New 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

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

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Janet Witt (DBFZ)






This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

Outline

- Overview over SECTOR
- New results on
  - Torrefaction
  - Densification
  - Logistics
  - End use
- Summary and 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

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

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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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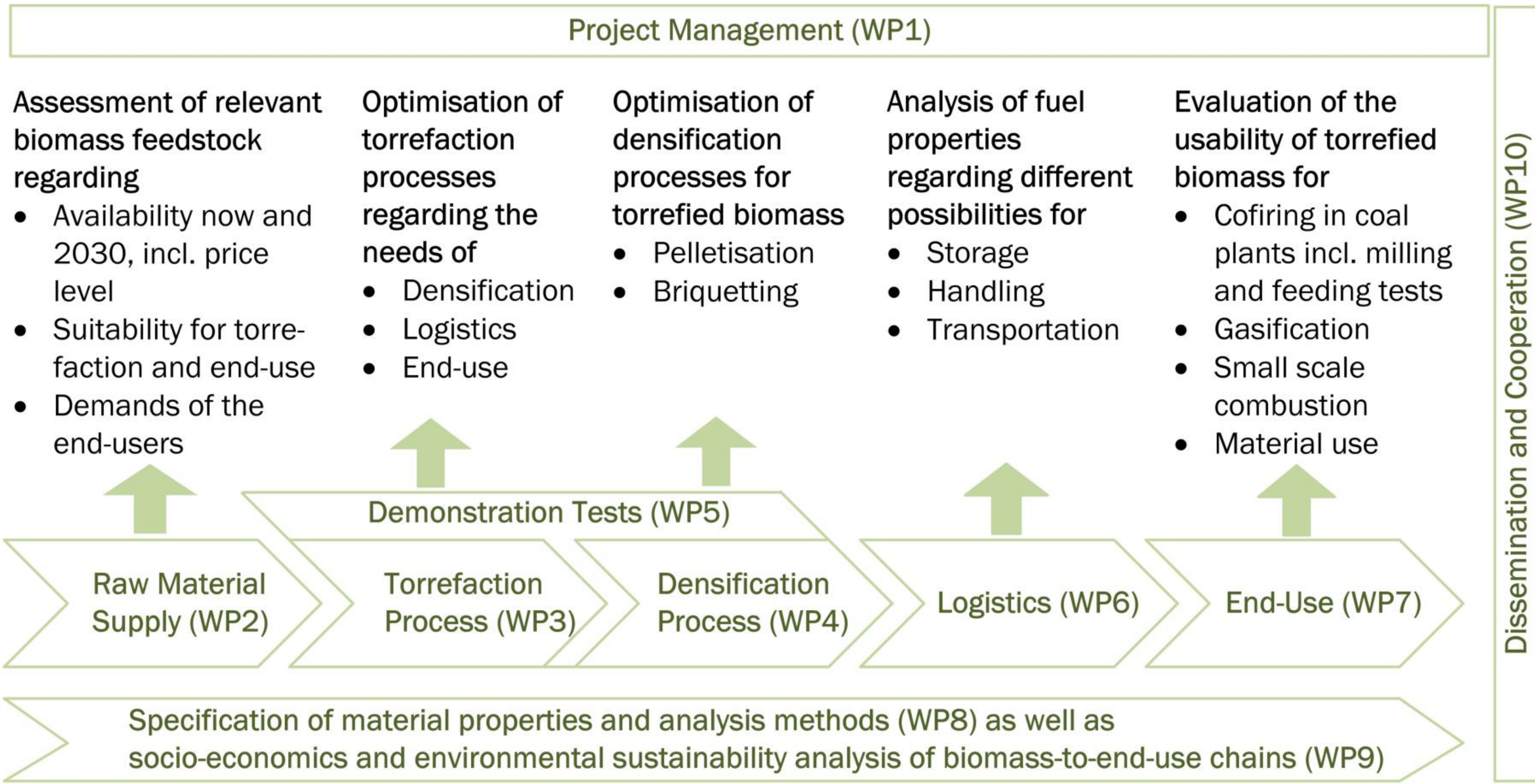
SECTOR project structure



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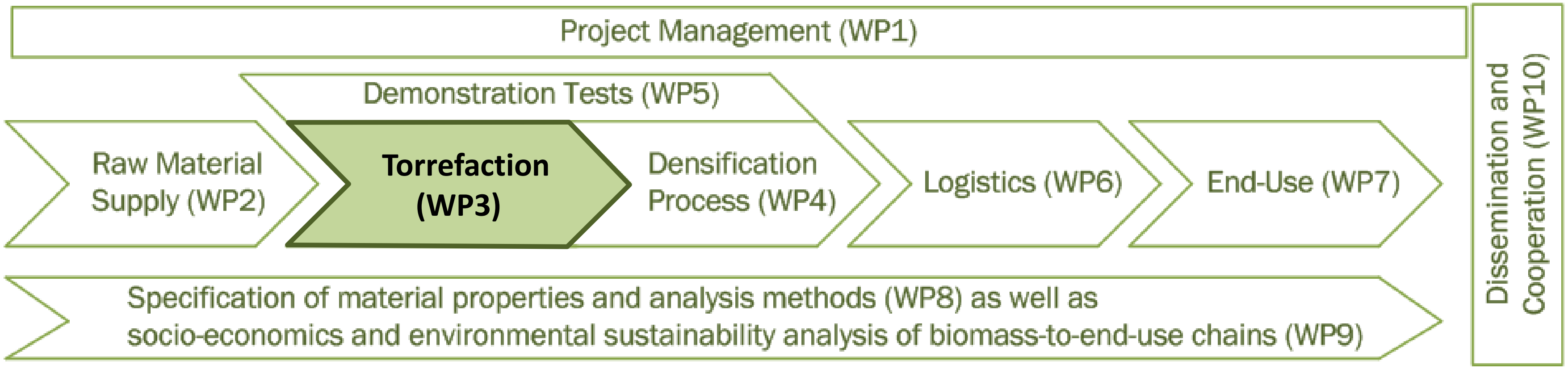

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TORREFACTION

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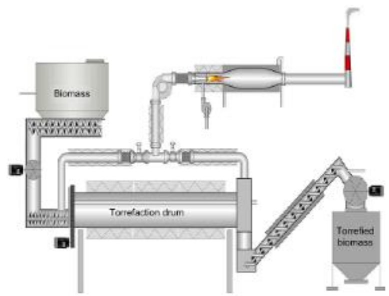
Torrefaction technologies

Different technologies

Moving bed
(ECN)
pilot



Rotary drum
(Umeå University)
pilot

Rotary drum
(CENER)
pilot

Toroidal
(Topell)
demo

Production with available **pilot scale facilities**
Typical test runs 50-100 hours
Typical production per test few tons
3-6 different feedstocks

Production with available **demo plant**
Continuous operation
Production of 100-200 tons
Specific feedstock

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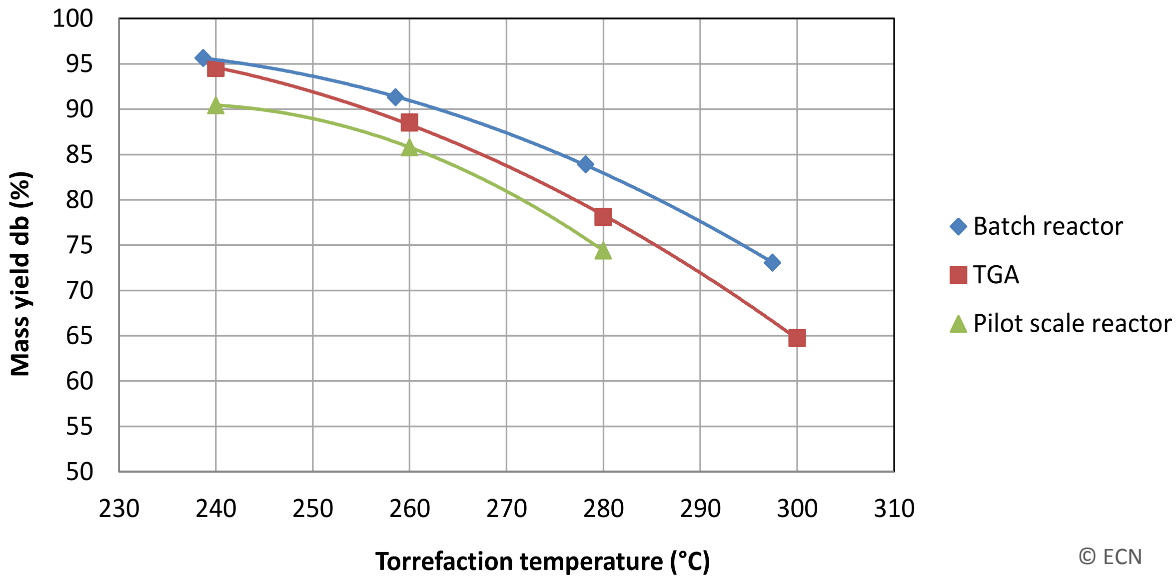
Torrefaction - Mass yield comparison (ECN)

- 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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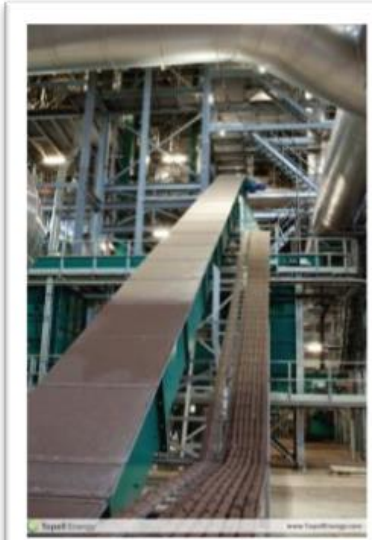
Torrefaction - Demonstration Tests (Topell)

- Proof of concept of Topell torrefaction system in 2013 at commercial scale
- Material used: Forest residue
- Developing torrefaction recipes for different feedstocks
- Achieved and demonstrated continuous production of pellets from torrefied biomass at commercial scale with the product quality required by end consumer (co-firing biomass in power plants)
- Achieved and demonstrated full heat integration within the plant→use of torgas to supply most of the heat demand of the plant, including drying and the torrefaction



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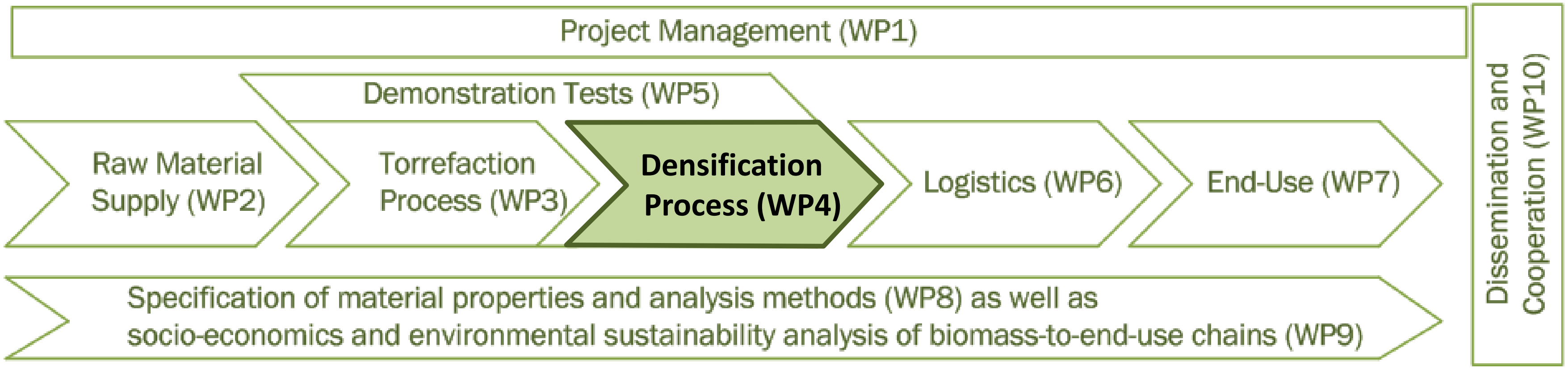

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DENSIFICATION

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Densification of torrefied biomass - Activities

- **Laboratory scale densification**
  - Testing of torrefied biomass provided by SECTOR partners
  - Parametric study
  - Data collection and analysis → Feedback and process optimisation
- **Bench/Industrial scale densification**
  - Production in pilot plants of CENER, UMU, ECN and Topell
  - Data collection and analysis → Process improvement
- **Product Quality**
  - Compilation of analysis data from SECTOR-partners
  - Comparison of analysis data

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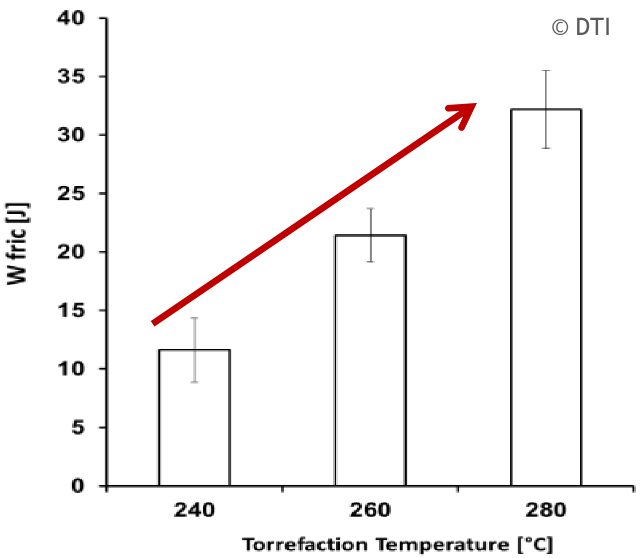
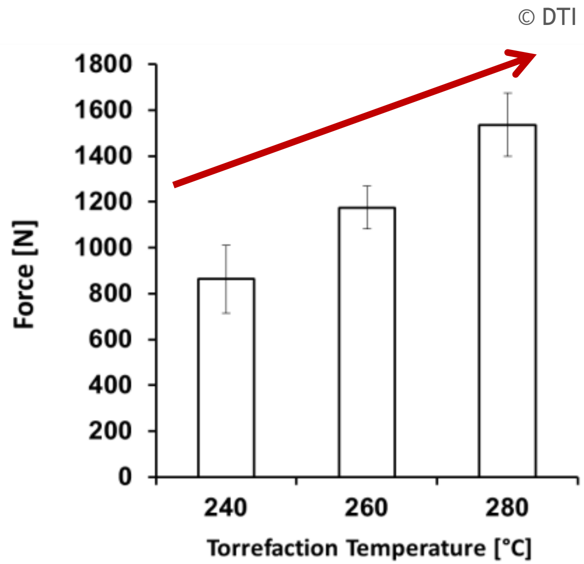
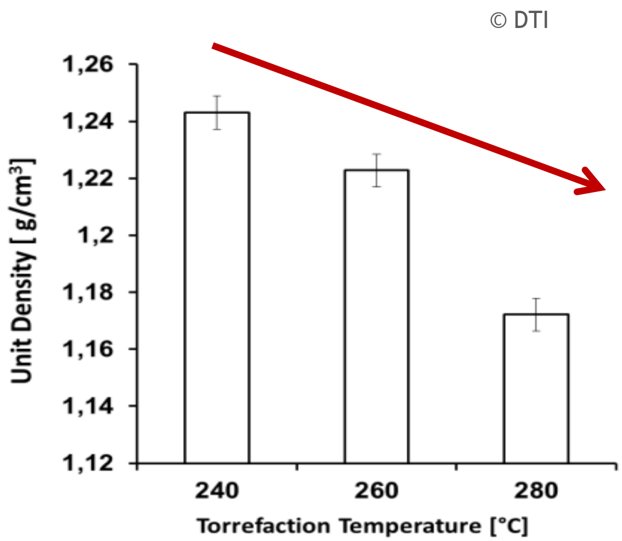
Densification - Single Pellet Tests - Torrefied Spruce (DTI)



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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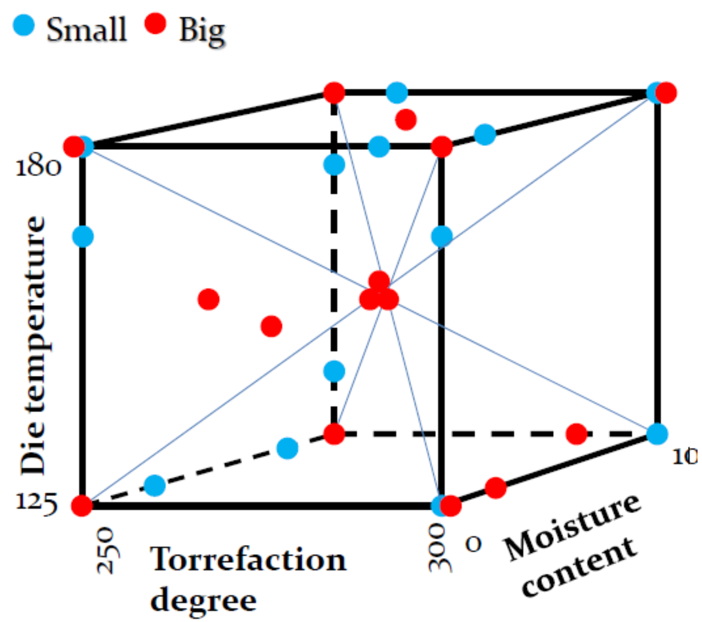
Densification: Laboratory scale densification (DTI, SLU)

Parametric study:

- 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 (<1 and 1-2 mm)



Material torrefied at SLU (Sweden) in batch reactor

Pelletizing tests at DTI (Denmark)

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Densification: Pilot scale densification (DTI)

Briquetting tests:

Material torrefied at ECN: Spruce and Bamboo
Briquetting tests DTI in cooperation with CF Nielsen

Materials tested

Spruce
240 °C
260 °C
280 °C

Bamboo
245°C
255°C
265°C

300 kg each material

→ Briquetting gets more challenging with increasing torrefaction degree
→ Keeping the briquette hot and under pressure for extended time improves quality
→ Good quality: Smooth surface, high density, stability but still optimization potential

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Densification: Demonstration Tests (CENER)

- Optimisation of densification process

PINE			STRAW		
Date	Pellet dur. (%)	Pellet photo	Date	Pellet dur. (%)	Pellet photo
Oct. 2012	88,8		Feb. 2013	84,2	
Jan. 2013	92,3		Sept. 2013	94,3	
Jun. 2013	94,7		Oct. 2013	96,6	
Nov. 2013	95,7		Nov. 2013	97,6	

Parameters optimized:

- Particle size of feedstock
- Moisture content of feedstock
- Torrefaction degree of feedstock
- Die: diameter/length
- Die rotation speed

Analysis type	Laboratory test	Units	Value	Pellet photo
Ultimate analysis	C	% daf	51,5	
	H	% daf	6,2	
	N	% daf	0,58	
Proximate analysis	Moisture content	% wb	8,5	
	Ash content	% db	4,8	
Net Calorific Value	NCV	MJ/kg daf	19,6	
Physical analysis	Bulk density	kg/m3 ar	710	
	Energy density	GJ/m3	13,9	
	Fines content	%	0,02	
	Pellet durability	%	97,6	

Source: CENER

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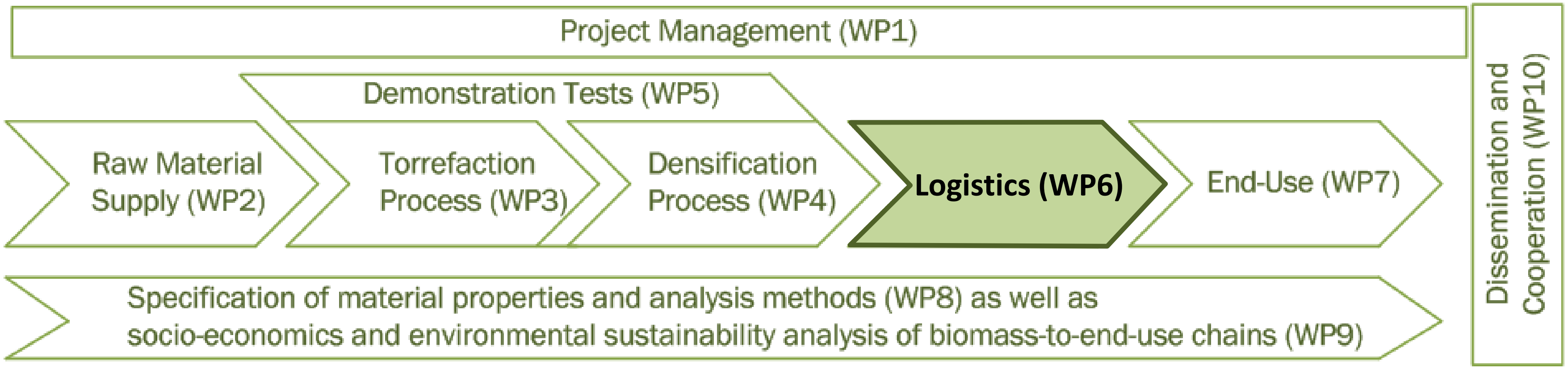

LOGISTICS

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Logistics: Activities

- Characterise logistics performance:
  - First by small-scale tests, later followed by larger-scale outdoor storage and handling tests
  - Assess various logistic aspects and produce optimised torrefaction-based bioenergy carriers
  - Test optimised pellets under real case conditions, e.g. in existing coal-handling lines

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Logistics - Outdoor storage and handling tests (EON)

Two outdoor storage piles were built in June 2013:

Peaked-topped pellets

- Model the formation of pellets after it has been delivered.
- 4 tonnes
- 2.34 x 2.36 x 1.5 m

Flat-topped pellets

- Model the formation of pellets after com-paction (though no compaction has occurred)
- 3 tonnes
- 2.34 x 2.36 x 1.5 m

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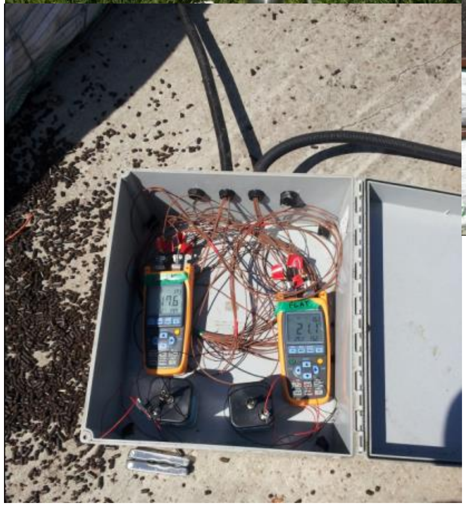
Logistics - Outdoor storage and handling tests (EON)

- In-situ measurements
  - Temperatures in piles
  - Weather data (ambient temp, humidity, wind speed, wind direction,rainfall)
- Sampling
  - Surface and middle of each pile
- Physical parameter tests
  - Pellet durability
  - Diameter
  - Particulate size
  - Particle distribution
- Proximate Analysis
  - Moisture
  - Ash
  - Volatiles
  - Calorific Value



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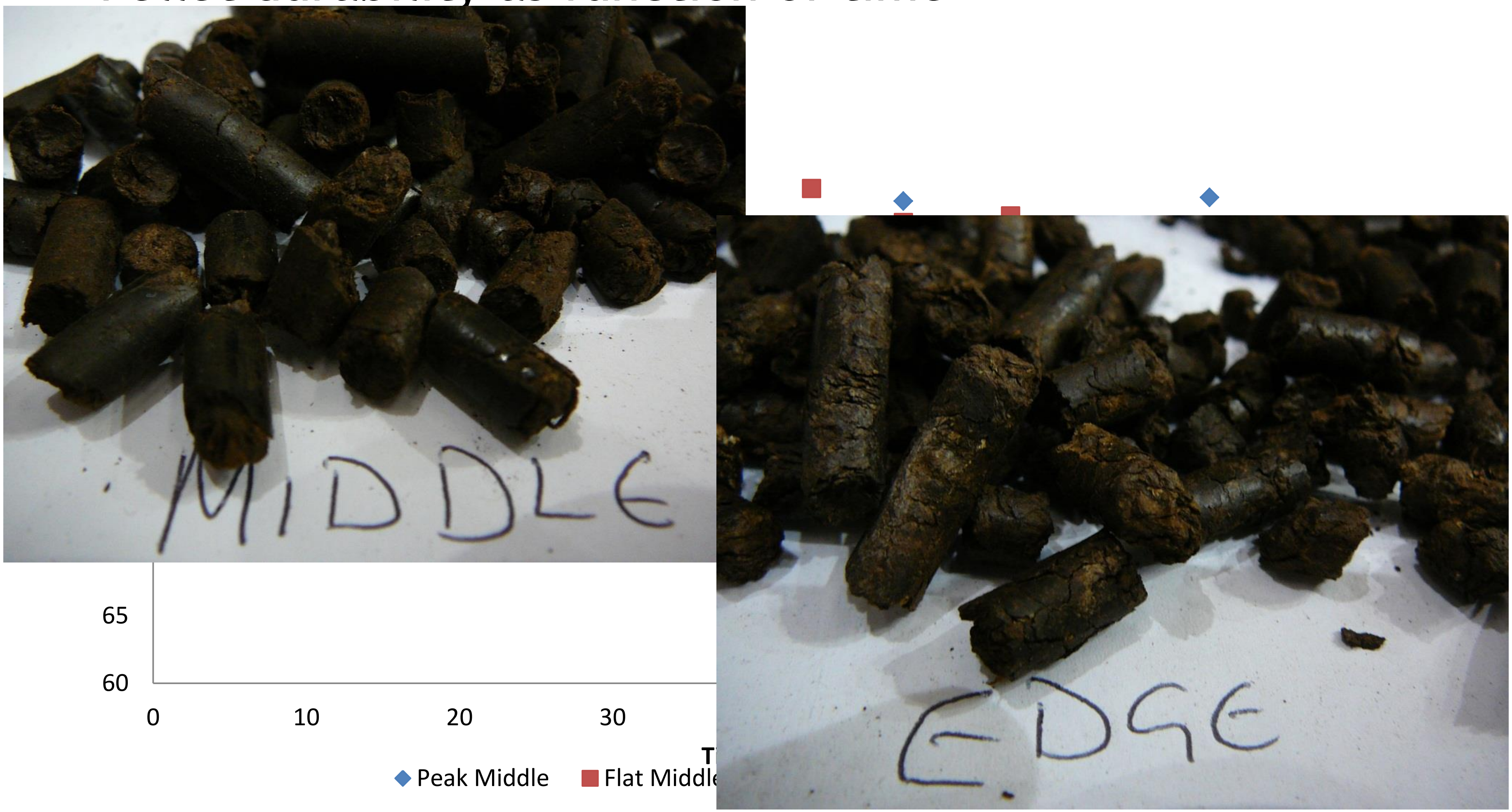
SECTOR Production of Solid Sustainable Energy Carriers from Biomass by Means of TORrefaction

Logistics - Outdoor storage and handling tests (EON)

- Pellet durability as function of time



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Logistics - Achieved results

- Outdoor storage and handling tests
  - Temperature profile in piles follows ambient temperature closely (few degrees C higher in piles)
  - Continuously increasing moisture content of pellets observed on a monthly basis. Inside as well as close to the surface of the piles
  - Heating value of pellets (LHV, as received) has decreased due to the increased moisture content. On dry basis no difference observed indicating very minor losses due to biological activity or losses through leachate
  - Mechanical integrity of pellets close to surface has decreased; pellets close to the surface are porous and disintegrate easily
  - Note: storage tests were conducted during 9-10 month period; strategic reserve at power plant is typically 2-3 weeks

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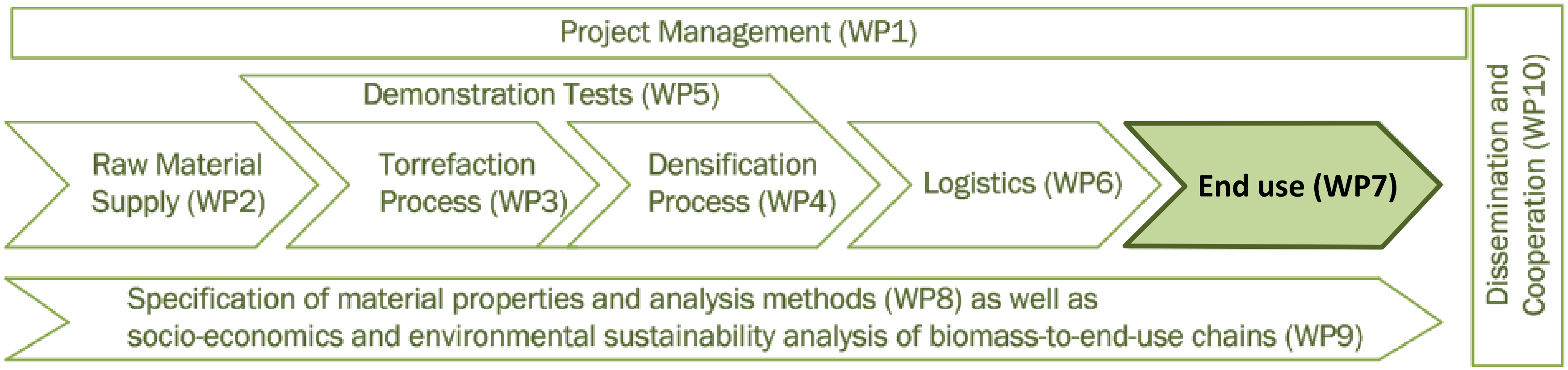

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END USE

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End Use - Activities

End-use applications of torrefied biomass:

- Milling and Feeding tests
- Medium-to-large scale firing and co-firing in pulverized-fuel boilers
- Medium-to-large-scale gasification and co-gasification in entrained-flow gasifiers
- Small-scale combustion in commercial pellet boilers
- As feedstock or co-product for the production of bio-chemicals or bio-materials

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End Use - Milling & feeding (USTUTT)

- Milling tests performed at USTUTT in a hammer mill (200 kg/h):
  - Torrefied pellets from Topell (woodmix), ECN (Spruce), CENER (Beech and Pine), and reference white wood pellets.
  - Preliminary results show significantly lower energy consumption for torrefied pellets with finer and more spherical material output.

- Preliminary results of feeding tests for both 20 kW and 500 kW PF burners at USTUTT show no bridging and agglomeration problems.

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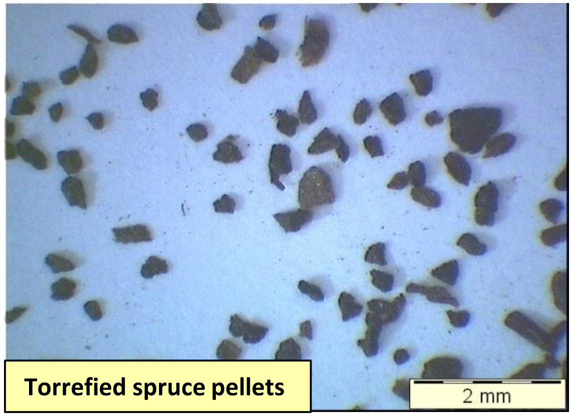
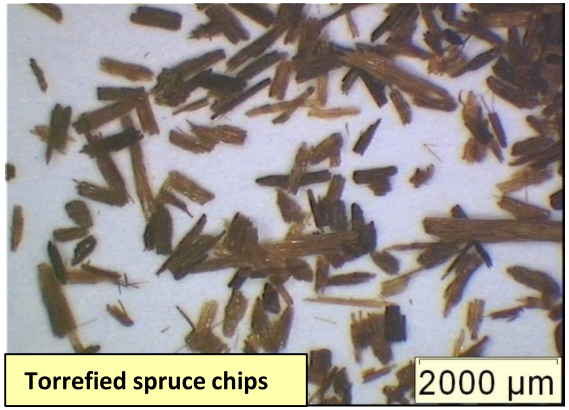
End Use - Milling & feeding (ECN)

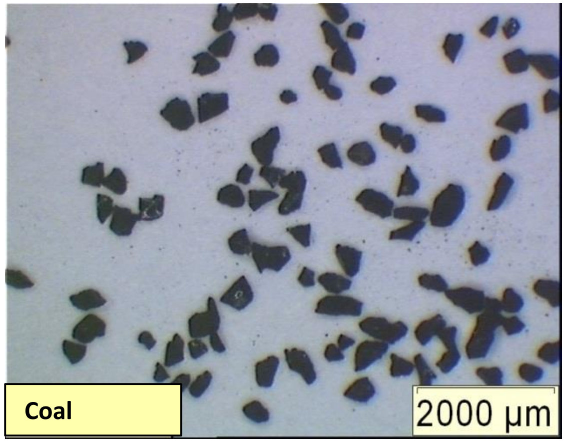
raw spruce chips



torrefied spruce pellets Andritz/ECN demo

torrefied spruce chips





coal

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End Use - (Co-)gasification in entrained flow gasifiers

Vattenfall presents results from tests performed outside SECTOR in 2012 in the Buggenum IGCC power plant in the Netherlands

Plant:

- 253 MWe power plant, entered service in 1993 as a coal gasification demonstration plant, and was closed in 2013
- Hard coal as main fuel with continuous co-gasification of saw dust up to 15 wt%
- Co-gasification of thermally treated wood was tested at the plant:
  - Torrefied pellets: ~1500 tons
  - Steam explosion pellets: ~5000 tons

Execution:

- Approximately 1200 tons of torrefied fuel was co- gasified together with hard coal in a 24 hours trial
- The mixing rate was ~70% on energy basis.

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End Use - (Co-)gasification in entrained flow gasifiers

Main observations:

- Tested torrefied pellets had a lower mechanical durability than white wood pellets resulting in a high dust formation during handling
- Long term outdoor storage of torrefied material requires an improvement in weather and water resistance of the pellets
- No big technical challenges were observed during conveying, sluicing and milling of the 70% mixture
- It was estimated to be possible to achieve 90% of the plant nominal capacity without major modification in fuel feeding system
- A higher heating value in the pellets was connected to better milling properties but less advantageous dust formation behavior

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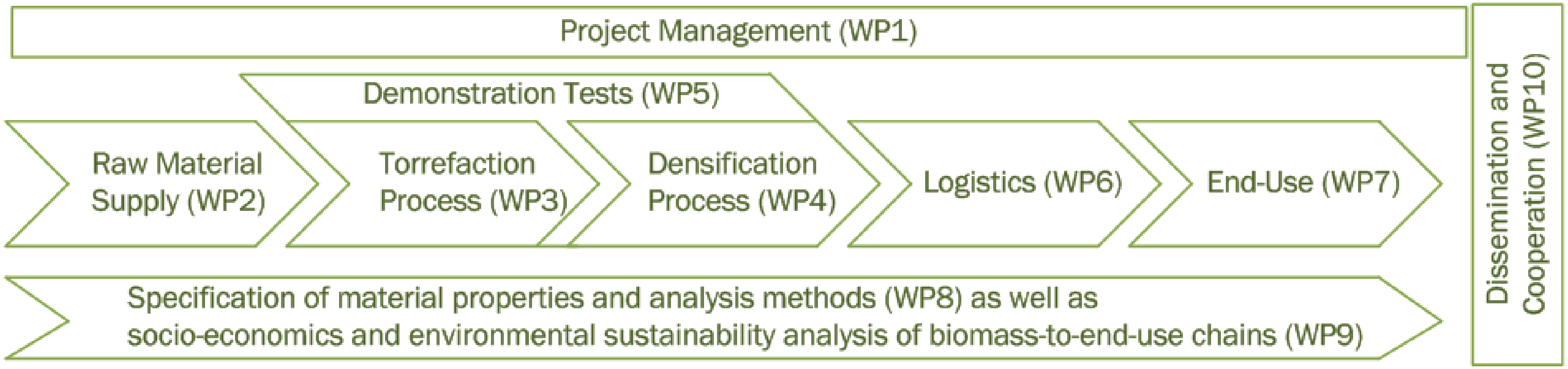

CONCLUSIONS

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Conclusions

- Torrefaction & torrefied products offer many advantages to reliably supply an energy efficient bioenergy carrier for use in entrained flow gasifiers
- Worldwide there are over 50 torrefaction developers / initiatives (planning capacities between 300 → 500 kt/a); first commercial demonstration projects are operative (e.g. Topell from NL 60 kt/a)
- Some highlights of the current work within SECTOR:
  - Up to 100 t of torrefied material have been produced and densified by project partners, further tests are scheduled
  - Extensive testing has been done with torrefied pellets in co-firing and gasification plants, as well as small scale combustion units
  - Standardisation work – proposal for a product standard including fuel specifications for torrefied material:
    - ISO 17225-1 publication date: April 2014
    - ISO 17225-8 work item accepted January 2014 – development until 2016
- **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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Torrefied biomass properties in perspective

	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)	7 – 12	15 – 17	18 – 22	30 – 32	23 – 28
Volatile matter (wt% db)	75 – 84	75 – 84	55 – 80	10 – 12	15 – 30
Fixed carbon (wt% db)	16 – 25	16 – 25	22 – 35	85 – 87	50 – 55
Bulk density (kg/l)	0.20 – 0.30	0.55 – 0.65	0.65 – 0.80	0.18 – 0.24	0.80 – 0.85
Vol. energy density (GJ/m³)	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	Moderate	Slow	None	None
Milling requirements	Special	Special	Standard	Standard	Standard
Product consistency	Limited	High	High	High	High
Transport cost	High	Medium	Low	Medium	Low





Abbreviations:
db = dry basis
LVH =Lower Heating Value

sources: ECN (table, fig.1, 3), Pixelio (fig. 2, 5), OFI (fig. 4)

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