**MESTRADO INTEGRADO EM ENGENHARIA DA ENERGIA E DO AMBIENTE**

# ENERGIA DOS RSU e BIOMASSA

# Aula N

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# Dry Biomass - bioenergy

- **Biomass** is the only renewable energy that **can be converted into gaseous, liquid or solid fuels by means of known conversion technologies**. It can be used in a wide range of applications in the energy sector.
- At present it is possible to provide biomass energy for the full range of energy applications, from heating structures to supplying transport fuels.
- The range of possible uses of biomass, the advantages of safe and harmless storage, and the ability to integrate local fuel suppliers, including agricultural and forestry companies, offer a wide range of sustainable applications.

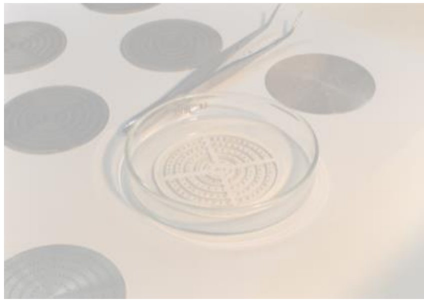
# Biomass - bioenergy

- The use of biomass as a renewable fuel can reduce the ecological footprint of all nations with regard to energy,
- It may be the solution for minimizing climate change and other environmental problems.
- The energy from biomass sources is considered to be **neutral in terms of climate damage** due to the greenhouse effect, because although the energy stored in the biomass emits greenhouse gases such as carbon dioxide, the amount released is the same which was consumed during the process of photosynthesis.
- In contrast to the direct use of solar or wind energy, biomass as a carrier of renewable energy is available and can replace the various forms of energy (electricity, heat, and fuel) produced by fossil sources.

# *Solid Biomass sources*

- **<u>Energy crops</u>**: They capture the solar radiation to store it in the biomass. Examples of energy crops are rapeseed, sunflower, miscanthus sinensis and corn.
- **<u>Agricultural and forestry wastes</u>**. Generated by harvesting cereals and cutting trees, such as straw and wood waste.
- **<u>Urban Solid Wastes:</u>** High-wood MSW residues, which can be subjected to drying and burning or converted to CDR

# Caracterization of solid fuels



Volatile matter (organic)
Water
cinder
Mineral Carbon

**Imediate Analisys**


**Elementar Analisys**

**Carbon**
**Hydrogen**
**Oxygen**
**Sulfur**
**Metals**
**Halogens**

Densidade
Fusibilidade das Cinzas
Temperatura de fusão das cinzas
Granulometria

Poder Calorífico

# – Variety of biomass










# Wood and subproduts processing

**Straw**

**Wood prepared**

# Wood waste processing

# From biomass to energy source

- Biomass is transformed into **liquid, solid or gaseous energy** sources by various, more or less complicated methods and can then be turned into heat, electricity or fuel.
- Whereas **it is relatively easy to turn the chemical energy fixed in the raw material into heat through oxidation during combustion**, **other methods are more complex.**
- **Gasification**, for example, takes place **without oxygen**. The aim is to obtain the largest possible quantity of inflammable gas from the raw material so that it can be cleaned and then used for example in a gas engine.
- It is also possible to **liquefy biomass by pyrolysis**.

# Calorific Energy

- Biomass has high heat power
- Usually heat is produced in combustion systems.
- For stationary combustion systems whose sole function is the production of heat, solid fuels predominate with respect to biomass.
- Wood, as waste or raw material, can be used for heat generation, with low processing, grinding or drying costs.

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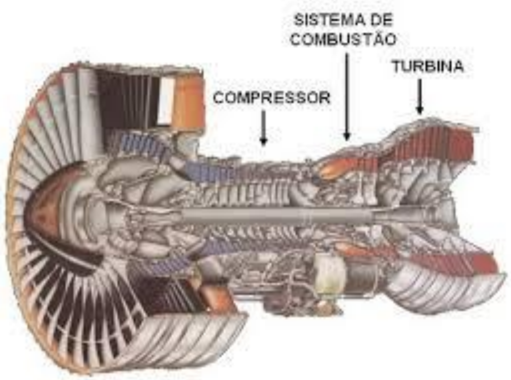
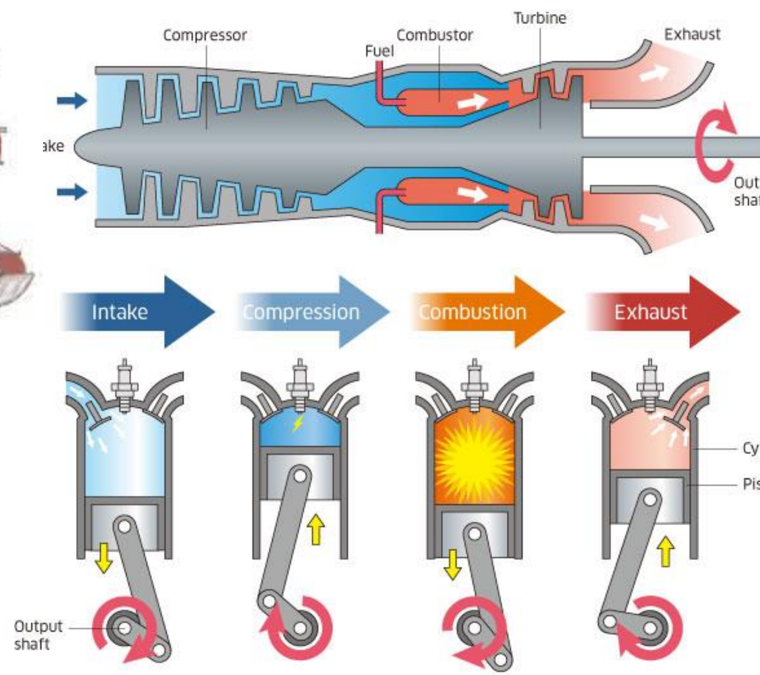
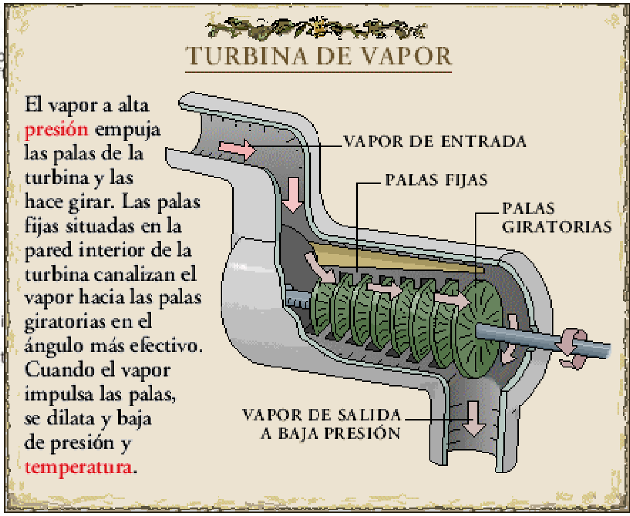
# Mechanical energy

- Mechanical energy is produced by means of heat and power generators, such as **<u>steam-type TURBINE OR PISTONS</u>** machines.
- Or through a gas turbine that receives the combustion gases

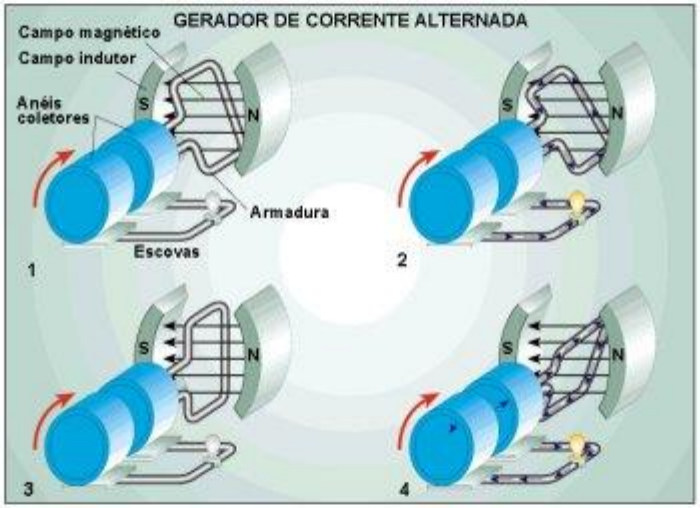


# Electric Energy

- Systems which produce mechanical energy, in combustion engines or in direct and indirect combustion turbines, are coupled to electric generators. These convert the mechanical energy into electrical energy.
- The use of mechanical energy for the production of electricity generates approximately two thirds of heat, for a third of electricity, which demonstrates the increase of the economic efficiency of cogeneration (simultaneous production of heat and electricity) in stationary applications.



# Solid Biomass

- The most important quality feature, for any power source, is its calorific value. In the case of solid biomass this characteristic is directly influenced by the water content.
- The lower calorific power PCMB can be calculated using the following mathematical formula:

$$PCMB = \frac{PC_{seco} \times (100 - \%_{H_2O}) - 2{,}44 \times \%_{H_2O}}{100}$$

Where PCseco is the calorific value of the wood without water and% H2O is the water content in the wood in the state in which it is found.



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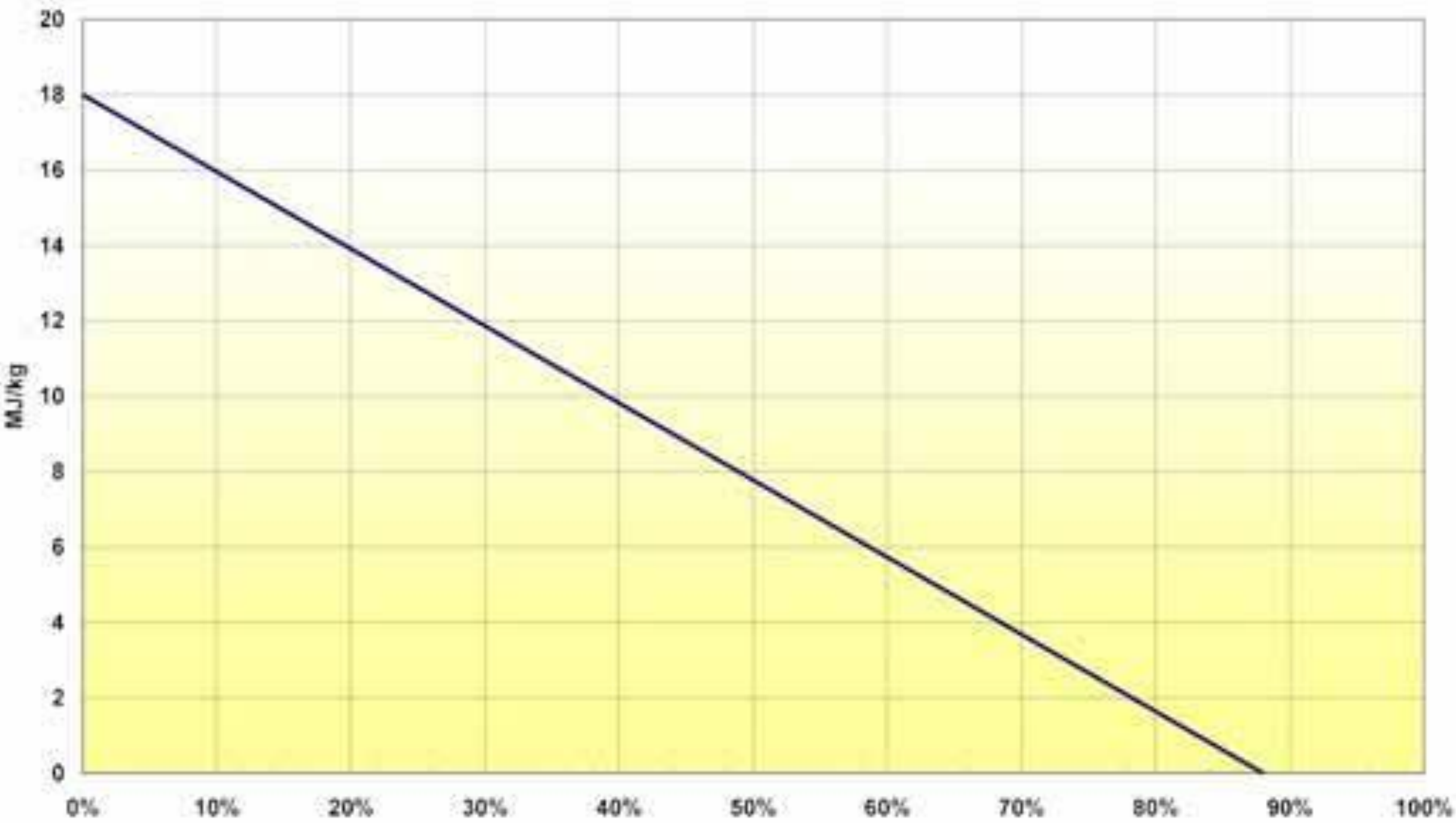
# Water content and calorific value of biomass



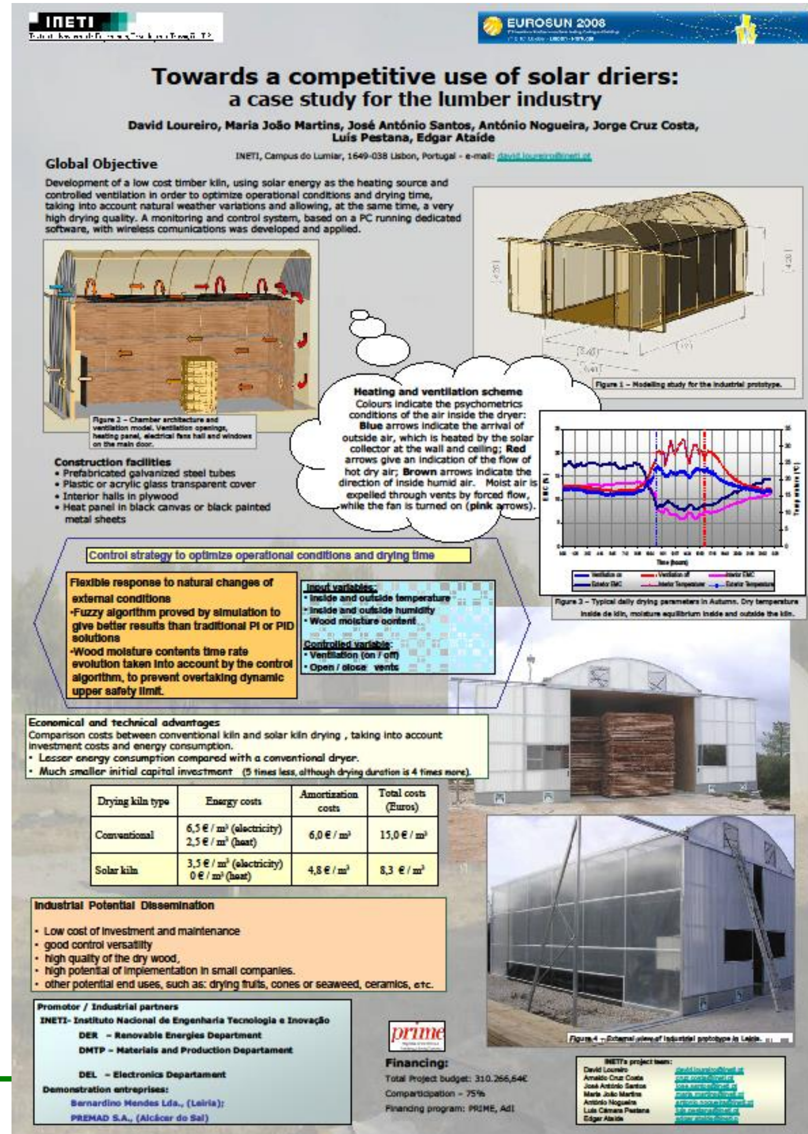
# Humidity

- Being biomass is a natural product, it has a very varied water content varies.
- The typical water content for fresh woody biomass is between 40 and 60%.
- Solid wastes moisture is between 40 and 60%.
- Green plants may have a higher water content, up to 80%.

# Drying

- Biomass with outdoor drying achieves a water content that, depending on the season and the ambient humidity, varies between 12 and 18%.
- **Biomass products with artificial drying, such as briquettes**, have a maximum **water content of 10%.** However, improper storage can lead to water absorption by them.
- It should be noted that a **water content above 10% makes briquettes unusable**. Due to the influence of weight, biomass sources are treated in volume measurements.
- Consequently, the storage method and the geometric shape are very important for determining the calorific value, based on the volume of the solid biomass
- .

# Experimental solar Dryer



INETI

EUROSUN 2008

## Towards a competitive use of solar driers: a case study for the lumber industry

David Loureiro, Maria João Martins, José António Santos, António Nogueira, Jorge Cruz Costa, Luís Pestana, Edgar Ataíde

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### Global Objective

Development of a low cost timber kiln, using solar energy as the heating source and controlled ventilation in order to optimize operational conditions and drying time, taking into account natural weather variations and allowing, at the same time, a very high drying quality. A monitoring and control system, based on a PC running dedicated software, with wireless comunications was developed and applied.

Figure 2 – Chamber architecture and ventilation model. Ventilation openings, heating panel, electrical fans hall and windows on the main door.

Figure 1 – Modelling study for the industrial prototype.

**Heating and ventilation scheme**
Colours indicate the psychometrics conditions of the air inside the dryer: **Blue** arrows indicate the arrival of outside air, which is heated by the solar collector at the wall and ceiling; **Red** arrows give an indication of the flow of hot dry air; **Brown** arrows indicate the direction of inside humid air. Moist air is expelled through vents by forced flow, while the fan is turned on (**pink** arrows).

**Construction facilities**
- Prefabricated galvanized steel tubes
- Plastic or acrylic glass transparent cover
- Interior halls in plywood
- Heat panel in black canvas or black painted metal sheets

Figure 3 – Typical daily drying parameters in Autumn. Dry temperature inside de kiln, moisture equilibrium inside and outside the kiln.

**Control strategy to optimize operational conditions and drying time**

**Flexible response to natural changes of external conditions**
- Fuzzy algorithm proved by simulation to give better results than traditional PI or PID solutions
- Wood moisture contents time rate evolution taken into account by the control algorithm, to prevent overtaking dynamic upper safety limit.

**Input variables:**
- Inside and outside temperature
- Inside and outside humidity
- Wood moisture content

**Controlled variable:**
- Ventilation (on / off)
- Open / close vents

**Economical and technical advantages**
Comparison costs between conventional kiln and solar kiln drying, taking into account investment costs and energy consumption.
- Lesser energy consumption compared with a conventional dryer.
- Much smaller initial capital investment (5 times less, although drying duration is 4 times more).

| Drying kiln type | Energy costs | Amortization costs | Total costs (Euros) |
|---|---|---|---|
| Conventional | 6,5 € / m³ (electricity)<br>2,5 € / m³ (heat) | 6,0 € / m³ | 15,0 € / m³ |
| Solar kiln | 3,5 € / m³ (electricity)<br>0 € / m³ (heat) | 4,8 € / m³ | 8,3 € / m³ |

**Industrial Potential Dissemination**
- Low cost of investment and maintenance
- good control versatility
- high quality of the dry wood,
- high potential of implementation in small companies.
- other potential end uses, such as: drying fruits, cones or seaweed, ceramics, etc.

Figure 4 – External view of industrial prototype in Leiria.

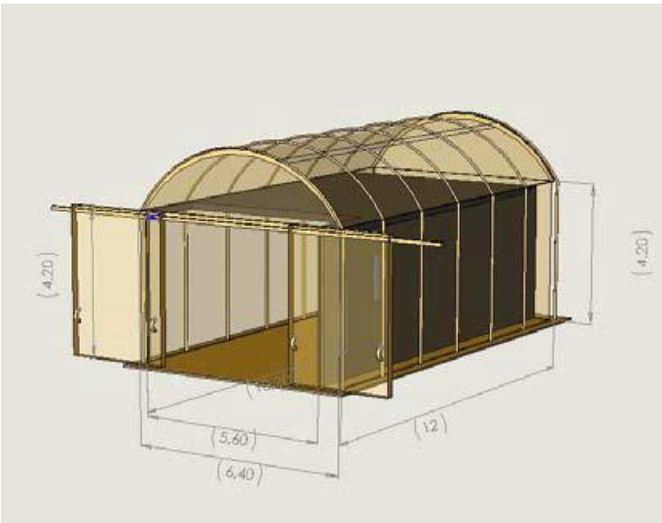
**Promotor / Industrial partners**
INETI- Instituto Nacional de Engenharia Tecnologia e Inovação
DER – Renovable Energies Department
DMTP – Materials and Production Departament
DEL – Electronics Departament
Demonstration entreprises:
Bernardino Mendes Lda., (Leiria);
PREMAD S.A., (Alcácer do Sal)

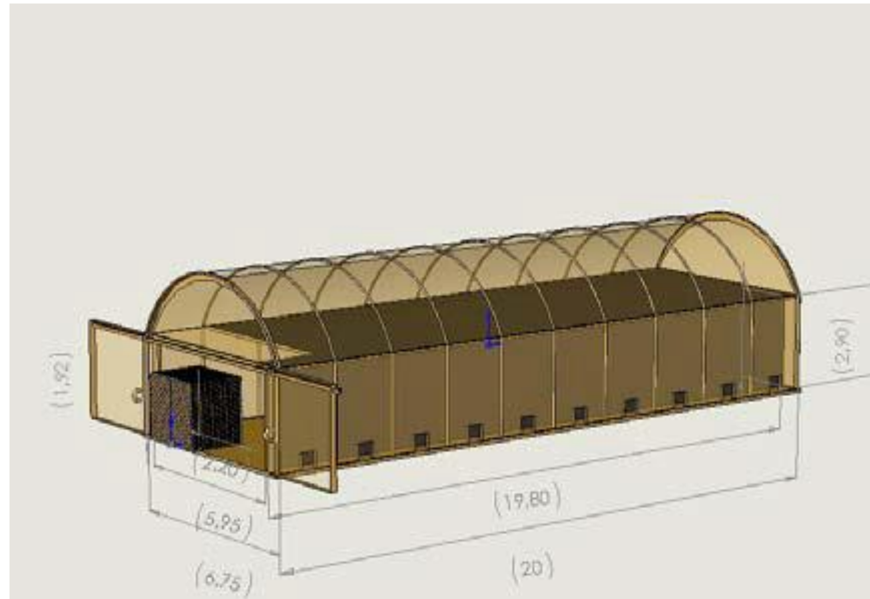
prime

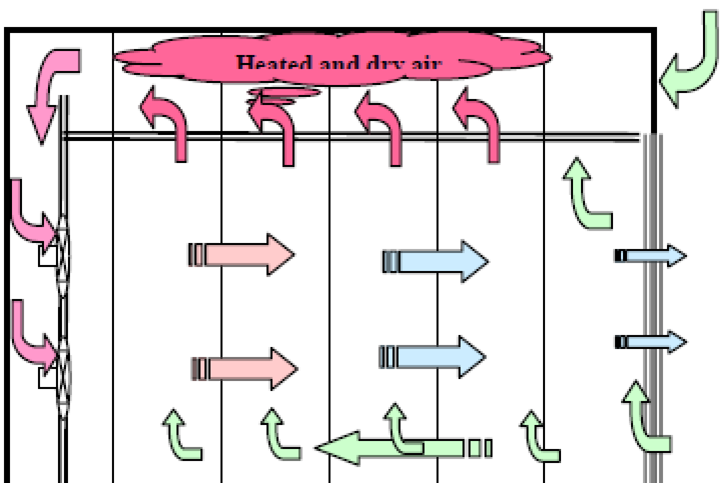
**Financing:**
Total Project budget: 310.266,64€
Comparticipation – 75%
Financing program: PRIME, AdI

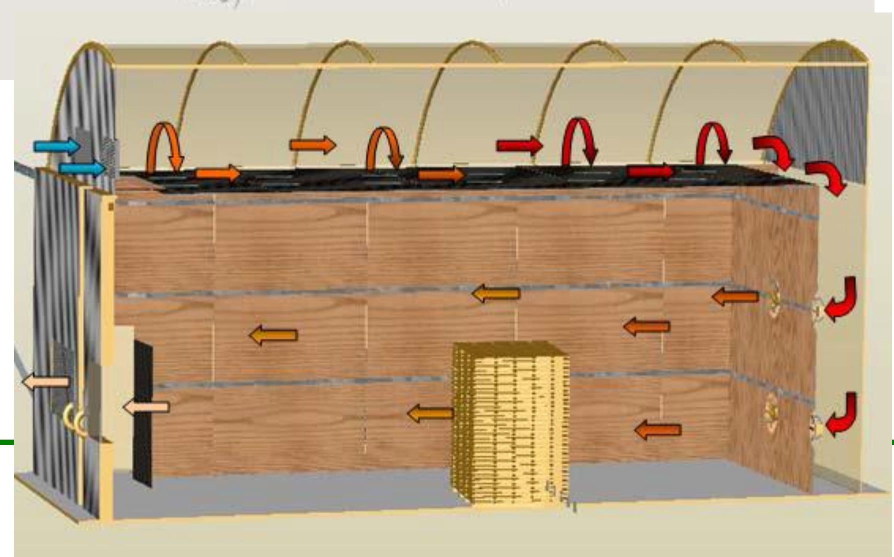
INETI's project team:
David Loureiro
Arnaldo Cruz Costa
José António Santos
Maria João Martins
António Nogueira
Luís Câmara Pestana
Edgar Ataíde

# Solar dryer for wood



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# Solid fuels from wood

- In the dry state, which can only be achieved with artificial drying, wood has a calorific value of 18.5 MJ per kilogram.
- Ashes, resulting from burning wood**, have a high nutrient content**, such as calcium, magnesium, potassium and phosphorus. Residues of ash with a density above 900 kg / m3 have a low metal content. Consequently, these are usually allowed for application as fertilizer.
- During combustion of wood waste in systems with thermal capacities of more than 150 kW, large quantities of fine ash (density less than 400 kg / m3), containing such high concentrations of heavy metals, may occur for environmental reasons, their use as fertilizers.

# Solid Fuels

- Prepared wood
- Briquettes
- Ashes from pyrolysis

# Briquetes

# Plant manufacturing Briquetes at CBE

# Biomass from green wastes

- With the biomass of the cherry, the ash content and its melting behavior, under the influence of temperature, play an important role. In contrast to the wood, the ashes of this type of biomass begin to melt for temperature between 710 to 930ºC. During combustion these temperatures are rapidly reached.
- In this way, combustion systems for this type of biomass are designed to prevent the occurrence of slag or ash agglomerates within the grids or walls of the furnace, in particular by means of a water cooling system.
- The cherry has an average chlorine content of 0.5%, and because of this high content and the presence of potassium in the biomass from the straw, they have a high corrosive potential. Chlorine, like the other natural components, sulfur and nitrogen, is present in amounts that constitute a relevant emission factor. Thus, it is necessary to fit in the current legislation, the operating activities, in facilities burning products straw. This applies both to gaseous emissions and to the subsequent use of ash residues, which have a density of 150 kilograms per cubic meter.

# Technologies for the use of biomass and waste

- In addition to thermochemical processes, certain physical-chemical methodscan also be used. For example, pressing or chemical extraction to produce oil from sunflower seeds or oilseed rape.
- **biochemical methods** are responsible for converting biomass into biogas or to ferment biomass with a high sugar, starch or cellulose content into alcohol.
- It is obvious that some of the options are in competition with each other; for example, a given amount of wood can either be burnt directly or transformed into synthesis gas by a gasification process or into a liquid energy source.
- The choice of transformation method is in many cases not just a technical question but above all an economic question: the more complex the procedure is, the higher the cost of the finished energy source will necessarily be.
- The choice and use of these technologies depends on the biodegradability of the wastes, their chemical status and their moisture content

# Processing solid biomass


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# Processing biofuels

- Mechanization of the collection of forest residues.
- Cutting, Compression
- Granulometric homogenization and densification
- Anaerobic Digestion
- Saccharification, fermentation, distillation and dehydration
- Hydrolysis of lignocellulosic products
- Extraction, refining and transesterification

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# Thermochemical methods

| Biomass source | Methods |
| --- | --- |
| Wood and derivatives,<br>Straw,<br>Pruning waste,<br>Processing residues (bark, nuts, etc.)<br>Urban solid waste | Carbonization<br>Gasification<br>Pyrolysis<br>Steam explosion<br>Direct combustion<br>Co-combustion |

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# Biomass Conversion Technologies

| Conversion Technique | Temperature (ºC) | Pressure | Main Products |
|---|---|---|---|
| Combustion | 800 – 1400 | atm. – high | heat |
| Pyrolysis | 400 – 800 | atm. – high | char, liquids, gas |
| Gasification | 650 – 1100 | atm. – high | $CO$, $H_2$, $CH_4$ |
| Hydrothermal Upgrading | 250 – 600 | very high | liquids, char, gas |
| Aerobic Fermentation | << 100 | atm. | Ethanol |
| Anaerobic Fermentation | < 100 | atm. | $CH_4$ |

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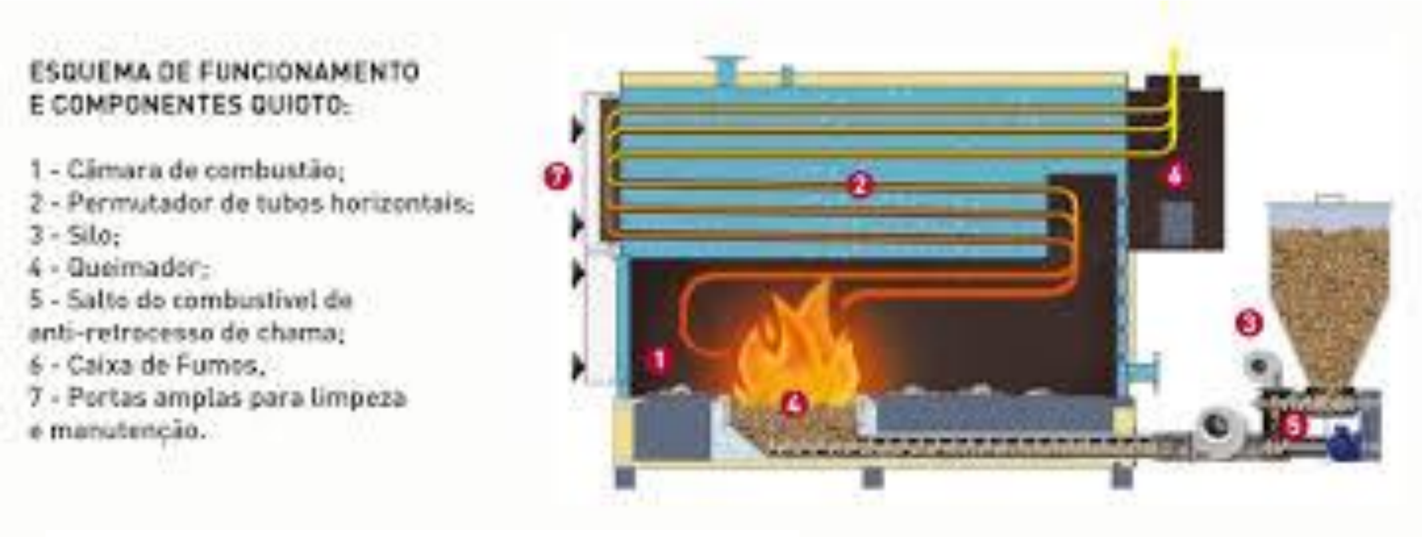
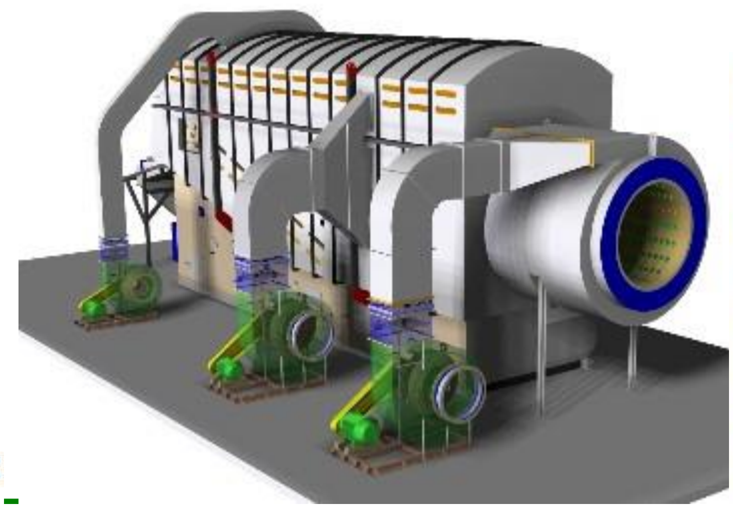
# Thermochemical Tecnologies

- **Carbonization: biphasic conversion of lignocellulosic materials into coal. By-products: ketones, acetic acid and tar.**
- **Gasification: incomplete oxidation of biomass at 900 - 1000 ºC for the production of syngas. Three types of gasifiers: air, water vapor and O2.**
- **Pyrolysis: thermochemical degradation of biomass at 400 - 800 ºC, in the absence of oxygen. Solid, liquid or gaseous final products.**
- **Steam explosion: use of high pressure water vapor. It separates the components of the vegetal biomass (hemicellulose, cellulose and lignin), allowing the total use.**
- **Co-combustion: addition of up to 20% of biomass to coal in thermoelectric plants. It reduces emissions of NOx, SO2 and CO2.**

# Biomass burner



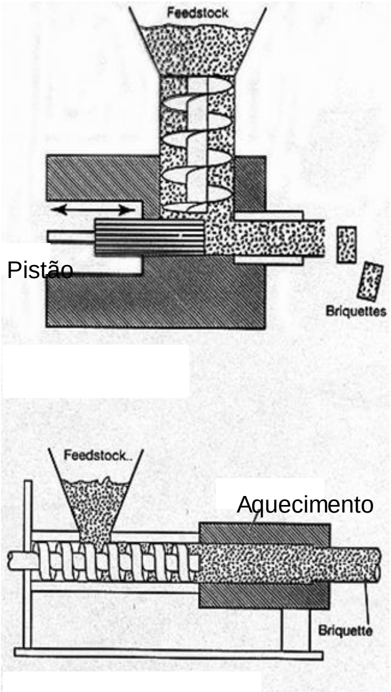



# Combustion characteristics

- Easy Ignitions pretended
- Using **<u>large blocks</u>** of guel is formed a layer of ash on the top that burns slowly
- In the **<u>pulverized form</u>** it burns almost instantly
  A long, smoke-free flame is formed in enclosed spaces provided that there is sufficient air (excess)

# Solid biomass pretreatment

- The need of treatment and preparation of fuels depends on:
  Physical state
  Composition
  Viscosity in the case of liquids
  Size and shape in the case of solids
  Moisture content
  Kind of equipment
  Feed Type



# Thermal technologies in the state of the art: Thermovalorisation

- Current incineration name (turn to ash).
- Thermo-recovery technologies by means of fixed or fluidized bed boilers
- Leverages the biomass energy for the production of heat or steam or electricity
- Higher emissions requirement

# Emerging thermal technologies

- Gasification-Form gaseous fuel
- Pyrolysis-Form liquid or gaseous fuel
- Plasma: Vitrifies the highest temperature
- Wet oxidation- Decomposes non-biodegradable matter
- Steam explosion- Decomposes non-biodegradable material

# INCINERATION

- Process that uses the burning, as treatment of solid waste or biomass, greatly reducing its original volume and providing its thermal stabilization.
- From **the sanitary point of view, it is the safest waste treatment process**.
- It reduces to ashes the combustible materials, for the most part also decomposable, making them, therefore, inert. This process is used interchangeably as waste treatment and disposal, due to the large reduction in the original volume of processed waste caused by the disappearance of combustible materials.
- After incineration, the resulting ash and non-combustible materials are usually landfilled. Recently treatments have been applied for the recovery of metals and the rest have use as inert in construction

# Aplication

- Until a few years ago this process was currently applied to the treatment of garbage from large communities. Afterwards it has been losing some popularity (existence of toxic compounds in the fumes).
- It begins to be contested the concept of burning everything and putting in the oven even the compounds that do not burn.
- The current trend is to allocate only those waste compounds that are combustible and non-recyclable to incineration, and encourage the application of pre-treatments to recover and recycle a component, in accordance with the concept of sustainable growth.
- However, incineration is a process that can quickly resolve the problem of thousands of tons of waste per day, while reuse and recycling schemes are slow to be implemented in the short term.
- Incineration could still be applied in the less correct way of putting everything in the kiln, in a phase of transition to a more efficient waste management model.

# Advantages of waste incineration

- Incineration of waste can reduce waste by up to 90% in a landfill or landfill. Thus, these sites gain in operational area;
- This process avoids that much of the waste is disposed of intentionally or accidentally in green areas, rain gutters and in springs;
- When incinerating garbage, all substances considered to be hazardous (such as hospital waste) are disposed of. Thus, the risk of contamination is reduced considerably;
- By incinerating garbage, it is possible to obtain heat energy which, in turn, can be converted into electrical energy.

# Disadvantages of waste incineration

- In order to incinerate safely and efficiently, it is necessary to invest time and resources in the training of professionals;
- The incineration process releases gases and toxic substances that can cause air pollution and generate serious environmental impacts;
- In order to prevent large quantities of toxic substances from being released into the environment, waste must undergo specific treatment before incineration - which requires more investment;
- Equipment used for the incineration of waste is subject to considerable wear and tear due to the chemicals used and substances released during work. Therefore, it is necessary to have a planning of preventive and corrective reviews, which requires a considerable investment.

# World Solid Wastes Incinerators

| Regione | Rifiuti trattati in impianti WTE nel 2004, stima (milioni di tonnellate) |
|---|---|
| Europa-25 | 48.8 |
| Giappone | 40.0 |
| Stati Uniti | 26.3 |
| Taiwan | 7.0 |
| Singapore | 4.0 |
| Cina | 3.0 |
| Svizzera e Norvegia | 3.8 |
| Corea del Sud | 1.0 |
| Altri | 9 |
| **Totale** | **143** |

**Tabella 1** - Quantità di rifiuti trattati in impianti di termovalorizzazione (WTE = Waste To Energy)) nel mondo (Simmons *et al.*, 2006).

# European diffusion

| Stato | Numero di Impianti WTE | Rifiuti trattati (Milioni di tonnellate) |
|---|---|---|
| Francia | 123 | 11.25 |
| Spagna | 11 | 1.86 |
| Portogallo | 3 | 1 |
| Regno Unito | 15 | 3.17 |
| Belgio | 17 | 1.64 |
| Olanda | 12 | 5.18 |
| Lussemburgo | 1 | 0.12 |
| Svizzera | 29 | 2.97 |
| Italia | 49 | 3.47 |
| Austria | 5 | 0.88 |
| Germania | 58 | 13.18 |
| Repubblica Ceca | 3 | 0.4 |
| Polonia | 1 | 0.04 |
| Ungheria | 1 | 0.19 |
| Danimarca | 31 | 3.28 |
| Norvegia | 21 | 0.79 |
| Svezia | 28 | 3.13 |
| Finlandia | 1 | 0.15 |

**Tabella 2** - Impianti di Termovalorizzazione (WTE) operanti in Europa nel 2003 (CEWEP, 2004).

# Incineration in Portugal

- 3 Plants for the treatment of the MSW of Lisbon Porto and Funchal
- 1 Center for Forest Biomass in Mortagua

# Valorsul and Mortagua plants

# Process Description

- The incineration process of solid waste consists of the burning of such waste in a facility specially constructed for that purpose and called an incinerator.
- Combustion is fueled by combustible materials in the trash, such as paper, rags, etc. Oxygen is supplied by feeding the combustion chamber with the required amount of air.
- Due to the wide variety of materials in the waste, the amount of heat energy released depends on the composition of the heterogeneous mixture that makes up the waste.
- The "calorific value" of garbage increases with the percentage of combustible materials in the garbage, and decreases with the increase of humidity and ashes in it, being of the order of 2000-3000 Kcal / kg.

# Use of Heat power

- Most of the heat energy generated by the incineration **is released in the form of gases with a very high temperature**, of the order of 1000-1200 ° C. This heat is recovered by lowering the temperature of the gases to about 300 ° C before releasing them into the atmosphere in order to protect the equipment installed in the incinerator, including those for pollution control.
- To lower the temperature of the gas, an evaporator is placed in which the vapor is generated by changing the heat of the gas, which decreases in temperature. the steam to drive a steam turbine connected to a generator producing electrical energy, which is necessary for the incineration plant and the surplus sold to the distribution network
- The generated steam may not be used in a turbine, being condensed and returning to the boiler. Cooling and condensation of the steam can generate hot water.
- In countries with a cold climate, excess thermal energy is used for home heating of the adjacent urban area.

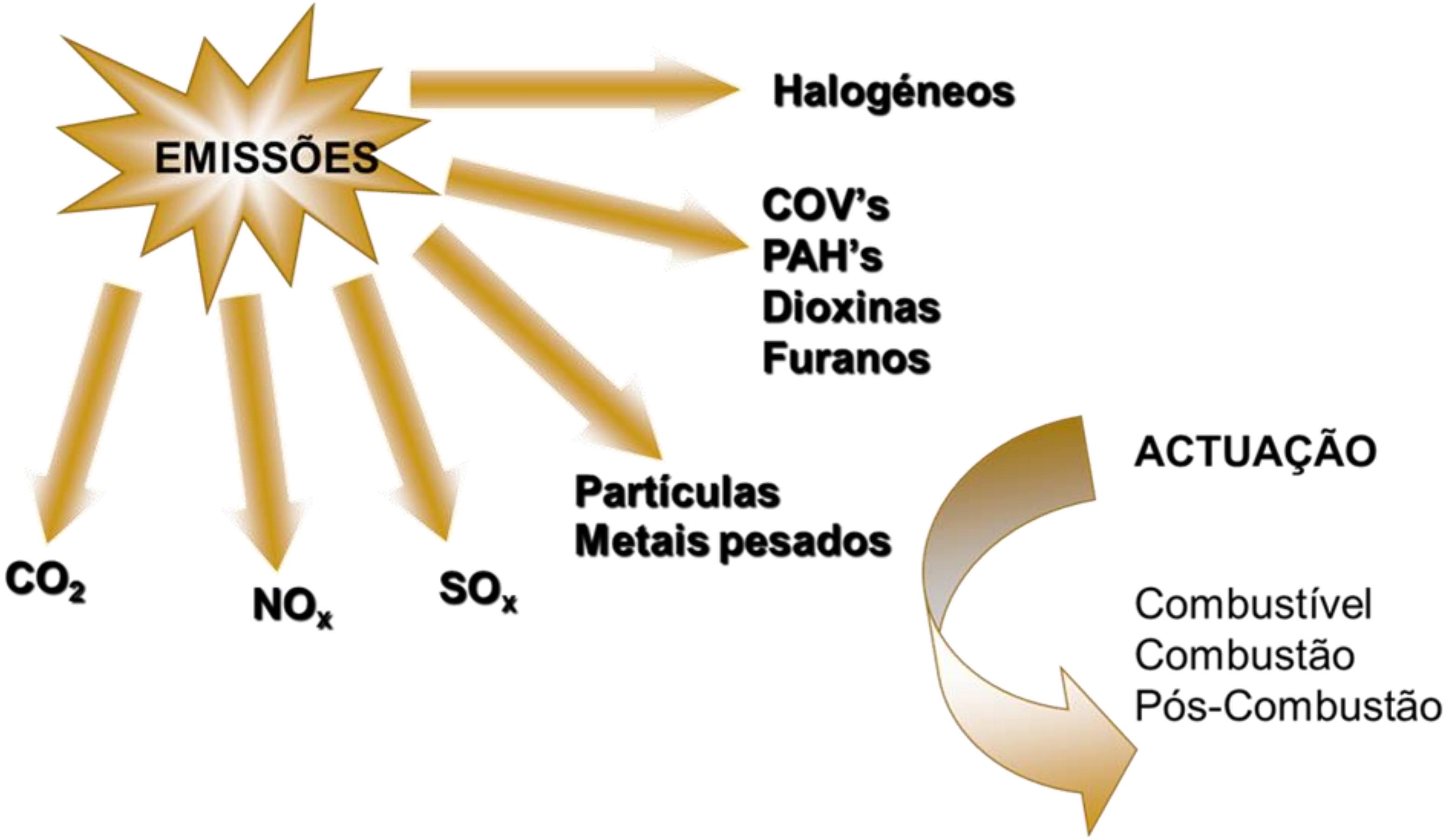
# Pollution control

- Incineration plants, when not well operated and do not operate at high temperature, cause air pollution with harmful compounds.
- In the solid waste tank, whose capacity is greater than the daily load processed by the incinerator, the accumulated waste decomposes, generating bad odors as well as polluted waste water. Odor control must be carried out by means of an air suction and treatment system.
- When flaring is imperfect, the flue gases have offensive odor, which can be eliminated, keeping the incineration temperature above 1000 ° C. Gas-borne dust must be collected by electrostatic precipitators which remove the larger-diameter solid particles from the gases, releasing a non-polluting gas into the atmosphere.
- The waste water produced in the incineration plant results from the decomposition of solid waste in the tank, from the quenching and cooling of the ashes, from the flushing of gases, in order to remove the poisonous compounds.

# Process use

- The waste incineration process is generally used in densely populated areas that do not have landfill sites or where the transport distance is too large to reach such areas.
- Ashes resulting from incineration are transported for landfill and are much smaller than originally incinerated and chemically stabilized wastes.

# Emissions


EMISSÕES
Halogéneos
COV's
PAH's
Dioxinas
Furanos
Partículas
Metais pesados
$CO_2$
$NO_x$
$SO_x$
ACTUAÇÃO
Combustível
Combustão
Pós-Combustão

# Emissions Loss of Organic Voltile compounds VOV

- The 20 major pollutants (british coal corporation, 1998)

| Volatile organic compounds | |
|---|---|
| Tolueno | i-Butano |
| Etanol | 2-Metilpentano |
| n-Butano | n-Pentano |
| Etileno | 2-Butano |
| m-Xileno | Metilheptano |
| p-Xileno | Propileno |
| 1,2,4-Trimetilbenzeno | Etilbenzeno |
| Metiletilcetona | 2-Pentano |
| o-Xileno | n-Hexano |
| i-Pentano | 1,3,5Trimetilbenzeno |

# Thermochemical conversion of wood to gas-Gasification

- It converts a solid fuel by means of thermochemical reactions at high temperatures and **limited oxygen** to produce a gaseous fuel, a mixture of gases such as carbon monoxide, carbon dioxide, nitrogen, hydrogen and methane (CO, H2, CH4, CO2 and N2),
- This method is more efficient than direct combustion by producing a cleaner, cleaner atmospheric emissions, creating less pollution problems.

# Gasification

- The gas obtained from this method can be used in gas turbines or even in internal combustion engines to obtain the energy, proving its greater versatility..
- Methane can be treated as natural gas and used for the same purposes.
- Under appropriate circumstances, it may produce synthesis gas, a mixture of carbon monoxide and hydrogen, to be used to produce hydrocarbon (e.g., methane and methanol).
- Hydrogen is a potential fuel of the future.

# Gasification

- The gasification process, discovered in the early nineteenth century, in relatively recent times (20-30 years) was proposed for waste treatment as an alternative to "classical" thermovalorization based on the combustion process.
- Gasification is the conversion of the organic substance contained in the waste or biomass into a mixture of combustible gases through partial oxidation at high temperature (400-1500 ° C).
- The gas produced, consisting essentially of a mixture of CO and H2, has a calorific value less than about 4-6 MJ / Nm 3 and can be used to power internal combustion engines or gas turbines. Gas can also be used as a feedstock for the production of chemicals (such as methanol).

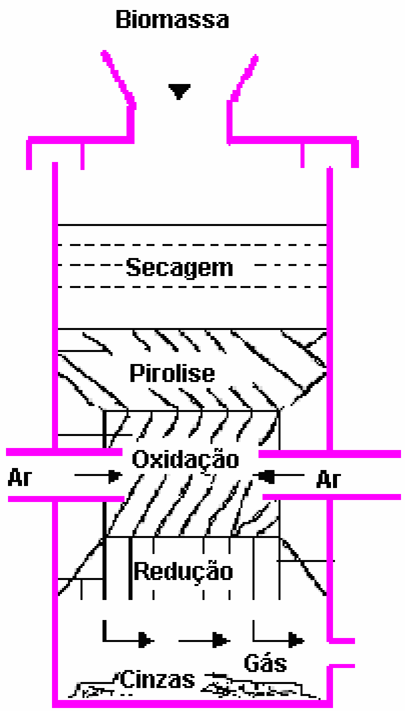
# Thermochemical gasification: the great hope for the future

- for over 80 years gasification try to resolve the problems connected with the combustion of solid materials. **During gasification, the fuel is heated under oxygen deficient conditions and converted into an inflammable gas, which** is often then cleaned before further use. Electricity and heat are then produced from this gas in a gas engine or gas turbine.
- Present-day gasification techniques achieve a 70 to 80 % conversion rate of fuel energy into the product gas.

# gasificators

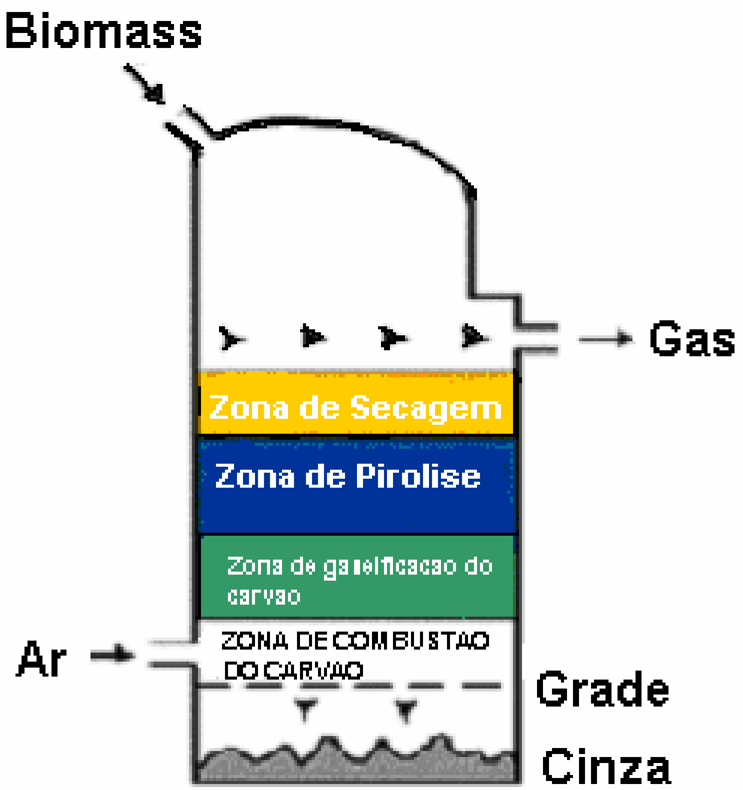
- Fixed bed gasifiers are being tested in the 2 to 5 MWth range,
- fluid bed systems are preferred for larger power ranges.

# Fixed be Gasificador FD

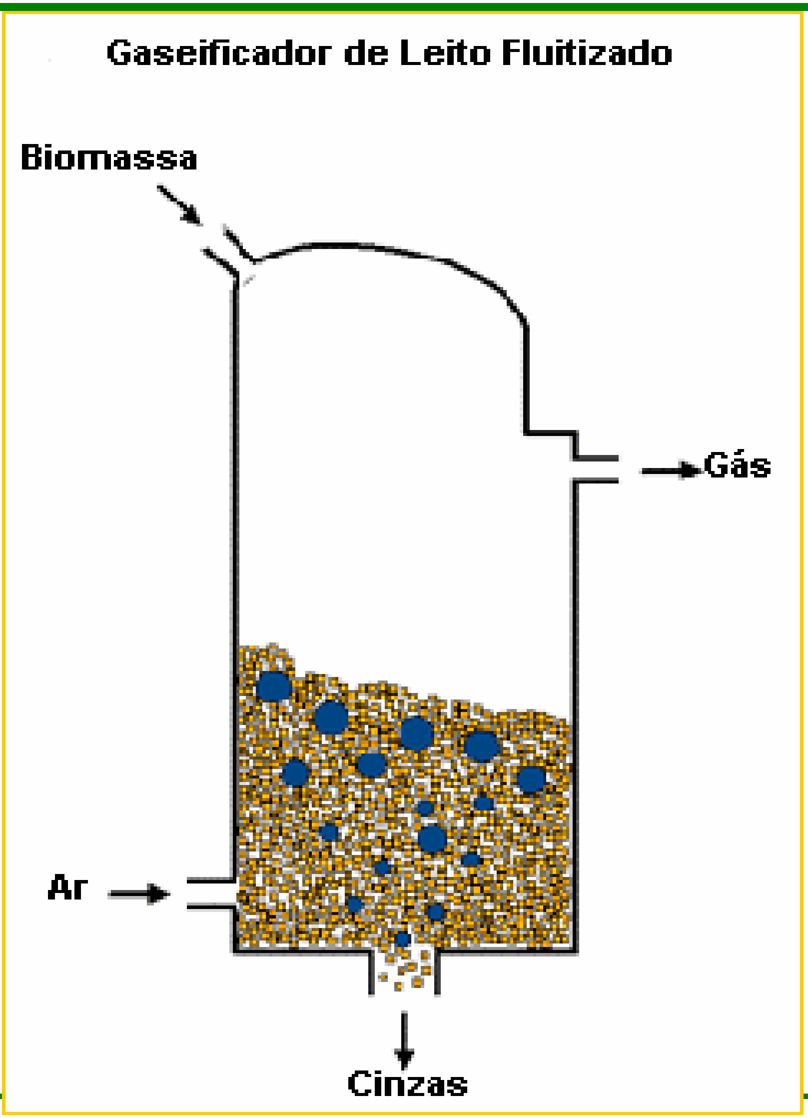



Downflow system

Gaseificador leito fixo, fluxo ascendente



# Fluidized be Gasificator



# gasificators

- In the future, larger plants (with furnace thermal capacities over 20 MWth)might well grow in importance. In these, gasification takes place under pressure(20 to 100 bar) and leads to the production of synthetic fuels.
- With an electrical efficiency of about 30 percent, gasification is already an interesting way of converting biomass into electricity. People are hoping for over 40 percent from an integrated gas and steam turbine process (IGCC: Integrated Gasification Combustion Cycle).

# Gasificators

- The use of fuel cells should also be successful in the long term and the electrical efficiency could well exceed 50 percent.
- For the time being though, thermochemical gasification has not yet become the technical standard for any range of capacity. There are not only problems with the quality of the product gas but also with a lack of stability in the gasification process. In the medium term however, thermochemical gasification could provide a suitable alternative for electricity production from biomass.

# Pyrolysis and gasification

- The level of maturity and reliability of the technologies based on these processes in Europe, considered as not yet optimal, in relation to the energy and economic balance sheet.
- While in our continent these technologies do not play a very significant role, although the discussion on their application is tight, in Japan several gasification and pyrolysis plants have been operating successfully for years, probably also because of the different quality of treated wastes.

# Upflow Fixed Bed Gasifier

- The upflow gasifier produces gases with few particles, but with high tar rates, not suitable for motor vehicles.
- Air and steam streams are injected to keep the ashes below the melting temperature and to facilitate conversion to charcoal. The gas produced in this process has low speed and low temperature.
- The low operating temperature creates a considerable amount of condensed oil and tar in the produced gas. The bed filtering effect and low vapor velocity produce a gas with a low concentration of solid particles. The fuel supply should be dense and uniform.

# Fluidized bed gasifier

- Used in the thermo-chemical conversion of peat for many years. There is not yet much experience in biomass conversion, at least on a large scale. A material is used as a fluidizing medium, which entrains the biomass, increasing its contact with the oxidizing element and, consequently, increasing the reaction rates. with capacity between 10 and 20 tons of biomass per hour are already operational.
- They are more flexible regarding the characteristics of the consumption, and can be used in the conversion of biomass with minimum processing needs prior to feeding. Due to these advantages (in addition to easier control), it is the principle that has been used in almost all IGCC (Integrated Combined Cycle Gasification) systems development projects.

# Fluidized bed gasifier

- It has higher operating costs and problems with the suitability of gases for their quality. Depending on the nature of the process, the amount of entrained particulate material tends to be larger; a second aspect is that the higher gas outlet temperature allows the alkalis to still leave the gas phase, imposing additional cleaning difficulties.
- There are two ways of providing heat, direct and indirect. In the supply of direct heat to the heat required for the gasification comes from the combustion of the coal in the reactor.
- In the indirect mode the charcoal removed from the gasifier is burned in a separate vessel. The advantage is that by-products from the burning of coal do not mix with the products of gasification.

# Comercial Unit

# Pyrolysis

- Pyrolysis is the endothermic transformation, in the absence of oxygen, of biomass or residues into liquid, solid and gaseous fractions. Heat may be supplied from the outside or internally by controlled combustion of a fraction of the wastes to be treated.
- The temperature and process pressure values determine the physical form of the obtained fuel products (liquid, solid, gaseous).
- Pyrolysis is also used for the production of bio-oils. Bio-oils can be used in engines or turbines or used directly as feedstock for refineries.
- The problems with the conversion process and the consequent use of the oils produced, the stability of the process and their corrosivity, which must still be completely solved for a reliable application of the full scale systems.
- In general, both technologies lead to the production of a vitrified residue that can make disposal easier to discharge

# Pyrolysis

- Pyrolysis is an old technology that has gained new life. It is the combustion of biomass (usually firewood) practically without the presence of oxygen, which causes it to become coal having twice the energy density of the original biomass.
- In its simplest form involves heating the biomass to release it from the volatile matter, leaving a solid residue that we know as coal. This has double the density of the original material. - making the fuel more transportable. The coal also burns at a higher temperature than the original biomass, making it more useful in the manufacturing processes.
- More sophisticated pyrolysis techniques have been developed recently to store volatile products that would otherwise be lost to the system. The collected volatiles produce a hydrogen-rich gas (a potential fuel and carbon monoxide.) These components, if desired, can be converted into methane, methanol and other hydrocarbons. Flash pyrolysis can be used to produce bio-crude - a fuel.
- Conventional pyrolysis produces tar and pyro-lignan acid as waste which, after pretreatment, can be used as fuel oil. The disadvantage is that about 4 t of biomass is needed to produce only 1 t of coal. Another type of more advanced pyrolysis, which uses higher temperatures, generates as products a gas rich in hydrogen and carbon monoxide (60%) and only 10% solid coal which makes it comparable to gasification.

# Plasma

- Plasma gasification technology is an innovative method of high-temperature treatment of waste, which is converted into combustible gas and an inert residue by the use of electrical energy.
- The term plasma refers to an electrically ionized conductive gas. Various gases, such as argon, helium, methane or steam, may be used. For applications involving the gasification of waste the normally used gas is air.
- In order to make the air electrically conductive, large differences in electrical potential apply, generating a stable electric discharge (arc) between two electrodes. The resistance that the air offers to the electron flow produces thermal energy, with temperatures that can reach 5000 and 10000 ºC.

# Plasma-application

- The process can be applied by using substantially two technologies, the plasma torch or the system with graphite electrodes.
- Regardless of the type of technology, plasma processes can be used to treat a wide variety of wastes, with high content of inorganic fractions and low calorific value. This is because much of the heat needed for the treatment comes from the plasma and not from the oxidation of the waste.
- The greater diffusion of these installations will occur when their design and realization will be simpler and economic. In the future, the system could represent a promising alternative to traditional thermovalorization systems, ensuring less polluting gas emissions and a vitrified solid residue. Also in this case, the gases produced can be used for the generation of energy or be converted into other compounds for other applications for gasification and pyrolysis.