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Densification of torrefied materials

Experiences from the EU research project SECTOR

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Center for Biomass and Biorefinery

Danish Technological Institute – DTI

SECTOR

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

SEVENTH FRAMEWORK PROGRAMME

Densification of torrefied materials

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- Torrefaction
  - Mild roasting of biomass in an inert atmosphere (270-310 °C / 5-20 Min)
  - Removal of water and volatiles from biomass → Increased heating value
  - Increased C/O ratio: better combustion / fuel properties
  - Fibers are converted into a brittle material → Easy to grind (coal mill)
  - Dry product with hydrophobic characteristics
    → Biomass with "coal like" properties

- Densification
  - Pelletization or Briquetting processes
  - Increase density and reduce dust formation
  - Lowering transportation and handling costs
  - Standardized size

Densification of torrefied materials

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- Densification is a very important process step
  - 200-300 kg/m^3 → 600-750 kg/m^3
  - Improving handling (less dust and more clean fuel)
  - Increasing energy density (lower transportation costs)
  - Standardized size and shape (automated feeding, trading)

Densification of torrefied biomass can be a challenge

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- Densification process
  - High energy uptake of pellet mill up to 150 kWh/t (usually 50-60 kWh/t for wood pellets)
  - Heat generation in pellet mill (risk of fire / dust explosion)
  - Lower capacity of the press
  - More wear on equipment parts
- Pellet quality
  - Durability
  - Self heating
  - Density
  - Hydrophobicity
  - Storage of torrefied pellets
  - Dust

Issues are closely linked to

- Biomass feedstock
- Torrefaction parameters
- Pelletization parameters
- Can be different case by case

Requires knowledge and further studies

SECTOR Project

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Production of **S**olid Sustainable **E**nergy **C**arriers from Biomass by Means of **Tor**refaction – **SECTOR**

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

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

University of Stuttgart Germany · ECN · DANISH TECHNOLOGICAL INSTITUTE · Deutsches Biomasseforschungszentrum gemeinnützige GmbH · DBFZ · ofi · VTT · JEN · e·on · SLU Swedish University of Agricultural Sciences · RWE The energy to lead · VATTENFALL · Topell Energy · UMEÅ UNIVERSITET · cener centro nacional de energías renovables FUNDACIÓN CENER CIEMAT · PROCEDE · DOOSAN Doosan Power Systems · HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ · Technologie- und Förderzentrum im Kompetenzzentrum für Nachwachsende Rohstoffe · TU WIEN · bioenergy2020+ · BIOS BIOENERGIESYSTEME GmbH

Objectives and motivation of the SECTOR project

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- **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 standardization 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

SECTOR Project

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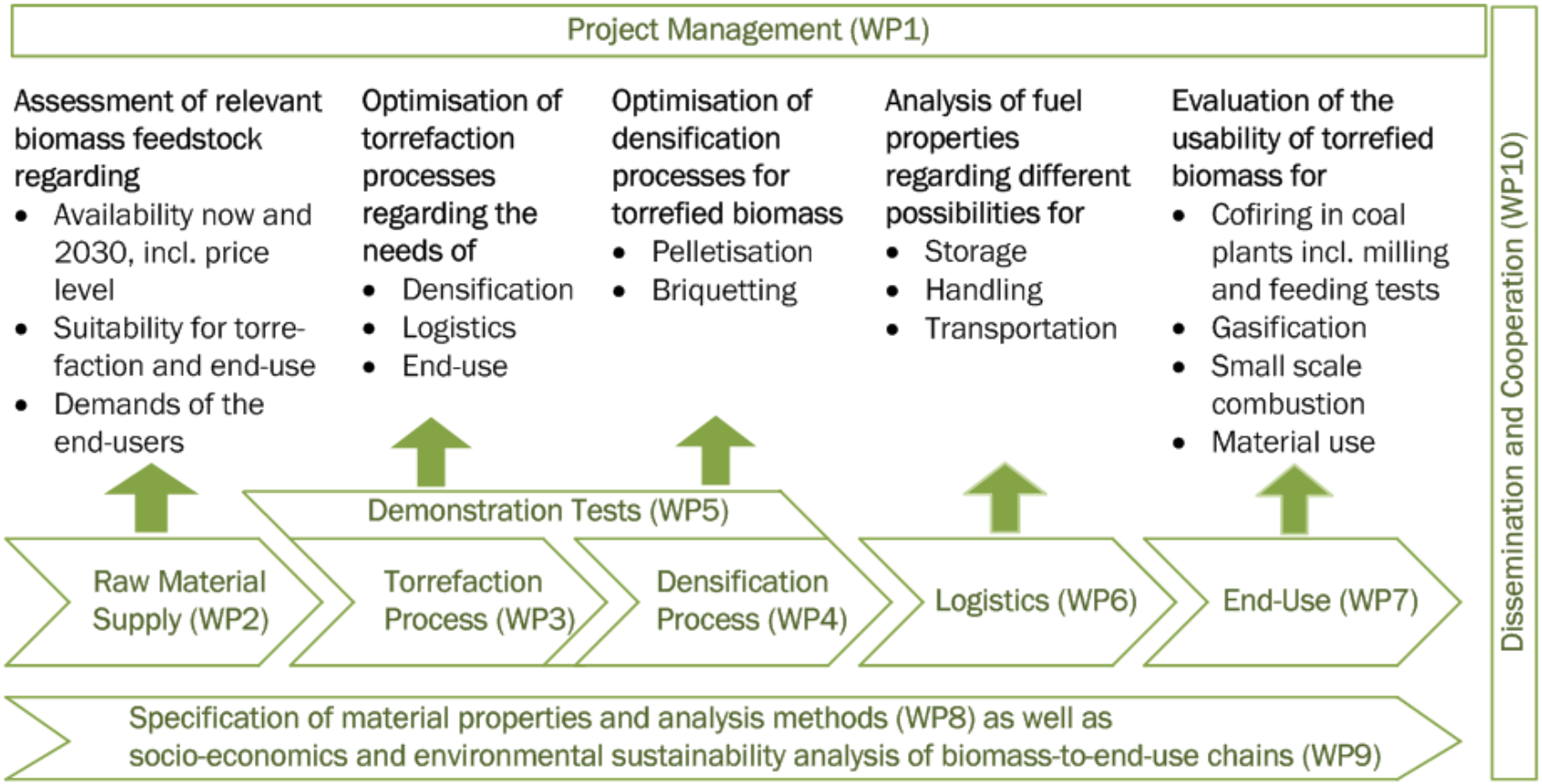

→ SECTOR Project is dealing with the whole chain from raw materials, process development, applications, product quality assessment and sustainability

Improving densification processes

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Densification Technology available in SECTOR project

- Laboratory scale
  - Single pellet press → Screening of new materials, processing parameters and additives
- Pilot scale
  - Pilot plants for pellet production → process optimization and scale up
  - Pilot plant for briquette production → process optimization and scale up
- Production scale
  - Full scale production facilities → production of sufficient material to be used in logistics and firing tests

Lab scale densification

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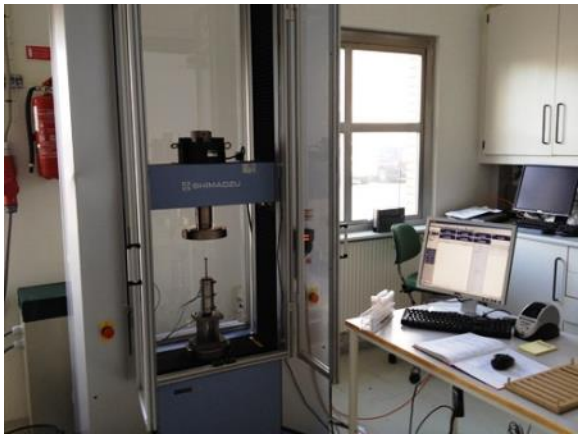
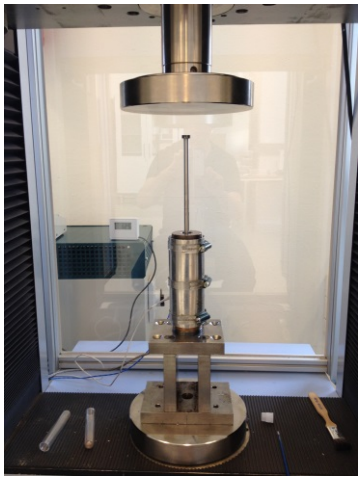
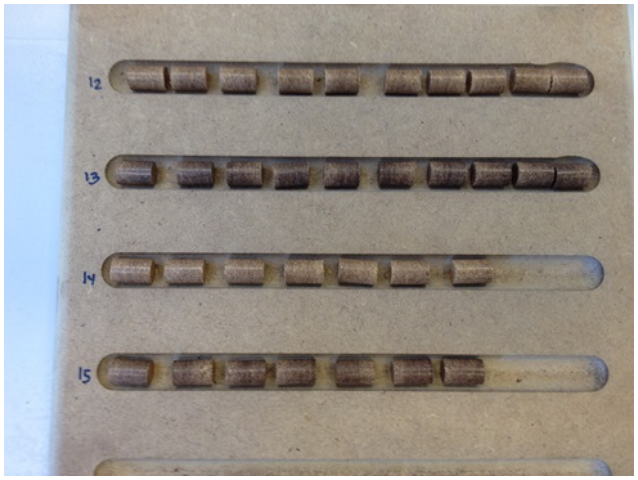
Single pellet press tool: Fast and only few grams of material needed

Set-up allows variation of: Temperature, pressure, particle size, moisture, and additive addition







Determination of: Compression energy, friction and quality analysis of pellets

Earlier tests have shown correlation between friction and energy consumption of industrial scale pellet press

Lab scale densification

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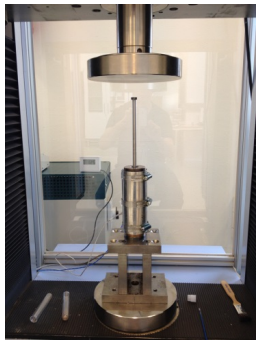
- Testing of torrefied materials provided by SECTOR partners
- Parametric study to identify key parameters and optimization

Key parameters for densification of torrefied biomass

- Biomass species (i.e. hardwoods, softwoods, straws, mixed resources)
- Torrefaction degree (mass yield as function of reaction time and temperature)
- Material moisture content
- Densification temperature
- Press channel design



Lab scale densification

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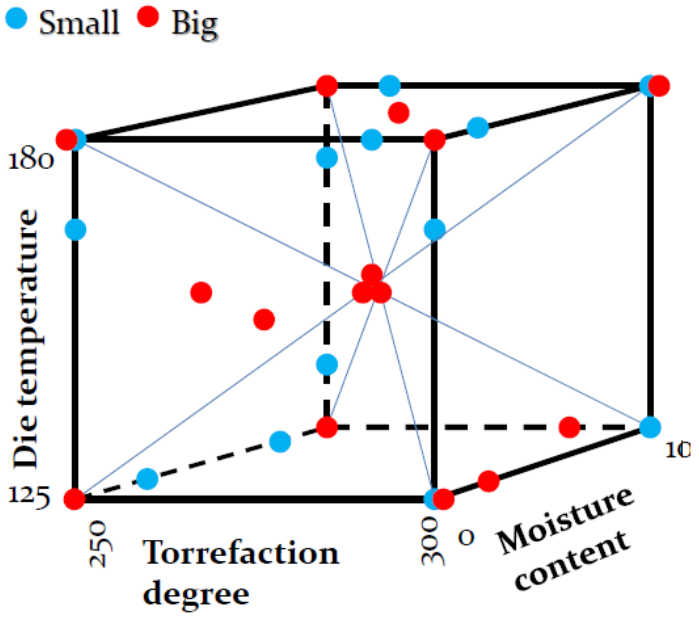
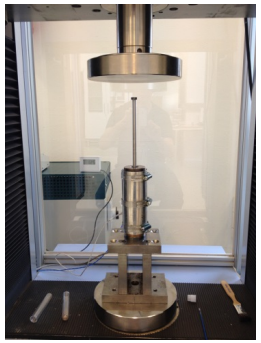
Parametric study – which parameters are the important ones

Design of experiments

- Torrefaction degree expressed as mass yield (90.5% - 71.1%)
  - Temperature 250 to 300 °C
- Moisture content (0 to 10%)
- Die temperature (125-180˚C)
- Particle size(small / big)





Lab scale densification

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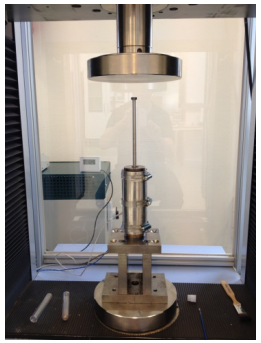
Some selected results from lab tests

- High torrefaction degree → increase of friction (power consumption of press) & decreased mechanical strength (durability)
- Increase of moisture content and temperature → reduce friction and improve mechanical strength of pellets
- Species related differences → some species are easy to pelletize after torrefaction others are more challenging
- Press channel length is an important parameter to optimize pellet quality and energy consumption of process



Pilot scale densification

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Images: Torrefaction demo plant at CENER in Aoiz, Spain

Pilot scale pelletization facilities in SECTOR are available at

ECN, SLU and CENER

CENER NATIONAL RENEWABLE ENERGY CENTRE

Pilot scale densification

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Parameter		Beech	Pine	Straw	Poplar
Anhydrous weight loss	% dry basis	14-22	14-19	13-22	14-23
Bulk density	kg/m^3	620-700	610-650	590-710	610-630
Durability	%	96.2-97.2	90.9-95.4	84-97.6	95.0-97.1
Moisture content	%	3.7-5.6	5.2-6.2	3.8-8.5	7.6-8.2
LHV	GJ/t (daf)	19.6-20.7	20.1-20.5	19.3-19.6	N.D.
C	% (daf)	52.0-54.3	53.5-54.2	50.5-51.5	N.D.
H	% (daf)	~6.0	5.8-6.2	~6.2	N.D.
N	% (daf)	0.12-0.18	0.12-0.14	0.58-0.77	N.D.
Ash content	% (db)	1.6-1.8	0.6-0.8	4.8-6.0	N.D.
Volatile content	% (db)	75.6-80.5	76.0-80.0	~74.8	N.D.

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Pilot scale densification

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Torrefied beech Torrefied pine Torrefied straw Torrefied poplar

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Briquetting of torrefied biomass

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Pilot trials in cooperation with C.F. Nielsen A/S and the Energy Centre of The Netherlands (ECN)

ECN

C.F. Nielsen

Briquetting of torrefied biomass

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- Torrefaction:
  - Reactor: Pilot Reactor at Energy Center of The Netherlands (ECN)
  - Moving bed principle (Drying and Torrefaction Section)
  - Capacity 50 kg/h – Continuous operation
  - 3 Batches: 240, 260 and 280 °C / 30 Minutes residence time
  - Raw material: Spruce chips (max 45x45x15 mm)

Feeding of biomass
on top of the reactor

Torrefaction Section
of the reactor

ECN

Briquetting of Torrefied Spruce

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Fuel	Ash (550°C) % (db)	H_2O (105°C) %	Volatiles % (db)	C % (db)	H % (db)	N % (db)	O % (db)	HHV MJ/kg	Yield %
Spruce	0,36	12,6	81,2	49,2	6,3	0,1	46,1	20,2	100
Spruce 240°C	0,32	2,5	80,1	50,8	6,4	0,1	45,4	20,4	94,5
Spruce 260°C	0,39	2,3	76,75	53,2	6,2	0,1	42,9	21,5	85
Spruce 280°C	0,4	0,6	70,9	56,3	6,2	0,1	40,1	22,7	73

Data from ECN

Spruce 240 °C 260 °C 280 °C

Increase of heating value and C/O Ratio

ECN

Briquetting of torrefied biomass

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- Results

Spruce 240 °C 260 °C 280 °C

Briquetting torrefied biomass

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- Results

Raw material		Spruce (fresh)	240 C	260 C	280 C	
Density (raw material)	*kg/m3*	153	181	157	162	
Moisture	*%*	13,4	5,2	4,3	4,8	Decrease of MC and particle size
Particle size min	*mm*	1x1	0,1x0,1	0,1x0,1	0,1x0,1	
Particle size max	*mm*	10x5	5x2	5x2	5x2	
Process						
Power consumption	*A*	70	85	85	80	
Die Temperature	*C*	160	165	200	205	Stable power consumption and capacity
Strokes per min	*1/min*	269	269	269	269	
Strokes number	*n*	13	9	16	17	
Capacity (measured)	*kg/h*	600	660	600	600	
Product						
Diameter	*mm*	59	59	60	59,5	
Length	*mm*	155	115	162	159	
Volume	*cm3*	424	314	450	442	Stable pellet quality
Weight	*g*	446	318	456	444	
Density (briquette)	*kg/m3*	1053	1012	1013	1005	

- **Thank you for your attention!**

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SEVENTH FRAMEWORK PROGRAMME