AgroBioHeat

Promoting the penetration of agrobiomass heating in European rural areas

Deliverable 6.3: Materials for training contents

Lead Beneficiaries

circe
RESEARCH CENTRE
FOR ENERGY RESOURCES
AND CONSUMPTION

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AgroBioHeat

Technologies and solutions for facilities operated with agrobiomass

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- Olive stones
- Nut shells
- Sunflower husks

Agricultural residues

- Straw
- Prunings and plantation removal

Dedicated energy crops

- Miscanthus
- Short rotation coppice

Biofuels based on agrobiomass:

STRAW

- One of the most abundant agricultural residue. Consists of dry stalks of cereal plants – Especially relevant in Denmark due to its current use and Spain and Ukraine due to its detected potential.
- Form: Bales
- Yield: 2,5-4 tons (dry matter) /hectare
- Use: Electricity or heat direct generation
- Potential: 127 million tons dry matter in the EU

Indicative fuel properties of straw

Property	Unit	Wheat straw
Moisture, M	w-% a.r.	15
Ash, A	w-% d.b.	5.0
Net Calorific Value, NCV	MJ/kg a.r.	14.6
Bulk Density, BD	kg/m^3 a.r.	100 (bales) / 60 (chopped)
Energy Density	MWh/m^3 a.r.	0.41 (bales) / 0.24 (chopped)
Nitrogen, N	w-% d.b.	0.5
Sulphur, S	w-% d.b.	0.1
Chlorine, Cl	w-% d.b.	0.4
Calcium, Ca	mg/kg d.b.	4,000
Potassium, K	mg/kg d.b.	10,000
Sodium, Na	mg/kg d.b.	500
Silica, Si	mg/kg d.b.	10,000

Note: indicative values shown

Source: AgroBioHeat D4.2 – Agrobiomass Fuels and Utilization Systems

Sources of additional information:

Annex B of EN ISO 17225-1

PRUNINGS & PLANTATION REMOVAL

- Established horticultural practice of cutting and removing selected parts of a tree - the term also refers to the residual biomass generated by the practice. Thick parts of pruning wood can be collected separately and used as firewood in some cases; however, most of the pruning biomass is left on the field and is either burned in open fires or – less frequently - mulched in the soil.
- Plantation removal is the clearing out of trees at the end of the lifetime of a plantation
- Form: Pruning – Bales or hog fuel; PR – firewood or hog fuel
- Yield: Pruning: 1-5 tons (dry matter)/hectare; PR: 50 tons /hectare
- Use: Mostly underutilized
- Potential: 11,5 million tons dry matter in the EU

Indicative fuel properties of agricultural prunings

Property	Unit	Olive tree pruning hog fuel	Vineyard pruning pellets
Moisture, M	w-% a.r.	27	10
Ash, A	w-% d.b.	4.2	4.5
Net Calorific Value, NCV	MJ/kg a.r.	12.9	15.7
Bulk Density, BD	kg/m^3 a.r.	230	710
Energy Density	MWh/m^3 a.r.	0.83	3.10
Nitrogen, N	w-% d.b.	0.93	0.81
Sulphur, S	w-% d.b.	0.08	0.07
Chlorine, Cl	w-% d.b.	0.04	0.02
Calcium, Ca	mg/kg d.b.	9,000	10,000
Potassium, K	mg/kg d.b.	5,600	5,400
Sodium, Na	mg/kg d.b.	460	170
Silica, Si	mg/kg d.b.	2,100	2,800

Note: indicative values shown

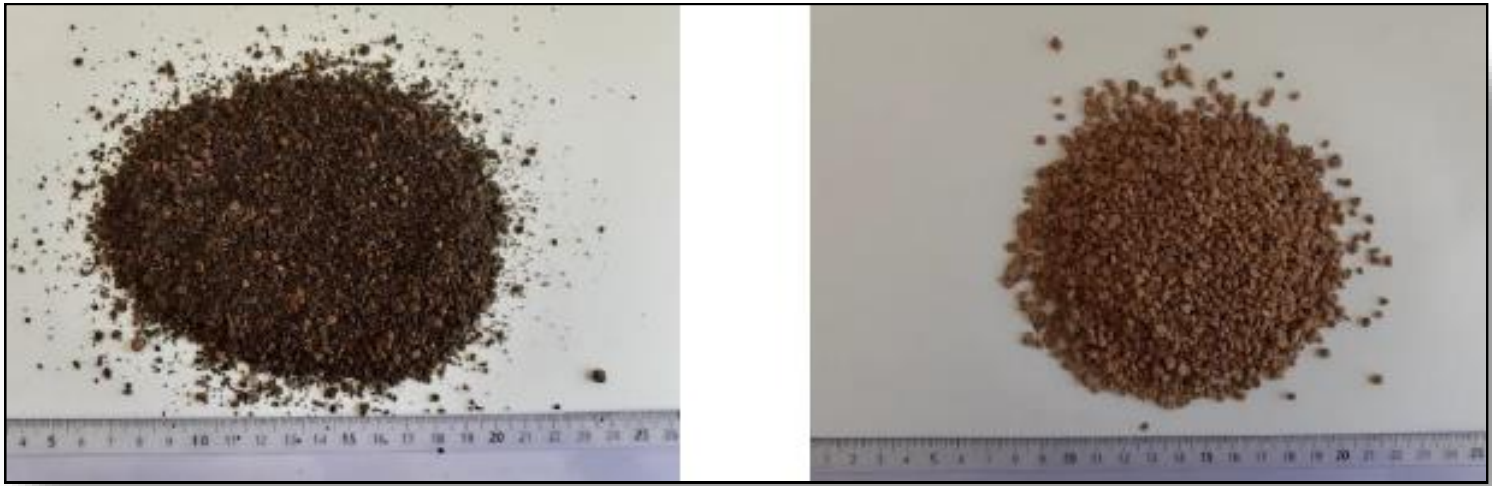
Source: AgroBioHeat D4.2 – Agrobiomass Fuels and Utilization Systems

Sources of additional information:

Annex B of EN ISO 17225-1, Deliverable D3.2 of the Biomasud Plus project

OLIVE STONES

- By-product of olive oil processing: Olive cake. Can be used as industrial fuel but has limitations. Olive stones could be used for domestic heating.
- Form: Crushed granular fuel
- Yield: 10-20 % of the whole fruit
- Use: Heating (industrial or domestic) + activated carbon production
- Potential: 770 000 dry tons (in the EU)
- Certification: BIOmasud



Indicative fuel properties of olive stones

Property	Unit	Olive stones	BIOmasud® class limits (v15.0)		
			A1	A2	B
Moisture, M	w-% a.r.	15	≤ 12	≤ 12	≤ 16
Ash, A	w-% d.b.	1.2	≤ 0.7	≤ 1.0	≤ 1.5
Net Calorific Value, NCV	MJ/kg a.r.	15.8	≥ 15.7	≥ 15.7	≥ 14.9
Bulk Density, BD	kg/m^3 a.r.	730	≥ 700	≥650	≥600
Energy Density	MWh/m^3 a.r.	3.20	≥ 3.05*	≥ 2.83*	≥ 2.48*
Nitrogen, N	w-% d.b.	0.3	≤ 0.3	≤ 0.4	≤ 0.6
Sulphur, S	w-% d.b.	0.02	≤ 0.03	≤ 0.04	≤ 0.05
Chlorine, Cl	w-% d.b.	0.1	≤ 0.03	≤ 0.04	≤ 0.05
Calcium, Ca	mg/kg d.b.	1,300	-	-	-
Potassium, K	mg/kg d.b.	2,300	-	-	-
Sodium, Na	mg/kg d.b.	600	-	-	-
Silica, Si	mg/kg d.b.	900	-	-	-

Note: indicative values shown

Source: AgroBioHeat D4.2 – Agrobiomass Fuels and Utilization Systems

Sources of additional information:

Annex B of EN ISO 17225-1, Deliverable D3.2 of the Biomasud Plus project

NUT SHELLS

- By-product of nut hulling industry. Good energy content and low moisture and ash.
- Form: Crushed granular fuel
- Yield: 50 % of the weight of the nut
- Use: Heating (industrial or domestic) + activated carbon production, furfural and soil cover
- Potential: 270 000 dry tons (in the EU)
- Certification: BIOmasud

Indicative fuel properties of almond shells

Property	Units	Almond shells	BIOmasud® class limits (v15.0)		
			A1	A2	B
Moisture, M	w-% a.r.	11	≤ 12	≤ 12	≤ 16
Ash, A	w-% d.b.	1.6	≤ 0.7	≤ 1.5	≤ 2.0
Net Calorific Value, NCV	MJ/kg a.r.	16.1	≥ 15.0	≥ 15.0	≥ 14.2
Bulk Density, BD	kg/m^3 a.r.	410	≥ 500	≥ 300	≥ 270
Energy Density	MWh/m^3 a.r.	1.83	≥ 2.08*	≥ 1.25*	≥ 1.07*
Nitrogen, N	w-% d.b.	0.4	≤ 0.4	≤ 0.6	≤ 0.8
Sulphur, S	w-% d.b.	0.01	≤ 0.03	≤ 0.03	≤ 0.04
Chlorine, Cl	w-% d.b.	0.02	≤ 0.02	≤ 0.02	≤ 0.03
Calcium, Ca	mg/kg d.b.	1,300	-	-	-
Potassium, K	mg/kg d.b.	4,600	-	-	-
Sodium, Na	mg/kg d.b.	2,500	-	-	-
Silica, Si	mg/kg d.b.	630	-	-	-

Note: indicative values shown

Source: AgroBioHeat D4.2 – Agrobiomass Fuels and Utilization Systems

Sources of additional information:

Annex B of EN ISO 17225-1, Deliverable D3.2 of the Biomasud Plus project

SUNFLOWER HUSKS

- Herbaceous oilseed crop. By-product of the sunflower oil extraction process. High energy content, low price and high energy density.
- Form: Granular fuel or upgraded to pellets / briquetts
- Yield: 20-30% of the total processed seed weight
- Use: Industrial fuel for heating/electricity production
- Potential: 18 million hectares

AgroBioHeat D4.2 – Agrobiomass Fuels and Utilization Systems

Indicative fuel properties of sunflower husk pellets

Property	Unit	Sunflower husk pellets
Moisture, M	w-% a.r.	10
Ash, A	w-% d.b.	4.0
Net Calorific Value, NCV	MJ/kg a.r.	15.7
Bulk Density, BD	kg/m^3 a.r.	550
Energy Density	MWh/m^3 a.r.	2.40
Nitrogen, N	w-% d.b.	0.8
Sulphur, S	w-% d.b.	0.1
Chlorine, Cl	w-% d.b.	0.06
Calcium, Ca	mg/kg d.b.	5,000
Potassium, K	mg/kg d.b.	11,000
Sodium, Na	mg/kg d.b.	50
Silica, Si	mg/kg d.b.	600

Note: indicative values shown

Source: AgroBioHeat D4.2 – Agrobiomass Fuels and Utilization Systems

DEDICATED ENERGY CROPS

- Plants grown specifically for their energetic value.
- ABH focus on those used in thermochemical conversion processes
- They can be either herbaceous (miscanthus) or woody (poplar, willow)
- Adaptable to different climate and soil conditions

MISCANTHUS

- 17 species of non-wood rhizomatous tall grasses.
- Exceptionally adaptable to different climates and resistance to diseases and pests.
- Form: Mowed or baled, chipped. Also upgraded into pellets/briquettes
- Yield: variable. 10 t dry matter/hectare
- Use: Fuel for combustion to produce heat, electricity or CHP.
- Potential: At least 24 620 hectares in Europe, with a yield between 10-50 tdm/ha·y depending on the harvest time, soil, climate conditions and management practices.*

AgroBioHeat D4.2 – Agrobiomass Fuels and Utilization Systems
*Ben Fradj, N. et al, Industrial Crops & Products 148 (2020) 1122814

Indicative fuel properties of miscanthus

Property	Unit	Miscanthus
Moisture, M	w-% a.r.	15
Ash, A	w-% d.b.	4.0
Net Calorific Value, NCV	MJ/kg a.r.	14.7
Bulk Density, BD	kg/m^3 a.r.	130 (chopped)
Energy Density	MWh/m^3 a.r.	0.53 (chopped)
Nitrogen, N	w-% d.b.	0.7
Sulphur, S	w-% d.b.	0.2
Chlorine, Cl	w-% d.b.	0.2
Calcium, Ca	mg/kg d.b.	2,000
Potassium, K	mg/kg d.b.	7,000
Sodium, Na	mg/kg d.b.	70
Silica, Si	mg/kg d.b.	8,000

Note: indicative values shown

Source: AgroBioHeat D4.2 – Agrobiomass Fuels and Utilization Systems

SHORT ROTATION COPPICE

- Woody fast-growing trees – high biomass yields in short periods.
- Willow, poplar and alder or eucalyptus. Three-year cycles over 20-25 years.
- Form: Chips, pellets
- Yield: variable. 5-18 tons dry matter/hectare
- Use: Combustion processes. Also pulp and paper industyr
- Potential: 206,910 ha of poplar (average dry biomass yield of 5.3 ton/ha·y *) and 19,378 ha of willow (average dry biomass yield of 6,6 ton/ha·y **)
- Certification: Enplus (SRC pellets) and GoodChips (SRC wood chips)

AgroBioHeat D4.2 – Agrobiomass Fuels and Utilization Systems
*Dillen, S.Y. et al., Biomass and Bioenergy, 56 (2013) 157-165
**Kulig B., et al., Plant Soil Environ., 65 (2019):377-386.

Indicative fuel properties of SRC (willow, poplar)

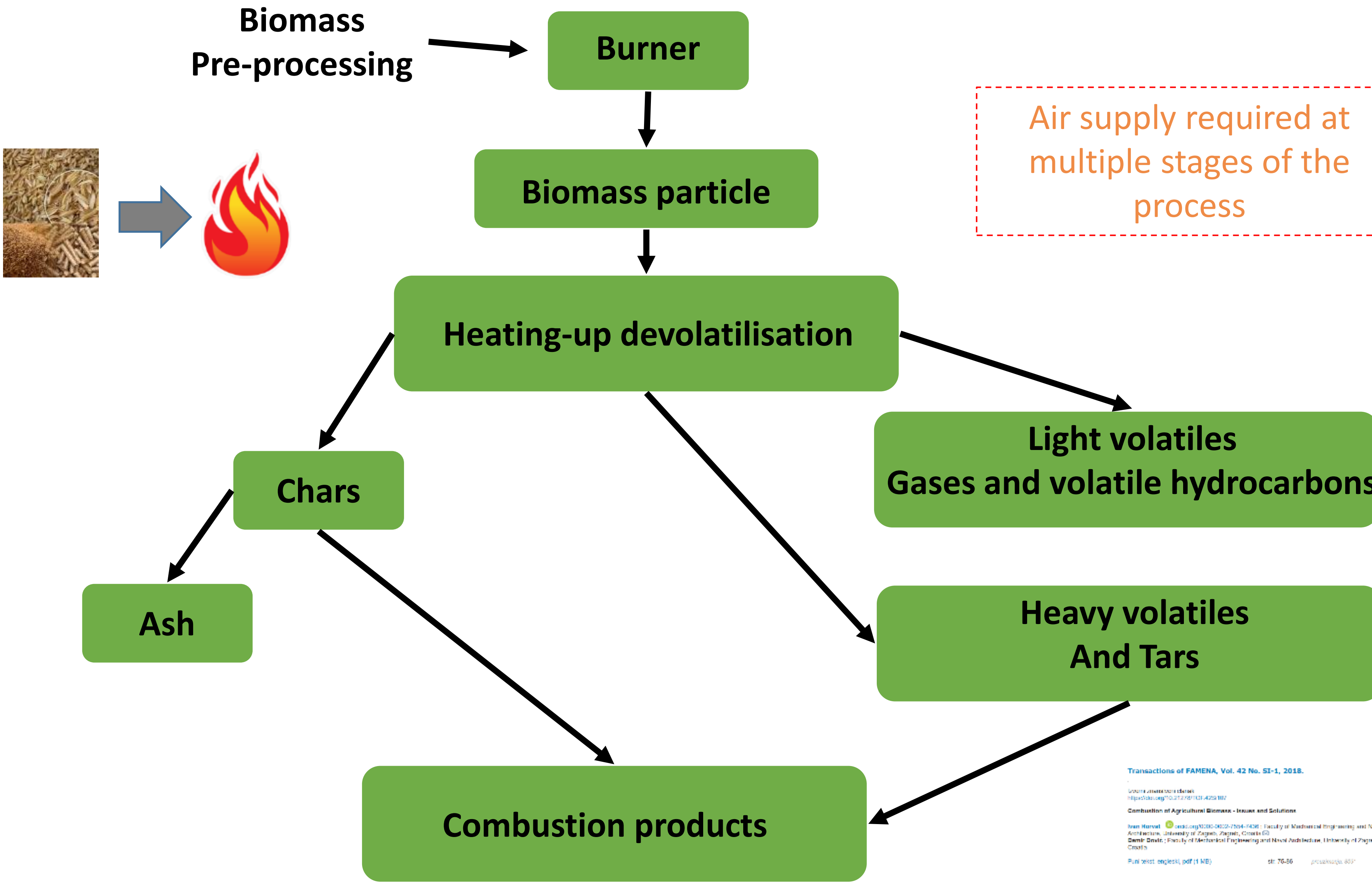
Property	Unit	Willow & Poplar
Moisture, M	w-% a.r.	50 (fresh)
Ash, A	w-% d.b.	2.0
Net Calorific Value, NCV	MJ/kg a.r.	8.0
Bulk Density, BD	kg/m^3 a.r.	250 (chips)
Energy Density	MWh/m^3 a.r.	0.56 (chips)
Nitrogen, N	w-% d.b.	0.5
Sulphur, S	w-% d.b.	0.04
Chlorine, Cl	w-% d.b.	0.02
Calcium, Ca	mg/kg d.b.	5,000
Potassium, K	mg/kg d.b.	2,500
Sodium, Na	mg/kg d.b.	25
Silica, Si	mg/kg d.b.	500

Note: indicative values shown

Source: AgroBioHeat D4.2 – Agrobiomass Fuels and Utilization Systems

Contents:

Mechanism of agrobiomass combustion

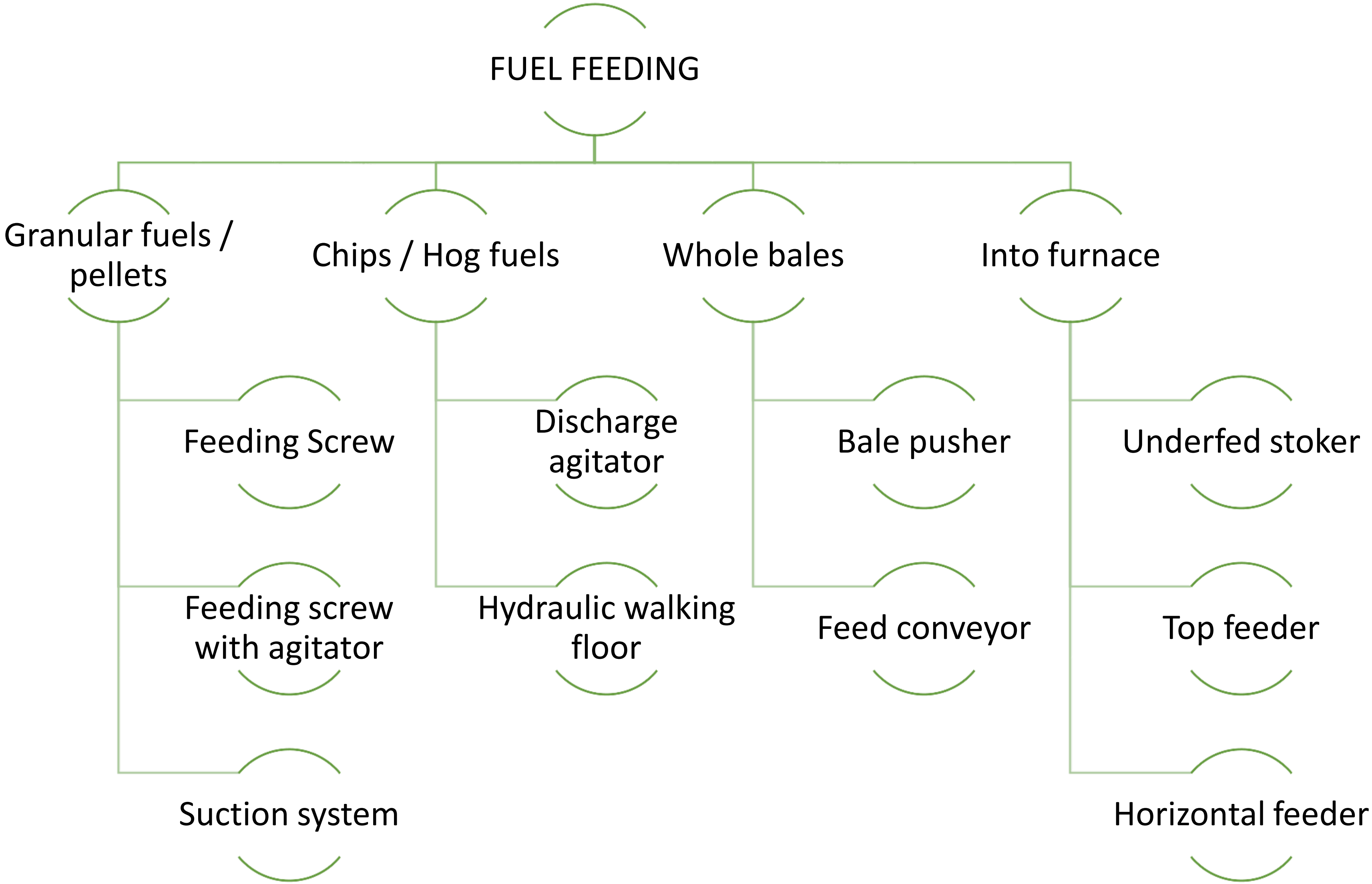


Air supply required at multiple stages of the process

Transactions of FAMENA, Vol. 42 No. SI-1, 2018.

Combustion of Agricultural Biomass - Issues and Solutions

Contents:



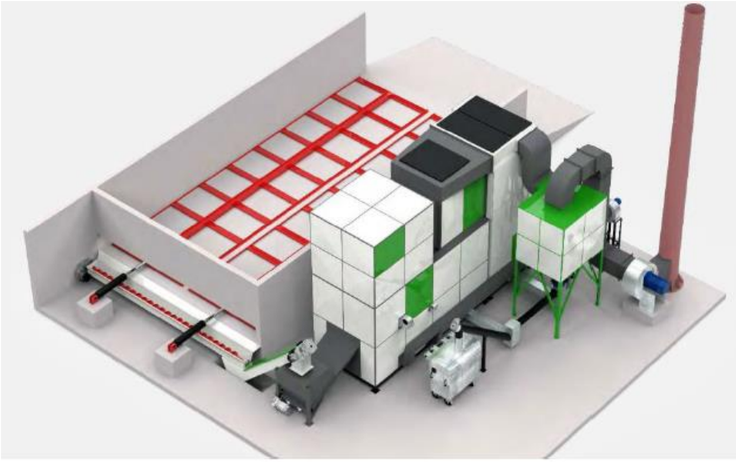
D4.2 Agrobiomass fuels and utilization system - Agrobioheat

- Feeding systems for granular fuels / pellets
  - Feeding screw
  - Feeding screw with agitator
  - Suction system

D4.2 Agrobiomass fuels and utilization system - Agrobioheat

FUEL FEEDING

- Feeding systems for chips / hog fuels
  - Discharge agitator
  - Hydraulic walking floor

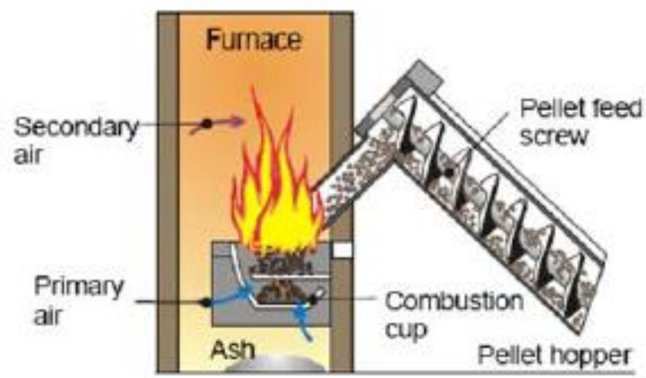


- Feeding systems for whole bales
  - Bale pusher with hydraulic piston
  - Bales that travel on a feed conveyor to a shredder and then to boiler via feeding screw
  - Semi-continuous systems

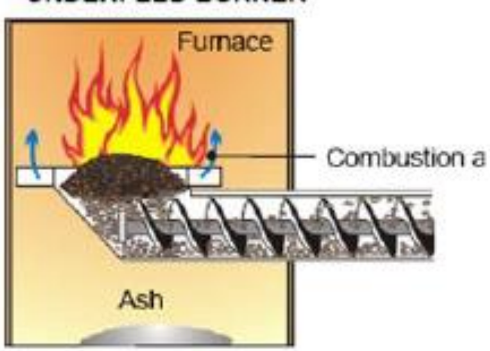
D4.2 Agrobiomass fuels and utilization system - Agrobioheat

- Fuel feeding system into furnace

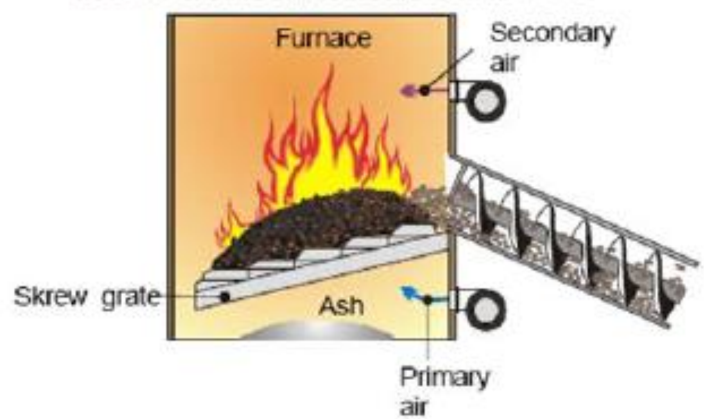
TOP FEED BURNER WITH DROPPING CUP



UNDERFEED BURNER



SCREW GRATE WITH HORIZONTAL FEED



D4.2 Agrobiomass fuels and utilization system - Agrobioheat

- Combustion systems:
  - Fixed bed combustion
    - Fixed grates
    - Moving grates
    - Travelling grates
    - Rotating grates
    - Vibrating grates
    - Underfed stokers
  - Fluidized bed
  - Pulverized combustion

Image Source: Camino Design / PelleTech

1. Moving grate
2. Primary air blower
3. Secondary air inlets
4. Reinforced auger
5. Automated fuel supply with back burn protection
6. Feed engines
7. Automatic ash extraction
8. Combustion chamber
9. Heat exchanger
10. Heat exchanger cleaning system
11. Forced draught
12. Lamda sensor
13. Hot air blower for ignition
14. Automated ash extraction

D4.2 Agrobiomass fuels and utilization system – Agrobioheat;
Reference Module in Earth Systems and Environmental Sciences, Comprehensive Renewable Energy. Volume 5, 2012, Pages 55-73

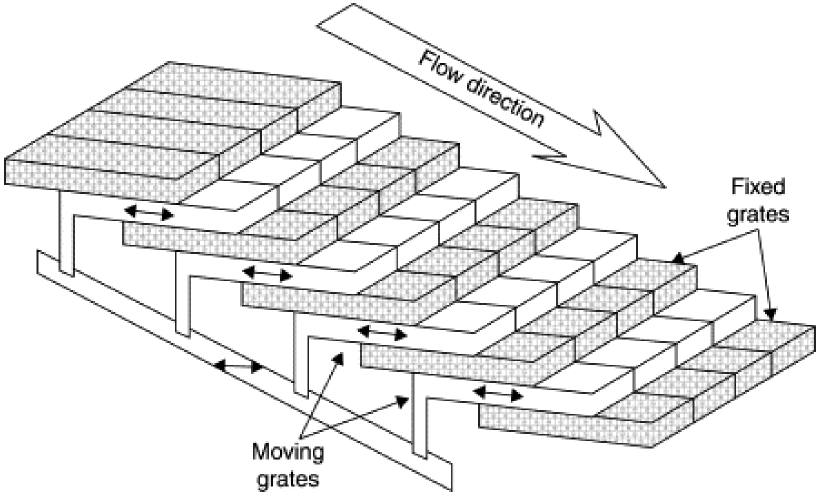
- Fixed bed combustion: for small and medium-sized biomass combustion systems. It can fire a wide range of fuels and requires less fuel preparation and handling.
  - Fixed grates: Simplest technology, only used in small-scale applications

D4.2 Agrobiomass fuels and utilization system - Agrobioheat

- Fixed bed combustion: for small and medium-sized biomass combustion systems. It can fire a wide range of fuels and requires less fuel preparation and handling.

  - Moving grates: Higher combustion velocity and efficiency – the solid fuel moves across the grate from the inlet section to the ash discharge section.

    - Travelling grates
    - Reciprocating grates: Horizontal, Inclined or combined (inclined + horizontal)
    - Vibrating grates



Example of reciprocating grates

D4.2 Agrobiomass fuels and utilization system - Agrobioheat

- Fixed bed combustion: for small and medium-sized biomass combustion systems. It can fire a wide range of fuels and requires less fuel preparation and handling.
  - Through-screw systems

D4.2 Agrobiomass fuels and utilization system - Agrobioheat

- Fixed bed combustion: for small and medium-sized biomass combustion systems. It can fire a wide range of fuels and requires less fuel preparation and handling.
  - Underfed stokers
  - Gasification boilers

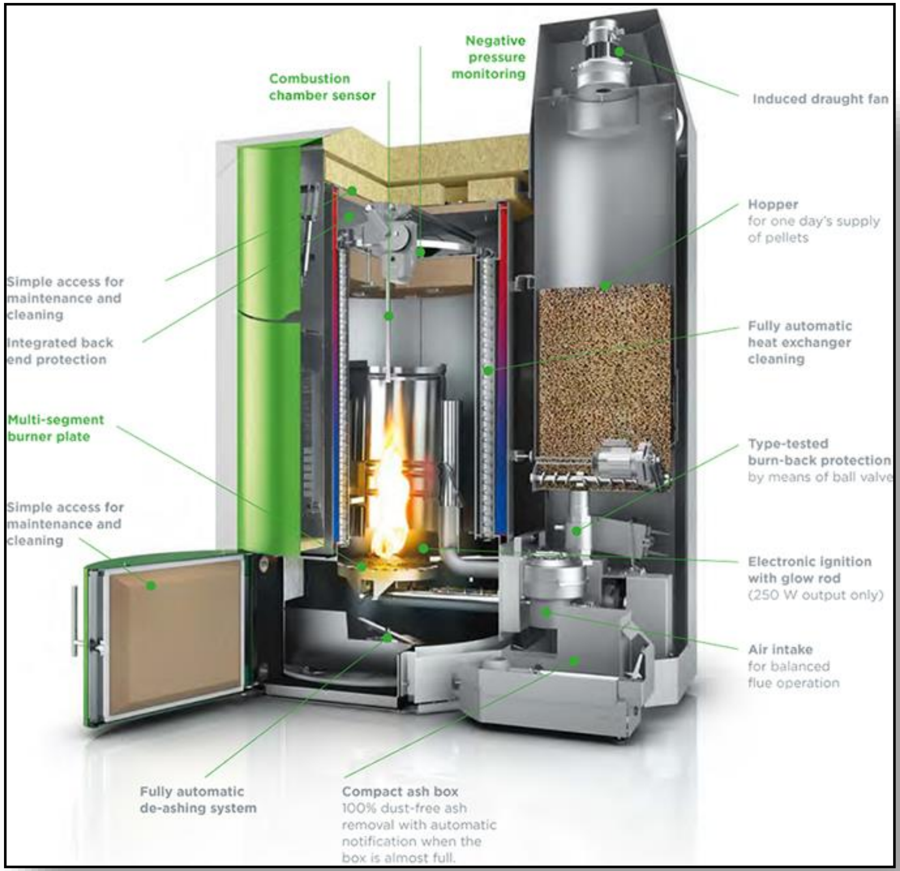
D4.2 Agrobiomass fuels and utilization system - Agrobioheat

- Domestic systems: Although modern units, such as increasingly popular pellet boilers, have an efficiency as high as 90%, the vast majority of domestic biomass devices in use are low efficiency (5-30%) traditional cooking stoves found mostly in developing countries.
  - Stoves
    - Up-draught
    - Down-draught
    - Cross-draught
    - S-flow or dual zone stove
  - Boilers
    - Over-fire
    - Under-fire
    - Down-draught

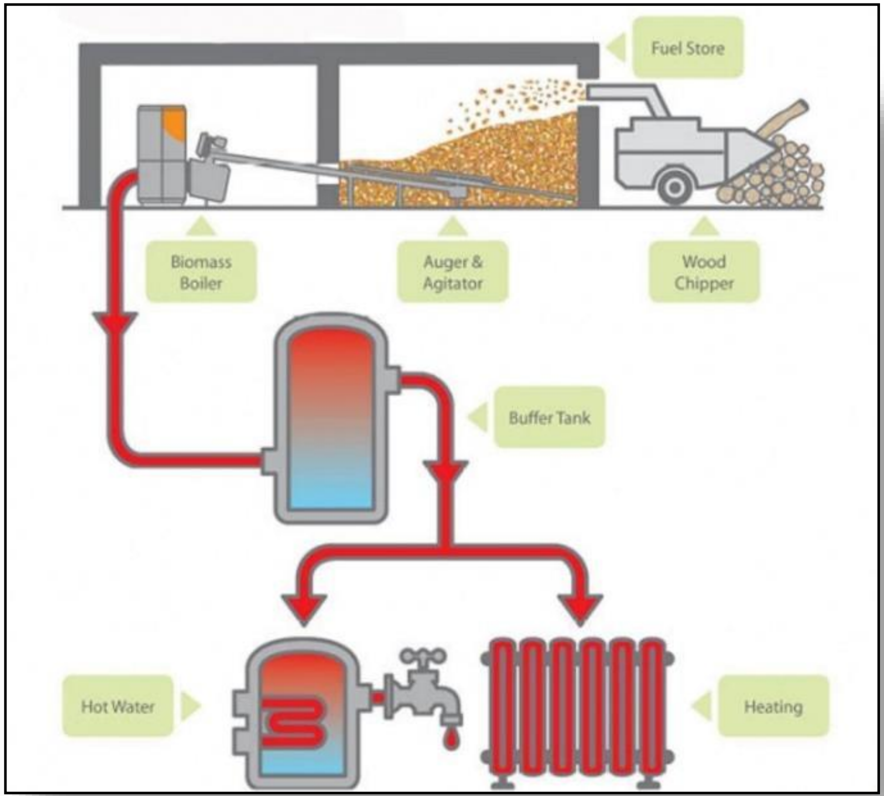
COMBUSTION SYSTEMS

- Pellet boilers: They present significant advantages compared to conventional combustion systems with biomass, such as reduced emissions, and use of a clean and easy to use and store fuel

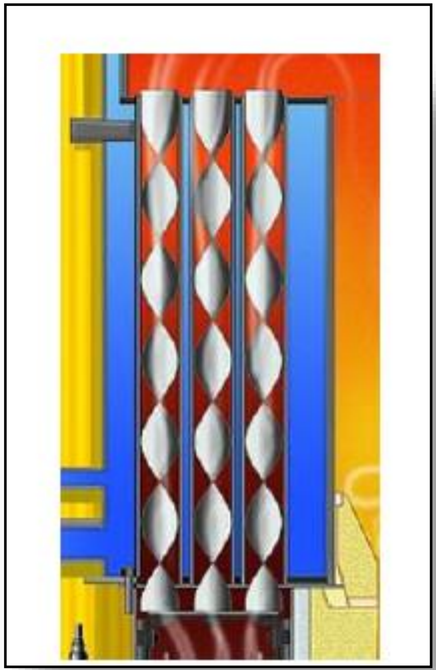
  - Vertical burners
    - Overfed burners
    - Underfed burners
  - Horizontal burners



- Wood chip boilers: Concerning small scale systems, the advantages of wood chip boilers over log wood boilers include automatic operation and low emissions due to continuous combustion



- HEAT EXCHANGERS
  - Automatic heat exchanger cleaning
    - Based on mechanical means
    - Based on pressurized air

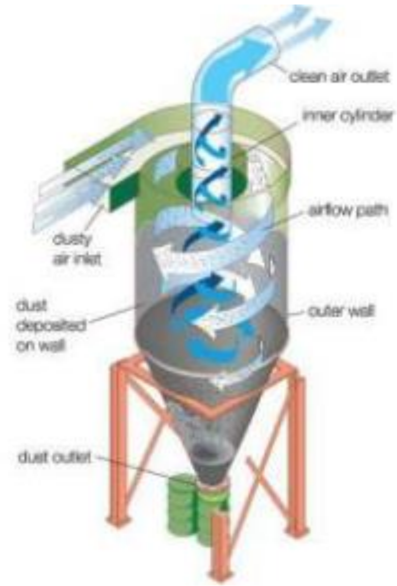


- ASH REMOVAL SYSTEMS

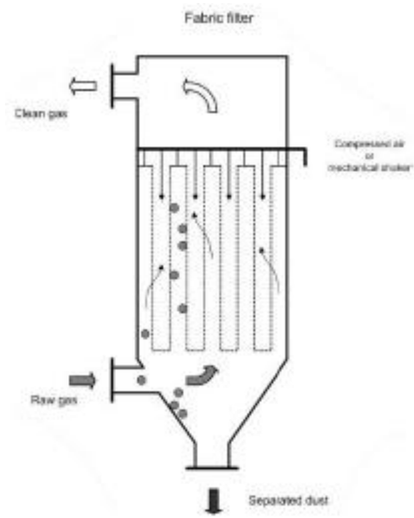
- Ash removal is often considered to be a main issue.
- The de-ashing system is of great importance.
- Grate ash and ash from the heat exchanger cleaning: ash box.
- De-ashing screw that conveys the ash into a container.
- Ash compaction systems are sometimes applied.

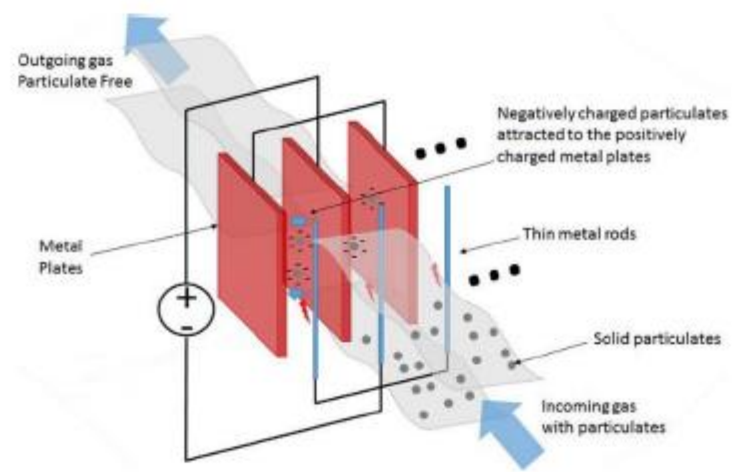
OTHER AUXILIAR SYSTEMS

- CONTROL SYSTEMS
  - Load control
  - Combustion control.
  - Furnace temperature control.
  - Furnace pressure control.
  - Control loops needed for operation safety aspects.



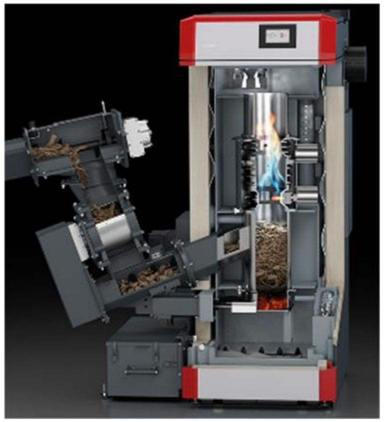
- FLUE GAS CLEANING SYSTEMS
  - Dust control
    - Cyclones
    - Fabric filters
    - Electrostatic Precipitators





Contents:

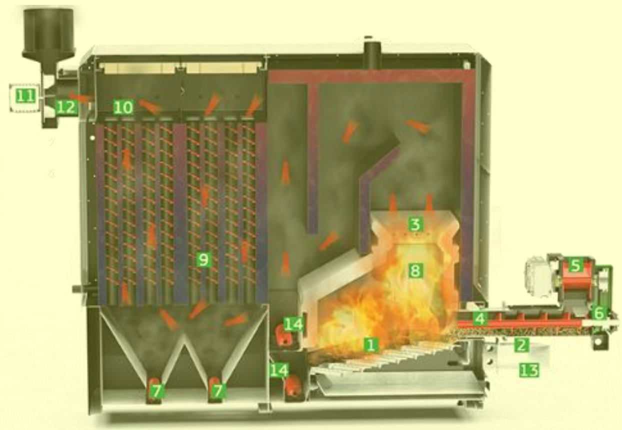
Main agrobiomass combustion technologies



	Moving grate	Gasification concept
Market maturity	Widely deployed / numerous manufactures and models	Innovative concept / currently offered by limited manufacturers
Capacity ranges	~ 30 kW - 150 MW	~ 30 kW – 20 MW
Unburnt pollutants	Conventional air staging	Extreme air staging
Particle emissions	Further reduction through secondary measures (e.g. ESPs, bag-filters)	Low emissions achieved without the need for secondary measures
NOx emissions	Primary measures Secondary measures may apply above the 1 MW scale	Primary measures (some potential for further reduction compared to grate-fired systems)

Images sources: Camino Design (left), Windhager (right)

Main agrobiomass combustion technologies



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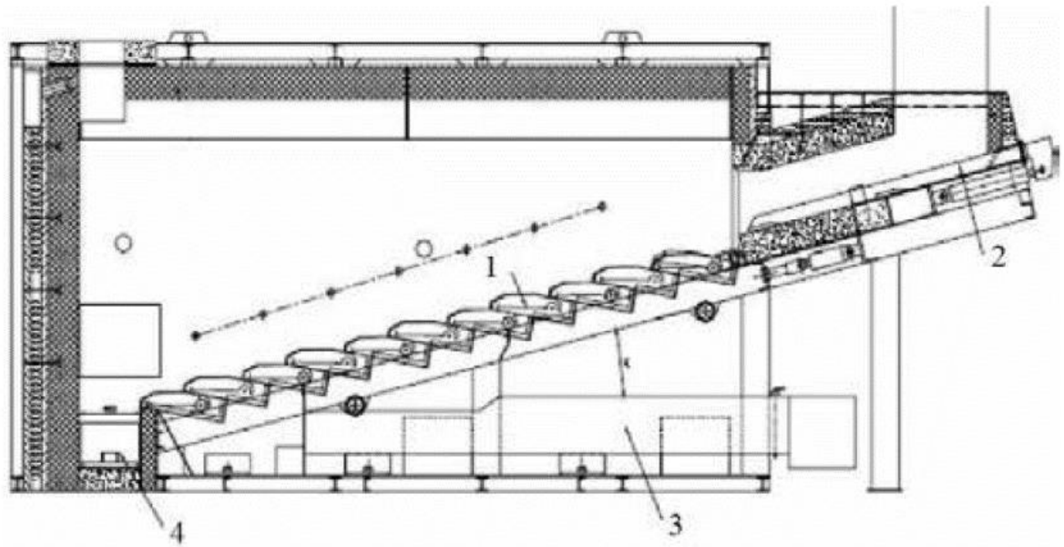
Images sources: Camino Design (left), Windhager (right)

“Standard” moving grate combustion 1/3

- Moving grate furnaces usually have an inclined grate consisting of fixed and movable rows of grate bars
- By alternating horizontal forward and backward movements of the movable sections, the biomass is transported along the grate
- Unburned and burned biomass particles are mixed
- Surfaces of the fuel bed are renewed and more even distribution of the biomass over the grate surface can be achieved
- Important for an equal primary air distribution across the biomass bed



1. Moving fire grates in the furnace
2. Biomass supply
3. Air channels
4. Ash scraper

Image source: Krawczyk D., 2019, Bulidings 2020+ . Energy sources, DOI: 10.24427/978-83-65596-73-4

"Standard" moving grate combustion 2/3

- Usually the whole grate is divided into several grate sections, which can be moved at various speeds according to the different stages of combustion
- The movement of the grate bars is achieved by hydraulic cylinders
- Grate bars are made of heat-resistant steel alloys
- Equipped with small channels in their side-walls for primary air supply

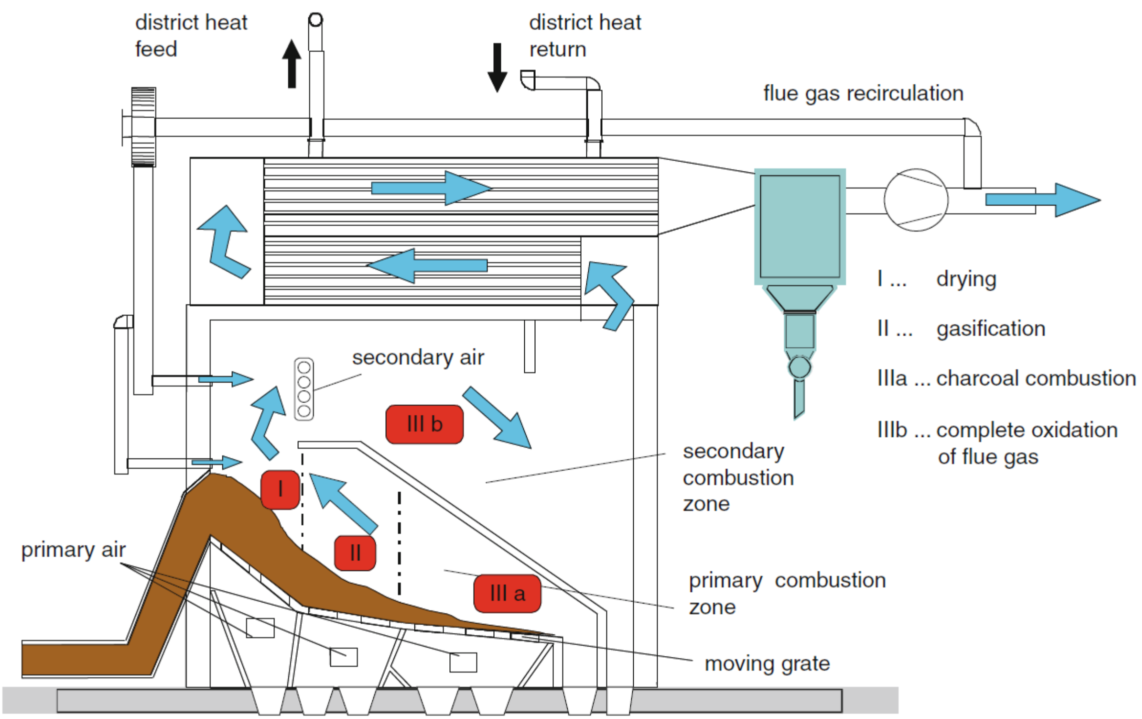
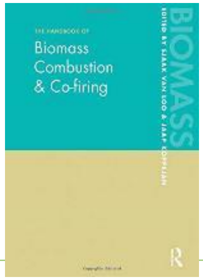


Image source: Obernberger, et al., "Biomass energy heat provision in modern large-scale systems." Encyclopedia of Sustainability Science and Technology. Springer US, 2012



“Standard” moving grate combustion 3/3

- Horizontal moving grates have a completely horizontal fuel bed due to the diagonal position of the grate bars
- Uncontrolled fuel movements over the grate by gravity are impeded
- Homogeneous distribution of material on the grate surface
- Les slag formation as a result of hot spots
- To avoid ash and fuel particles falling through the grate bars, these should be preloaded so that there is no free space between the bars

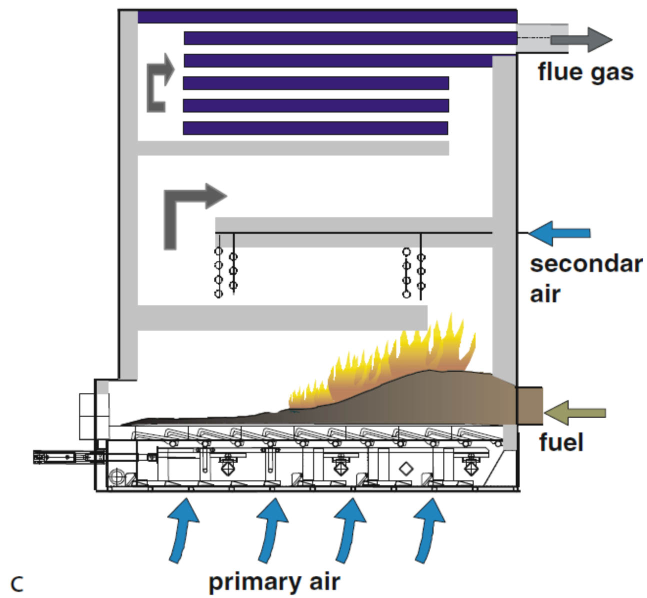
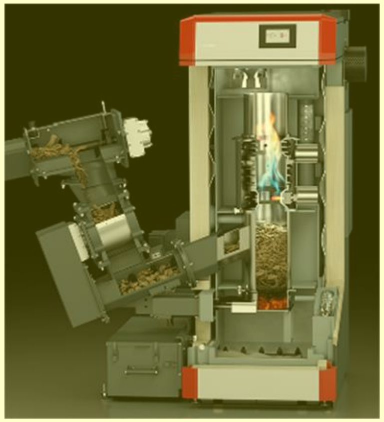


Image source: Obernberger, et al., "Biomass energy heat provision in modern large-scale systems." Encyclopedia of Sustainability Science and Technology. Springer US, 2012

Main agrobiomass combustion technologies



	Moving grate	Gasification concept
Market maturity	Widely deployed / numerous manufactures and models	Innovative concept / currently offered by limited manufacturers
Capacity ranges	~ 30 kW - 150 MW	~ 30 kW – 20 MW
Unburnt pollutants	Conventional air staging	Extreme air staging
Particle emissions	Further reduction through secondary measures (e.g. ESPs, bag-filters)	Low emissions achieved without the need for secondary measures
NOx emissions	Primary measures Secondary measures may apply above the 1 MW scale	Primary measures (some potential for further reduction compared to grate-fired systems)

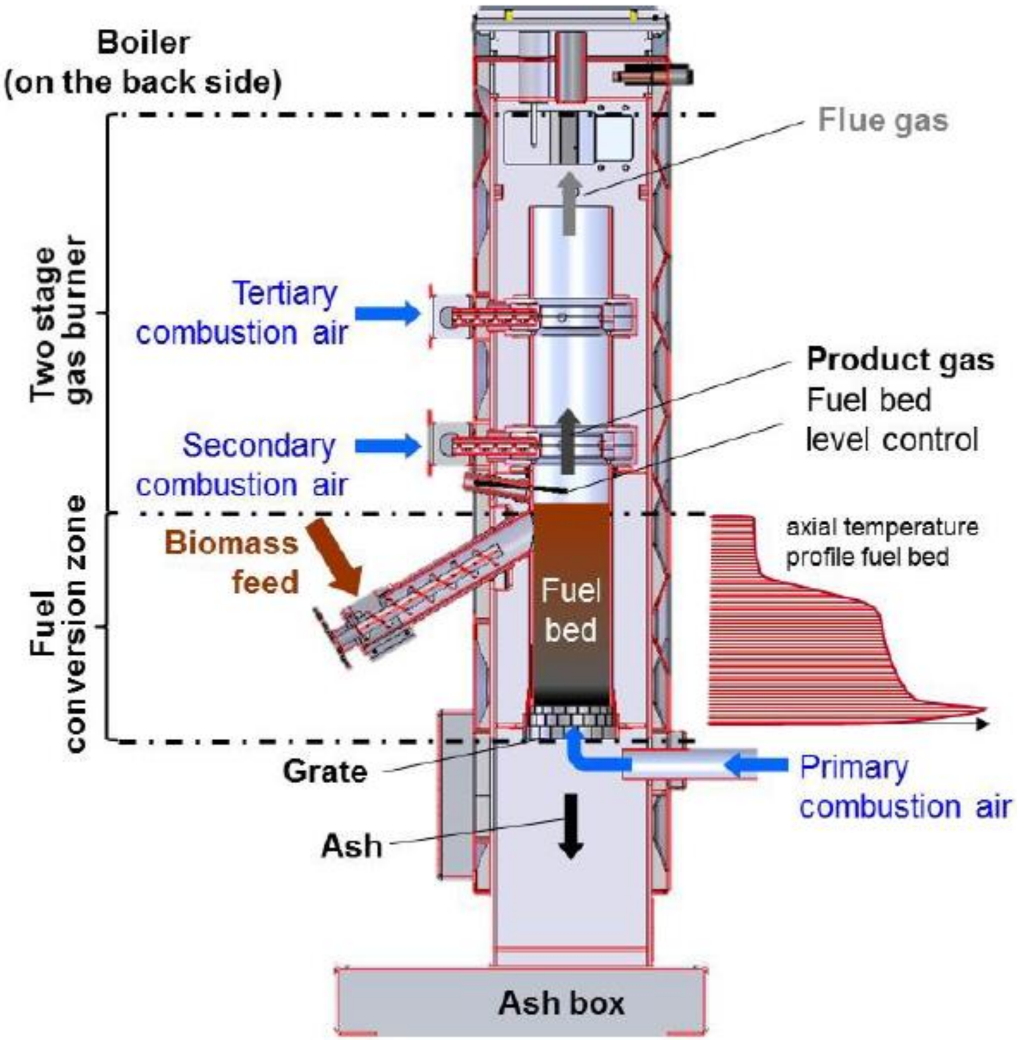
Images sources: Camino Design (left), Windhager (right)

The gasification concept

Towards enhanced fuel flexibility and zero emissions

Extreme air staging

- Fuel is fed from above to a comparably high fuel bed
- Primary air passes upwards through the fuel bed
- Product gas leaving the fuel bed is combusted in a gas burner

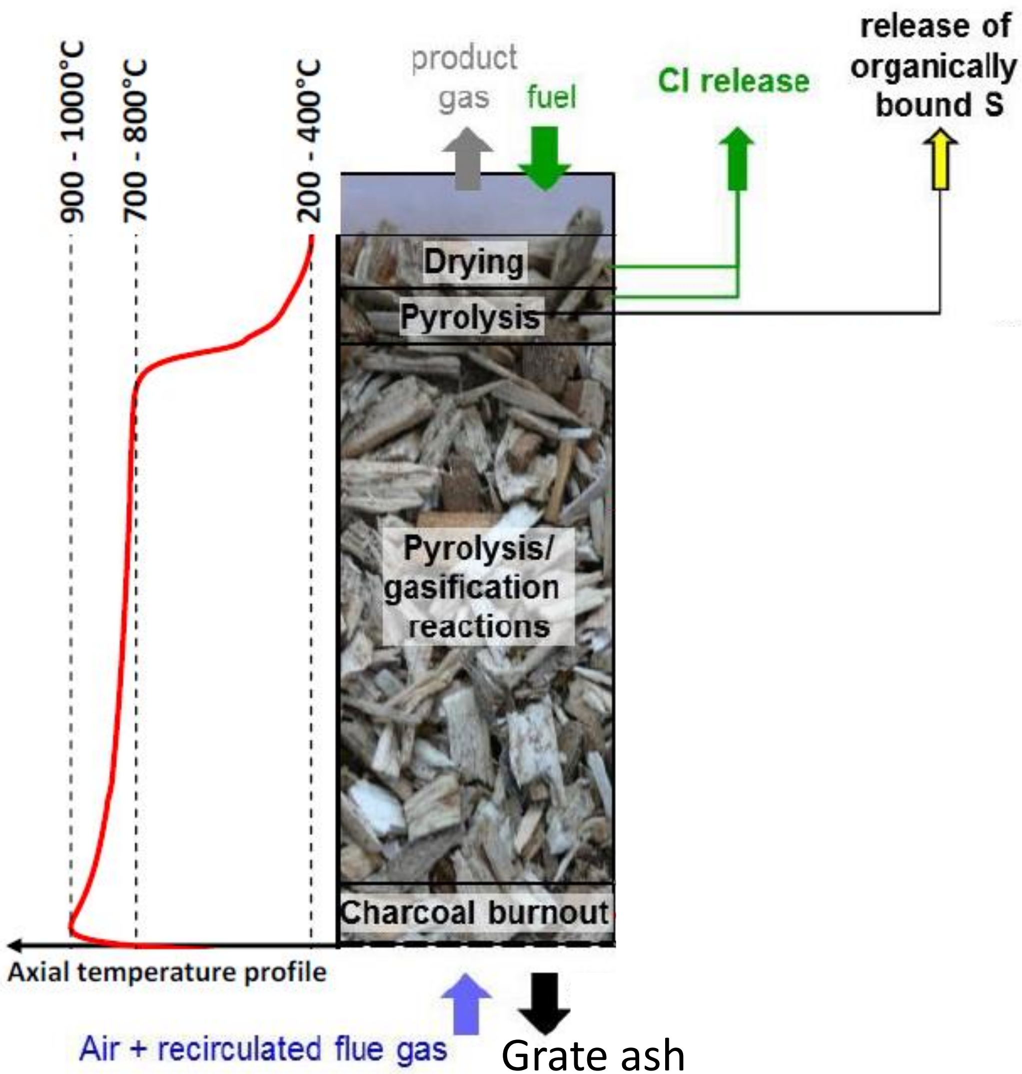


Obernberger Ingwald, 2019, Recent developments and future prospects for biomass combustión from small to large scale, European Biomass Conference and Exhibition.

The gasification concept

Zones with different conversion processes

- Charcoal combustion (ca. 100ºC)
- Pyrolysis and gasification at gradually decreasing gas and fuel bed temperatures
- Drying zone: on top of the fuel bed



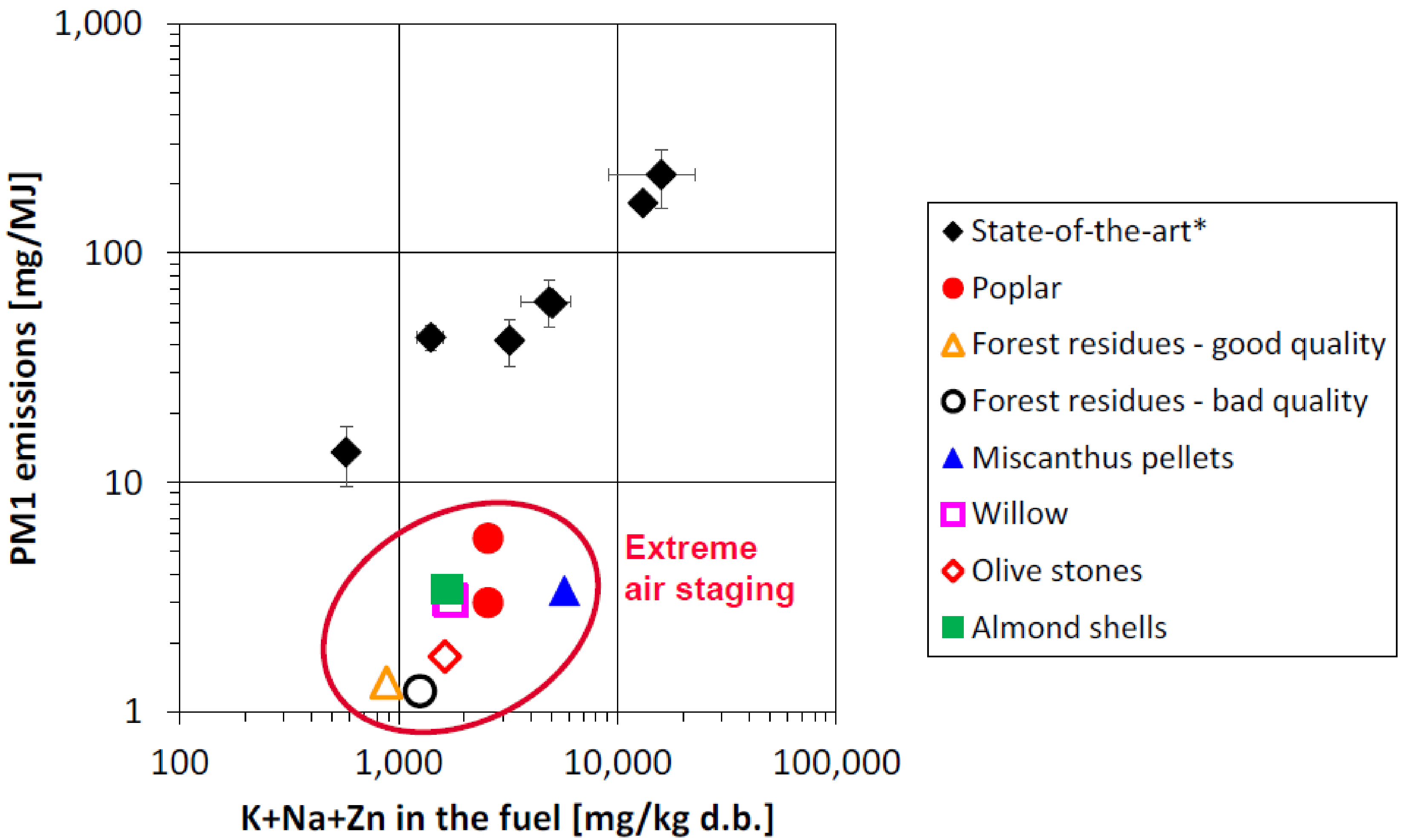
Obernberger Ingwald, 2019, Recent developments and future prospects for biomass combustión from small to large scale, European Biomass Conference and Exhibition.

Advantages compared with state-of-the-art fixed bed combustion systems versus extreme air staging

Characteristic	Advantage
Excess air ratio	• Increased termal efficiency (about +2% absolute) • Higher dew point of the flue gas (2-4ºC) enables more efficient implementation of flue gas condensation
Gaseous emissions	• Very low emissions can be achieved during full and partial loas
TSP emissions	• No dust precipitation devices needed • Significantly reduced boiler fouling
Fine PM emission	• No dust precipitation deviced (ESP, baghouse filters) needed • Significantly reduced boiler fouling

Obernberger Ingwald, 2019, Recent developments and future prospects for biomass combustión from small to large scale, European Biomass Conference and Exhibition.

Fine particulate matter emissions



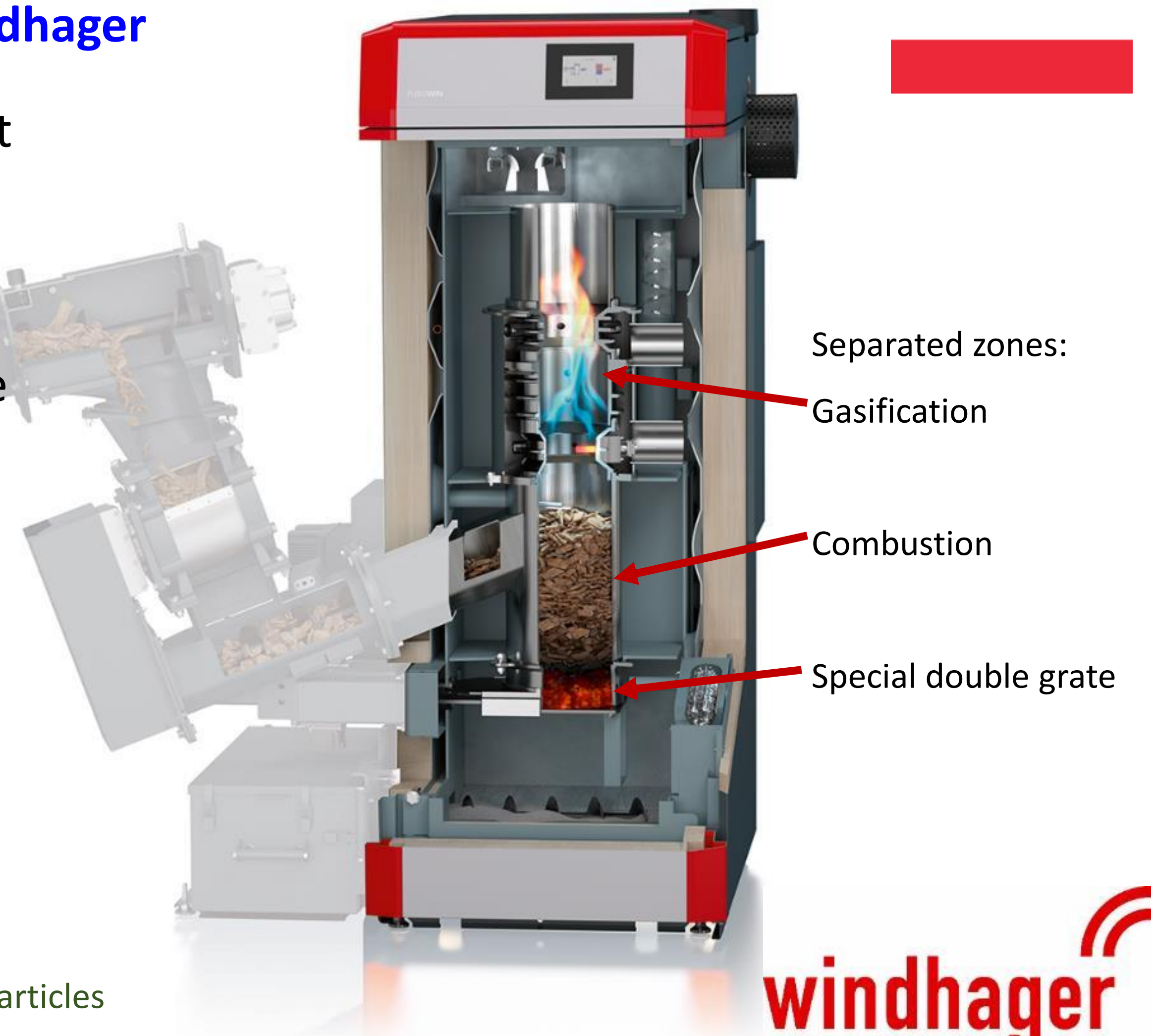
Obernberger Ingwald, 2019, Recent developments and future prospects for biomass combustión from small to large scale, European Biomass Conference and Exhibition.

The gasification concept – Application 1

Extreme air staging technology applied to small scale boilers

PuroWIN technology from Windhager

- **Low-emission combustion** at O_2 contents in the flue gas between 3-5% (vol)
- **Flexible load variation** between 25-100% is possible
- **Almost zero** emissions regarding **CO and OGC*** at nominal and partial load as well as during load changes
- **TSP**** emissions **below 2 mg/MJ$_{NCV}$** without application of any filter
- **High efficiencies** of 93-94%



*Organic gaseous carbon / **Total suspended particles

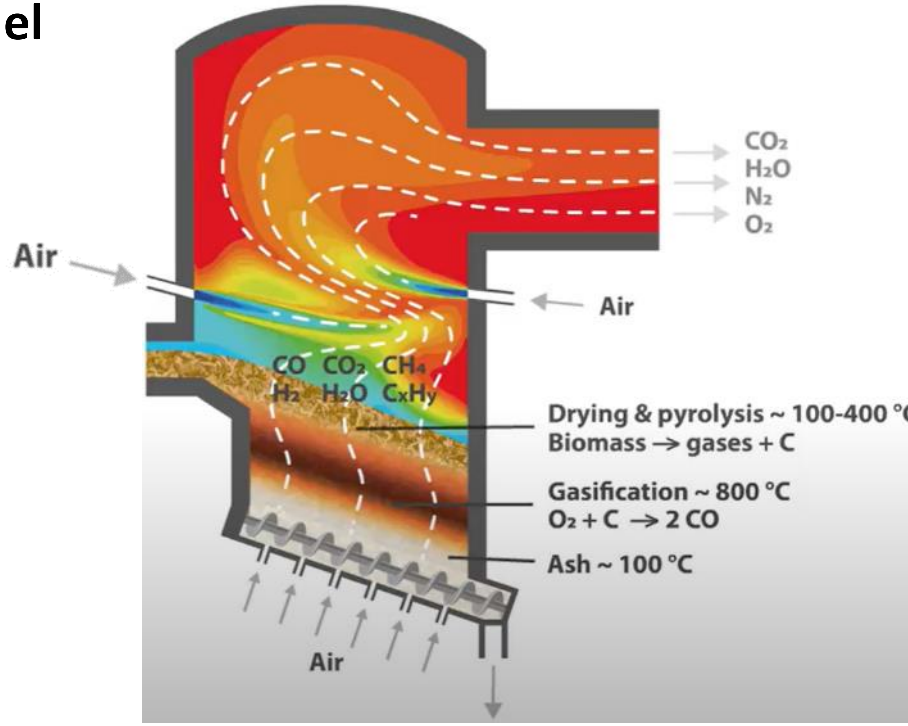
Obernberger Ingwald, 2019, Recent developments and future prospects for biomass combustión from small to large scale, European Biomass Conference and Exhibition.

CERTH CENTRE FOR RESEARCH & TECHNOLOGY HELLAS

Extreme air staging technology applied to small scale boilers

Biomass gasification furnace from Dall Energy

- **No grate**
- **Gas combustion directly above the fuel bed**
- **High fuel flexibility**
  - Moisture content (20-60 wt.%)
  - Particle size up to 40 cm
  - Ash content up to 30wt.%
- **Total suspended particles emissions below 20 mg/MJ without filter**
- **4 plants (2 to 9 MW) in opearion, 20 MW plant in construction**



Dall Energy NEW BIOMASS TECHNOLOGIES

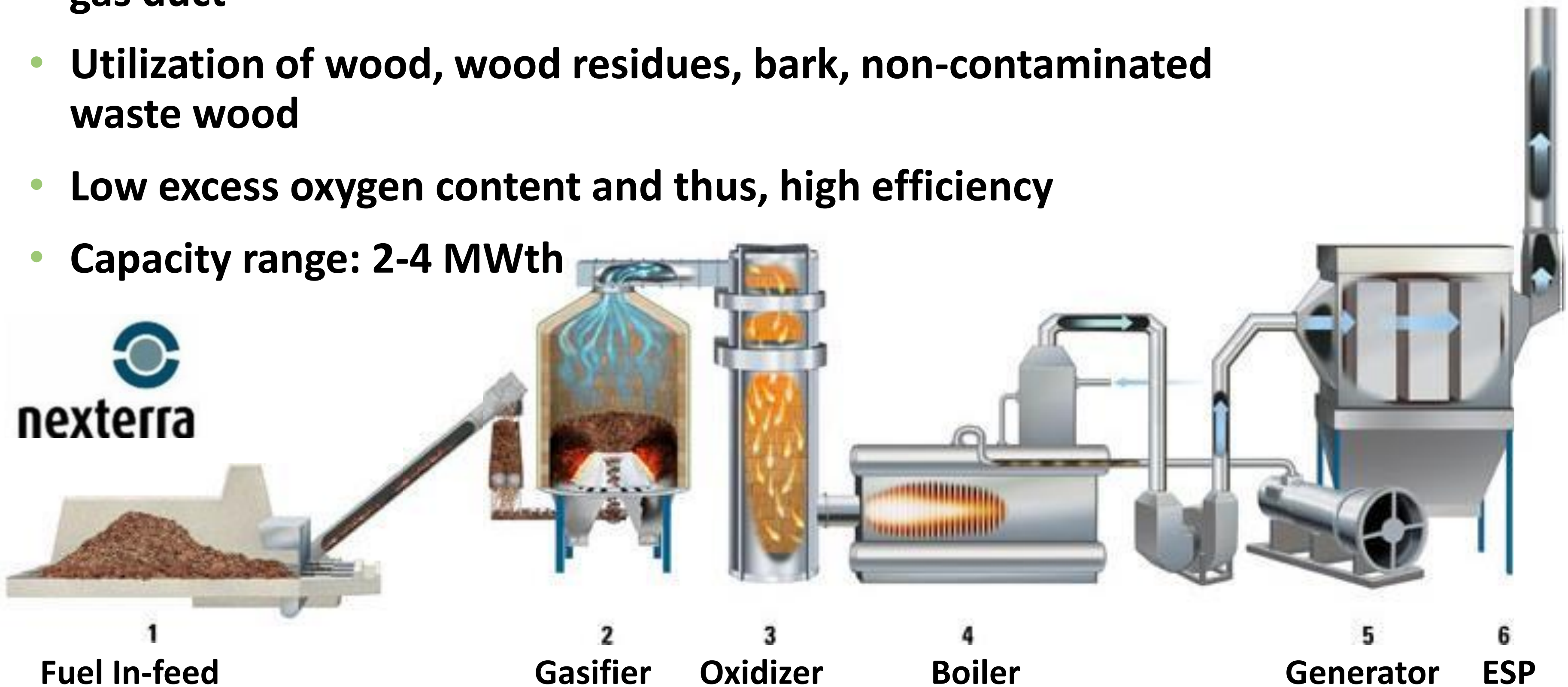
Obernberger Ingwald, 2019, Recent developments and future prospects for biomass combustión from small to large scale, European Biomass Conference and Exhibition.

The gasification concept – Application 3

Extreme air staging technology applied to small scale boilers

Nexterra's gasification / Combustion Technology

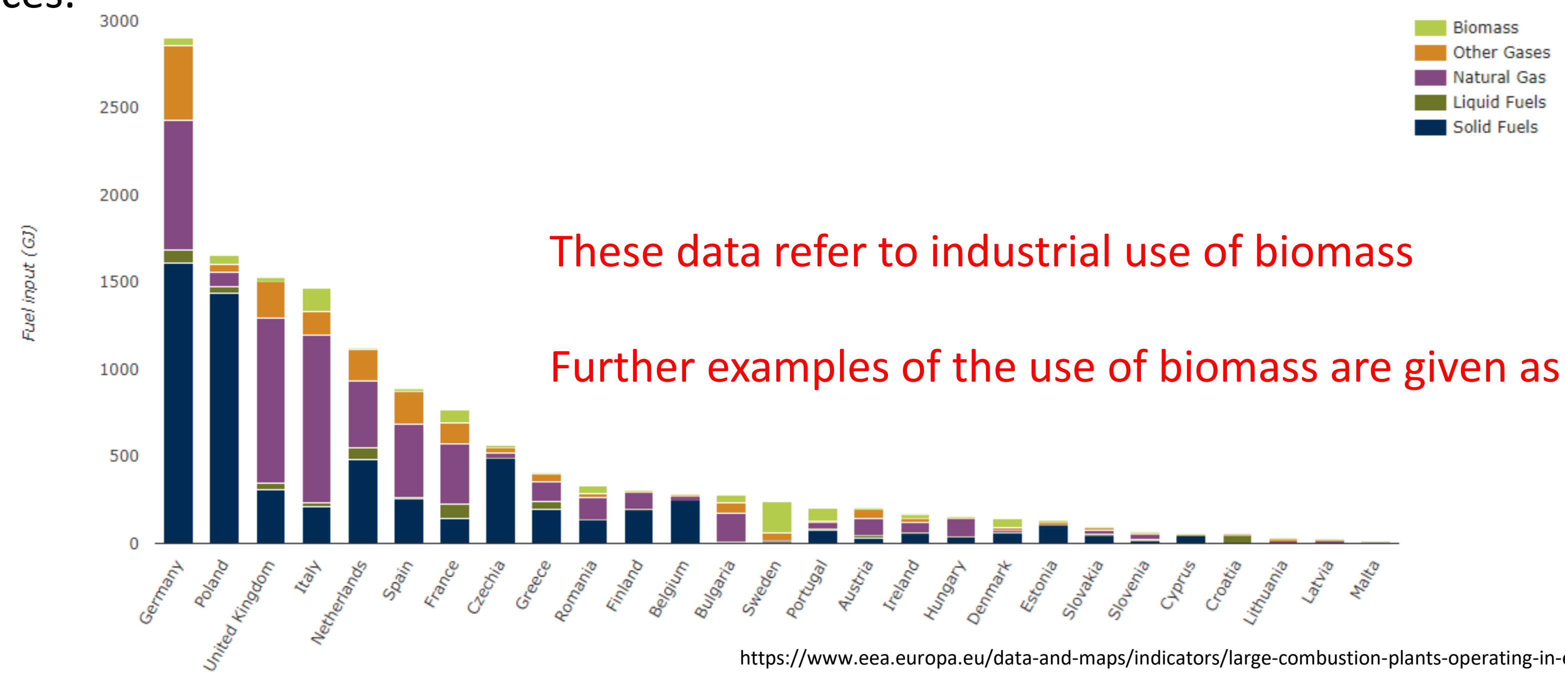
- Product gas combustion in a separated burner connected via a gas duct
- Utilization of wood, wood residues, bark, non-contaminated waste wood
- Low excess oxygen content and thus, high efficiency
- Capacity range: 2-4 MWth



Obernberger Ingwald, 2019, Recent developments and future prospects for biomass combustión from small to large scale, European Biomass Conference and Exhibition.

Contents:

- There are 3 664 large combustion plants in the EU-28. Installed capacity increased by 4 % overall between 2004 and 2017. The trend reached a maximum in 2012.
- The use of biomass, tripled from 2004 to 2017, although it was still used in relatively low amounts (**6 % of the total in 2017, 830 GJ**).
- Solid fuels (coal, lignite, peat and other solid fossil fuels) and natural gas remain the main sources of fuel input, but the amount used decreased by around 25 % in the period. This could reflect the shift in Europe's energy system from oil, coal and gas to renewable sources.

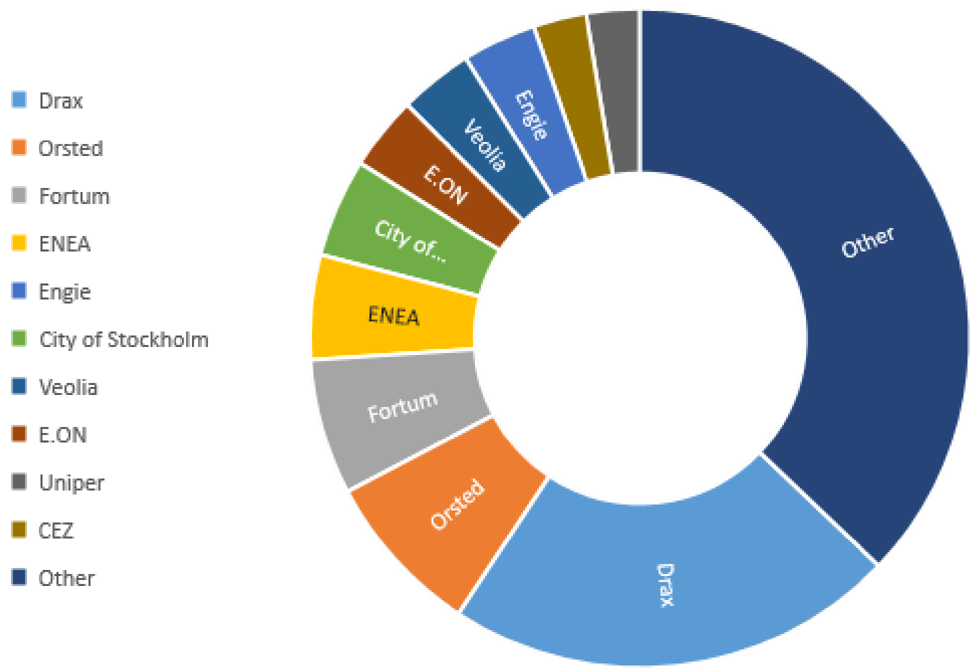


These data refer to industrial use of biomass

Further examples of the use of biomass are given as follows:

https://www.eea.europa.eu/data-and-maps/indicators/large-combustion-plants-operating-in-europe-3/assessment

- 76 plants currently burn a total of six million tonnes of biomass every year.
- A few biomass plants are responsible for burning most of the total biomass. For example Drax in the UK – the largest biomass power station – burns 22 per cent of the total. Together the 10 largest biomass plants burn half of the total.



https://shareaction.org/research-resources/european-biomass-plant-database/

CROATIA

- OPG Ravenšćak:
  - The main fuel used is sawdust in a 850 kW
  - The company has successfully used miscanthus and has plans to start cultivation of the crop from 2021.

- Utility company of the city of Križevci
  - Heating of two public buildings and compost
  - Using prunings from citizens orchards: 200 ton/year
  - 150 kW boiler from WVTerm + 20 kW PV system

Source: AgroBioHeat D3.1- Agrobiomass Heating Facilities

DENMARK

- Ulbjerg Kraftvarme:
  - Supplies the district heating network of the small municipality of Ulbjerg.
  - Mainly works with cereal straw bales. The boiler can burn other agricultural residues or wood chips with a moisture content up to 30 %.
  - 1,000 kW boiler
  - Total investment: Range of 1M€
  - Annual savings: 128.000 € fuel

Source: AgroBioHeat D3.1- Agrobiomass Heating Facilities

DENMARK

- Vennerslund, Frederiksdal kisebaervin, Holmegaard or Orupgard
  - Space heating
  - Season grain drying
  - Cherry wine production
  - Poultry farm heating
  - Straw boilers: 400 – 950 kW

Source: AgroBioHeat D3.1- Agrobiomass Heating Facilities

- Midtlangeland Fjernvarme
  - 7,700 kW hot water boiler supplied by Justsen.
  - Urea-based SNCR (selective non-catalytic reduction) deNOx system.
  - The total cost of the project (replacement of the older boiler) was in the range of 25 million DKK (around 3.3 M€)

- Boulstrup-Hou Kraftvarmeværk, Hjallerup Fjernvarme, Rødbyhavn Fjernvarme, Fors A/S / St. Merloese Varmevaerk, Lolland Varme A/S and Ørnhøj-Grønbjerg Kraftvarmeværk
  - Straw boilers supplied by Linka Energy
  - Thermal outputs ranging from 2,000 to 6,500 kW.
  - Have achieved dust emission values way below the MCP Directive limit (40 mg/Nm3), as well as CO emission values also below the limit (625 mg/Nm3).

Source: AgroBioHeat D3.1- Agrobiomass Heating Facilities

- AGRIS S.A. successful agrobiomass utilization.
  - greenhouse nursery facility of more than three hectares.
  - eight biomass boilers (total capacity of 9.28 MW).
  - Initially operated with exhausted olive cake →sunflower husk pellets (superior fuel with no odour problems).
  - annual heating bill has been reduced by 20-30 %, with the biomass heating system supplying up to 97 % of the total heat demand.

- BIOKARPOS S.A.
  - Peloponnese is another interesting case of agrobiomass heating.
  - three modern, moving-grate biomass boilers (PelleTech / Camino Design), each with a 350 kW capacity.
  - Currently fueled by sunflower husk pellets, the company has plans to install additional heating capacity as well as to start using own residues (greenhouse green waste) and chipped agricultural prunings.

Source: AgroBioHeat D3.1- Agrobiomass Heating Facilities

- Oniropetra Boutique Hotel
  - which illustrates the advantages offered by agrobiomass heating in the service sector under the correct conditions.
  - Karpenisi, a mountainous area with cold climate.
  - 200 kW biomass boiler (PelleTech / Camino Design) was installed in 2014 and it is currently operated with sunflower husk pellets. 75 tons biomass/year. CAPEX: 23.000€, payback 1.5 years

Source: AgroBioHeat D3.1- Agrobiomass Heating Facilities

FRANCE

- AgroBioHeat project partner Agronergy includes in its portfolio of biomass heating plant such as facility at the small town of Chevresis:
  - Miscanthus is used to heat a municipal retirement home – affordable heat to residents.
  - Association involving local farmers and local council since 2018.

Source: AgroBioHeat D3.1- Agrobiomass Heating Facilities; Photo: Agronergy

- Abbaye Notre Dame d'Ourscamp.
  - miscanthus heating since 2014.
  - Annual fuel cost savings of 60,000 € were observed. Payback time of less than 5 years (total investment of 267,000 € (92,000 € for the boiler and 175,000 € for the network and installation)).
  - A reduction of 210 tons of CO_2 emissions per year was also calculated.
  - Miscanthus supplied by a small number of farmers near the monastery.

- CALYS pellets produced by RAGT Energie.
  - Identifyes suitable biomass streams for mixing and applying additives, assisting agropellet suppliers to produce a high quality, cost-effective product that can be used even in small-scale installations.

Source: AgroBioHeat D3.1- Agrobiomass Heating Facilities

- Vilafranca del Penedés:
  - Vineyard prunings – energetic utilization
  - 500 kW Heizomat boiler
  - Small district heating network

Source: AgroBioHeat D3.1- Agrobiomass Heating Facilities

- Quesos del Cerrato (cheese factory):
  - Agropellets used in a steam boiler (4t/h, 9 bar)
  - Used for cheese production proces.
  - Boiler – SUGIMAT
  - Cost: 500.000€, savings: 30-40%

Source: AgroBioHeat D3.1- Agrobiomass Heating Facilities

- Hotel Los Mallos:
  - Straw-bale boiler
  - 250 kW – ACR Ecocalderas + cyclone for particle emissions
  - 280 tons/year of Straw bales.

Source: AgroBioHeat D3.1- Agrobiomass Heating Facilities

- UMAN city: 83,000 inhabitants.
  - Fuel supply (Straw pellets) and combustion technology (Straw pellet boilers)
  - Installed in schools and kindergartens
  - 50% anual fuel cost savings over natural gas.
- Pultry Complex “Dneprovskiy”:
  - 2x5 MW biomass boilers – TTS
  - Straw bales as fuel
  - Fabric filters – particle emisión

Source: AgroBioHeat D3.1- Agrobiomass Heating Facilities

- ITC Shabo:
  - Wineyard prunings as heating source
  - 1,6 MWth steam boiler – 1,500 tons /year of vineyard pruning
- Shopping mall ACADEM-CITY:
  - Sunflower husk pellets.
  - Located in Kyiv
  - Cyclones used to reduce particle emissions (urban setting)

Source: AgroBioHeat D3.1- Agrobiomass Heating Facilities

- DALIA Greenhouse
  - Heating of a 1 hectare of greenhouse
  - Fuel supply (energy willow chips) and pasture clearing biomass -> 2,000 tons per year
  - modern biomass boilers developed by Romanian manufacturer BioSistem, equipped with cyclones for particle emission control
  - annual fuel savings in the range of 20 % compared to natural gas
  - Installed capacity: 4 x 750 KW and 2 x 500 kW

Source: AgroBioHeat D3.1- Agrobiomass Heating Facilities

- Avicol Prod Consult Ltd. In Cornatelu village, Dambovita county
- Heating of the chicken farms
- The main fuel is sunflower husks from Dambovita region
- Biomass boilers installed over the years: 1x60 kW, 1x100 kW, 1x150 kW
- feeding system automatized by installation of 3 20 m^3 silos, connected directly to the boilers

Source: AgroBioHeat D3.1- Agrobiomass Heating Facilities

Contents:

4.1 Commonly encountered technical problems and solutions

Problems caused by the agrobiomass composition

Problems of low melting points of the ashes

-Agglomeration problems in fluidized bed combustion systems

-Fouling and slagging

-Corrosion

Image source: https://www.searchenginejournal.com/diagnosing-technical-seo-problems-guide/322973/

Mean contents of the principal oxides found in biomass

Substances in agrobiomass that might lead to operational problems:

Wood and woody biomass	CaO	SiO_2	K_2O	MgO	Al_2O_3	P_2O_5
Herbaceous and agricultural grass	SiO_2	K_2O	CaO	P_2O_5	MgO	Al_2O_3
Herbaceous and agricultural straw	SiO_2	K_2O	CaO	MgO	P_2O_5	Al_2O_3
Herbaceous and agrobiomass	K_2O	SiO_2	CaO	P_2O_5	MgO	Al_2O_3
Animal biomass	CaO	P_2O_5	K_2O	SiO_2	MgO	Al_2O_3
Contaminated biomass	SiO_2	CaO	Al_2O_3	P_2O_5	MgO	K_2O

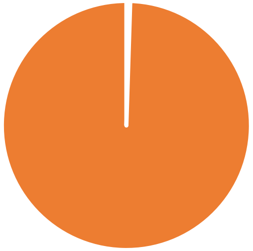
Source of information and image: Alam, Md Tanvir, et al. "A critical review of ash slagging mechanisms and viscosity measurement for low-rank coal and bio-slags." Frontiers in Energy 15.1 (2021): 46-67.

Ash content of biomass

- The ash content varies from one kind of biomass to another:

Wood biomass

0.5% < Ash



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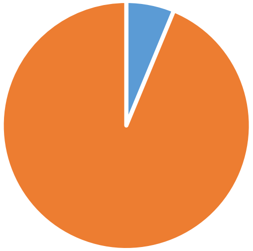
Ash < 5.0%

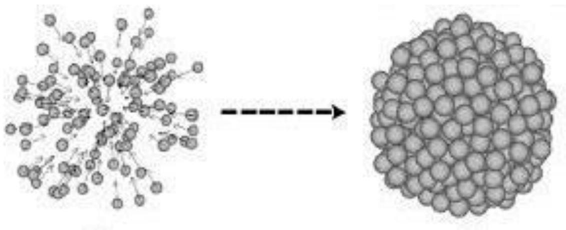


Crop residues

Photo source: https://www.alternative-energy-tutorials.com/biomass/wood-biomass-energy.html

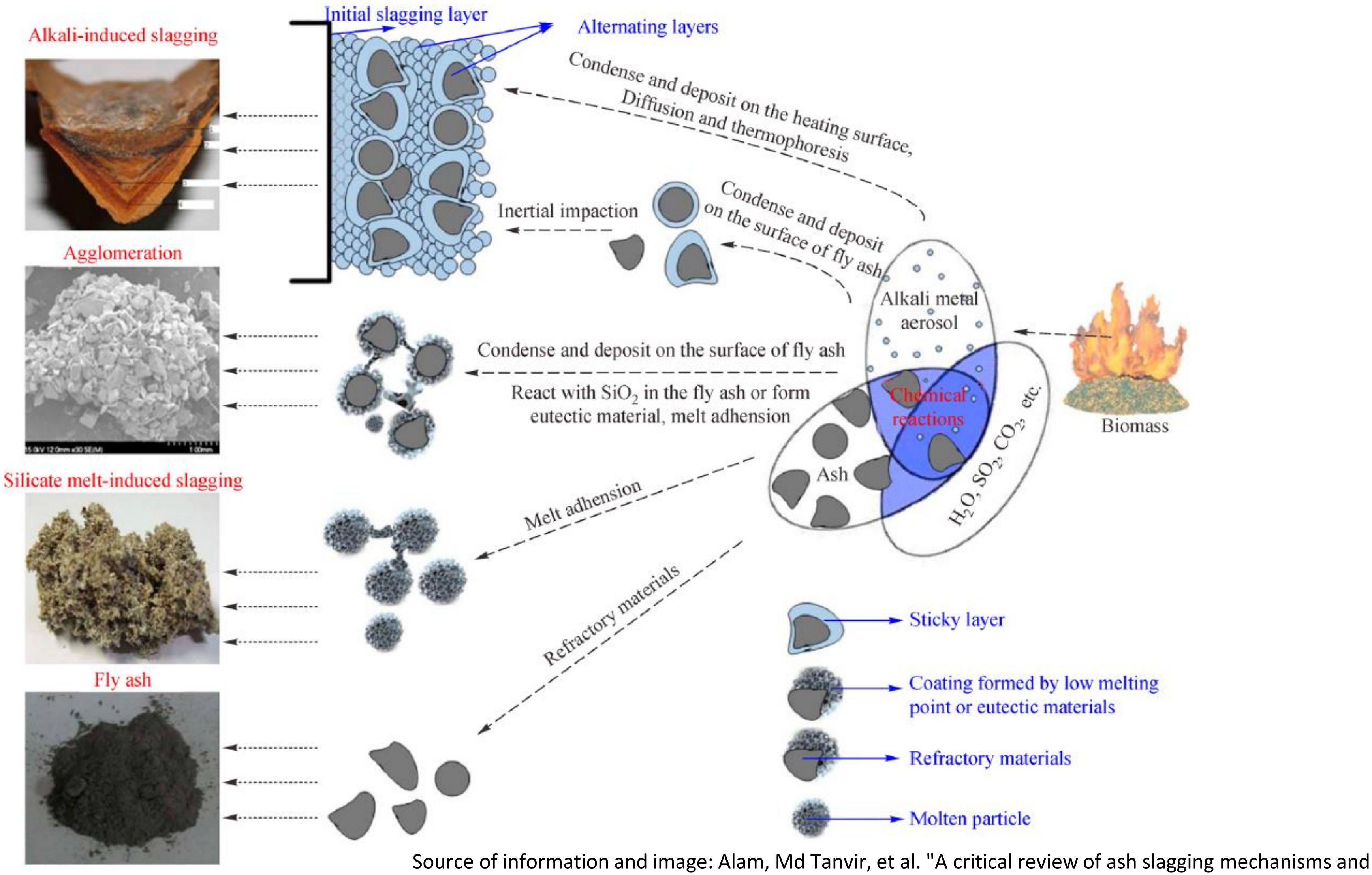
Photo source: http://biomassmagazine.com/articles/5318/chinaundefineds-crop-residue-capacity

- Due to the ash content biomass, care must be given in incorporation of an efficient ash removal system in order to reduce the particulate pollution
- A particular ash related problem is its low melting point during the combustion which can result in agglomeration, fouling, scaling and consequently corrosion of the heat exchanger surfaces



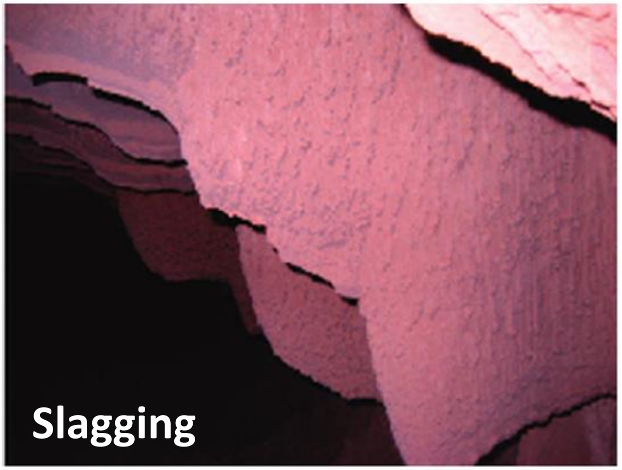
Source of information and pictures: Horvat, Ivan, and Damir Dović. "Combustion of agricultural biomass-issues and solutions." Transactions of FAMENA 42.SI-1 (2018): 75-86.

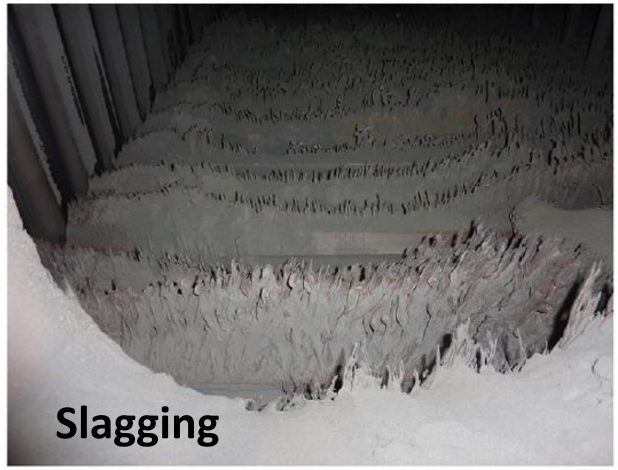
Formation mechanism of slagging and agglomeration during biomass combustion



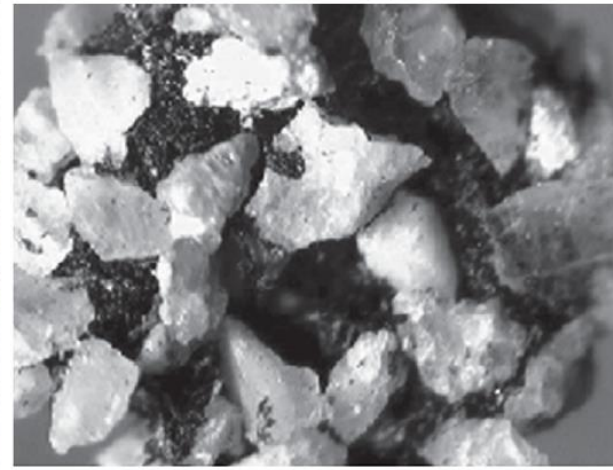
Source of information and image: Alam, Md Tanvir, et al. "A critical review of ash slagging mechanisms and viscosity measurement for low-rank coal and bio-slags." Frontiers in Energy 15.1 (2021): 46-67.

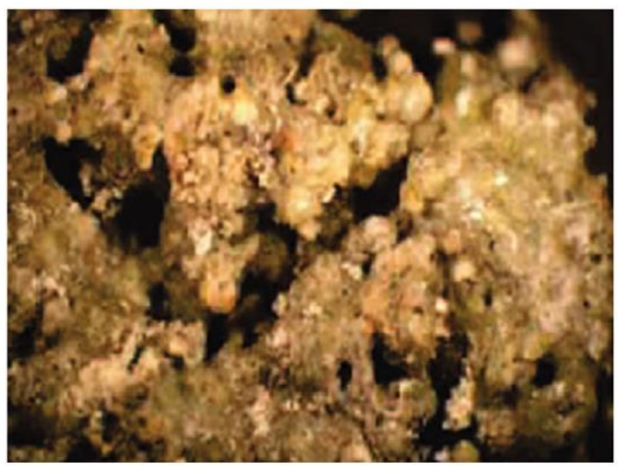
Various ash-related issues in biomass-fired furnaces



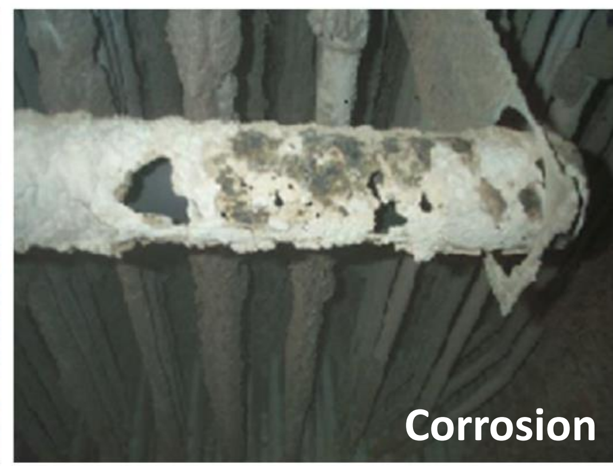


Agglomeration





Slagging



Source of information and pictures: Niu, Yanqing, and Houzhang Tan. "Ash-related issues during biomass combustion: Alkali-induced slagging, silicate melt-induced slagging (ash fusion), agglomeration, corrosion, ash utilization, and related countermeasures." Progress in Energy and Combustion Science 52 (2016): 1-61.

Commonly encountered technical problems and solutions

Ash content

Results of poplar pellets combustion tests (ash content in %w/w)

2%

6%

12%

- If an equipment is operated with a fuel with a higher ash content, the equipment should increase the extraction of ash and thus increase its cleaning frequency
- Otherwise, the ash content within biomass might cause the agglomerations shown in the picture during the combustion process

Source of information and pictures: Training curse on "Energy from biomass" / "Biomass characterization" elaborated by CIRCE. Date June, 13-15th, 2017

Commonly encountered technical problems and solutions

Adjustment of fuel feeding, grate movements and air distribution

Brassica pellets

Poplar pellets

Sorghum pellets

Source of information and pictures: Training curse on "Energy from biomass" / "Biomass characterization" elaborated by CIRCE. Date June, 13-15th, 2017

Commonly encountered technical problems and solutions

Obstruction of the feeding system and air distribution

Before → **combustion** → **After**

Source of information and pictures: Training curse on "Energy from biomass" / "Biomass characterization" elaborated by CIRCE. Date June, 13-15th, 2017

Commonly encountered technical problems and solutions

Deposits on heat exchange surfaces

Loss of surface for heat transfer



Source of information and pictures: Training curse on “Energy from biomass” / “Biomass characterization” elaborated by CIRCE. Date June, 13-15th, 2017

Challenges & solutions in agrobiomass combustion

- Different agrobiomass assortments may present different challenges during combustion
- Solutions available, but always a question of techno-economic feasibility
- For large applications (typically above 1 MW), possibilities for tailored solutions
- Good boiler design is key to many potential issues

Characteristic	Potential challenges	Solutions
Ash	High ash content → Large volumes to handle	Adequately designed ash handling system
Sulphur	High fuel-S → SOx emissions & corrosion	Secondary measures (lime injection) High water-side temperatures and high grade steel
Nitrogen	High fuel-N → NOx emissions	Primary measures (air staging) Secondary measures (SNCR / SCR)
Chlorine	High fuel-Cl → HCl and dioxin emissions & corrosion	Proper boiler design Sufficiently high return temperatures
Potassium	High fuel-K → Fouling & high PM emissions	Large combustion volume to lower flue gas temperatures before first boiler tube pass Use of inorganic fuel additives Secondary measures for PM control
Ash melting temperature	Low ash shrinkage starting temperature → Slagging / clinker formation & fouling	Water cooled grate Flue gas recirculation below the grate
Physical properties	Debaling, inhomogeneity, stickiness, low bulk density, etc.	Good design of fuel handling / pre-treatment system

Table adapted from L. Justsen / Justsen Energiteknik A/S, WBA Webinar: Agricultural residues to energy / Latest technological developments

Contents:

Agronergy

Agronergy
Fournisseur de chaleur renouvelable
AND CONSUMPTION

- An integrated heating supplier
- 31 biomass boilers in operation
- Use of alternative biomass : pruning / miscanthus / agropellets…

Start of works
Acceptance of works

EPC

O&M

DESIGN
- In-house engineering studies are designed for the infrastructure depending on the project size and the energy mix

INSTALLATION
- Boiler rooms are assembled in a dedicated workshop in Ozoir and then installed on site
- Boiler equipment are purchased from leading international OEM

P1: ENERGY SUPPLY
- Multi renewable energy: classical and alternative biomass, geothermal energy

Maintenance

P2: SMALL MAINTENANCE
- Preventive and curative maintenance

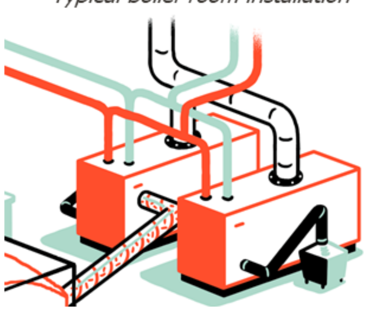
P3: EQUIPMENT REPAIRS
- Scheduled equipment renewal

P4: FINANCING
- The asset is subject to a leasing contract with a fixed fee

P5: ADDITIONAL WORKS
- Including construction supplements related to the project life

Construction period
5 months to 2 years

Typical boiler room installation



Long term contracts
10 years to 30 years

Revenue drivers
- # of MWh consumed
- Prices defined by contracts

Integrated services
Management of all operations

Recurring revenue
Services charged monthly

Examples of facilities using agrobiomass

Agronergy's facilities currently using (or having used in the past) Agrobiomass

- Old people home in Chevresis Monceau (north of France)
- Heated area : 60 rooms
- Installed capacity : 400 kW biomass + 750 kW gas
- Heat consumption : 110M MWh / year
- Fuel : miscanthus
- Start of operations: Oct 2019
- Contract duration : 12 years

Practical experiences 1/3

Issues while operating facilities for agrobiomass combustion:

1. **Fuel feeding**

   Miscanthus density is very low : 100kg/m3 => can only transport from very near area (10 to 20 km max)

   Miscanthus is very dry : it sucks the humidity from the air or from the silo => A raised floor has been put in place for the problems of infiltration and humidity

   Apart from that, that feeding system is the same as pellets => no need for specific equipment

2. **Slagging**

   Slagging can appear very easily with agrobiomass => requires a specific adjustment with a large excess of air as well as a modification of the boiler to cool the ashes

Issues while operating facilities for agrobiomass combustion:

3. Corrosion

Very aggressive ash soot.
Risks of corrosion for the stainless steel of the flue pipes and all the conveyors located outside.
Risk of corrosion for the combustion chamber and heat Exchanger inside the boiler
⇒ Solution: keep a high temperature (above temperature of condensation of the fumes) at all points of the system

4. Emissions

Difficult to get good emission results at every power level
Stable emissions only at 100% load
⇒ Solution: avoid the on/off running mode. Keep regular combustion mode = undersize the agrobiomass boiler and keep gas back up.

Practical experiences 3/3

Issues while operating facilities for agrobiomass combustion:

5. Ash disposal

The ash quantity is much higher than woodchips (about 10 times more ashes)

⇒ Requires regular maintenance and ashes disposal

⇒ Requires a cheap and convenient output for ashes

In our case, the ashes are spread in the fields by the farmers.

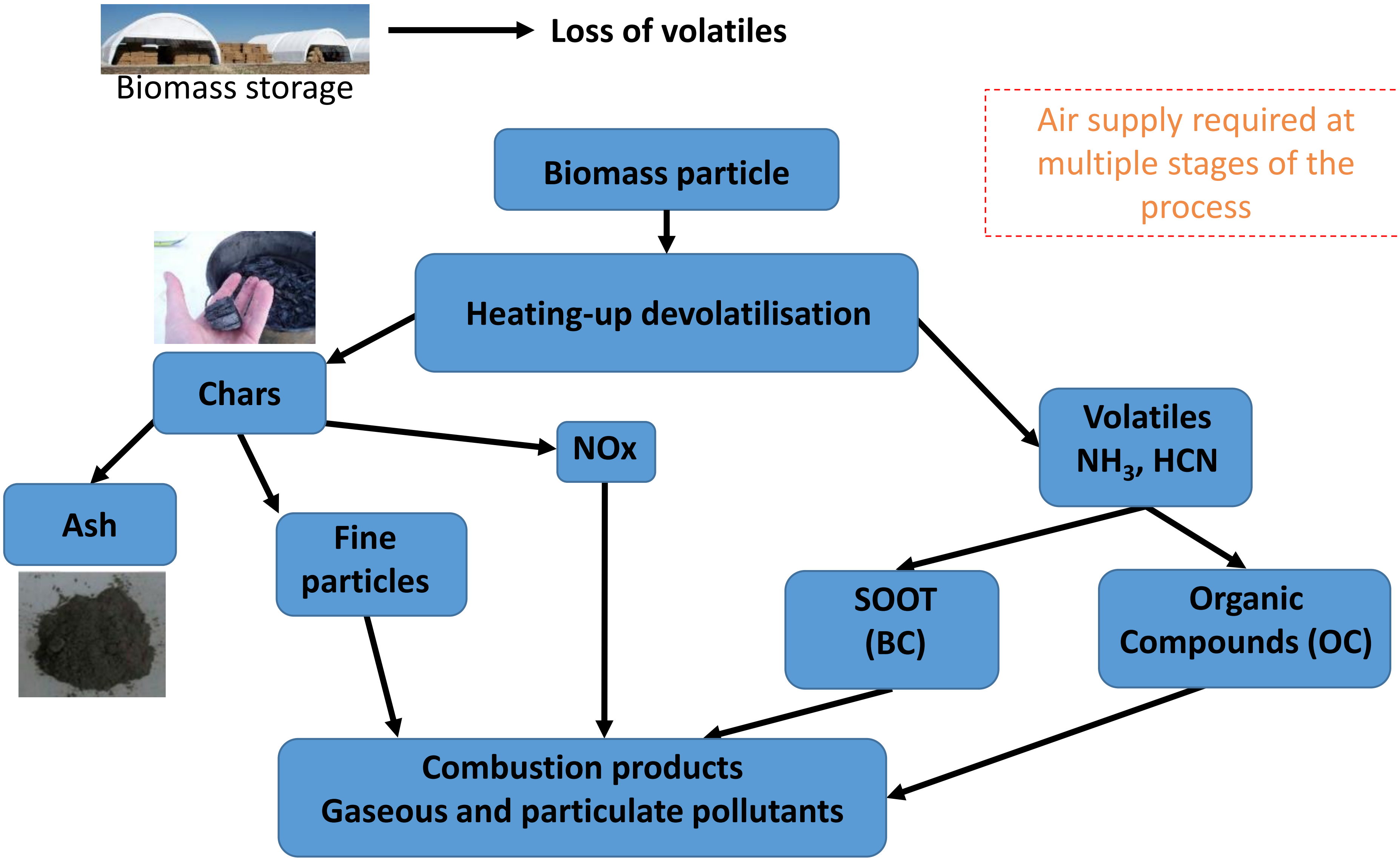
Seasonality and quantity are not sufficient to make a reliable resource for the farmers

Final remarks on agrobiomass utilization

Pros	Cons
• Low-cost source of energy • Uses a resources that would otherwise not be used • Does not generate mechanical problems	• Product easily absorbs moisture and greatly influences combustion setting • High volatility of the material causing a nuisance on dwellings directly nearby • Difficult to optimize CO emission • Disturbing smell during combustion phase transitions • Significant production of ash and slag • Low energy density • Non-qualitative ash

Contents:

Formation of pollutants during agrobiomass combustion



Source of information: Horvat, Ivan, and Damir Dović. "Combustion of agricultural biomass-issues and solutions." Transactions of FAMENA 42.SI-1 (2018): 75-86.

Type of emissions

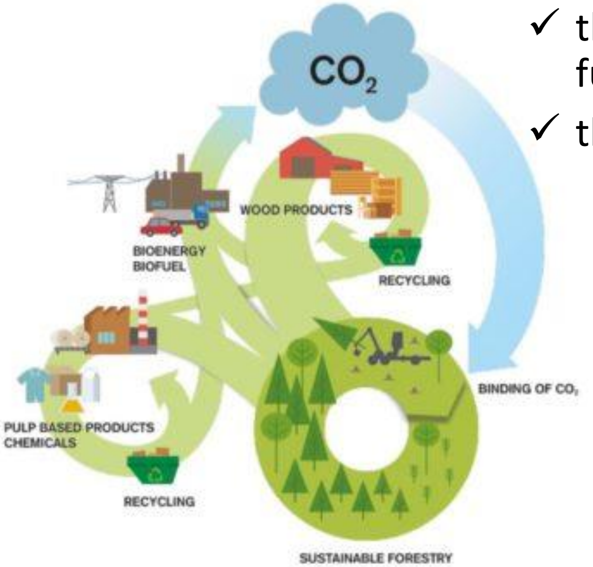
- Polycyclic aromatic hydrocarbons
- CO emissions
- NO_x emissions
- SO_x emissions
- Dust emissions
- Dioxins and furans

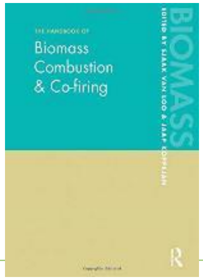
Forest chips ignition, with generation of heavy fumes and steam at low temperatures
In the presence of O_2, the volatile oxidation temperature is reached

Photograph source: Training curse on "Energy from biomass" / "Biomass characterization" elaborated by CIRCE. Date June, 13-15th, 2017

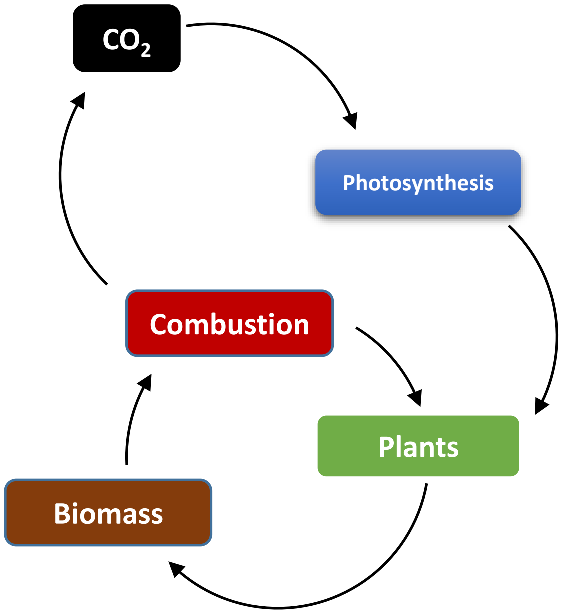
Environmental impacts of biomass combustion 1/2

- The environmental impacts of air pollution from most modern and well-maintained biomass combustion applications today are far from negligible
- Compared to fossil fuel combustion applications there are several advantages
- Biomass is a renewable fuel considered CO_2 neutral with respect to the greenhouse balance
  - This is only true if:
    - ✓ very low levels of emissions from incomplete combustion are achieved
    - ✓ the use of fossil fuels in harvesting and transportation of biomass fuels are not included
    - ✓ the use of electricity produced form fossil fuels is excluded

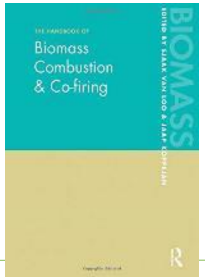




- To evaluate the real environmental impacts of biomass combustion, a life cycle analysis should ideally be carried out
- This type of evaluation includes the various stages of the life cycle of the biomass:
  - Fuel
  - Transportation
  - Storage
  - Conversion
  - Discharge and handling of ashes



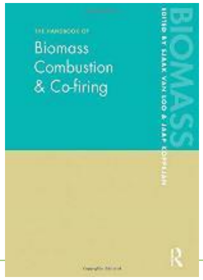
⚠ Construction, operation, maintenance and decommissioning of the energy converting technology should also be included in the assessment



Emission components and their main influencing factors

Complete combustion	INcomplete combustion
• Carbon dioxide (CO_2) • Nitrogen dioxide (NO_x) • Nitrous oxide (N_2O) • Sulphur oxides (SO_x) • Hydrogen chloride (HCl) • Particles • Heavy metals	• Carbon monoxide (CO) • Methane (CH_4) • Non-methane volatile organic components (NMVOC) • Polycyclic aromathic hydrocarbons (PAH) • Particles • Polychlorinated dioxins and furans (PCDD/PCDF =PCDD/F) • Ammonia (NH_3) • (Ground level) Ozone (O_3)

Photograph source: Munsif, et al. "Industrial Air Emission Pollution: Potential Sources and Sustainable Mitigation." Environmental Emissions. IntechOpen, 2021



Pollutants from COMPLETE biomass combustion and their impacts

Component	Biomass sources	Impacts
Carbon dioxide (CO_2)	Major combustion product from all biomass fuels	**Climate:** direct green house gas
Particles	Soot, char and condensed heavy hydrocarbons (tar) from incomplete combustion of all biomass fuels / Fly-ash and salts	**Climate and environment:** reversed greenhouse effect through aerosol formation / Indirect effects of heavy-metal concentrations in deposited particles **Health:** negative effect on the human respiratory system / carcinogenic effects
Nitrogen oxides (NO_x (NO, NO_2))	Minor combustion product from all biomass fuels containing nitrogen / Additional NO_x may be formed from nitrogen in the air under certain conditions	**Climate and environment:** indirect green house gas through O_3 formation / Reversed greenhouse effect through aerosol formation / Acid precipitation / Vegetation damage / Smog formation / Corrosion and material damage **Health:** negative effect on the human respiratory system / NO_2 is toxic
Sulphur oxides (SO_x (SO_2, SO_3))	Minor combustion product from all biomass fuels containing sulphur	**Climate and environment:** reversed greenhouse effect through aerosol formation / Acid precipitation / Vegetation damage / Smog formation / Corrosion and material damage **Health:** negative effect on the human respiratory system / Asthmatic effect
Heavy metals	All biomass fuels contain heavy metals to some degree, which will remain in the ash or evaporate	**Health:** Accumulation in the Food chain / Some are toxic and some have carcinogenic effects
Hydrogen chloride (HCl)	Minor combustion product from all biomass fuels containing chlorine	**Climate and environment:** Acid precipitation / Vegetation damage / Corrosion and material damage **Health:** Negative effect on the human respiratory system / Toxic

Source: Koppejan & Van Loo, *The handbook of biomass combustion and co-firing*. 2012

Pollutants from INCOMPLETE biomass combustion and their impacts

Component	Biomass sources	Impacts
Carbon monoxide (CO)	Incomplete combustion of all biomass fuels	**Climate:** indirect green house gas through O_2 formation **Health:** reduced oxygen uptake especially influences people with asma, and embryos / suffocation in extreme cases
Methane (CH_4)	Incomplete combustion of all biomass fuels	**Climate:** direct green house gas /indirect green house gas through O_3 formation
Non-methane volatile organic components (NMVOC)	Incomplete combustion of all biomass fuels	**Environment:** indirect green house gas through O_3 formation **Health:** negative effect on the human respiratory system
Polycyclic aromathic hydrocarbons (PAH)	Incomplete combustion of all biomass fuels	**Environment:** smog formation **Health:** carcinogenic effects
Ammonia (NH_3)	Small amount may be emitted as a result of incomplete conversión of NH_3 formed from pyrolysis / gasification, to oxidized nitrogen-containing components / Secondary NO_x reduction measures by NO_3 injection (SNCR, SCR)	**Climate and environment:** Acid precipitation / Vegetation damage / Corrosion and material damage **Health:** negative effect on the human respiratory system
(Ground level) Ozone (O_3)	Secondary cobustion producto formed from atmospheric reactions including CO, CH_4, NMVOC and NO_x	**Climate and environment:** direct green house / Vegetation damage / Smog formation / Material damage **Health:** indirect effect due to O_3 depletion in the stratosphere / Negative effect on the human respiratory system / Asthmatic effect
Dioxins and furans (PCDD/PCDF)	Small amount may be emitted as a result of reactions including carbon, chlorine, and oxygen in the presence of catalysts (Cu)	**Health:** Highly toxic / Liver damage / Central nervous system damage / Reduced immunity defence / Accumulation in the Food chain

Source: Koppejan & Van Loo, *The handbook of biomass combustion and co-firing*. 2012

Emissions data: comparison between different fuel types

Emissions at 11% O_2	Fuel type		Typical Data
NO_x (mg/Nm^3)	Native wood (soft wood)		100 - 200
	Native wood (hard wood)		150 - 250
	Straw, grass, miscanthus, chip boards		300 - 800
	Altholz		400 - 600
HCl (mg/Nm^3)	Native wood		< 5
	Altholz, straw, grass, miscanthus, chip boards (NH_4Cl)		raw gas: 100 - 1000 with HCl absorption: < 20
Particles (mg/Nm^3)	Native wood	after cyclone:	50 -150
	Straw, grass, miscanthus, chip boards	after cyclone:	150 - 1000
	Altholz	after cloth or electric filter:	< 10
Σ Pb, Zn, Cd, Cu (mg/Nm^3)	Native wood		< 1
	Altholz	raw gas:	20 - 100
	Altholz	after cloth or electric filter:	< 5
PCDD/F ($ng\ TE/Nm^3$)	Native wood	typical:	< 0.1
		range:	0.01 - 0.5
	Altholz : urban waste wood & demolition wood	typical:	2
		range:	0.1 - 20

It is worth noting that the following ranges have been represented in the table above

Above 5 MW	Larger boilers developed for biomass combustion include conventional travelling grates with spreader stoker which is the most common boiler, dedicated folded boiler designs like straw-fired boilers, bubbling fluidized beds (BFB) and circulating fluidized beds (CFB)
Around and below 1 MW	The cyclone fumace is commonly used / Underfeed stoker and the fixed grate are the most common used firing systems in boilers
Below 0.02 MW	Various types of wood log boilers, wood stoves and fireplaces exist on the market

Source: Nussbaumer and Hustad. "Overview of biomass combustion." *Developments in thermochemical biomass conversion*, 1997

AgroBioHeat

Emission reduction measures

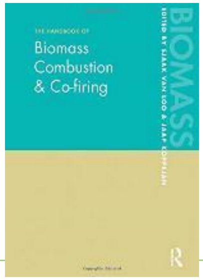
circe RESEARCH CENTRE FOR ENERGY RESOURCES AND CONSUMPTION

Reduction of harmful emissions through flue gases and effluents can be obtained by either:

Primary measures	Avoiding creation of such substances	Modification of the combustión process
Secondary measures	Removing the substances from the flue gas	Measure that takes place after the combustión process

Primary emission reduction measures aim to prevent or reduce the formation of emissions and/or a reduction of emissions within the combustion chamber:

- Modification of the fuel composition
- Modification of the moisture content of the fuel
- Modification of the particle size of the fuel
- Selection of the type of combustion equipment
- Improved construction of the combustion application
- Combustion process control optimization
- Staged-air combustion
- Staged fuel combustion and reburning
- Catalytic converters



PRIMARY emission reduction measures 1/2

Measure	Description
Modification of the fuel composition	-Untreated biomass fuels are solid fuels, with limited possibilities for decreasing the amount of specific elements in the fuel -For the case of Straw, washing (rain exposicion) the fuel has been shown to be effective -Experiments with barley Straw in Denmark showed that after 150 mm of rain, the chloride content had dropped from 0.49 to 0.05 % and the potassium content had dropped from 1.18 to 0.22 %
Modification of the moisture content of the fuel	-Wood for Energy purposes for instance may vary in moisture content from approximately 10 and 60% from the Industry where Wood has been previously dried and fresh wood from the forest, respectively -High moisture makes difficult to achieve a high temperature -A temperature above 850ºC is desired to ensure a sufficiently low level of CO -On the contrary incomplete combustión might occur -Waste heat from another process can be used to remove moisture
Modification of the particle size of the fuel	-Fuel size in biomass combustión applications may vary from whole Wood logs to fine sawdust -If the fuel consists of both very small and very large pieces, a schredder or chipper can be used to reduce the particle size of the largest particles
Selection of the type of combustion equipment	-Fuel characteristics such as composition, moisture content and particle size are iportant -For Wood fuels, only the nitrogen content may limit the choice of combustión technology, if there are NO_x emisión limits to emit -Moisture content is decisive for Wood fuels such as woodchips and bark if drying of the fuel prior to combustión is not an option
Improved construction of the combustion application	-Sufficiently high combustión temperaturas -Sufficiently long residence times -Optimal mixing of fuel gases and air, also with changing heat and/or power output

Source: Koppejan & Van Loo, *The handbook of biomass combustion and co-firing*. 2012

PRIMARY emission reduction measures 2/2

Measure	Description
Combustion process control optimization	-Minimizing emissions: the combustión quality can be modified by adjusting the amounts of fuel and primary and secondary air, based on measured concentrations of CO, C_xH_y, O_2 and the combustión chamber temeperature -Control heat output: based on using measured temperature difference and mass Flow of boiler wáter -Modification of an existing biomass boiler

- For a 500 KWth Nolting underscrew feeder wood combustion plant with cyclone
- TNO* installed an oxygen sensor in order to control the combustion process and heat output (*Netherlands Organisation for Applied Scientific Research)
- Gas recirculation was applied and combustion chamber modified

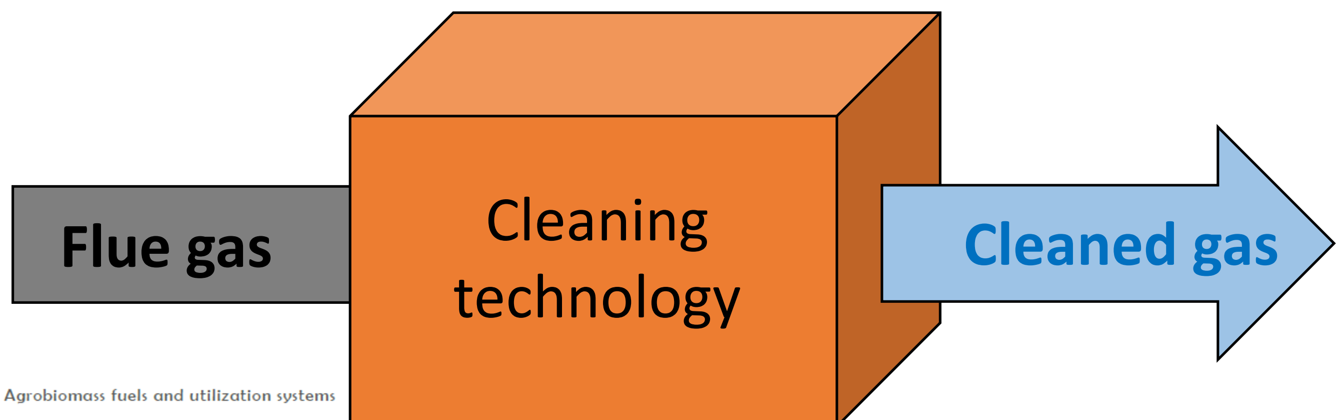
Property	Before optimization	After optimization
CO (mg/m3)	3516↘	82
CxHy (mg/m3)	262 ↘	2
NOx (mg/m3)	772↘	652
Dust (mg/m3)	219 ↘	99
Flue gas temperature (ºC)	163 ↘	109
Flue gas losses (%)	17 ↘	7
Losses due to incomplete combustión (%)	1.5 ↘	1.1
Overal efficiency (%)	81 ↗	93

Source: Koppejan & Van Loo, *The handbook of biomass combustion and co-firing*. 2012

Flue gas cleaning systems

Even though modern boilers aim to achieve not only high combustion efficiency but low emissions as well when using agrobiomass, compliance with the emission limits of various regulations without the use of additional flue gas cleaning equipment is not always possible

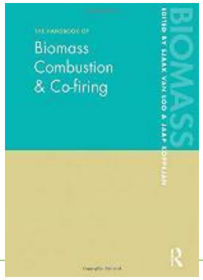
Depending on the application, there are multiple solutions available in the market for the abatement of pollutants such as particulate matter (dust), acidic gases and nitrogen oxide emissions



Source: AgroBioHeat Deliverable 4.2 Agrobiomass fuels and utilization systems Version 1.0, 13 July 2020

SECONDARY emission reduction measures

- Secondary measures can be applied to remove emissions from the flue gas once it has left the boiler
- For untreated wood combustion, particle removal is of particular relevance
- For other type of biomass, additional secondary measures may be necessary, depending on the elementary composition and the fuel characteristics of the selected biomass fuel and the combustion technology
  - ✓ Particle control technologies
  - ✓ NO_x control technologies
  - ✓ SO_x control technologies



Nitrogen oxides removal:

- In cases for which reduction of nitrogen oxides (NOx) emissions from agrobiomass boilers is required, the application of Selective Non Catalytic Reduction (SNCR) techniques can be very effective
- For the denitrification of exhaust gases in agrobiomass boilers the selective non-catalytic reduction (SNCR) method is very effective and can achieve NOx reductions in the range of 20 to 70 %22
- Selective Catalytic Reduction (SCR) technologies can achieve even higher NOx reduction (up to 90 %), however such systems are only applied in larger scale, industrial applications

Selective non-catalytic reduction (SNCR)

- SNCR involves injecting either ammonia or urea into the firebox of a boiler at a location where the flue gas is between 900 and 1,100 °C to react with the nitrogen oxides formed in the combust process
- The resulting product of the chemical redox reaction is molecular nitrogen (N_2), carbon dioxide (CO_2) and water (H_2O)
- Since a certain furnace volume is needed to disperse and evaporate the additive, SNCR is not meaningful for small—scale boilers

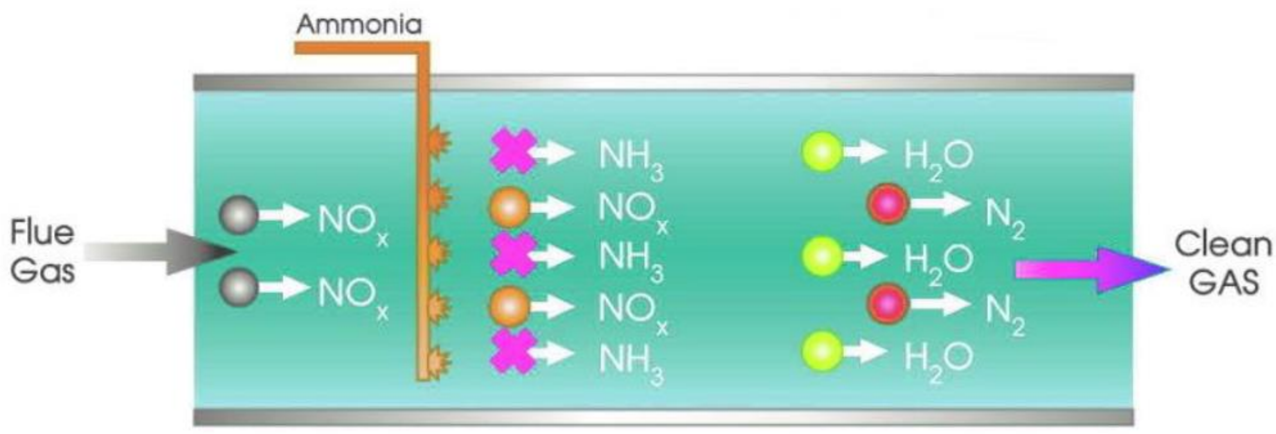


Figure 23: Selective non-catalytic reduction [Image source: IFS[23]]

Dust control: For dust emission abatement, cyclones, electrostatic precipitators (ESP) or bag filters may be used

Cyclones

- Cyclones are conical containers that remove particulates from high-speed rotating flue gas flows through vortex separation
- Flue gas flows in a helical pattern before exiting the cyclone in a straight stream through the centre of the cyclone and out the top
- Particles in the rotating stream have too much inertia to follow and thus strike the outside wall and then fall to the bottom of the cyclone, from where they are removed

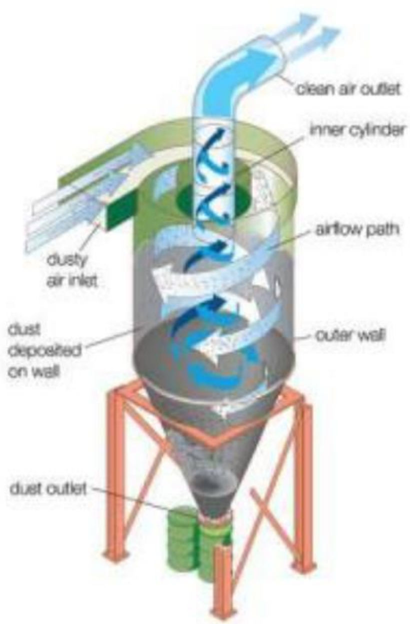


Figure 17: Flow pattern through a typical cyclone

Figure 18: Example of cyclone [Image source: Indiamart.com]

Source: AgroBioHeat Deliverable 4.2 Agrobiomass fuels and utilization systems Version 1.0, 13 July 2020

Fabric filters

- Fabric or bag filters use filtration to separate dust particulates from dusty gases
- They are one of the most efficient types of dust collectors available and can achieve a collection efficiency of more than 99 % for very fine particulates
- Fabric filters are not applied in small-scale applications due to their demand for compressed air for cleaning, the high space demand and the fact that condensation of water vapours in the filter has to be avoided, which cannot be guaranteed during partial load operation of small-scale boilers

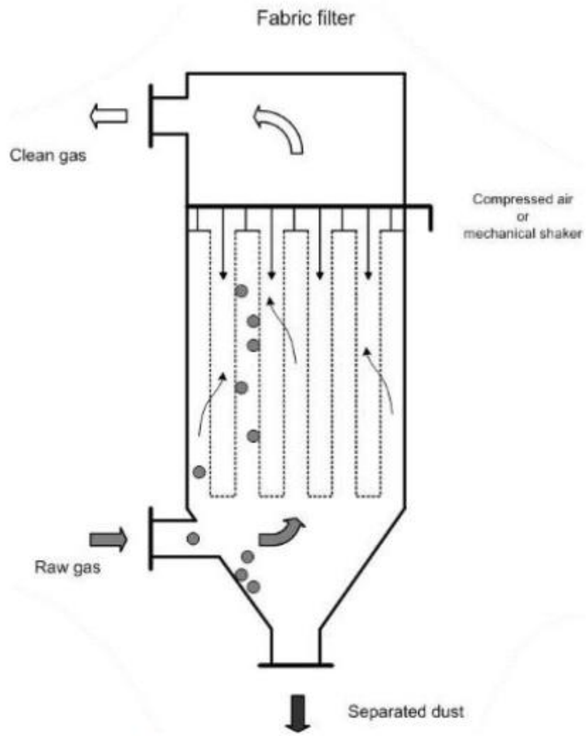


Figure 19: Fabric filter diagram [Image source : EMIS[19]]

Figure 20: Example of baghouse [Image source: www.baghouse.com]

Electrostatic precipitators (ESP)

- ESPs use electrostatic forces to separate dust particles from flue gases
- One or more (depending on filter size) high-voltage discharge electrodes are placed between grounded collecting electrodes
- Particles receive a negative charge as they pass through the ionized field between the electrodes and are then attracted to a grounded or positively charged electrode and adhere to it

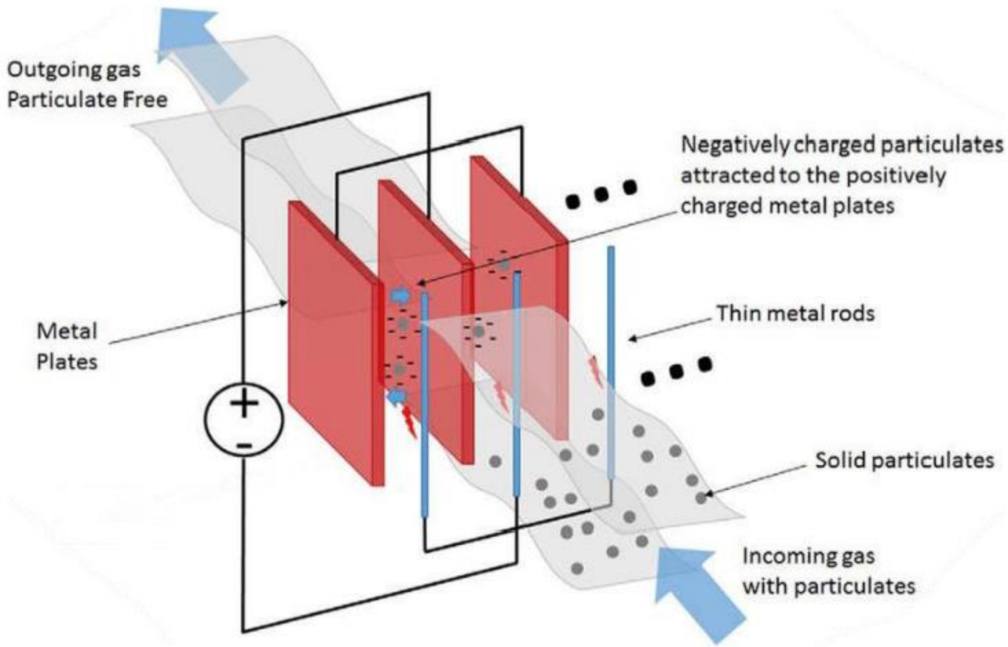


Figure 21: ESP conceptual diagram [Image source: (Becker et al., 2016)[20]]

Figure 22: Example of ESP for up to 100 kW [Image source: OekoSolve[21]]

Acidic flue gas constituents' control: For HCl and SO_2 removal, dry sorption systems may be used in agrobiomass heating applications

Selective non-catalytic reduction (SNCR)

- The separation of acidic flue gas constituents via dry sorption is a simultaneous and absorptive gas/solid reaction which takes place in the sorbent employed in the process
- In this process, the gaseous pollutants are bound to the surface of the introduced solid
- The additives can then be separated from the flue gas together with the dust particles (typically in a subsequent fabric filter)
- These systems are characterised based on the additive applied and can be either sodium based (application of NaHCO3) or lime based (application of Ca(OH)2) systems

Contents:

Emission limits for agrobiomass boilers

The ecodesign regulation

The Regulation provides the following definitions:

-“woody biomass” means biomass originating from trees, bushes and shrubs, including log wood, chipped wood, compressed wood in the form of pellets, compressed wood in the form of briquettes, and sawdust





-“non-woody biomass” means biomass other than woody biomass, including straw, miscanthus, reeds, kernels, grains, olive stones, olive cakes and nut shells







As such, Ecodesign excludes from its scope many agrobiomass types; it does however include agricultural prunings and plantation removal biomass, since it can be classified as “woody”





Source: AgroBioHeat

Deliverable 4.2 Agrobiomass fuels and utilization systems

Version 1.0, 13 July 2020

Emission limits for agrobiomass boilers

Ecodesign Regulation seasonal efficiency and emission limits for solid biomass boilers

Feeding Method	Nominal heat output	Seasonal space heating energy efficiency	Seasonal space heating emission limits (mg/m^3 at a 10 % oxygen concentration)			
			Carbon Monoxide, CO	Organic Gaseous Compounds, OGC	Particle Matter , PM	Nitrogen Oxides, NOx
Manual	≤ 20 kW	≥ 75 %	700	30	60	200
	> 20 kW	≥ 77 %				
Automated	≤ 20 kW	≥ 75 %	500	20	40	
	> 20 kW	≥ 77 %				
Benchmarks for Best Available Techniques (BATs)		90 % condensing 84 % non-condensing	6	1	2	97
Note: At the time of entry into force of the Regulation, no single solid fuel boiler was identified meeting all the benchmark values. Several solid fuel boilers met one or more of these values.						

Source: AgroBioHeat D4.2 – Agrobiomass Fuels and Utilization Systems

Emission limits for agrobiomass boilers

The Medium Combustion Plant Directive

The Medium Combustion Plant (MCP) Directive regulates emissions from combustion plants with a thermal input between 1 and 50 MW

The MCP Directive includes agrobiomass in its scope and in fact introduces some specific emission limits for straw

Some facilities are excluded from its scope, such as “on-farm combustion plants with a total rated thermal input less than or equal to 5 MW, that exclusively use unprocessed poultry manure, as a fuel”

The main emission limits for combustion plants using solid biomass are provided in Annex II of the Directive; it should be noted that some exceptions for specific installations may apply

Medium combustion plant type (other than engines and gas turbines)	Rated thermal input (MW)	Emission limits (mg/m^3 at a 6 % oxygen concentration) for solid biomass		
		Sulphur Dioxide, SO_2	Nitrogen Oxides, NOx	Dust
Existing	1 - 5	200 * / 300 (straw)	650	50
Existing	> 5	200 * / 300 (straw)	650	30
New	1 - 5	200 *	500	50
New	5 – 20	200 *	300	30
New	20 – 50	200 *	300	20
* Not applicable for plants firing exclusively woody biomass				

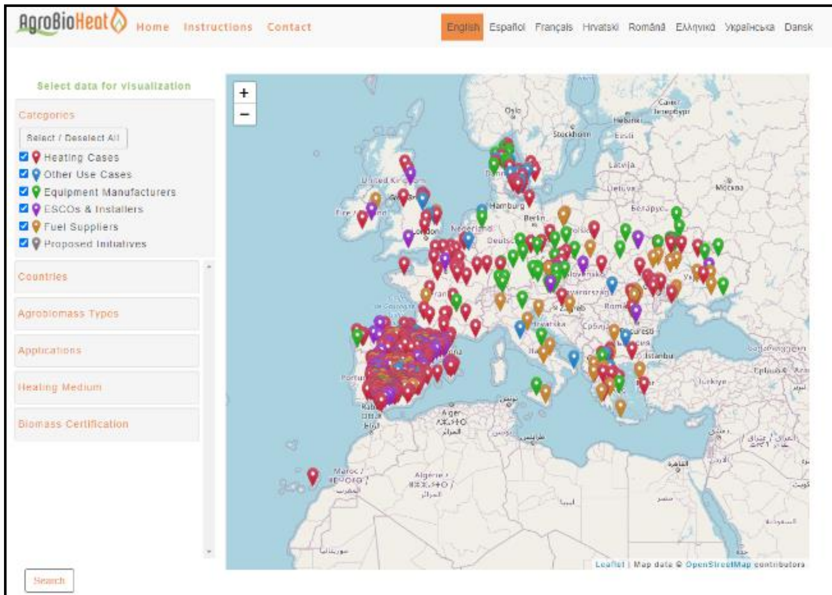
Source: AgroBioHeat D4.2 – Agrobiomass Fuels and Utilization Systems

Technologies and solutions for facilities operated with agrobiomass

Contents:

BIOMASS LOCATION TOOLS

- **AgroBioHeat observatory**: Allows to visualize data for Europe, regarding biomass types, different stakeholders, biomass certifications…

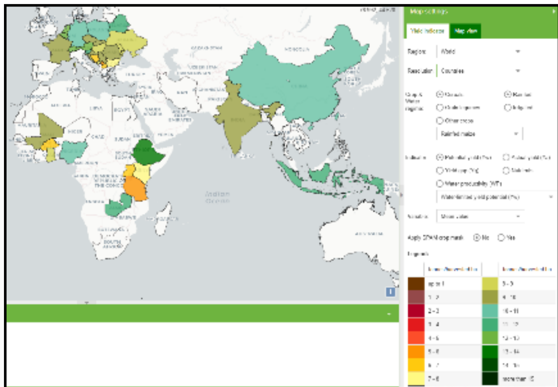


Show 25 entries | Search:

Category	Case name	City	Country	Website
Fuel Suppliers	PJSC «Zaporozhye Oil Extraction Plant»	Zaporizhzhya	Ukraine	zmez.com.ua
Equipment Manufacturers	Wichlacz	Zaporizhzhia	Ukraine	www.wichlacz.com.ua
Heating Cases	Ørnhøj-Grønbjerg Kraftvarmeværk	Ornhoj	Denmark	www.vtv-vildbjerg.dk/varme/oernhoej-groenbjerg-kraftvarmevaerk
Other Use Cases	Masnedø Kraftvarmeværk	Nørre Alslev	Denmark	www.vordingborgforsyning.dk
Equipment Manufacturers	Volyn-Kalvis Ltd	Kovel	Ukraine	www.volyn-kalvis.com.ua
ESCOs & Installers	VIVENDIO SOSTENIBILIDAD ENERGETICA, S.L.	GRANADA (GRANADA)	Spain	www.vivendio.es
Other Use Cases	VIOPAR Energia S.A.	Volos	Greece	www.viopar-energy.gr
Other Use Cases	Vioenergiaki Patridas	Patrida Imathias	Greece	www.vioenergiakipatridas.gr/
Heating Cases	Domaine Xavier Muller	Marlenheim	France	www.vin-alsace-muller.fr
Heating Cases	Vilafranca del Penedes	Vilafranca del Penedès	Spain	www.vilafranca.cat
Equipment Manufacturers	Viessmann Holzfeuerungsanlagen GmbH	Hard	Austria	www.viessmann.com
Heating Cases	Vennerslund	Norre Alslev	Denmark	www.vennerslund.dk
ESCOs & Installers	VALPLUS ENERGIA, S.L.E	CAMPILLOS (MÁLAGA)	Spain	www.valplus.es
ESCOs & Installers	URBIC, S.L.	ZARAGOZA (ZARAGOZA)	Spain	www.urbic.es

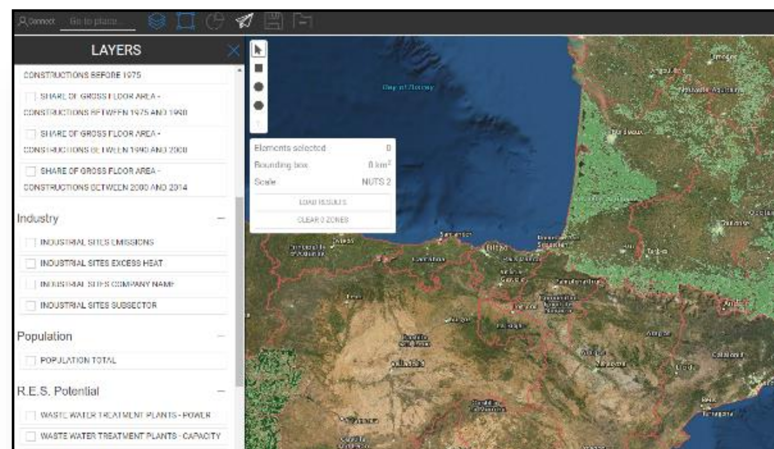
https://www.agrobiomass-observatory.eu/?handler=Search

- **Yielgap**: Atlas where you can filter and find different crop yields in the whole world.



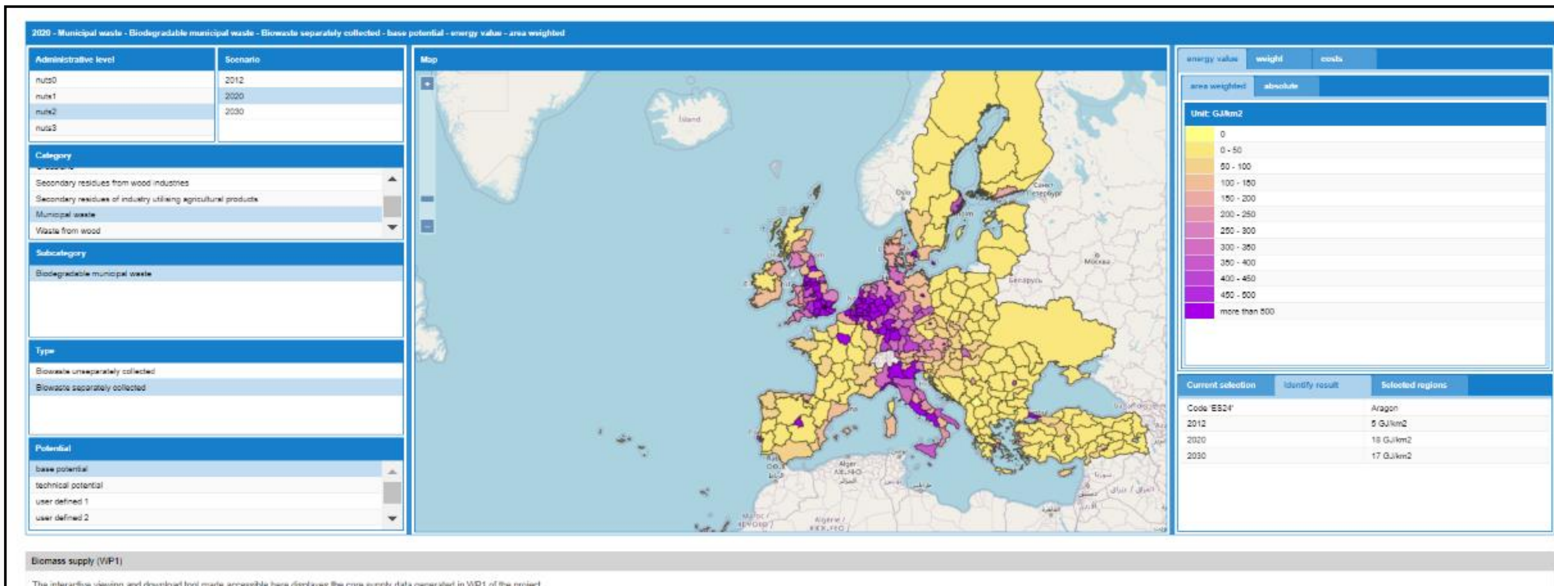
https://www.yieldgap.org/gygaviewer/index.html

- **Hotmaps**: Hotmaps is a GIS-based online software that supports authorities and energy planners to set up a strategic heating and cooling plan for their region.



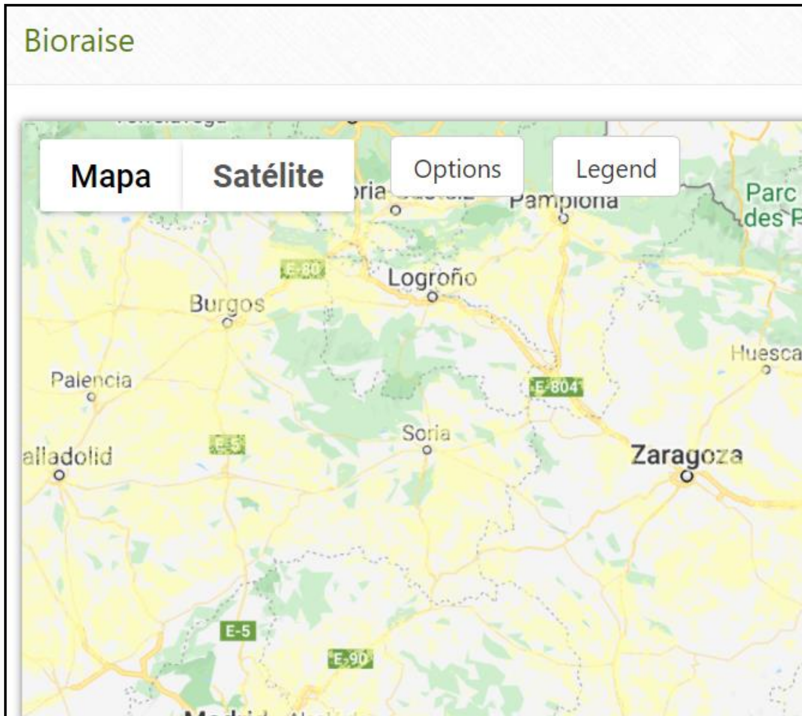
https://www.hotmaps.eu/map

- **S2BIOM:** The main objective of the S2Biom project is to support the sustainable delivery of non-food biomass feedstock at local, regional and pan European level through updated harmonized datasets at local, regional, national and pan European level for EU28, Western Balkans, Moldova, Turkey and Ukraine.



https://s2biom.wenr.wur.nl/home

- **BioRaise:** A tool that provides information on agricultural and field forest biomass resources with potential for energy use in Croatia, Slovenia, Spain, France, Greece, Italy, Portugal and Turkey, as well as agro-industrial by-product producers and bioenergy market actors. The platform allows the calculation of the mentioned biomass resources and their harvesting and transport costs.



Calculation results

Forest Biomass	Potential resources (tDM/year)	Available resources (tDM/year)	Average cost of collection (€/tDM)	Surface of potential resources (ha)	Surface of available resources (ha)	Average transport cost (€/tDM)
Conifers	39,435.51	13,330.76	57.28	71,846.47	66,557.17	14.4
Broadleaved species	47,367.88	15,914.92	48.66	36,769.06	34,518.74	15.26
Mixed	16,952.18	6,082.64	51.89	25,783.82	25,193.79	15.02
Shrub	133,166.84	31,342.93	41.27	266,164.22	155,047.75	14.51

Transportation fuel cost 1,2 €/liter Apply

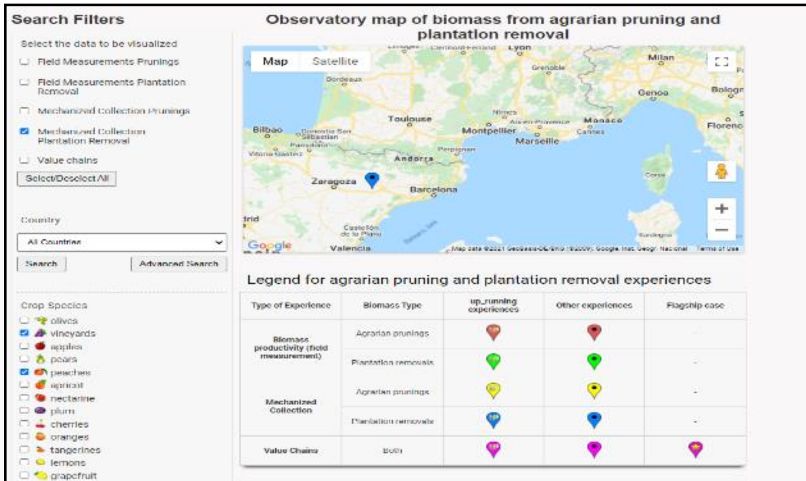
Energy content

Agricultural Biomass	Available resources (tDM/year)	Moisture content (% w.b.)	Available resources (tWM/year)	Ash value mean reference (% d.b.)	Energetic content (GJ/year)	Average cost of collection (€/GJ)	Average transport cost (€/GJ)
Rainfed crops	448,987.13	35	690,749.43	6.1	7,077,625.91	2.58	0.82

http://bioraise.ciemat.es/Bioraise/home/main

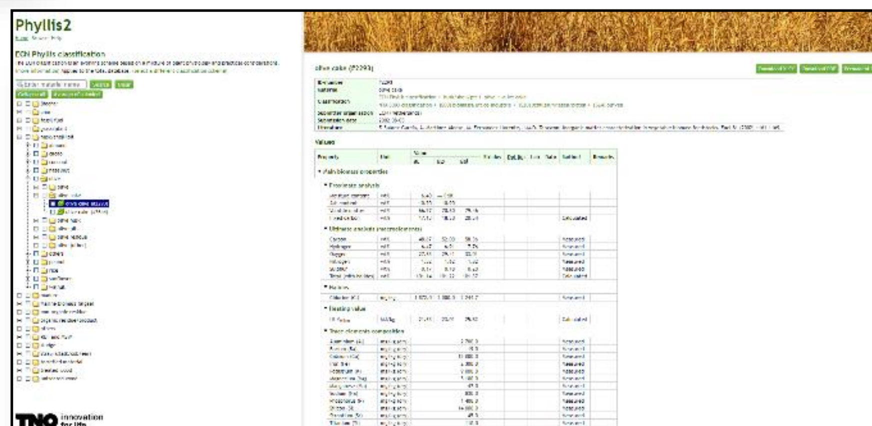
BIOMASS LOCATION TOOLS

- **uP_Running**: Observatory map of biomass from agrarian pruning and plantation removal



http://www.up-running-observatory.eu/en/

- **Phyllis2**: Database for the physico-chemical composition of (treated) lignocellulosic biomass, micro- and macroalgae, various feedstocks for biogas production and biochar.



https://phyllis.nl/Browse/Standard/ECN-Phyllis

Contents:

Group of operations that take place on a value chain

Farming
- Pruning
- Gathering of pruning
- Windrowing

Collection
- Investment on machine (tractor, mulcher, harvester, etc.)
- Provide services of harvesting, pruning, storage, transport

Transformation
- Investment on biomass conversion plant (pellet plant, moisture reduction , etc.)
- Biomass storage
- Biomass transport

End Use
- Electricity
- Heat
- Own consumption (replacing existing systems)

- The activities required to supply agrobiomass from its production point to heating plants are the following:
  - Harvesting/collection
  - In-field handling and transport Storage
  - Loading and unloading road transportation vehicles
  - Processing biomass
  - Transport

- The biomass supply chain presents several characteristics that diversify it from a typical supply chain
  - Seasonal availability
  - Low density materials
  - Customized collection and handling equipment

↓

  - Seasonal needs for resources
  - Increased need for transportation/handling equipment and storage space
  - Complicated structure of the supply chain

↓

Increases supply chain costs and require specific designing

Key actors on the value chain of woody biomass or plantation removal

- The three groups of key actors participating in the biomass value chain: types of actors, interrelations and main roles

PRODUCERS OF THE BIOMASS

Agreement and collaboration to transfer the residue

BIOMASS SUPPLY & PROCESSING

Agreement on APPR biomass format, quality and price

CONSUMERS (Energy conversion)

Producers of the biomass

Key role:
Find the best form to produce savings in the management of biomass
Establish dialogue and collaboration with actors downstream

- Farmers
- Cooperatives
- Fruit/olive/grape producing companies

SELF-CONSUMPTION

- Farm heating
- Greenhouse heating
- Energy demand for food/feed processing

Biomass supply & processing

Key role:
- Establish dialogue and agreement with producer of the biomass residue
- Organise the logistics and processing to preserve quality whilst keeping expenses low

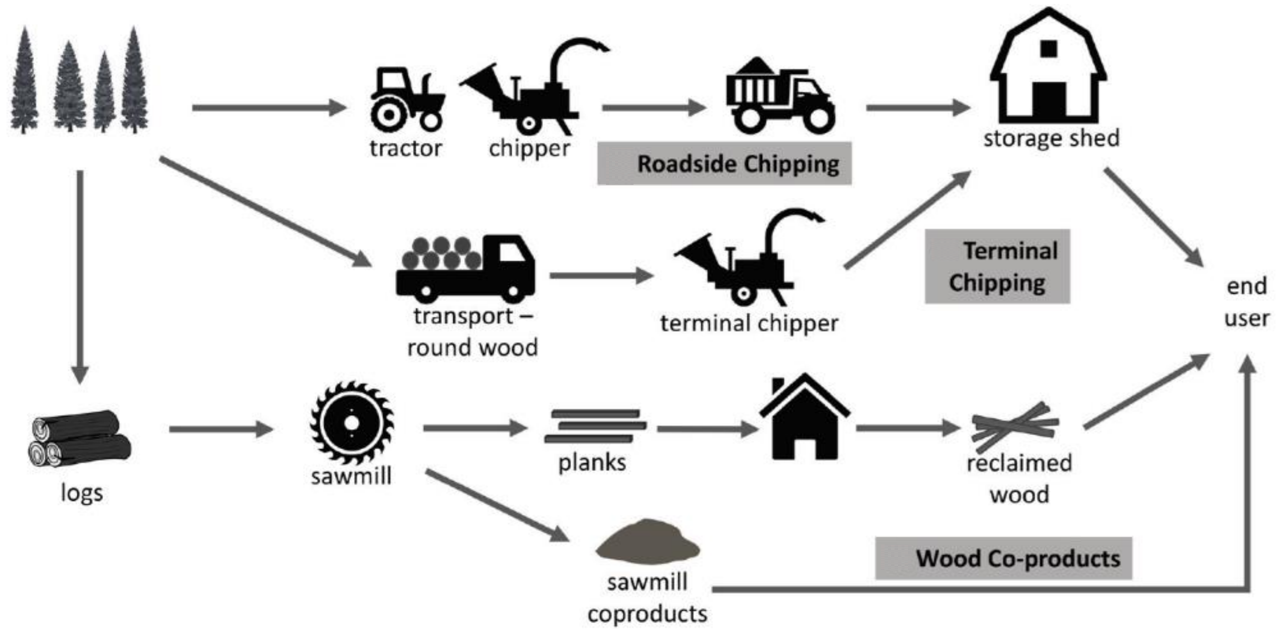
- Agro-service companies
- Forest service comp.
- Biomass suppliers
- Residues retailers
- ESCOs
- Biomass conversion plants
- Biomass platforms
- Public services

Consumers

Key role:
Provide suppliers with quality parameters to be satisfied
Ensure this biomass can be utilized in its facilities prior any actor performs an investment

- Household
- Agro-industries
- Industrial heat
- Tertiary sector
- District heating networks
- Power and CHP plants

- It is essential that heating plants receive a smooth, consistent supply of biomass fuel that meets the specified quality criteria. Therefore, the biomass supply system must be able to operate in an efficient and reliable manner
- A typical biomass supply chain is comprised of several discrete processes. These processes may include harvesting, handling, storage, in-field/forest transportation, road transportation and utilization of the fuel at the heating plant.



https://www.bioenergyconsult.com/biomass-collection/
http://www.worldbioenergy.org/uploads/Factsheet%20-%20Biomass%20Supply%20Chains.pdf

Example of different paths from forest feedstock to energy conver

BIOMASS COLLECTION

- Biomass collection involves gathering, packaging, and transporting biomass to a nearby site for temporary storage.

Baling

Loading

Chipping

Whole Crop Harvest

OTHER OPERATIONS

Preprocessing: It’s interesting to perform as little preprocessing as posible, because this increments the price of the fuel throughout the value chain, but it might be needed or usefull to decrease the contamination, or the transport prices (more density, less transport cost per volume unit)

Feedstock Supply System Design and Analysis “The Feedstock Logistics Design Case for Multiple Conversion Pathways” Pag 47

https://www.bioenergyconsult.com/biomass-collection/

OTHER OPERATIONS

- Comminution: Transporting the whole tree is not efficient, and a field-side comminution is a good alternative (its easier to transport after beeing shred to smaller parts than to transport the whole tree). Chippers are only adequate for the aerial part of the tree, if the roots and stumps are included, a crusher or a shredder should be employed, in order to avoid soil and stones contaminating the biomass.

  Sequential two stage grinding

  Pneumatic separation

  Fractional milling

- Drying
- Densification: Drying and densification increases the energy density of the fuel making it more feasible to burn and in a more environmental friendly way.

Feedstock Supply System Design and Analysis "The Feedstock Logistics Design Case for Multiple Conversion Pathways" Pag 47

https://www.bioenergyconsult.com/biomass-collection/

FACTORS INFLUENCING TRANSPORT DISTANCE

- The catchment area for the biomass resource and hence the transport distance over which biomass will have to be moved between storage locations and heating plants will depend upon a number of key factors. These include:
  - Size of the heating plant and the conversion technology used
  - Crop yield that is achieved
  - Proportion of land around the heating plant planted with biomass energy crops, or crops that have biomass as a byproduct (ie straw) or density of forestry in the case of forest fuel
  - Availability of the material for biomass resource (e.g. straw has competing uses and therefore only a proportion of the total produced will be available for use in biomass schemes).
- As well as being significant in any consideration of biomass fuel systems because of the role it plays in making the fuel flow smoothly between the point of production and consumption, transport is also important as a result of the costs associated with it.

Rentizelas, A. A., Tolis, A. J., & Tatsiopoulos, I. P. (2009). Logistics issues of biomass: The storage problem and the multi-biomass supply chain. Renewable and sustainable energy reviews, 13(4), 887-894.

- The transport infrastructure is usually such that road transport will be the only potential mode for collection of the fuel.

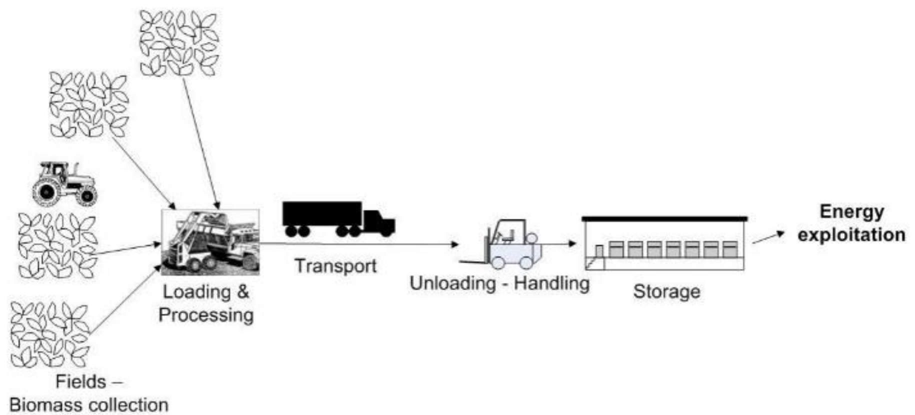
IMPACT OF BIOMASS CHARACTERISTICS ON TRANSPORT COSTS:

- When considering the logistic costs associated with a particular load such as a biomass fuel, there are a number of key factors about the characteristics of the producto that need to be considered
    - Volume to weight ratio
    - Value to weight ratio
    - Special characteristics

https://www.osti.gov/etdeweb/servlets/purl/374067

BIOMASS STORAGE

- Different options for storage: In most cases the lowest possible cost solution is adopted, without examining the effect this solution may have on the total system cost
  - Direct storage in the field
  - Intermediate storage (between field and power plant) – need to pay twice for transport costs
  - Storage next to the power plant (Using storage facilities attached to the power plant is the only viable case of accelerating the drying process of the biomass, as dumped heat may be used without need for extra energy consumption)



Rentizelas, A. Tolis, A. Tatsiopoulos, I.P. (2009), 'Logistics issues of biomass: the storage problem and the multi-supplier biomass chain', *Renewable & Sustainable Energy Reviews,* Vol. 13 (4), pp. 887-894 [Introducción interesante]

https://www.researchgate.net/publication/223824022_Logistics_issues_of_biomass_The_storage_problem_and_the_multi-biomass_supply_chain

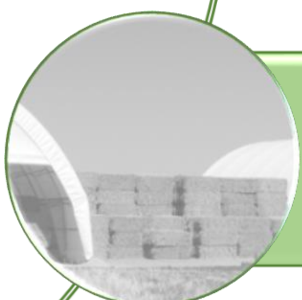
COLLECTION LOGISTICS

Harvesting

- Baling
- Loafing
- Chopping
- Whole crop harvest

Transportation

- Distance
- Biomass properties
- Terminal time



Storage

- Field storage
- Intermediate storage
- On site storage

Contents:

HARVESTING COSTS

Table 3 – Overview of the (distribution of) capital expenses and labour input.

	Capital expenditure				Labour, h ha^{-1} y^{-1}
	Establishment and planting	Harvesting, field transport and storage	Miscellaneous	Total, € ha^{-1} y^{-1}	
Lignocellulosic crops					
Poplar[a]	94%	5%	0%	143	5.1
Willow[b]	76%	23%	1%	156	5.1
Eucalyptus[c]	*Not specified*			172	5.1
Herbaceous lignocellulosic crops					
Miscanthus[d]	36%	64%	0%	576	6.6
Switchgrass[e]	13%	84%	3%	512	9.7
Reed canary grass[f]	36%	58%	6%	194	10.6
Oil crops					
Rapeseed[g]	29%	68%	3%	292	7.2
Sunflower[h]	35%	65%	0%	290	8.6
Sugar crops					
Sugar beet[i]	38%	59%	3%	839	8.8
Starch crops[j]					
Wheat	47%	42%	11%	356	4.4
Rye	47%	42%	11%	356	4.4
Triticale		42%	11%	356	4.4
Corn	47%	42%	11%	356	4.4

Note: indicative values shown

Source: https://edepot.wur.nl/352633 Biomass Resources Potential and Related costs, REFUEL

BIOFUELS COSTS

	Pellet	Olive stone	Wood chips
15 kg bag			
€/tn	290,67	194,7	-
c€/kWh	6,1	4,09	-
Bag Pallet			
€/tn	282,12	192,94	-
c€/kWh	5,92	4,05	-
Bulk in tipper			
€/tn	235,89	149,09	-
c€/kWh	4,95	3,13	-
Bulk in tanker			
€/tn	259,83	161,6	111,54
c€/kWh	5,45	3,39	2,53

Source: AVEBIOM; Annual prices of biomass for domestic use in Spain.

Evolution of the average olive stone price (€/tn) in Spain. Source: AVEBIOM, Price index of OIL KERNS for domestic use in Spain

Required machinery (for Woody biomass)

- Processors: The processors, whose main application is to fell and chop the timber part, can also chop large branches and tops to facilitate the subsequent work of waste management

- Self loaders: Used to carry out the unloading of materials, whether for timber or energy purposes. Generally, this means of extraction is used in conjunction with other equipment

- Chipping and shredding: Used to reduce the volume of different types of biomass.
  - Static chippers
  - Semi-mobile chippers
  - Mobile chippers (trailed or self-propelled)

REQUIRED MACHINERY

- Agricultural machinery can be classified according to the work it performs:

  - Tillage equipment: Its purpose is to prepare the arable soil or sowing bed, which is the 30 cm where the maximum root development of the plants takes place, by decompacting the soil. From 2,000 to 40,000€, with a mean price of 31,000 €, depending on technology and capacity.

  - Fertiliser equipment: From 500 to 70,000 € depending in the capacity and technology of the machinery, with a mean price of 10,500 €.

  - Sowing, planting and transplanting equipment: From 4,500 to 43,000€, with a mean price of 16,000€.

  - Harvesting and packing/shredding machinery

Source:Tractorhouse.es

- Forage harvesting and processing machinery

Mowers (5,000-180,000€)	Alternatives	Single Blade
		Double blade
	Rotary	Horizontal axis (flails)
		Vertical axis (discs, drums, mixed)
Rakes (3,000-150,000€)	Power take-off driven	Horizontal reel, sun chains
	Horizontal axis take-off driven	Vertical and horizontal forks, oscillating combs
Actuators	Rollers (10,000-60,000€)	
	Fingers	
Balers	Square balers (20,000-100,000 €)	
	Round balers (10,000-50,000 €)	
Shredders (5,000 – 20,000€)		
Pelletizers	Mobile pelletizers	
	Static pelletizers	

Price Source:Tractorhouse.es

https://www.idae.es/uploads/documentos/documentos_10737_Biomasa_Maquinaria_Agr_Forestal_A2007_4baf4f41.pdf

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REQUIRED MACHINERY COSTS

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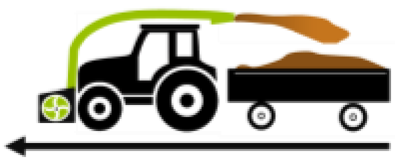
Mower: 2020 Krone EC320CV – 18,500€

Rake: 2021 AGRO-MASZ BT40 – 10,000€

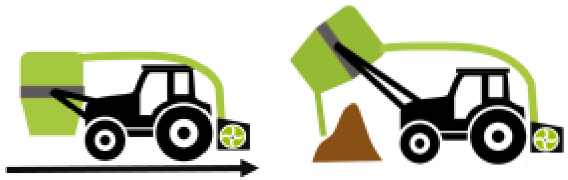
Bale Shredder: 2019 KUHN PRIMOR 3570M – 15,000€

PRUNING INTEGRATED COLLECTION AND SHREDDING



Shredder mounted in front with discharge on agric. trailer

Shredder mounted at rear with discharge on agric. trailer



Shredder mounted at rear with discharge on a bin mounted at front lift

Automotive shredder

Multiple systems and solutions in the market

Shredder towed with discharge on big-bags

Shredder towed with discharge on agric. trailer

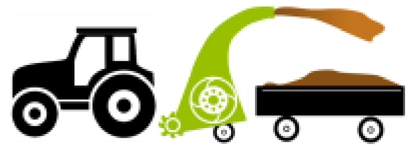
Shredder towed with built-in dump / tilting container

Shredder towed with built-in tilting container discharging on height

Source: upRunning – D4.1 Training Materials

PRUNING INTEGRATED COLLECTION AND CHIPPING

Chipper mounted in front



Chipper towed with discharge on agric. trailer

Chipper towed with built-in tilting container discharging on height

Chipper towed with discharge on big-bags

Few systems and solutions in the market

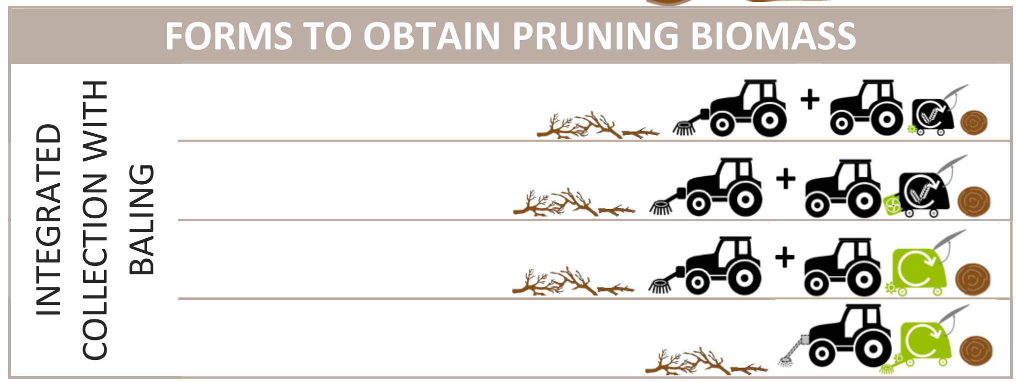
Source: upRunning – D4.1 Training Materials

REQUIRED MACHINERY COSTS

- Tractor driven Wood chippers: From 1,000-10.000 € (AgriEuro)
- Petrol Wood chippers/garden shredders: 500 – 14,000€ (AgriEuro)
- Electric Wood chippers and garden shredders: 200-1,400€ (AgriEuro)

Ceccato Tritone Mega Monster P.T.O. profesional tractor chipper shredder

PRUNING INTEGRATED COLLECTION & BALING



Pruning [baler (small round bales)](#) with integrated storage

Hay [round baler](#) utilized for pruning baling

Pruning [round baler](#)

From 10,000 to 150,000€ approx. for new models, with a mean Price of around 50,000€

Hay [square baler](#) utilized for pruning baling

Pruning [square baler](#)

Source: upRunning – D4.1 Training Materials

Source: Tractorhouse.es

- Feasibility of the value chain selected

- Based on the actors identified, the costs declared, and the performance results obtained during demos, economic feasibility is assessed:
- This chart is an example of the prices in the case study of Cooperativa San Juan Bautista (Spain).

Description	CAPEX (€)	OPEX (€/year)	Savings (€/year)	Comments
Pruning and haulage	-	-	-	Same as usual, avoiding the necessary time of burning by improving the haulage with the rake
Collection and transport	-	2,426 €	-	Subcontracted
Shredding	-	4,662 €	-	Subcontracted
End user	110,000 € (to be confirmed by ESCOs)	13,500 €	26,000 €	CAPEX: Investment for new biomass boiler, feeding system, storage area and a loader to feed the hoper OPEX: Personal, fuel oil for the loader, maintenance cost, etc. Savings: replacement of fossil fuels

Note: indicative values shown

Source: upRunning – D4.1 Training Materials

AgroBioHeat

Promoting the penetration of agrobiomass heating in European rural areas

Thank you for your attention

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