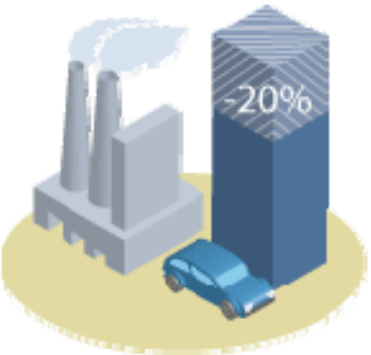
A photograph of a biomass combustion furnace. The furnace is dark-colored with a large glass window in the center. Through the window, a bright, intense flame is visible, indicating active combustion. The furnace is set against a dark red background. The text is overlaid on the image in white with a black outline.

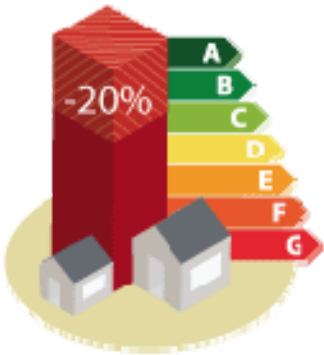
**Characterization, use and  
management of the ash residue from  
the combustion of solid biomass**

**Dott. Giovanni Mastrolonardo**

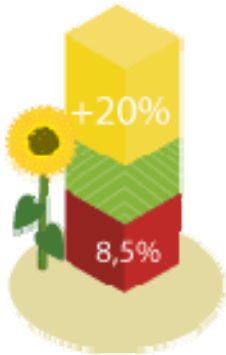
# EUROPE 2020 – the 20-20-20 strategy:



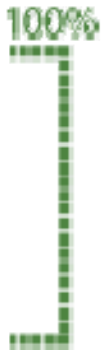
• Emissions



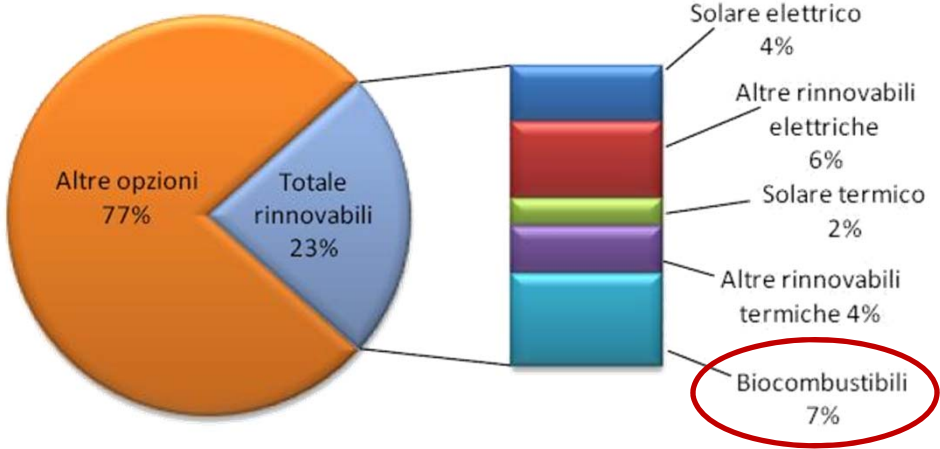
• Energy use



• Renewables



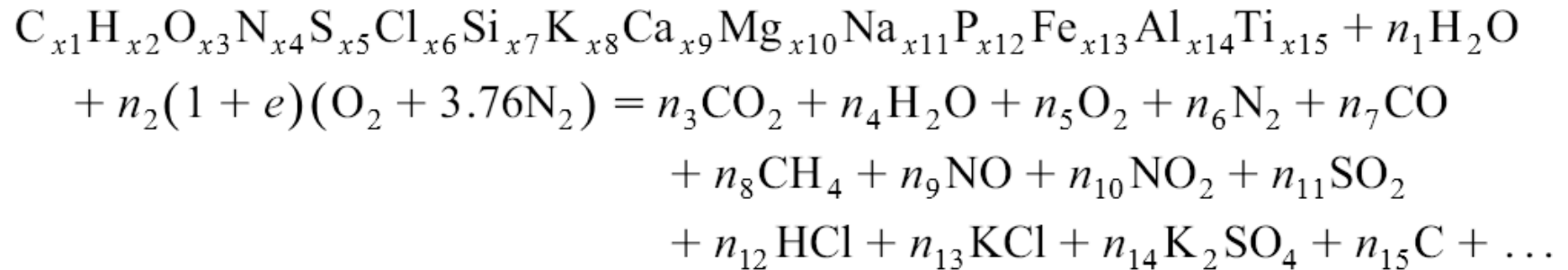
Contributo delle fonti rinnovabili alla riduzione delle emissioni di CO2 nello scenario di accelerazione tecnologica (2020)



- Wood
- Crops
- Residues

Fonte: elaborazione ENEA

# Combustion:



Ash can be defined as the solid residue of the combustion.

Woody biomass (DMB):

98%      organic matter

2%        minerals



Ash matter: in Europe ash production is about  $5.6 \times 10^5$  tons/year

Country	Ash from woody residues ( $10^5$ tons)	Ash from wood ( $10^5$ tons)
Cina	1,2 – 2,4	9,5 – 19,1
Brasil	1,1 – 2,2	1,4 – 2,7
USA	1,0 – 2,1	0,99 – 2,0
Russia	0,6 – 1,3	1,99 – 4,0

modified, from James et al., 2012

- Ash matter: a waste to dispose?

Alternative use: saving 30-60% of the net costs (Pitmann, 2006).

Possible uses:

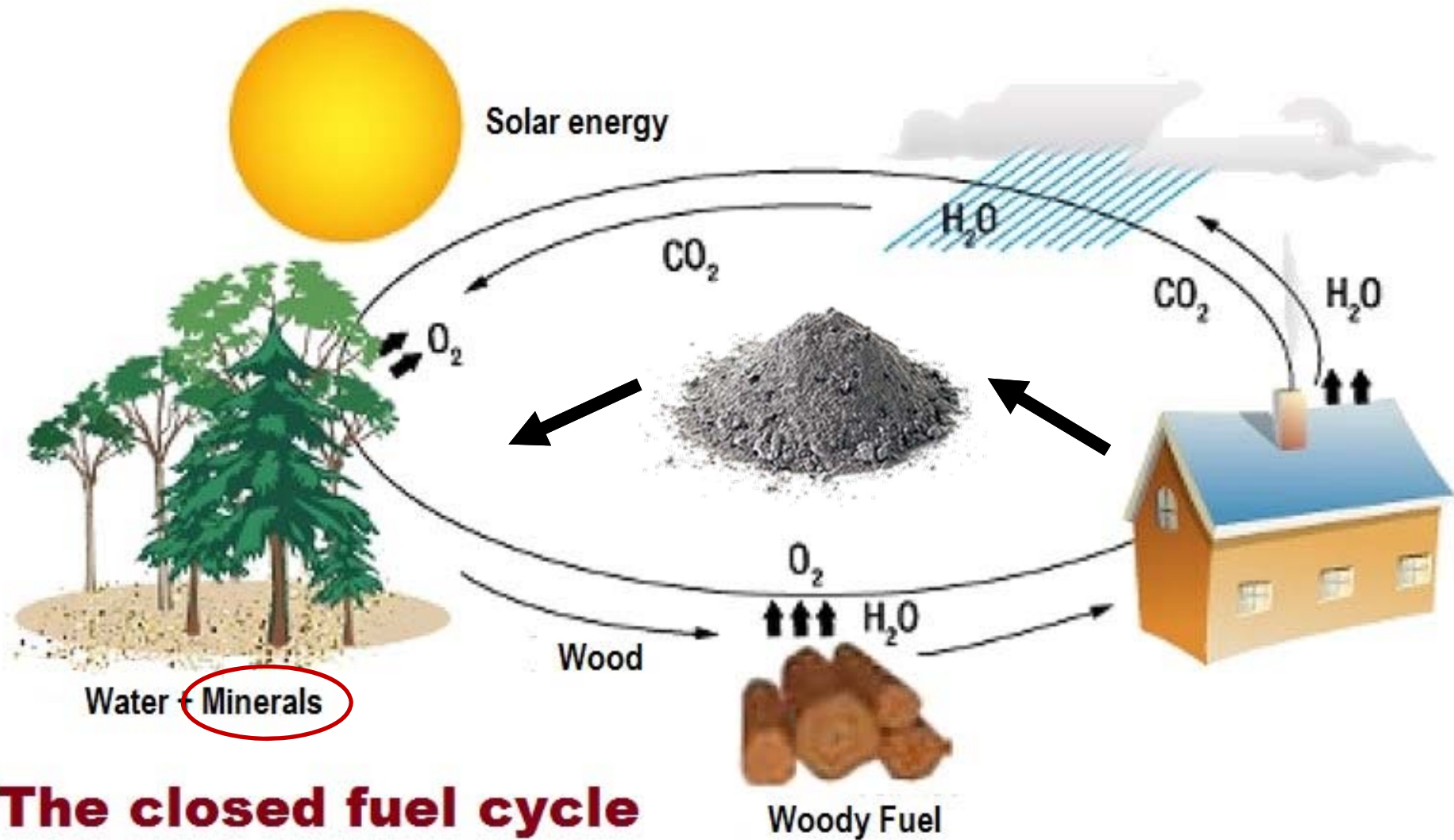
1. Fuel
2. Constructions
3. Agriculture and forestry



## Agriculture use of ashes:

- **Fertilizer**, adding to the soils minerals useful for plant growing, saving on the use of chemical fertilizers
- **Soil improver**, correcting the pH of soil towards higher values, containing cations in the form of oxides, hydroxides and carbonates.





Risks for the environment? Soil, plants, microorganisms?  
 How to use them? What are the benefits?

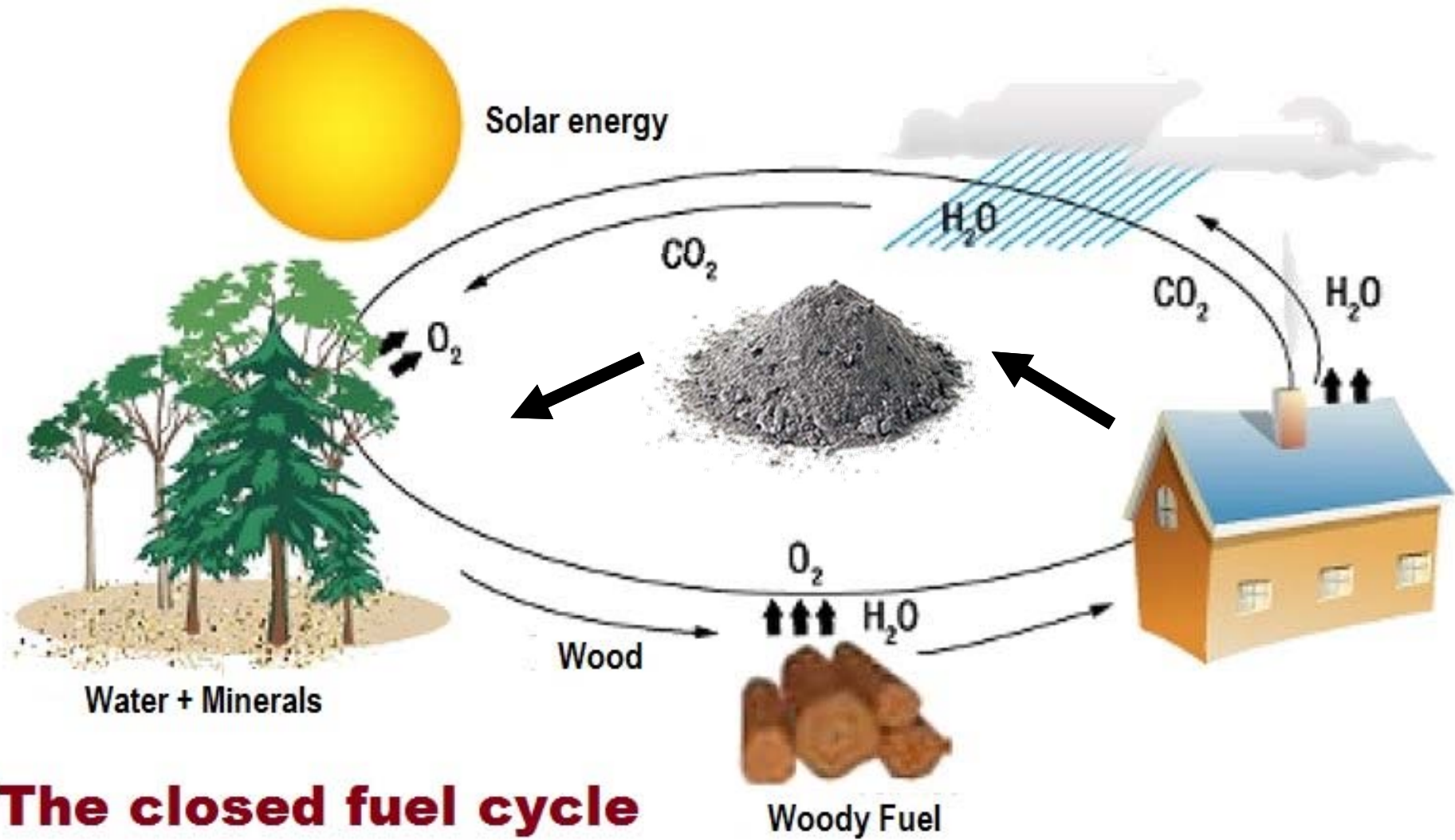
Ash quantity and composition can vary depending on plant type, part of the plant, soil conditions, fertilizers used, combustion etc.

Specie	T (°C)	Ash %	K %	Na %	Ca %	Mg %	Mn %	Fe %	Zn %	Si %	P %	S %
Pinus halepensis	600	3.27	13.00	1.78	19.2	8.84	1.12	0.91	0.28	2.55	3.13	3.61
	800	2.97	6.78	2.18	22.3	8.81	1.20	0.85	0.02	2.59	3.17	3.69
	1000	2.93	1.40	0.49	25.4	9.75	1.37	1.25	0.01	2.68	3.30	3.81
Olea europaea	600	4.94	13.01	0.52	32.8	4.22	1.15	1.67	0.50	0.55	1.56	2.89
	800	4.13	7.05	0.92	42.8	5.81	1.23	1.54	0.04	0.58	1.64	3.04
	1000	4.05	0.61	0.17	46.4	6.26	2.07	2.15	0.01	0.67	1.86	3.44
Cupressus	600	3.86	7.74	0.87	22.2	6.24	0.74	1.05	0.32	1.29	2.08	2.90
	800	3.43	4.61	1.02	28.9	7.93	1.14	1.62	0.03	1.33	2.14	2.99
	1000	3.05	0.47	0.15	35.8	9.12	1.81	1.95	0.01	1.40	2.26	3.15
Quercus coccifera	600	3.79	10.71	0.51	25.9	7.79	1.45	1.23	0.37	1.13	1.73	2.62
	800	2.78	4.64	0.96	37.1	10.2	2.04	1.41	0.03	1.24	1.91	2.87
	1000	2.70	1.23	0.12	38.8	14.1	2.33	2.05	0.01	1.51	2.30	3.49

Other elements are: As, Ba, B, Cd, Cu, Cr, Ag, Mo, Mg, Ni, V.....



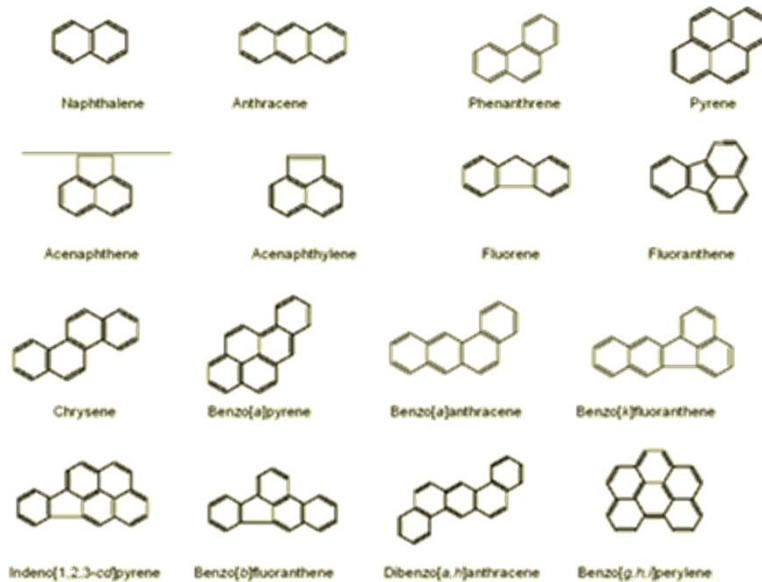
# Exogenous elements (pollutant)?



# Pollutants

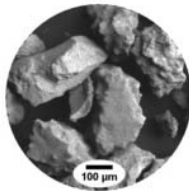
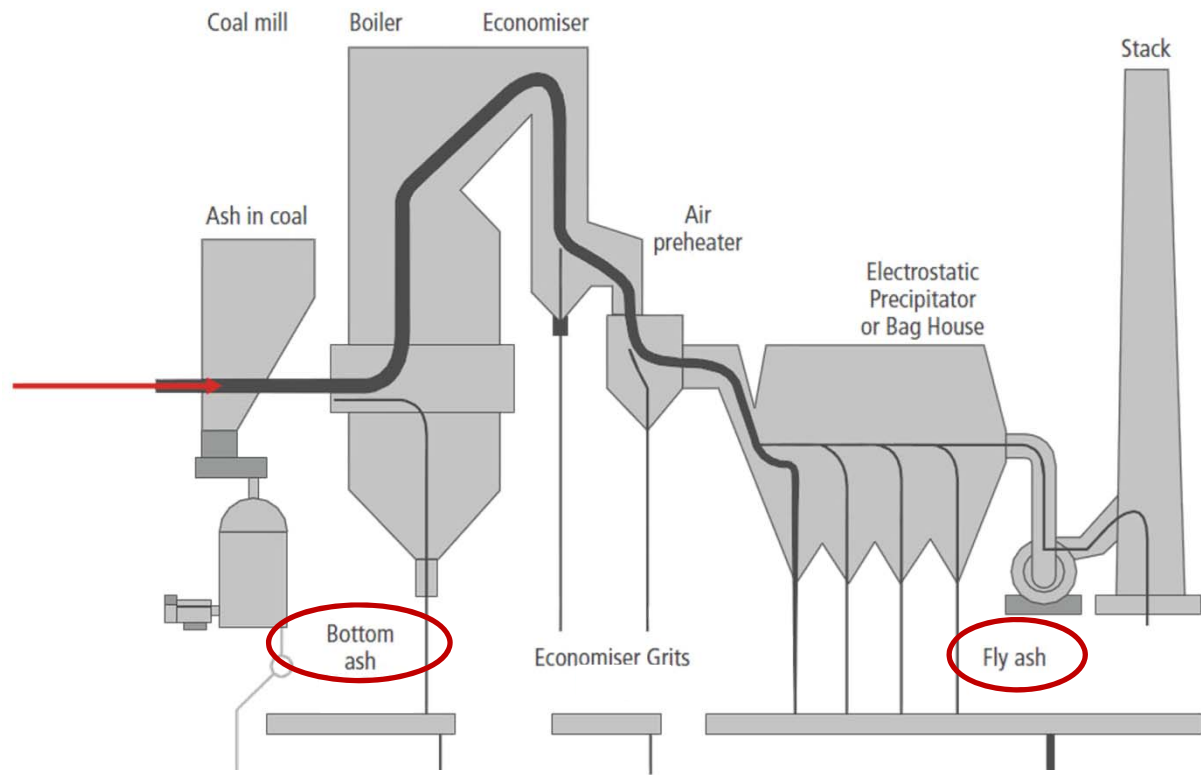
Ashes contains some elements that are potentially dangerous for humans and the environment, like chlorobenzenes.....

... Polycyclic Aromatic Hydrocarbons (PAH)...

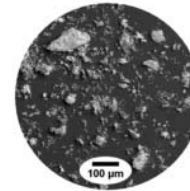


... heavy metals

- Copper
- Aluminum
- Manganese
- Lead
- Nickel
- Cadmium
- Cobalt
- Chromo
- Vanadium
- Arsenic
- Silicon



**Bottom ashes**  $> 1.3 \text{ g cm}^{-3}$



**Fly ashes**  $< 1 \text{ g cm}^{-3}$



PAH,  
Pb,  
Cd, Ar,  
Hg

# Ashes addition effects

## Effect on soil:

- Liming effect, neutralization of soil acidity
- Enrichment in soil nutrients

Potassium (K)

Calcium and magnesium (Ca; Mg)

Phosphorus (P)

=> High solubility

=> Average solubility

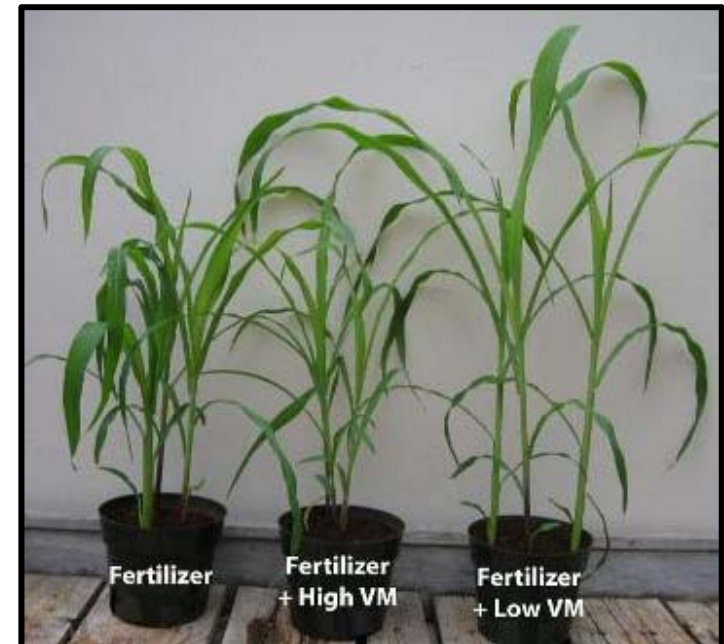
=> Low solubility



## Effects on plants:

- Plant growth and yield

**Cannot replace the nitrogen fertilization!!!**



# Ashes use

## Stored unaltered



- + Cheap
- Shorter storage times
- More difficult land spreading

## Pretreatment (granular)



- + Better preservation
- + Easier land spreading
- Expensive

# Spreading of ashes

Spreading of ashes can be done together with the other agronomic practices and can be performed by conventional fertilizer spreading equipment.



## Important:

- Ashes must be incorporated into the soil (tillage)
- Referring to the Good Agricultural Practice (GAP)

# How much in agricultural soils?

- In theory rebalancing the elements removed by the plants
- But, ashes contain some pollutants
- Maximum quantity 5-8 tons/hectare

Crop	Yield	Removal			Removal	Suggested quantity of ashes
		(kg/t crop)				
	(t/ha)	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	K <sub>2</sub> O (kg/ha)	(t/ha)*
Apple tree	20	2,3	0,8	3,8	76	1,1
Pear tree	8,5	2,3	0,8	3,8	76	1,1
Grapevine	8,5	2,2	0,6	4,8	40,8	0,6
Alfa alfa	10	/	5	16	160	2,3
Sunflower	2,5	27	11,7	9	22,5	0,3
Soy	3,5	/	13	20	70	1
Rapeseed	3,5	31	13	10	35	0,5

\* Referred to ashes containng an average K<sub>2</sub>O quantity of 7%

# What about ash use on forest lands?

- The harvest of trees can remove 20 - 60% of Ca and 2 – 10% of K, P, Mg
- Very complex ecosystems (animals, m.o., mosses and lichens)
- Very different duration of the “crop” cycle (up to 120 years)
- Application of ash on forest land is more difficult
- Limited effects on forest trees, except in peat soils.
- Higher mineralization of N soon after ash addition





# How much in forest soils?

- Whole tree-harvesting > 300% of log harvesting
- 10 - 30 t ha<sup>-1</sup> should recover the loss of nutrients (3 t ha<sup>-1</sup> each 10 years)
- Ash needs to be pre-treated for avoiding damages to forest *flora* and *fauna*



# Indirect application of ash

- Addition to manure or compost (2% w/w)

+ no pretreatment

+ acid neutralization

+ moisture absorption



# Legal issues about ash

There is not an European directive about ash use. Ashes are cited in the EU regulation 2092/91 that allow the use of ashes from virgin biomass in the organic productions.

**Finland and Sweden:** not strictly rules, limitation for Cd content and 3 t ha<sup>-1</sup> as suggested amount for forest soils.

**Holland:** similar

**Austria:** guidelines for each land use ->

**Forests:** max 3 t ha<sup>-1</sup> each 50 years

**Arable lands:** max 1 t ha<sup>-1</sup> year<sup>-1</sup>

**Grasslands:** max 0.7 t ha<sup>-1</sup> year<sup>-1</sup>

**Denmark:**

- Cd < 15 ppm
- Pb < 120 ppm
- Hg < 0.8 ppm
- Ni < 60 ppm
- PAH < 3 ppm



# Legal issues about ash

Ash as by-product (EU directive 2008/98):

1. The by-product is not the first goal of production
2. Certainty of the use of the by-product
3. By-product cannot undergo further treatment
4. By-product must be safe

# Concluding...

**Ash use as soil improver could be valuable, but not always or everywhere.**

- Ash from woody biomass are better, as those from hardwood.
- Avoiding using cork
- Combustion between 500-900 °C (high nutrients, low metals content)
- Avoiding fly ashes
- Pre-treatment of ashes is always strongly suggested
- As general rule: low ash load, long intervals
- Do not use ash along with weed killers as they can react
- The best soils are those with a low pH (4 – 5.5)
- Don't use ashes with acidophilus species



*Thank you for your  
attention!*

*[giovanni.mastrolonardo@gmail.com](mailto:giovanni.mastrolonardo@gmail.com)*