Volatile Yields and Solid Grindability after Torrefaction of Various Biomass Types

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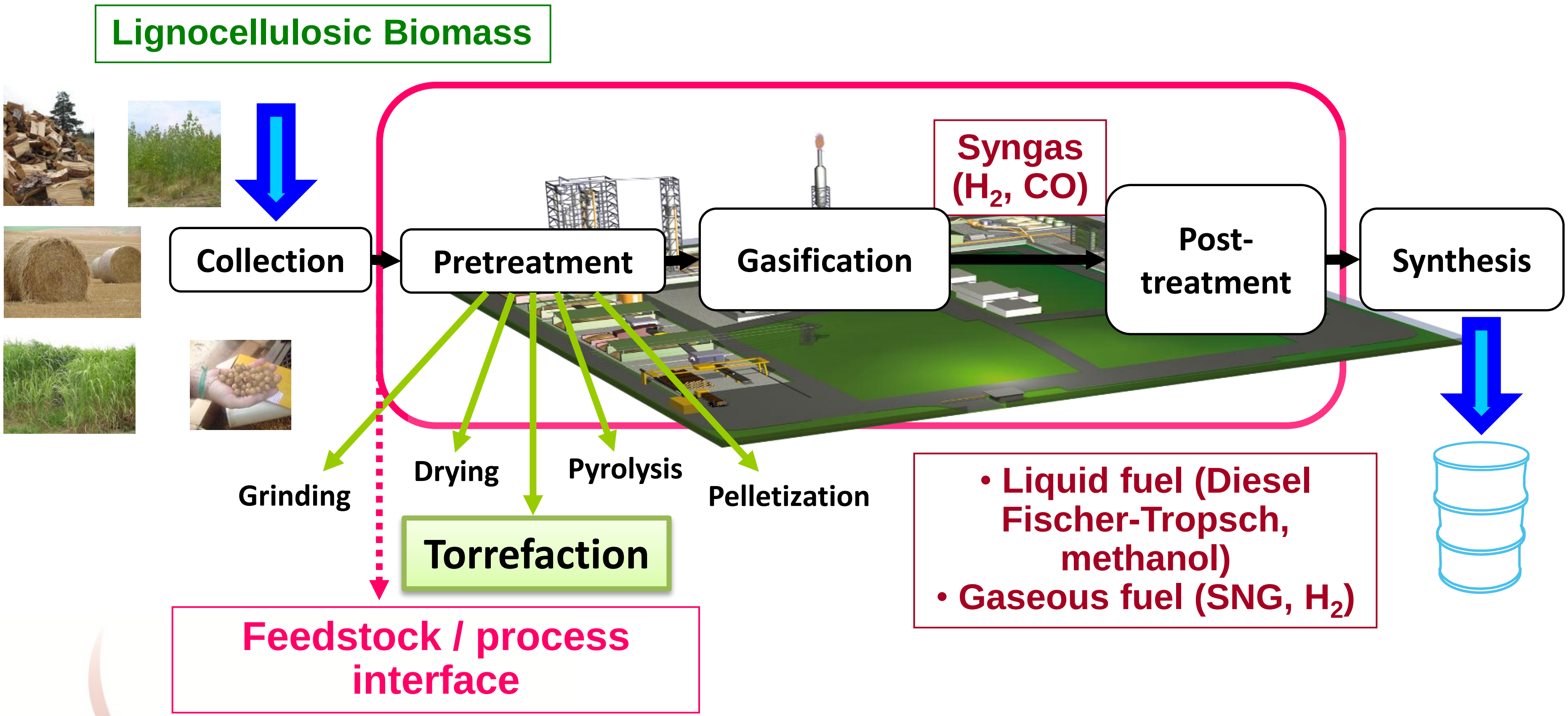
The process: from biomass to fuel



High feedstock variability ➡ Crucial issue for process industrialization!

↳Suitability feedstock / process?

Biomass torrefaction

- Smooth thermal transformation under inert atmosphere

→ Between drying and pyrolysis

  - T = 200-300°C
  - Residence time = 15 min – several hours
  - Atmospheric pressure

Biomass $C_6H_9O_4$
+ moisture~20%

→ **Volatile matter:**
- Gas (CO, CO_2)
- Condensable species (H_2O, acids...)

→ **Torrefied biomass**
$C_6H_8O_3$
+moisture~3%

- Solid properties get more coal-like
  - Decrease of H/C and O/C
  - Hydrophobic nature
  - Higher energy content
  - Improved grindability and powder flowability

Suitable for entrained flow gasification ←

Biomasses

Pine	Miscanthus	Wheat straw	Poplar
			

- Sampling according to XP CENT/TS 14786
- Grinding ≈ cm

Biomass	Proximate analysis (wt. %)				Ultimate analysis (wt. % daf)				LHV
	Moisture	Ash (db)	VM (db)	FC (db)	N	C	H	O	(MJ/kg db)
Pine	11.9	0.3	85.2	14.5	0.2	49.7	6.1	44.0	18.1
Miscanthus	8.2	2.2	80.9	16.9	0.3	49.2	6.2	44.3	18.0
Wheat straw	9.0	6.4	73.5	20.2	1.0	49.9	6.1	43.0	18.4
Poplar	9.0	3.4	81.0	15.6	0.2	51.0	5.9	42.8	18.4

Objective and working plan

Objective:

Characterization of products released during torrefaction of various biomass nature:

- Products mass balance
- Solid grindability

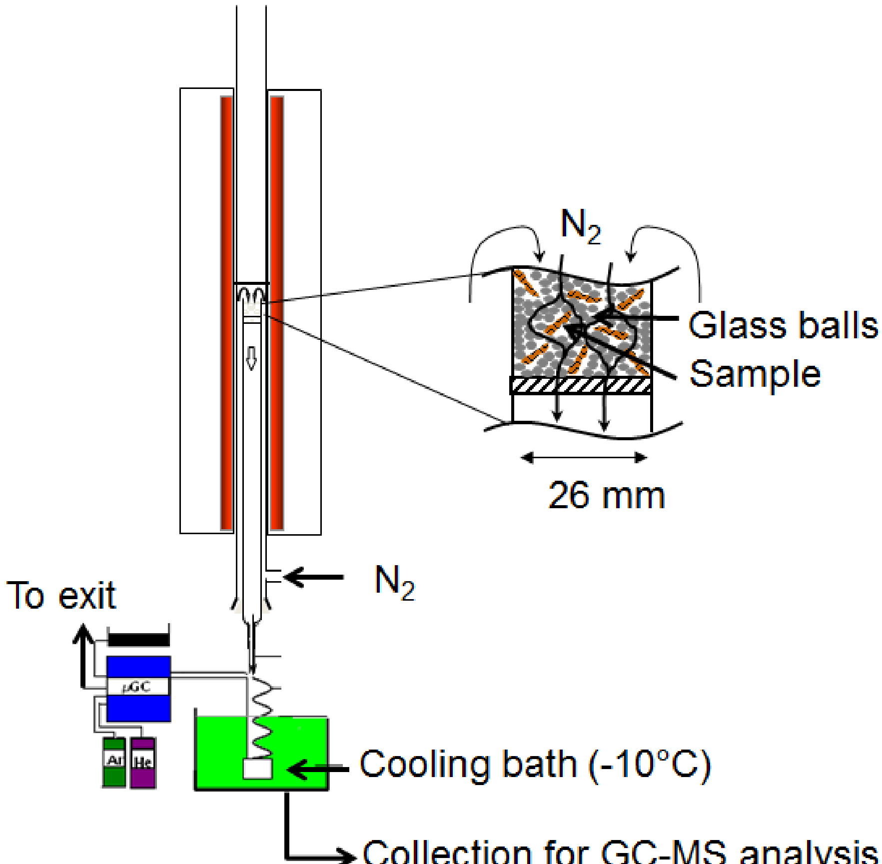
Working plan:

- Torrefaction experiments in lab-scale reactor
- Grindability tests on raw and torrefied biomasses

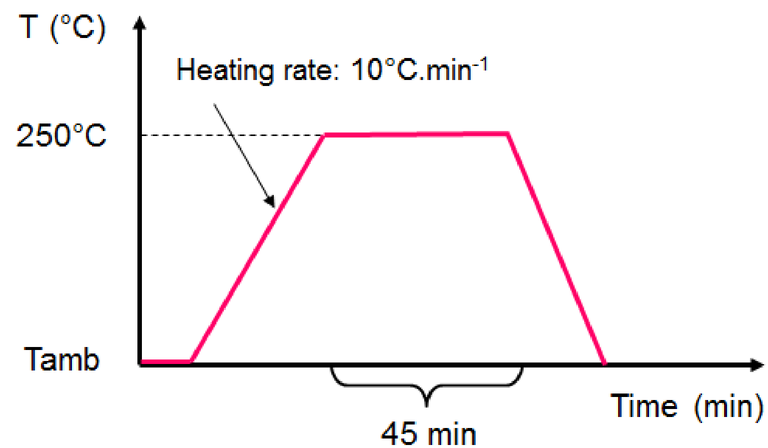
Lab-scale tests:
Products mass balance

The lab-scale device ALIGATOR

> Samples dried at 105°C according to XP CEN/TS 14774

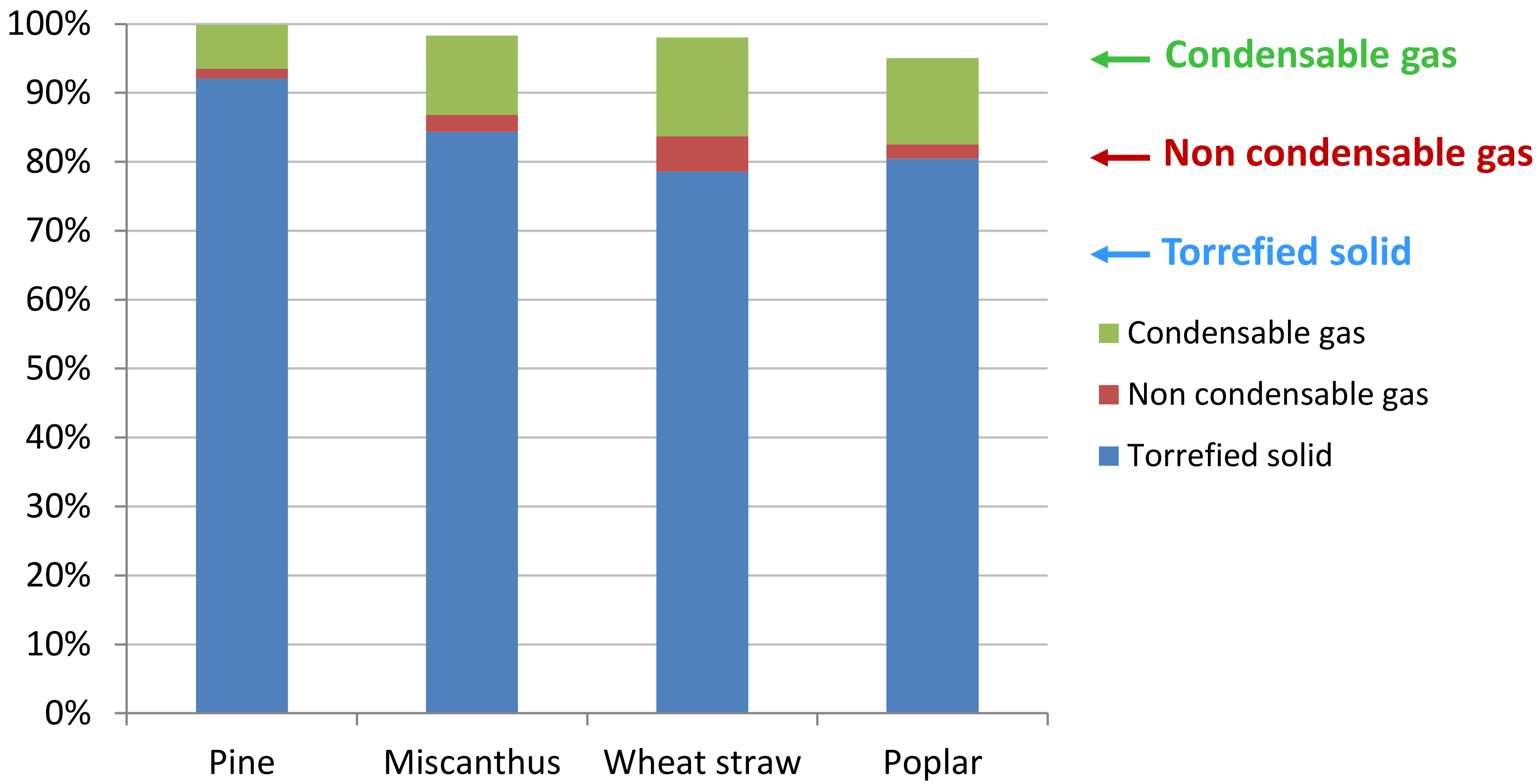


Temperature	250° C
Gas atmosphere	N_2
Gas flow	100 $mL.min^{-1}$
Pressure	atmospheric
Sample mass	~1.5 g



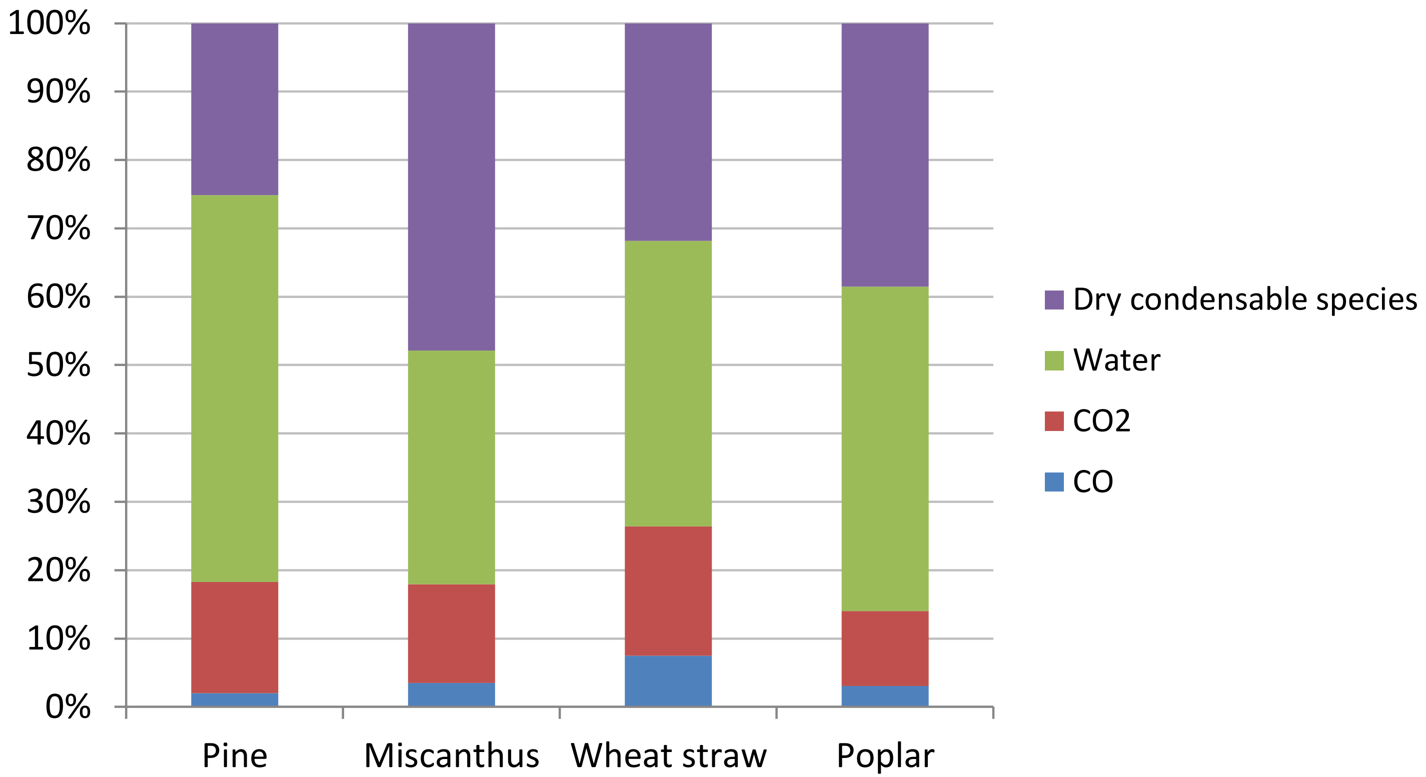
Global mass balance

Closure: 95 - 100%



- Global distribution depends on nature of biomass
  - Higher mass loss for agricultural by-products and SRC
- For all biomass types: Volatile species are mainly condensable

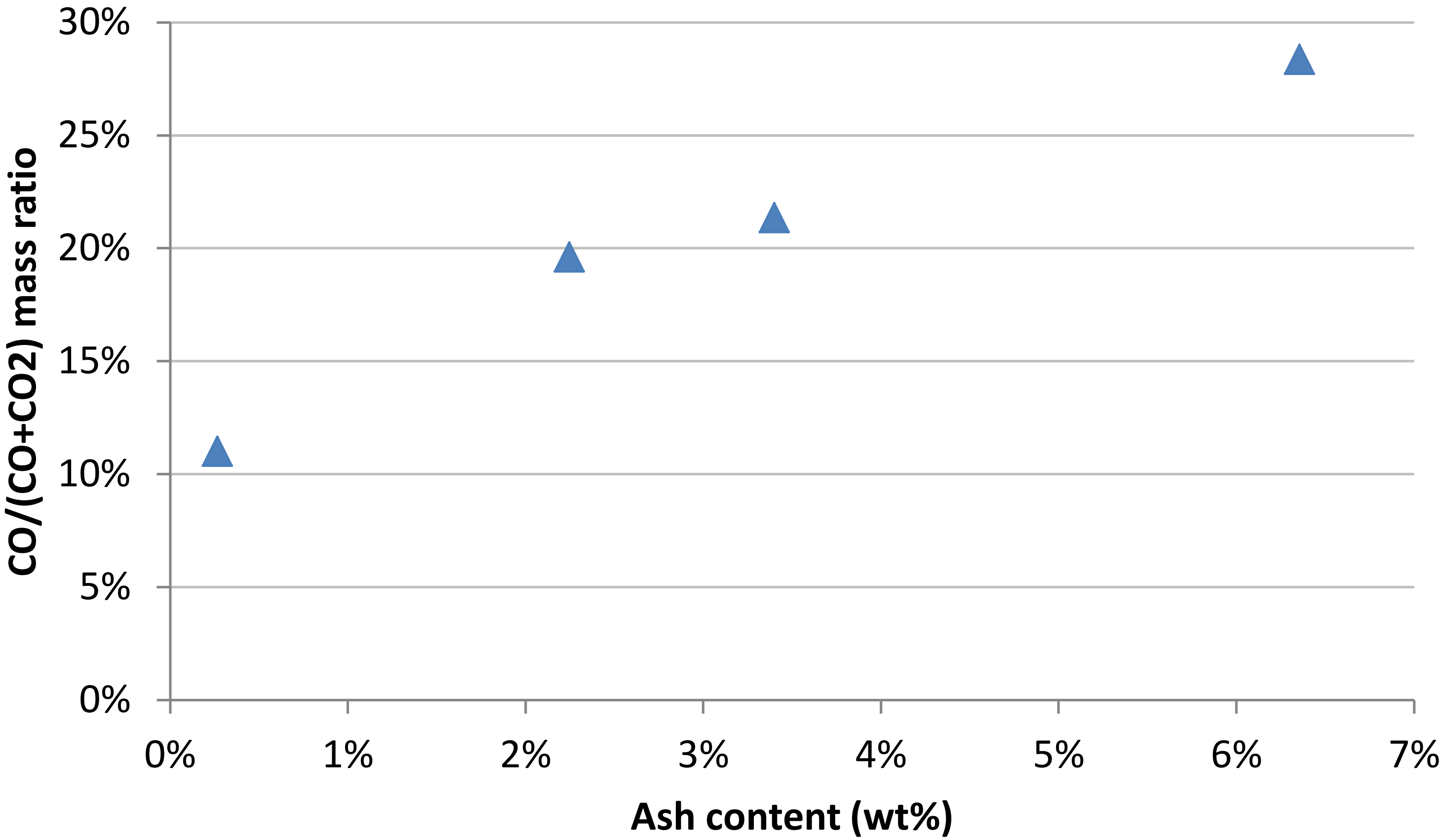
Mass balance: Volatile species



- Water and dry condensable: difference softwood/agricultural biomass
- CO: high content for agricultural by-products
  - Litt: CO_2 <= decarboxylation of acid groups

    CO ? Not clearly explained; catalytic reaction between CO2 and C?

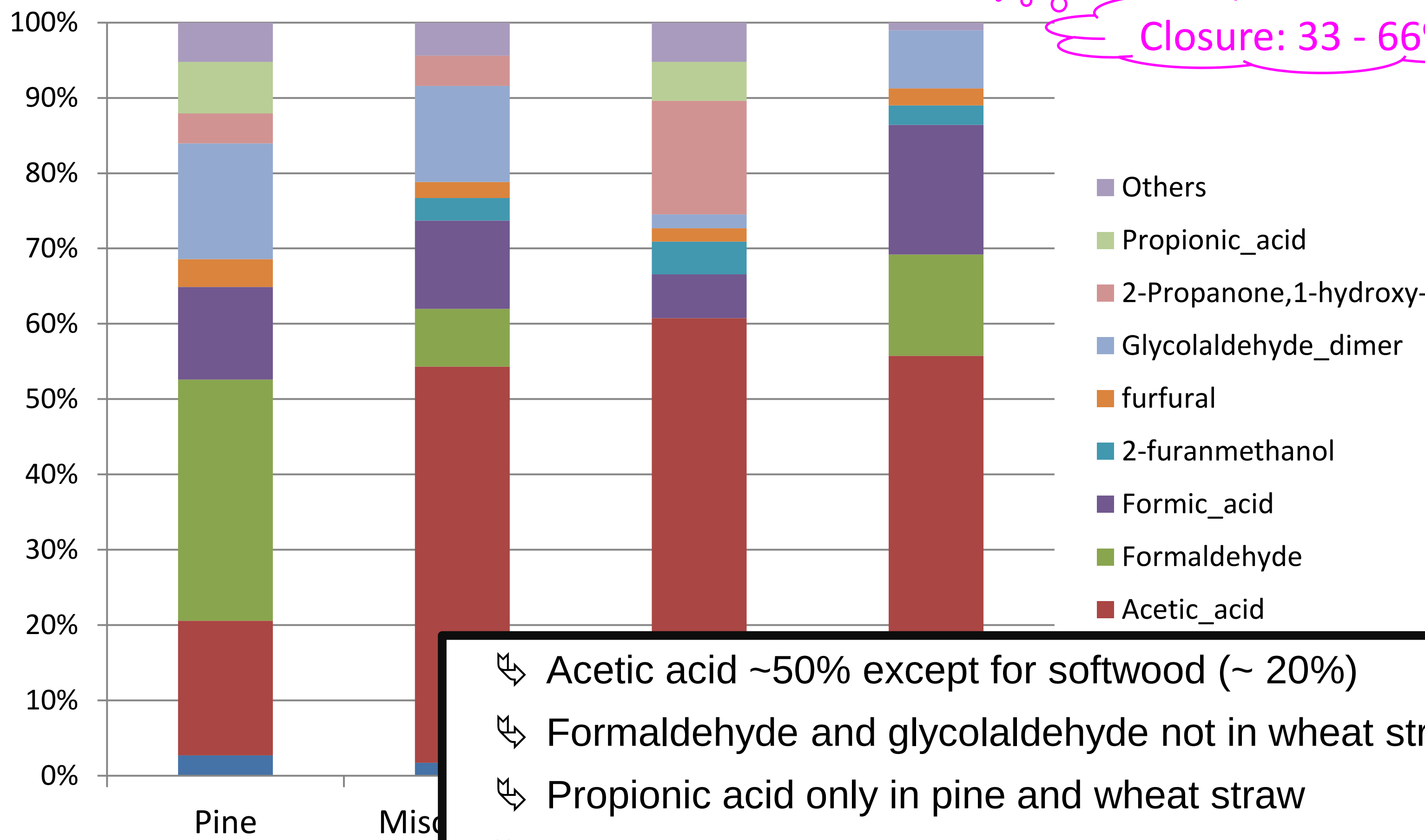
Mass balance: Volatile species



- CO/gas ratio increases with ash content
  - ↳ Mineral matter catalytic effect

Mass balance: dry condensable species

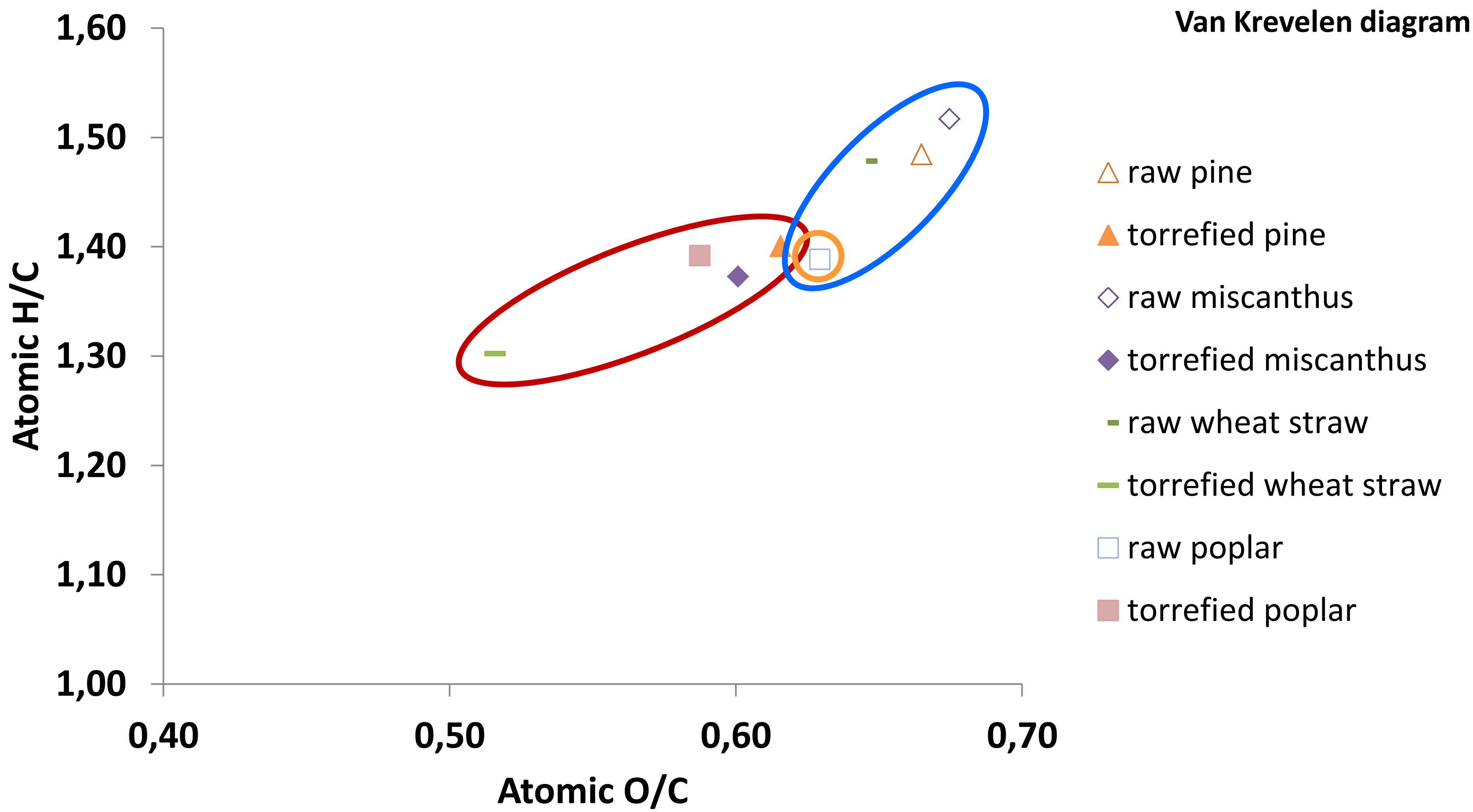
Closure: 33 - 66%



- Acetic acid ~50% except for softwood (~ 20%)
- Formaldehyde and glycolaldehyde not in wheat straw
- Propionic acid only in pine and wheat straw
- Furanmethanol not in pine
- Propanone high in wheat straw and absent in poplar
- Furfural in all biomasses

Impact on torrefaction cleaning step!

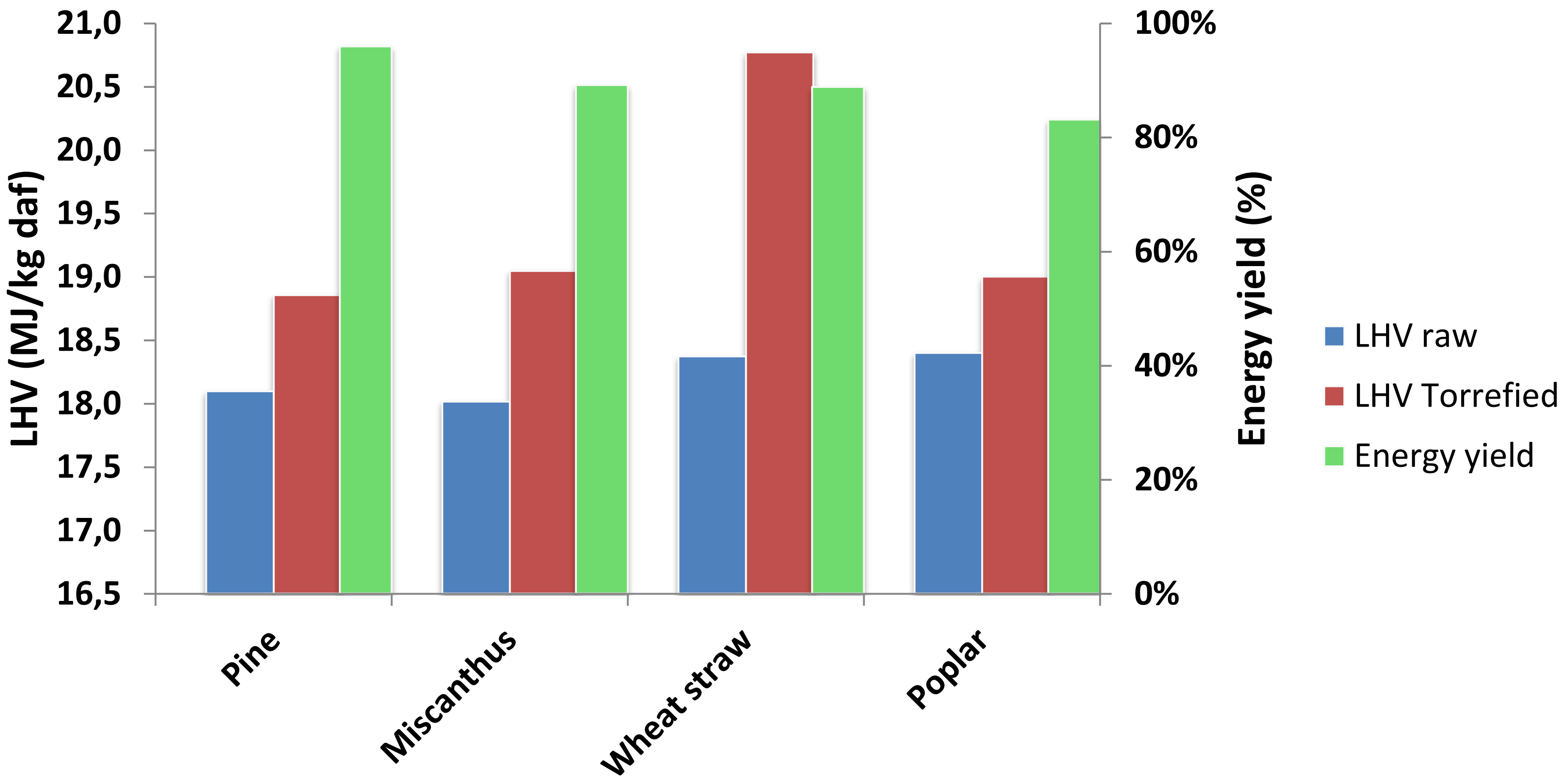
Torrefied solid composition



- Ratios H/C and O/C are similar for all raw biomasses, except for poplar
- Torrefied solids have lower ratios than raw biomasses

Torrefied solid: energy yield

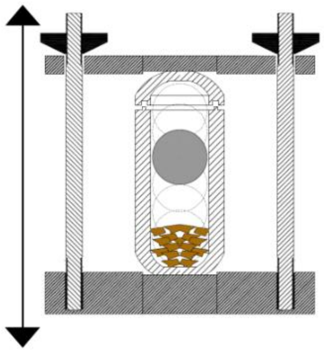
$$\text{Energy yield (\%)} = \frac{M_f}{M_o}\frac{GCV_f}{GCV_o} \times 100$$ (Arias, 2008)



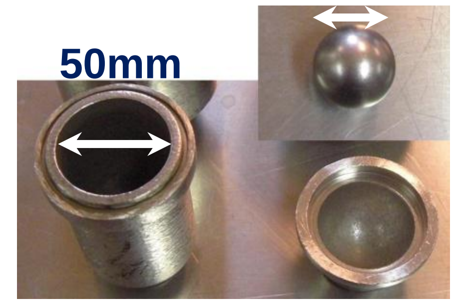
- LHV similar for raw biomasses ; LHV increases after torrefaction
- Highest energy yield for pine

Grindability tests

Grinding device



- Ball mill
- Protocol
  - ↳ volume of biomass: 50 cm^3
  - ↳ grinding time: 1 min



Particle size distribution

- Sieving following standard NF EN 15149
- Low weight sieves of ϕ = 60mm
  - ↳ 6 sieves from 1mm to 50µm

Torrefaction protocol

Objective:

To assess influence of nature of biomass on grindability

⇨ **mass loss ~ 17% for all biomasses**

↳ Adjustment of torrefaction temperature

	Torrefaction temp. (°C)	Mass loss (wt. %)
Pine	275	17.0
Miscanthus	250	16.9
Wheat straw	240	17.2
Poplar	245	17.6

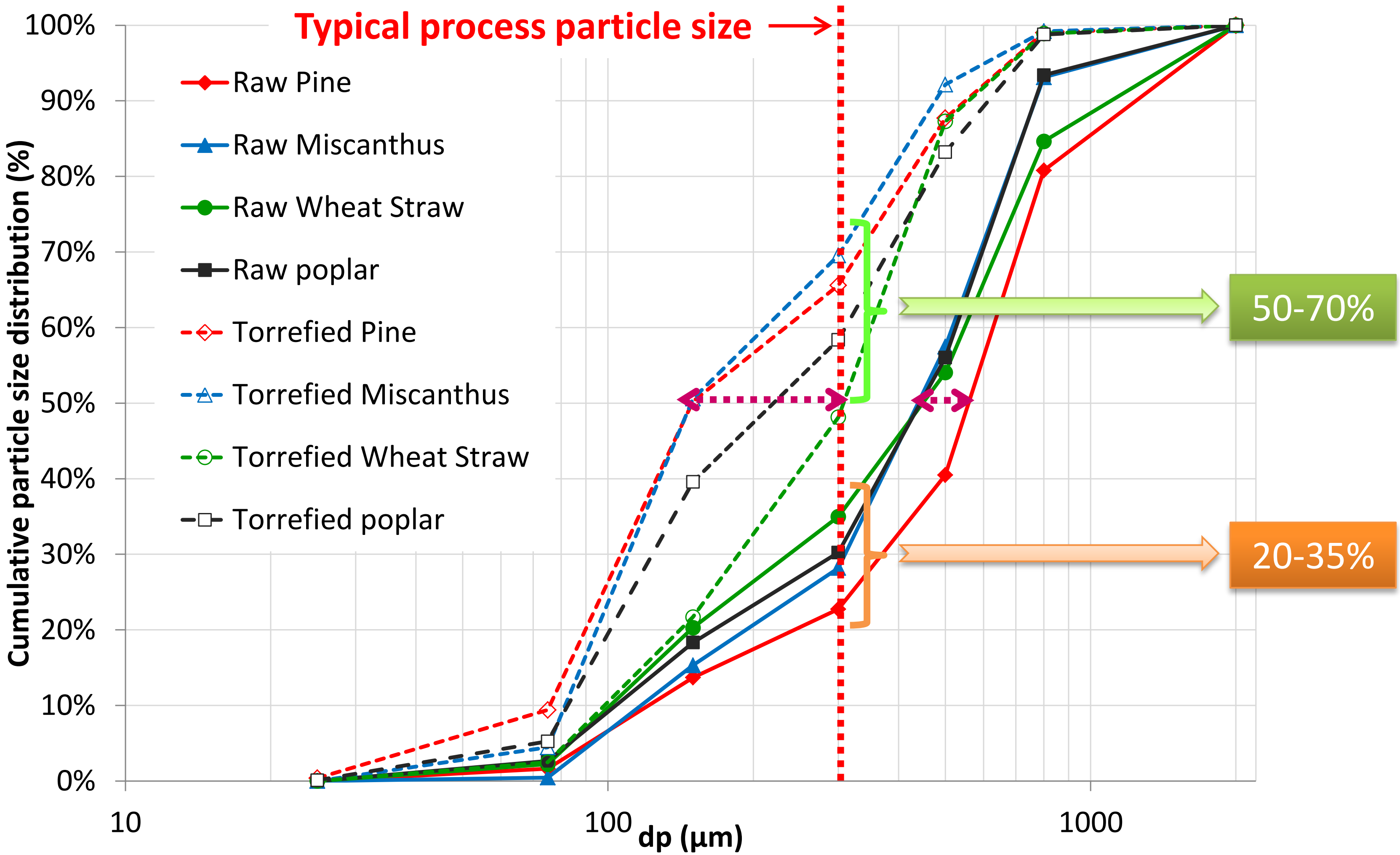
Relative grinding energy

Assumptions:

- Proportional to surface created
- Particles are spherical
- Same density whatever particle size

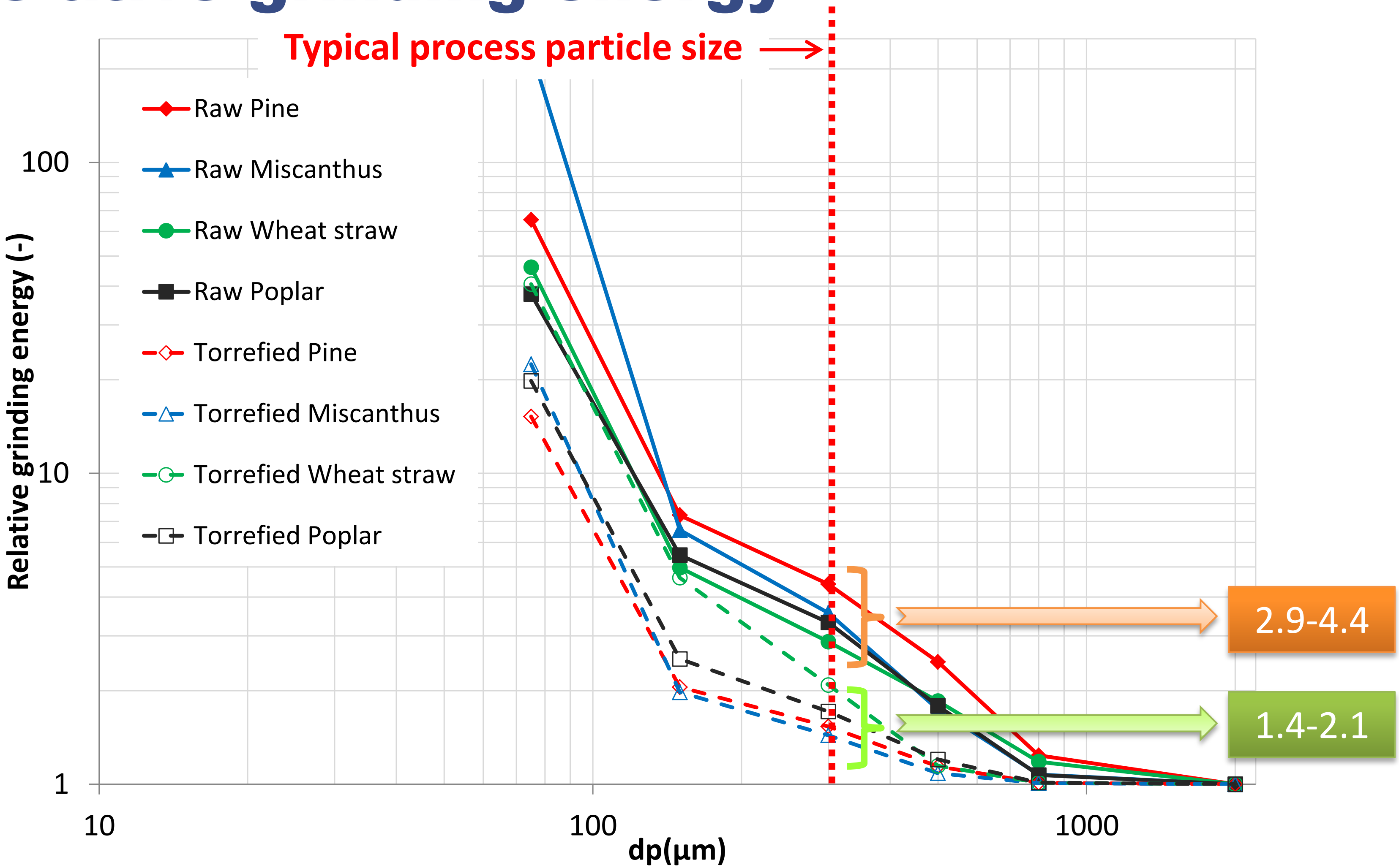
⇨ $$\text{Relative grinding energy} = \frac{1}{\text{Cumulative mass fraction}}$$

Particle size distribution



- Smaller particle sizes after torrefaction than raw biomass
- Large fraction of torrefied particles suitable to gasification

Relative grinding energy



- Torrefaction: energy ↘ by factor 2-3 at 300µm except for wheat straw (1.4)

Conclusion

Properties of products released during torrefaction of various biomasses?

- Torrefaction improves biomass grindability:
  - Grinding energy significantly reduced by torrefaction
  - Trend less marked for wheat straw

☺ Pine, Miscanthus, SRC ☹ Wheat straw

- Gaseous products composition depends on nature of biomass
  - To be considered for cleaning step
  - Interesting for species valorization in biorefinery process

☺ All biomasses???

⇨ depend on nature of the relevant species for chemical valorization

What's next?

- Tests on other samples
- Pilot scale tests ⇨ continuous torrefaction
- Comparison of grindability tests with measures on grinding energy at large scale
- Improvement of condensable species quantification

Thank you very much!

Merci de votre attention !

If you have any questions or want more details, please contact:

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