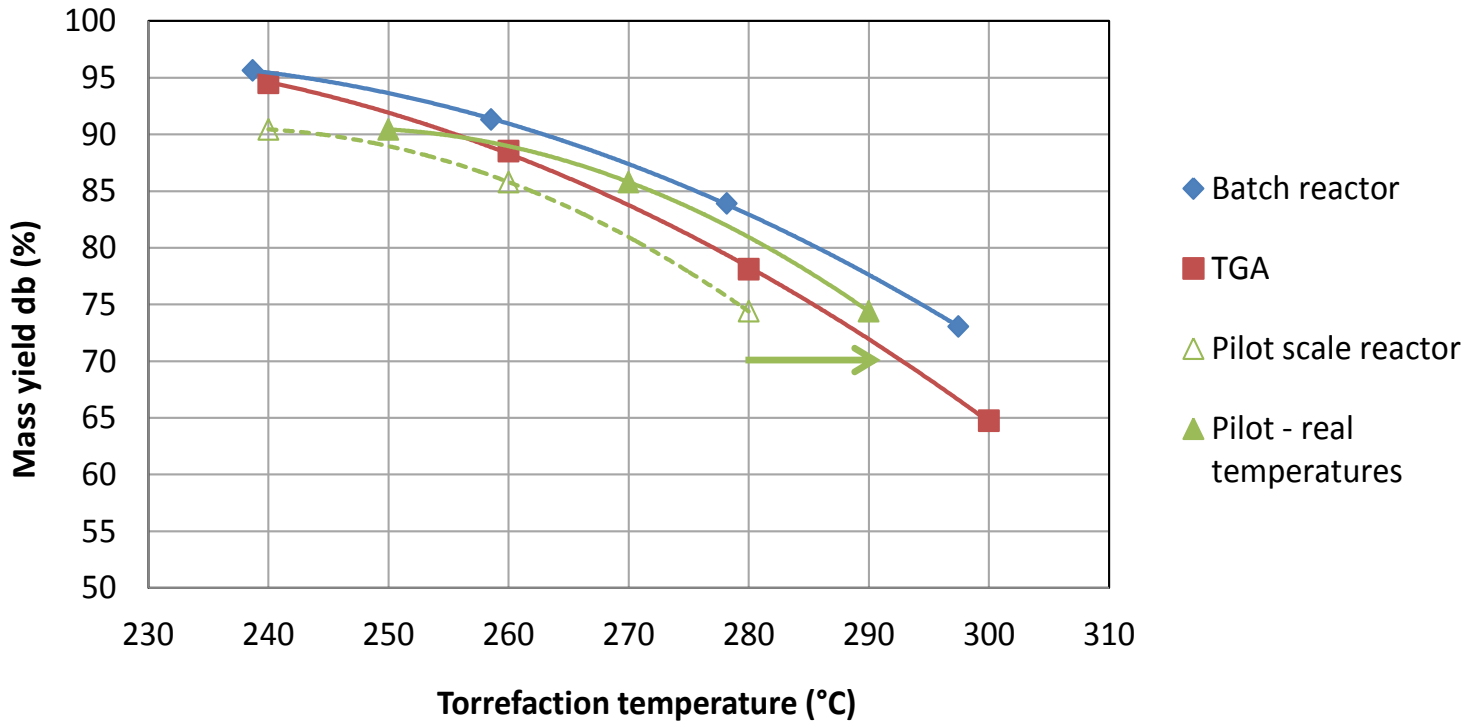
# Torrefaction (WP3) - Mass yield comparison (ECN)

- Pilot-scale temperatures may have been 10°C higher, due to exothermicity of spruce

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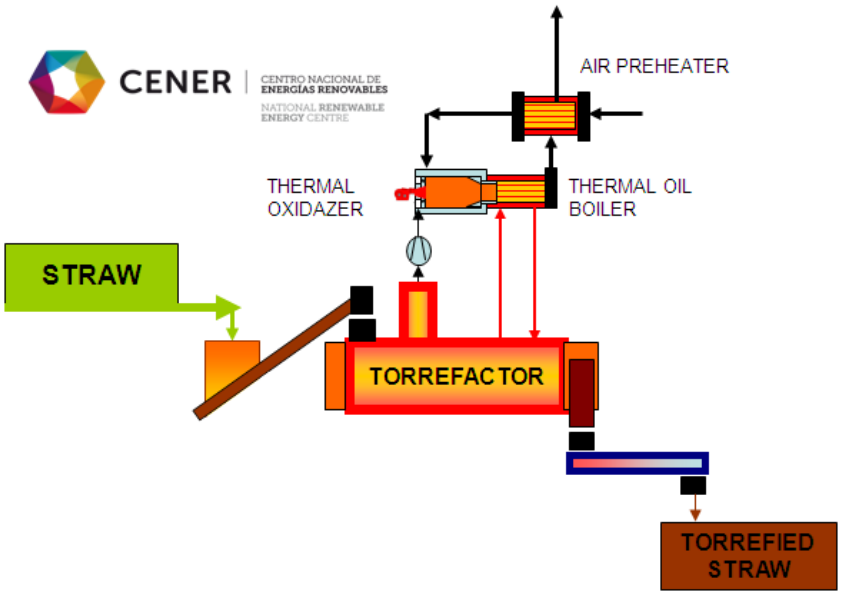
# Cereal Straw Torrefaction at CENER (WP3) - Torrefaction pilot plant in Aoiz (ES)

- Pilot scale production of torrefied straw (output > 200 kg/h)
- cylindrical horizontal reactor with an agitator shaft
- reactor heating is carried out indirectly through the hot reactor walls, the actively heated shaft tube and the actively heated internal shaft elements using
- thermal oil is used as heat transfer fluid at temperatures between 250 and 300ºC
- no drying is required
- for straw torrefaction:
  - Lower moisture content
  - lower torrefaction temperature

→ lower heat demand

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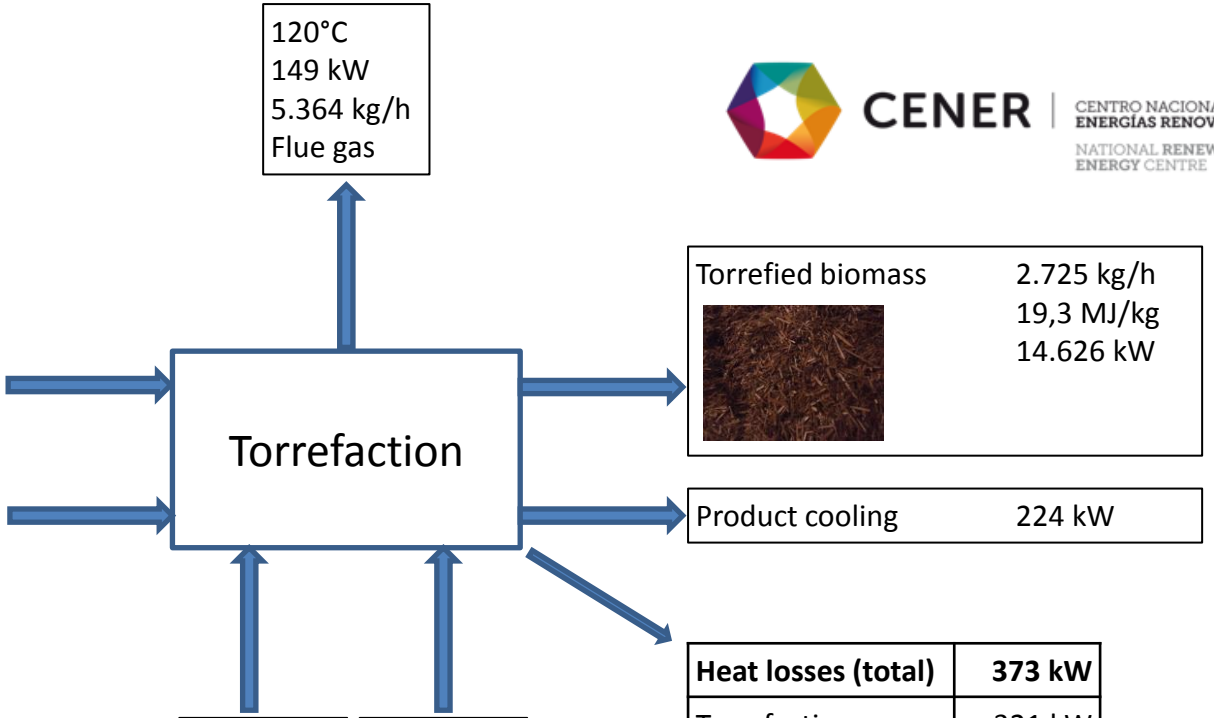
# Cereal Straw Torrefaction at CENER (WP3) – Mass and energy balance at autothermal conditions

**Biomass: Straw**
**Torrefaction degree (daf): 16 %**

CENER | CENTRO NACIONAL DE ENERGÍAS RENOVABLES
NATIONAL RENEWABLE ENERGY CENTRE




| Heat losses (total) | 373 kW |
|---|---|
| Torrefaction | 321 kW |
| Thermal oxidiser | 20 kW |
| Bioler | 23 kW |
| Air preheater | 9 kW |

| | |
|---|---|
| Net thermal efficiency: | 95,1 % |
| % of mass in product: | 74,7 % |

- Higher efficiency than woody biomass torrefaction due to the lower moisture content and higher reactivity (lower torrefaction temperature for straw)

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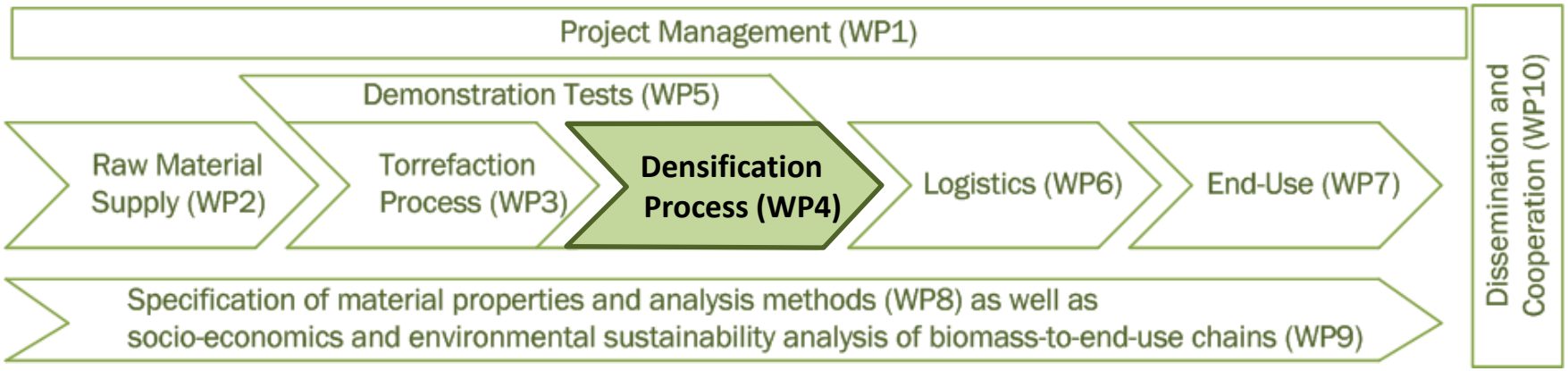


Production of Solid Sustainable Energy Carriers by Means of Torrefaction

# WP4 – DENSIFICATION: SINGLE PELLET TEST

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# Densification (WP4) - Single Pellet Tests by DTI

- Give indication what equipment and parameters should be used for pelletization
- Experiences have shown correlation between lab trials and production size pellet mill
- Objectives within SECTOR:
  - Screening of pellet properties for torrefied biomass
  - Tests and optimisation on laboratory scale
- Methodology
  - Fast and simple test; just a few grams needed
  - Adjustment of different pelletizing parameters (temperature, moisture, particle size, binder… etc.)
  - Different raw materials (pine, beech, spruce, bamboo) and torrefaction conditions
  - Materials from different project partners

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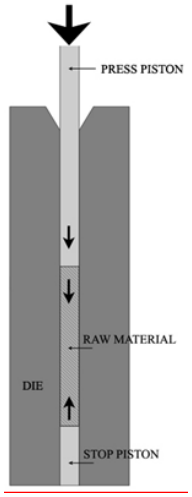
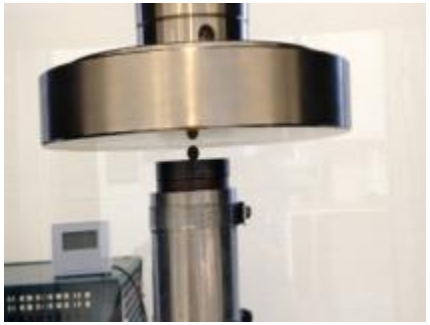
# Densification (WP4) - Single Pellet Tests

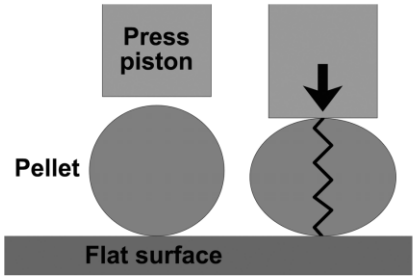
**4 parameters are tested:**

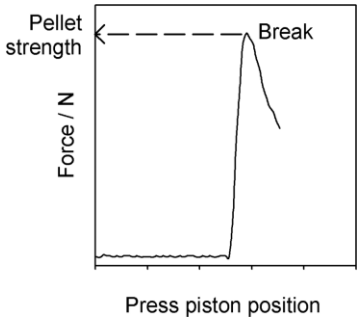
1. Compression of biomass
2. Static & dynamic friction
3. Pellet compression strength
4. Pellet density




Monitoring of forces during compression and extrusion of pellet from press channel






Force required to crush the pellet

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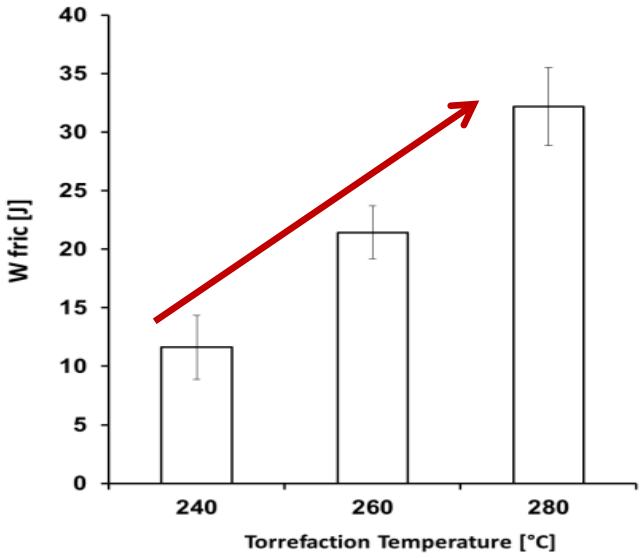
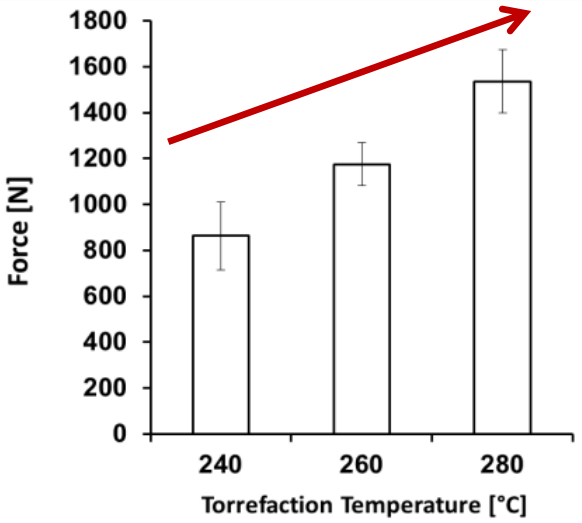
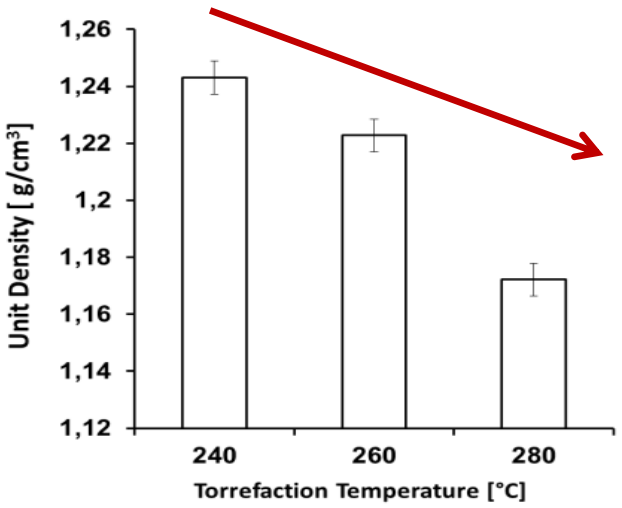
# Densification (WP4) - Example: Single Pellet Tests - Torrefied Spruce (ECN)




Energy to push pellet 1 cm in pellet die




Maximum force to initiate pellet movement




- with increasing torrefaction temperature:
  - Friction and max. force are increasing
  - Unit density is decreasing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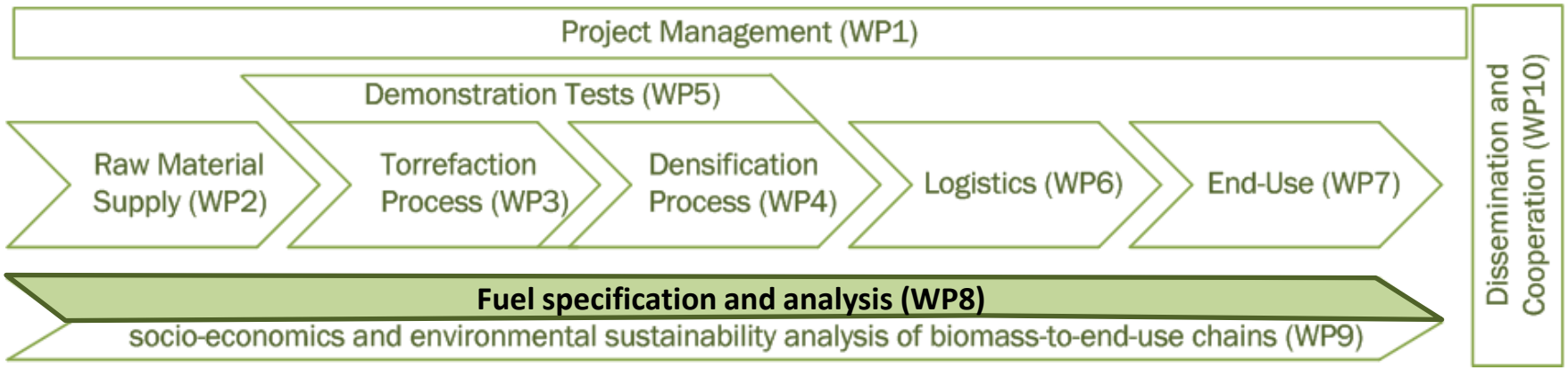


Production of Solid Sustainable Energy Carriers by Means of Torrefaction

# WP8 – FUEL SPECIFICATION AND ANALYSIS

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# Fuel specification and analysis (WP8) - Round Robin for torrefied wood pellets

Samples shipment July 2012

- 45 Registrations
- 43 Participants
- 18 Countries
- 11 Parameter

| Parameter | Method/ Standard |
|---|---|
| Bulk density | acc. EN 15103 |
| Mechanical durability | acc. EN 15210-1 |
| Moisture content | acc. EN 14774-1 or 2 |
| Ash content | acc. EN 14775 |
| Calorific value | acc. EN 14918 |
| Content of chlorine and sulphur | acc. EN 15289 |
| Content of volatile matter | acc. EN 15148 |
| Content of carbon, hydrogen, nitrogen | acc. EN 15104 |
| Content of major elements | acc. EN 15290 |
| Content of minor elements | acc. EN 15297 |
| Ash melting behaviour | acc. CEN/TS 15370 |

- 19-41 participants per parameter (goal DOW: 15 lab /parameter)

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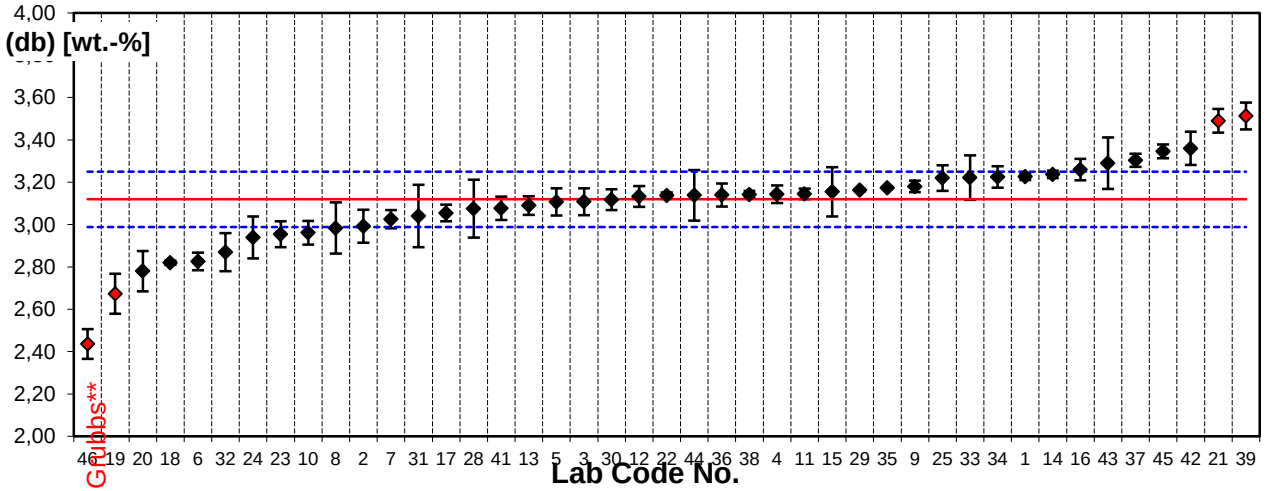
# Fuel specification and analysis (WP8) - Comparison of method precision to Biomass samples

| Ash content | | torr. Pellets | Orujillo | Woodchips | |
|---|---|---|---|---|---|
| General mean = assigned value | m | 3.12 | 11.13 | 0.59 | wt.-% |
| Repeatability limit | r | 0.20 | 0.56 | 0.05 | wt.-% |
| | | 6.40 | 5.03 | 9.15 | % |
| Reproducibility limit | R | 0.42 | 1.26 | 0.11 | wt.-% |
| | | 13.40 | 11.28 | 17.88 | % |
| Number of participants | n | 39 | 30 | 34 | |
| Over all number of individual results | l | 158 | 138 | 154 | |




For details see Deliverable 8.1: http://www.sector-project.eu/results.5.0.html

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# Fuel specification and analysis (WP8) - Conclusion and first results

- Most of the standardised solid biofuels test methods are applicable without any adoption for torrefied material, e.g.:
  - ash content analysis (EN 14775)
  - moisture content analysis (EN 14774-1 and 2)
  - Chlorine and Sulphur content analysis (EN 15289)
  - CHN analysis (EN 15104)
- For the following ISO standards
  - ISO/DIS 16948-Carbon, Hydrogen and Nitrogen content
  - 16968-Minor element
  - 16967-Major elements
  - 16994-Sulphur and Chlorine content

  torrefied material would be added without any modification.
- The results of these round robin results will be added to the existing performance characteristics tables
- SECTOR partners participate in the standard development: new proposed standard ISO 17225-x: "Solid biofuels - Fuel specifications and classes - Graded thermally treated densified biomass"

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# Fuel specification and analysis (WP8) - Development of new analysis methods

List of analysis methods to be developed until 2014/2015:

- NIR spectroscopy
- TGA method
- Leaching behaviour
- Hydrophobicity- water absorption
- Degree of torrefaction
- Grindability
- Particle size distribution and size distribution and flowability properties

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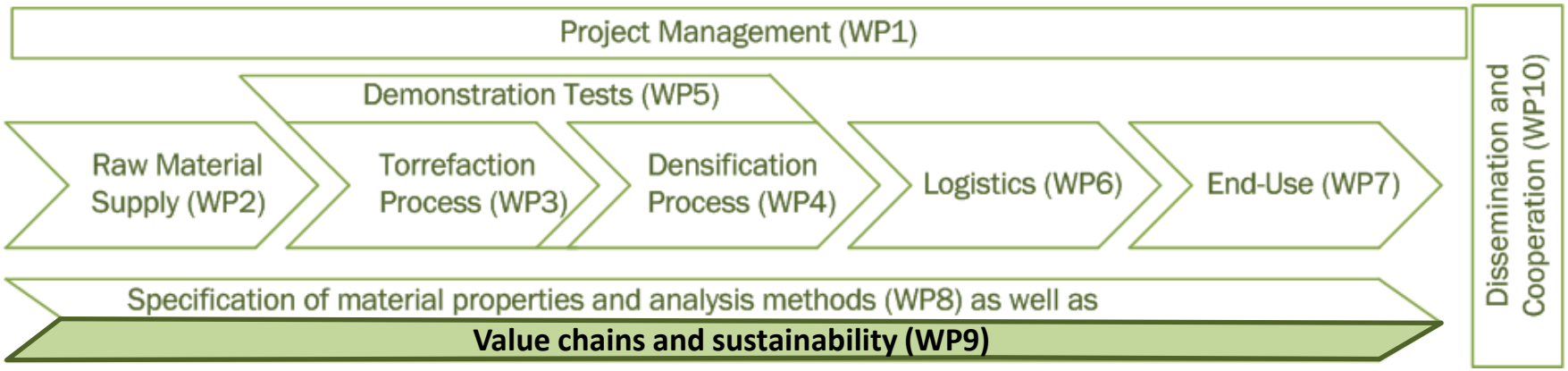


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# VALUE CHAINS AND SUSTAINABILITY - WP9

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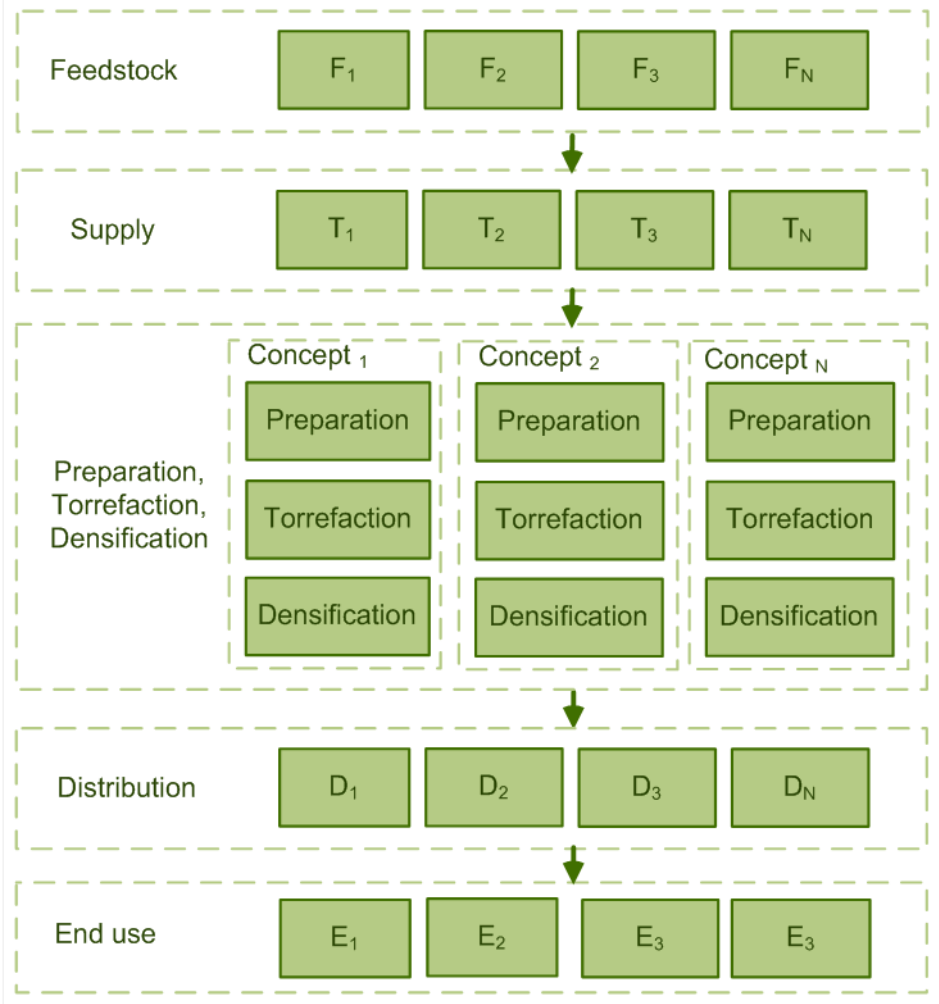
# Value chains and sustainability (WP9) - objectives

- WP9 aims to assess the environmental and socio-economic impacts of torrefied solid biomass in different value chains
- Each chain is characterized by certain properties regarding feedstock, torrefaction technology, transportation options (mode and vehicle selection) and storage strategy (shape and location), types of end-use and other parameters. Four basic types of the torrefaction technologies (rotary-drum moving-bed, torbed, fluidised-bed) will be considered.
- Building on these chains selective deployment scenarios for energy supply structures based on torrefaction up to 2030 will be analysed.




*Different (torrefied) biomass to end use chains investigated in WP9*

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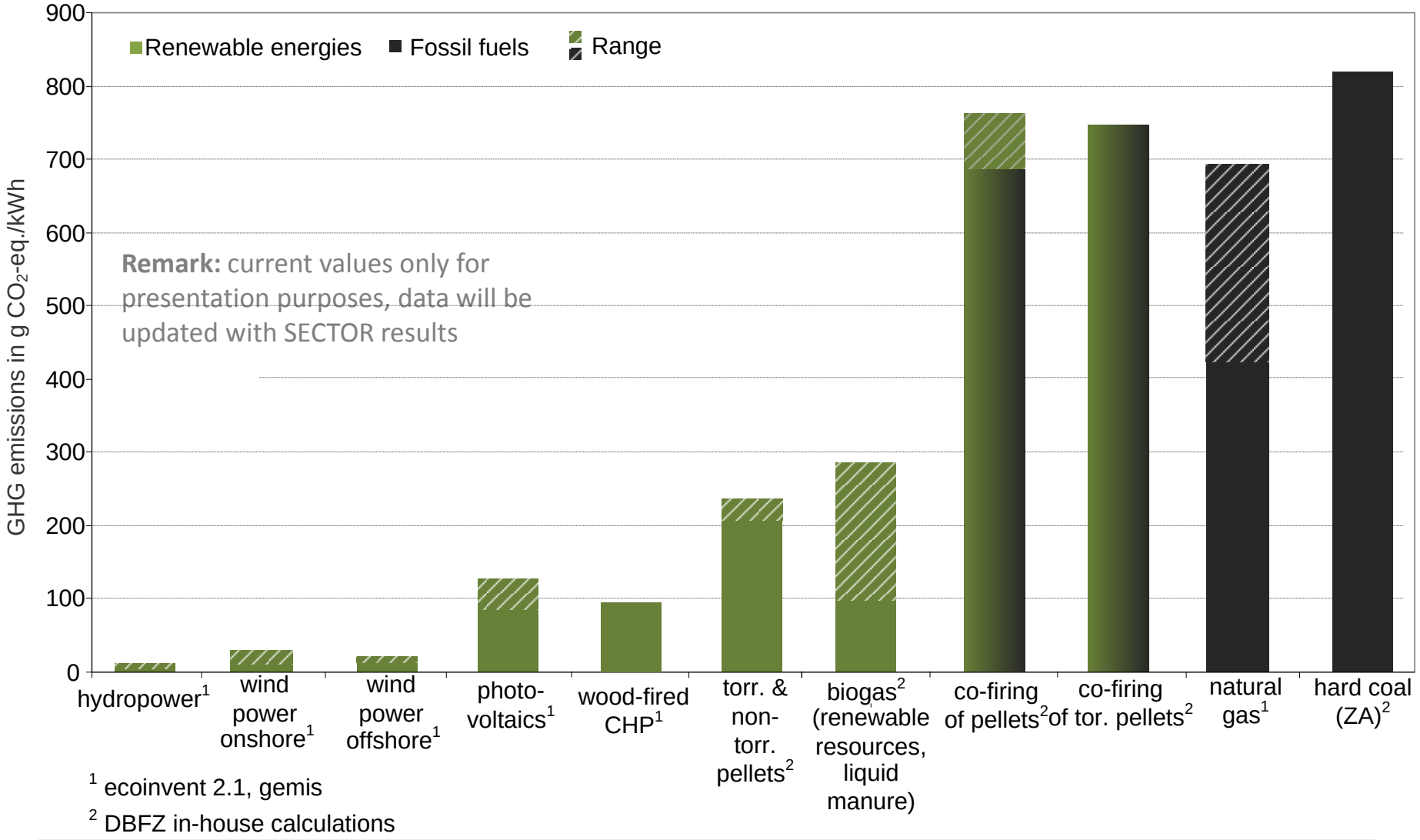
# Target: comparison of different electricity generation options




[1] ecoinvent 2.1, gemis

[2] DBFZ in-house calculations

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# Value chains and sustainability (WP9) - Case Studies

Objectives:

- Case studies for sustainability assessment of biomass production
- Assess current feedstock production & management practises under un-/certified conditions
- Identify and analyse comparable feedstock in all studies from agriculture and forestry
- Further development and improvement of indicators is envisaged

Envisaged study sites in

Central Europe (Austria, Germany)


Southern USA (Georgia, Mississippi)


Tansania (Arusha, Sao Hill/Iringa)


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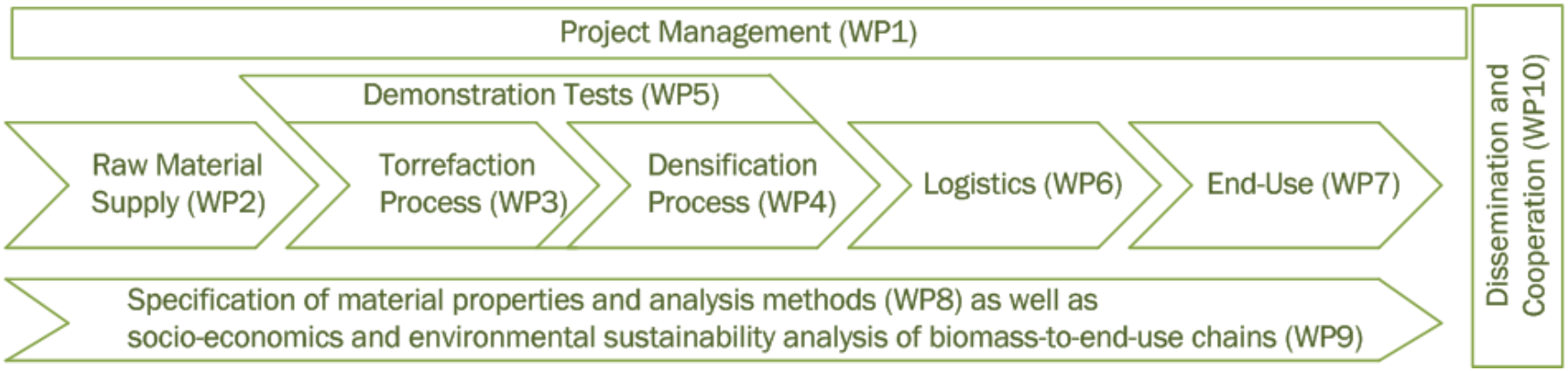


Production of Solid Sustainable Energy Carriers by Means of Torrefaction

# SUMMARY AND OUTLOOK

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# Summary and Outlook

- Torrefaction process & torrefied products offer many advantages to supply an energy efficient biofuel for the use in gasification and co-firing plants
- Worldwide there are over **50 torrefaction developers / initiatives** (planning capacities between 300 → 500 kt); however, no commercial plant exists today, but first demonstration projects are on the way (e. g. Topell from NL 60 kt/a)
- **Technical and commercial challenges** still need to be solved
- Some highlights of the current work within SECTOR:
  - 43 international laboratories have taken part in the first Round Robin test with torrefied material
  - More than 15 t of torrefied material have been tested by project partners till spring 2013, further tests are scheduled
- **The SECTOR project is expected to shorten the time-to-market of torrefaction technology and to promote market introduction within stringent sustainability boundary conditions**

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# thank you very much for your attention

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# Backup slides

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# Indicative fuel properties of woody biomass products

| | Wood chips | Wood pellets | Torrefied wood pellets | Charcoal | Coal |
|---|---|---|---|---|---|
| Moisture content (wt%) | 30 – 55 | 7 – 10 | 1 – 5 | 1 – 5 | 10 – 15 |
| Calorific value (LHV, MJ/kg) As received | 7 – 12 | 15 – 17 | 18 – 24 | 30 – 32 | 23 – 28 |
| Volatile matter (wt% db) | 70 – 84 | 75 – 84 | 55 – 65 | 10 – 12 | 15 – 30 |
| Fixed carbon (wt% db) | 16 – 25 | 16 – 25 | 22 – 35 | 85 – 87 | 50 – 55 |
| Bulk density (kg/l) | 0.20 – 0.3 | 0.55 – 0.65 | 0.65 – 0.80 | 0.18 – 0.24 | 0.80 – 0.85 |
| Vol. energy density (GJ/m$^3$) | 1.4 – 3.6 | 8 – 11 | 12 – 19 | 5.4 – 7.7 | 18 – 24 |
| Hygroscopic properties | Hydrophilic | Hydrophilic | (Moderately) Hydrophobic | Hydrophobic | Hydrophobic |
| Biological degradation | Fast | Fast | Slow | None | None |
| Milling requirements | Special | Special | Standard – feedstock specific | Standard | Standard |
| Product consistency | Limited | High | High | High | High |
| Transport cost | High | Medium | Low | Medium | Low |

Abbreviations:
db = dry basis
LHV = Lower Heating Value
wt% = weight percentage





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