MESTRADO INTEGRADO EM ENGENHARIA DA ENERGIA E DO AMBIENTE

Disciplina: Energia da Biomassa

Aula N 2 – Resíduos, Biomassa e Energia

Conceitos gerais

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Introduction

- Our development depends on natural resources and anergy supply, being necessary to diversify the sources and make them sustainables.
- Our future evolution is linked to this new supply sources.

ORGÂNIC MATTER and BIOMASS

ORGANIC MATTER

and

BIOMASS

Where is the difference ?

What is biomass?

- Biomass - a heterogeneous mix of organic matter, both by origin and nature, with **stored energy** in the form of chemical energy.
- Biomass is a form of storage of solar energy.
- Plants convert solar energy through photosynthesis, with an efficiency of 0.1%, and store it for a long time in leaves, stems, flowers, etc. At the limit, energy can be stored infinitely in the biomass without loss.

What is biomass?

- In principle, any material of organic origin counts as biomass. Not just plants and animals but also animal excrements or plant components such as straw.
- Paper and cellulose, abattoir waste, organic waste, vegetable oil and ethanol are all biomass and can be used to produce energy.
- Different methods are used to turn these various raw materials into liquid, solid or gaseous energy sources. Often there are several potential ways to transform a raw material into energy.
- Biomass can for example be burnt in a power station to produce heat, fermented in a anaerobic digester to make biogas and then electricity and heat, or converted into a synthetic gas and fuel by thermochemical gasifiction. Which variant imposes itself not only depends on the cost and expenses involved but also on the prevailing political conditions.

Biomass Definitions

- Biomass definition published by many different institutions is often variable and provides unclear view and slight differences.
- There are different definitions of biomass depending of the context (forestry, waste, energy, etc.)
- The following definitions present the most important features.

Biomass Definitions

- United Nations Framework Convention on Climate Change (UNFCCC):
  "The biomass is the non-fossil fraction of an industrial or municipal waste."
- Renewable energy directive, European Commission:

"The biodegradable fraction of products, wastes, and residues from biological origin from agriculture (including vegetable and animal substances), forestry, and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste"

Biomass Definitions
(European Tecnical Especification CEN/TS 14588)

- **"CEN/TS14588: The biomass is defined as material of biological origin excluding material embedded in geological formations and transformed to fossil"**

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Biomass

- Biomass can be converted into bioenergy through combustion, either directly or via derived products.
- 64.2% of total **primary energy production** of renewable energy in the EU-28 in 2013 is generated this way.
- Examples of derived products from waste streams include the conversion of waste oil into biodiesel, animal manure and organic household waste into biogas and plant or plant waste products into biofuel.

Biomass classification

- Biomass resources can be classified as **primary, secondary and tertiary** according to their provenience:
- **primary biomass** resources (or grown resources) are **produced directly by photosynthesis** and are taken directly from the land;
- **secondary biomass resources** (or residues resources) result from the processing of primary biomass resources either physically (*e.g.*,mechanical processes such as milling), chemically (*e.g.*, pulping processes) or biologically (*e.g.*,biomass processed by animals such as manures and slurries);
- **tertiary biomass resources** (or waste resources) are post-consumer residue streams such as animal fats and greases, used vegetable oils, packaging wastes and rubbish (Welfle et al., 2014).

PHOTOSYNTHESIS

- Biochemical process by which chlorophyllin plants, using the light energy of the sun (photons), manufacture **Glucose** ($C_6H_{12}O_6$) and **Oxygen**, from abiotic basic compounds abundant in the earth:
- the carbon dioxide (CO_2) is reduced and water (H_2O), by photolysis, provides the hydrogen required for the reaction. In chemical terms, the reaction of photosynthesis to the formation of sugar has the following formula:

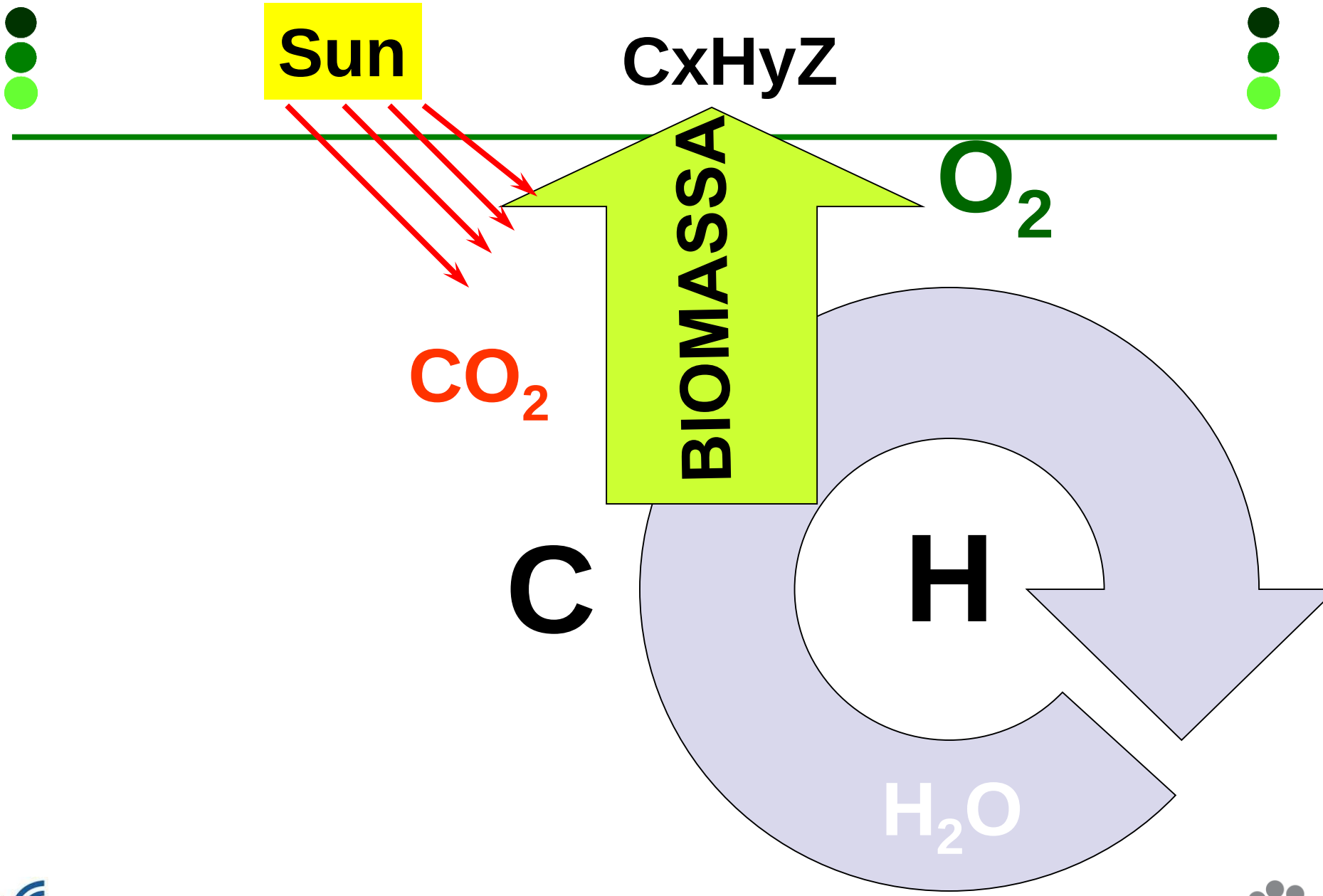
$$(CO_2)+(H_2O)+\text{energy light (673 Kcal)}=C_6H_{12}O_6+(O_2).$$

The Photosynthetic Process

- allows the creation of biomass from carbon dioxide in the atmosphere, from water and nutrients, through two key processes**. It is the basis of all life on earth.**
- Plants obtain energy from solar radiation, which allows their autotrophy and form the nutritional basis for other organisms, such as humans and animals which, being heterotrophic life forms, are not able to obtain their energy at from sunlight.
- On Earth, photosynthesis is the **only process that provides oxygen to organisms**, essential for life on Earth because it is used by heterotrophic organisms. Forests provide the oxygen that mankind and the animal kingdom need to live.

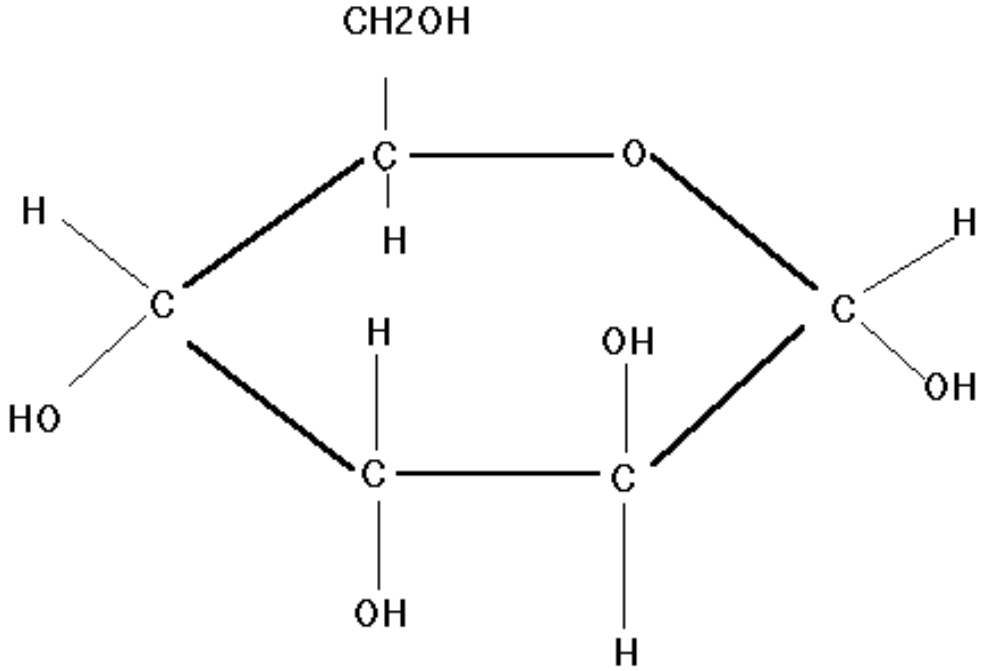
Photosynthesis - Operation

- The green pigment of the leaves, the chlorophyll, is the internal "power plant" of the plants. It converts carbon dioxide into biomass in the form of sugar and starch because of solar energy. In addition to solar radiation, water and minerals (plant nutrients) are needed in this process, which are removed from the soil through the roots.
- Depending on the type of plant, photosynthesis results in the creation of multiple carbon chains (carbohydrates). In fast-growing plants, such as corn, photosynthesis of young plants can achieve an energy conversion efficiency of solar radiation up to **2%**.


Sun
CxHyZ
BIOMASSA
O_2
CO_2
C
H
H_2O

Glucose

- Glucose produced by autotrophic beings is the source of energy and raw material for all living matter, allowing the synthesis of other compounds (by polymerization) forming ***macromolecules of starches or cellulose*** and, by synthesis, proteins and lipids, the main constituents of biomass of the planet.



PHOTOSINTHESIS – Stored energy

- The photosynthetic process stores about 10% of the energy of the sunlight emitted as potential energy (of the compound formed).
- The remaining part is reflected and absorbed by the atmosphere (60%), is reflected by soil or plants (10-25%) or is lost during conversion into chemical energy of the plant (15-40%).

PHOTOSINTHESIS -potential

- In the rural areas of the planet, about 200 billion tons of biomass are grown, with an energy capacity of approximately 30000 Hexajoule, equivalent to the volume of energy of all reserves of fossil energy sources. Annual growth of about 15 billion tons of biomass through photosynthesis represents an energy potential of 2250 Hexajoule.
- Only a part of this vast potential can be used directly for energy, as it is widespread throughout the earth mass. The technical potential available for use is estimated at about 150 Hexajoule.
- The technical potential of economically viable biomass depends on the market conditions of alternative fuels (economic value of gas and oil), and the political support instruments (subsidies, revenues, etc.). However, with rising prices for fossil energy sources, the potential of bioenergy increases.

autotrophic-primary Biomass

- Photosynthesis gives rise to the production of several forms of raw material (biomass), according to the cultivated autotrophic plant species:
- Forests, plants and undergrowth and algae.
- The **biomass removed from the forest plants** is largely composed of fibrous and lignocellulosic compounds, which are **poorly biodegradable**

Algae

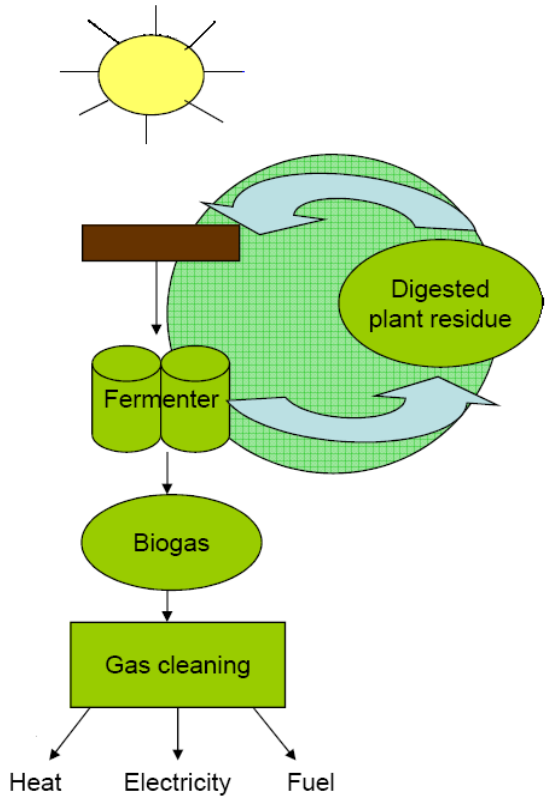
- They are an interesting source of raw materials and fuels, as they have a **high rate of growth**.
- In the cellular composition of the algae there are numerous **chemical compounds with high added value**, such as carotenoids, phospholipids, phytocyanins, etc. usable in numerous areas of medicine and cosmetics.
- In particular, **algae can be stimulated to produce hydrocarbons**.
- Algae can be grown in ponds outdoors or in closed systems. The conversion efficiency of solar energy is in the order of 4 - 6%.

Energy crop-new source of biomass

- **Paradigm shift through land productivity and energy balance; Crop productions needs large changes**
  - New energy crops that use the entire vegetation period
  - Total use of the whole plant
  - Nutrient recovery by cycle
  - Large installations eficiente and friendly towards enviror
  - **Biorefineries;**bioethanol/biogas/biodiesel and higher va

Product

- biogas enables complete utilisation of the crop



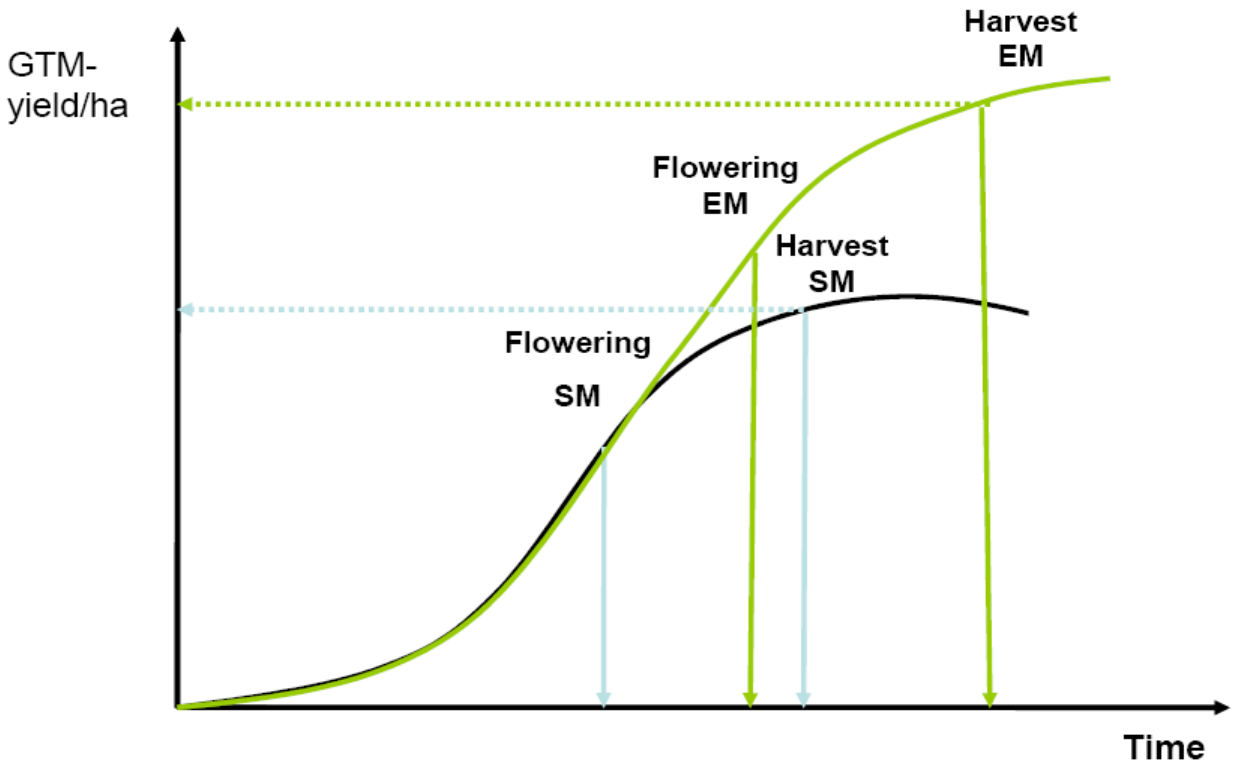
Source: KWS, D

Energy crop-the new solution

Growth Progress-more biomass from crops

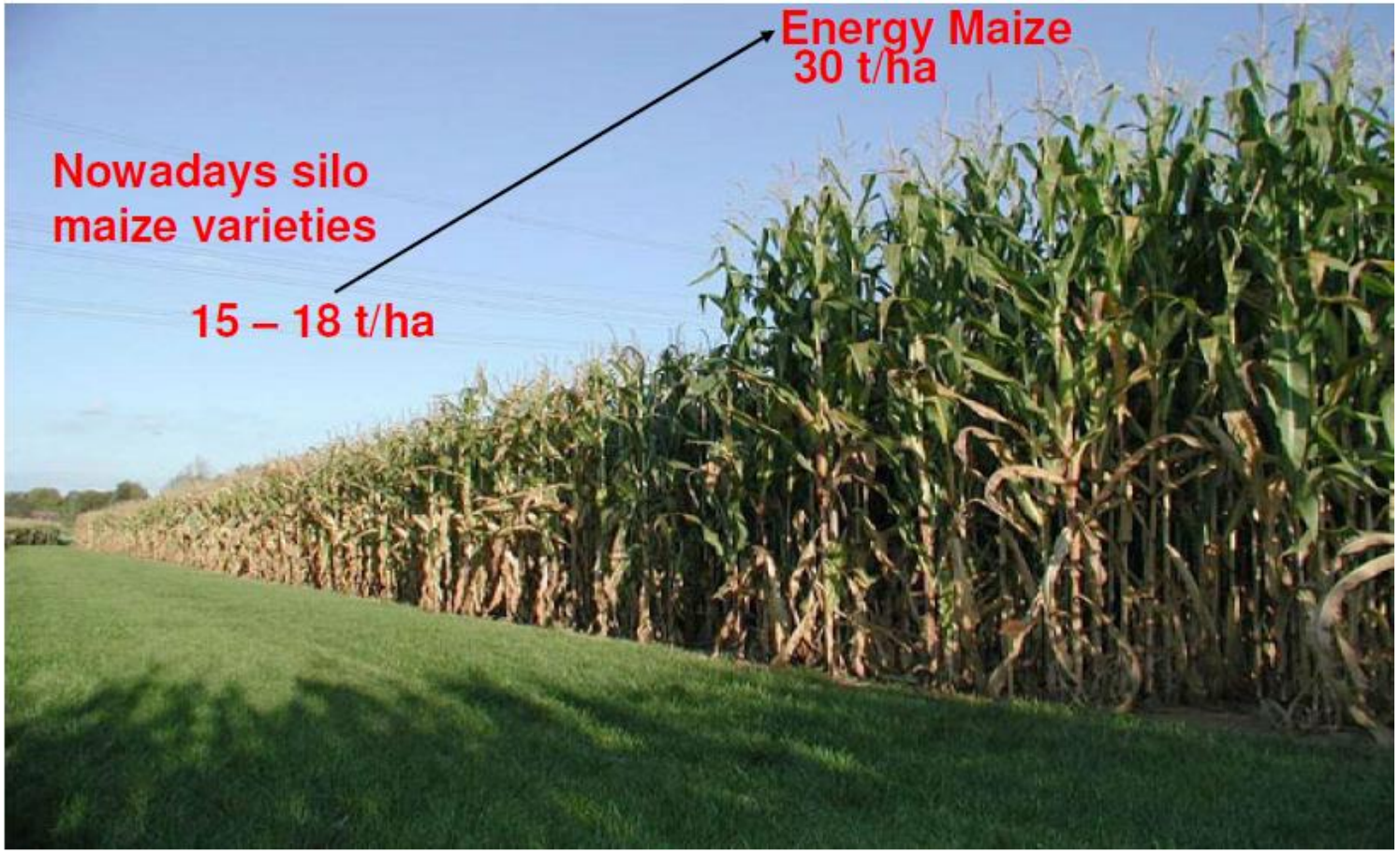
Conventional Silo Maize (SM) and an Energy Maize (EM)

- Clearly higher harvest of the Energy Maize



Increment of Crop target:

- **Increase of biomass production : 100 % in 10 years**



Source: KWS

Algae – “The solution?”

- Promissory process indeed still did not proved his feasibility
- Produces 30 times more oil per ha than current crops.
- High lipid contents
- no sulfur and non-toxic biodegradable
- not subject to a risk as is crude oil, corn & soybeans.

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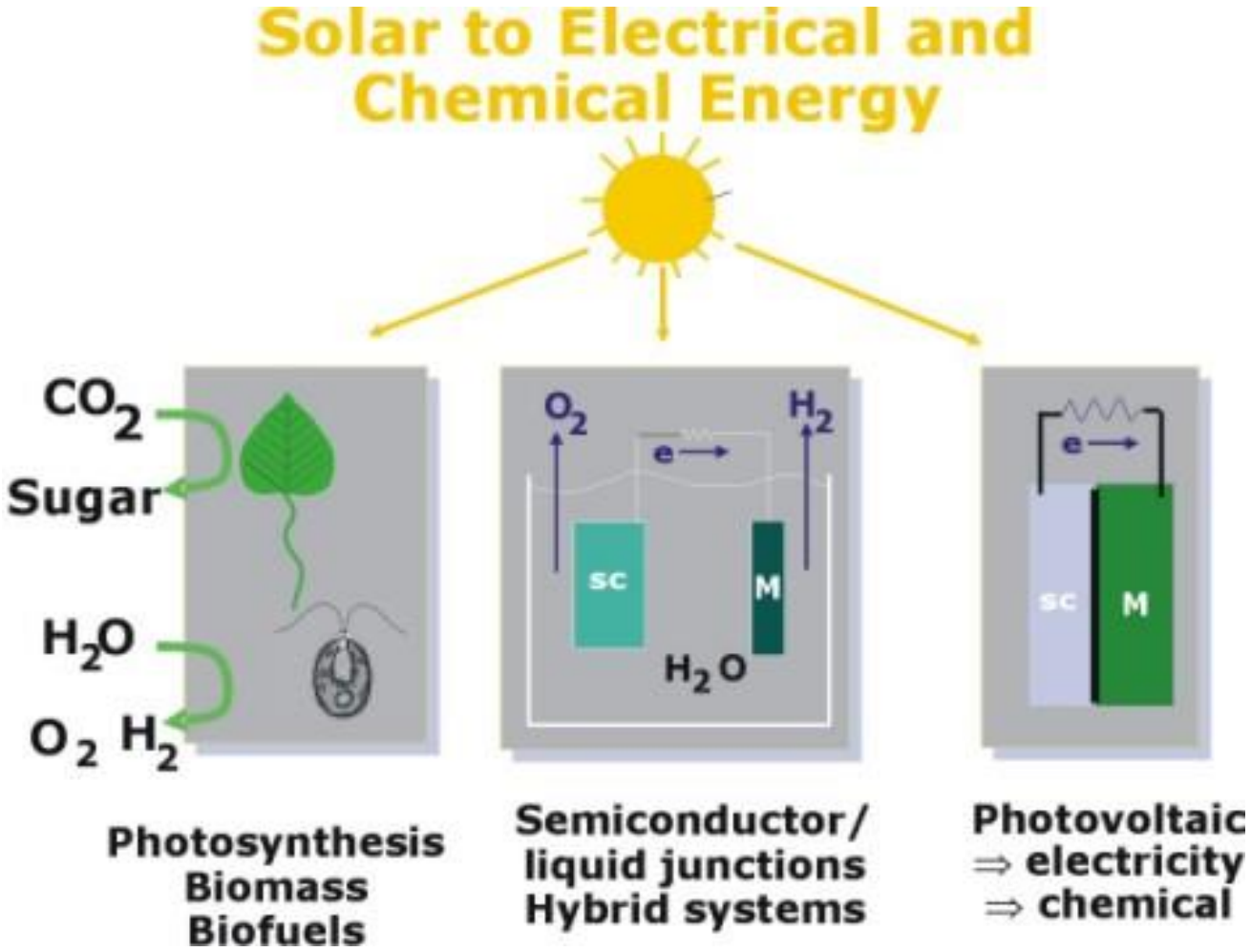
Direct conversion of solar energy “The future?”

- Scientist are developing the science needed to convert solar energy directly into fuels, improving Nature’s capabilities to produce fuels
- Natural biomass has a low efficiency (< 1%), direct conversion of solar energy into fuel has the potential of much higher efficiency.
- Emerging techniques in the life-, material-, and nano-sciences provide humankind with the capability of designing novel materials for energy and charge transport coupled to novel catalysts for fuels production. Primary and secondary biofuels efficiencies >5%

Direct convertion of solar energy "The future?"

- Existing natural microorganisms are able to convert solar energy directly into fuels by developing e.g. hydrogen.
- Within a few years, durable artificial devices mimicking solar energy conversion of plants to collect solar radiation and to split water or convert atmospheric CO2, thus producing environmentally clean fuels.
- The theoretical achievable limit for artificial solar to fuel converters is well above 10%. The technological transition to renewable solar fuels now critically depends on scientific progress.

Solar Direct Conversion



Organic Waste: Problem or resource?

- The organic wastes from agricultural and Industrial processes cause pollution due to the volume and nutrients load carried in the water
- They must be treated and disposed correctly and safely in the surrounding environment.
- Farm residues are one of the main pollution fonts in Portugal and in others European countries.
- When accumulated provoke emissions
- **But these wastes can be a resourse**

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Wastes are them a renewable energy?

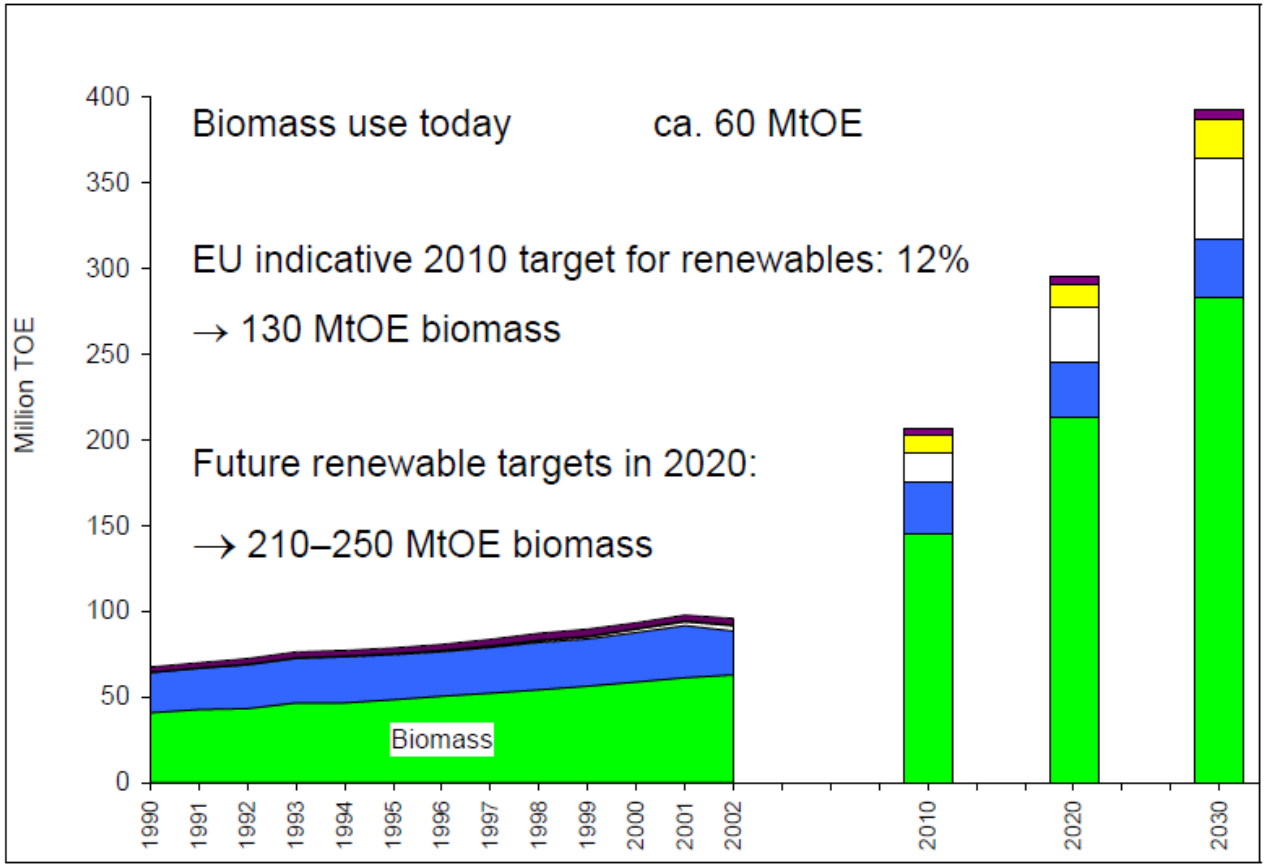
- As waste production is linked to human activities, they are always produced by trhe man society.
- Its life cycle frequently ends on lanfills and its chemical and energetic properties are not used.
- There is a large amount of wastes. There is still insuficient awareness. There is still abundancy.

Energy from wastes and biomass- Available Technologies

- Thermal
- Biologic
- Phisico-chemical

The choice of technology depends on residues biodegradability and water content (humidity).

Biomass Evolution in EU until 2020



Source: EEA (2006 + 2007)

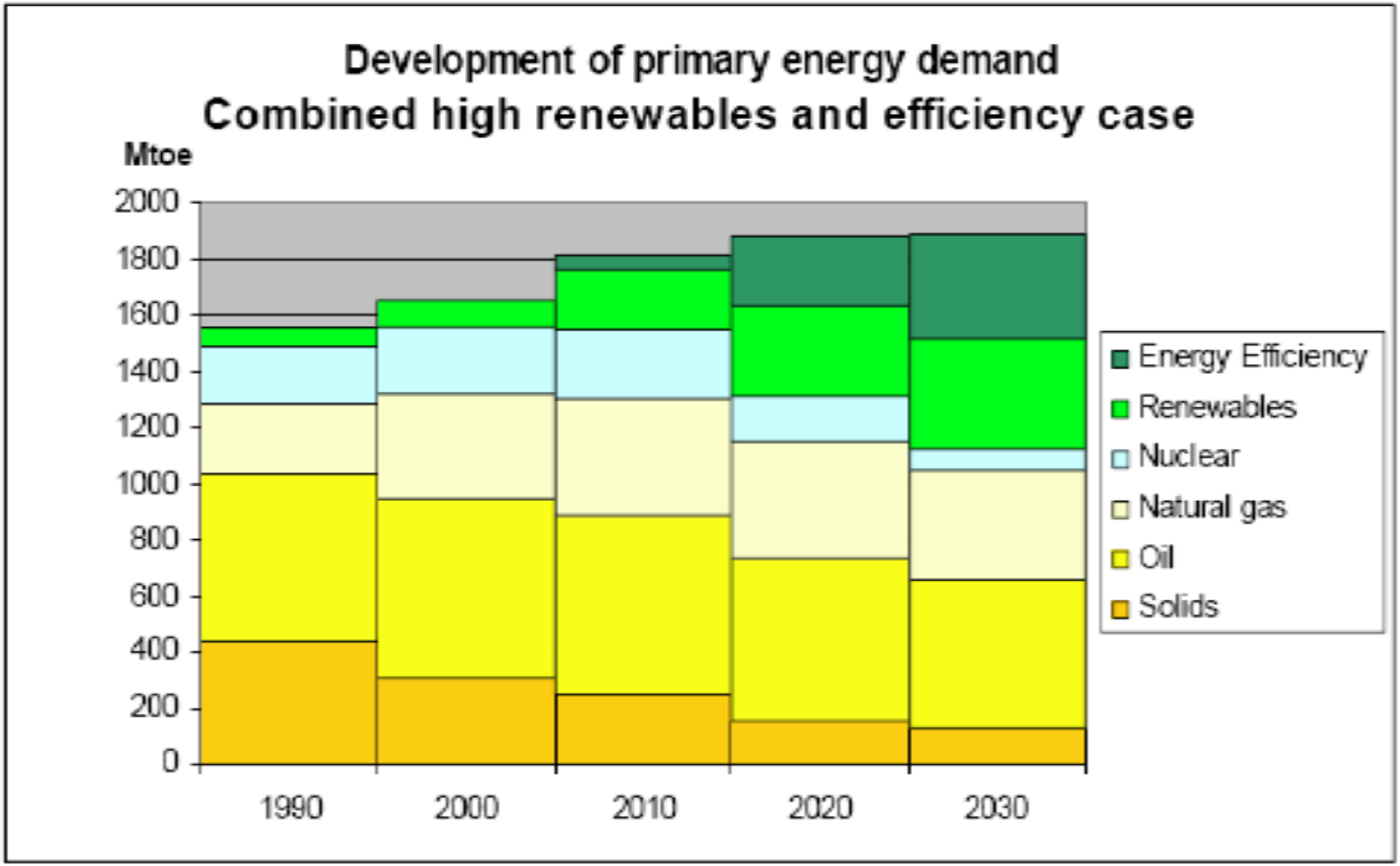
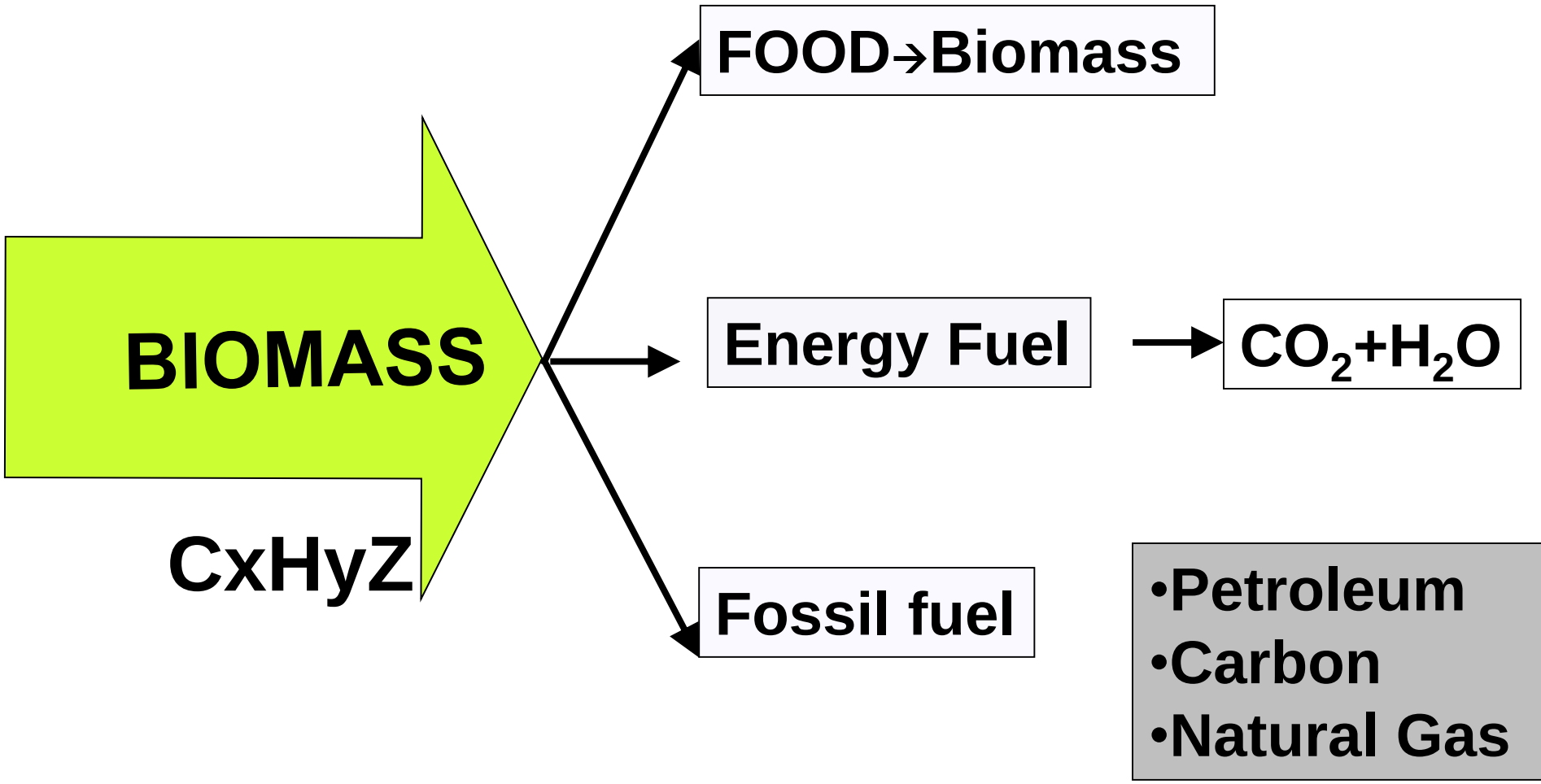


Figure 9: Impact of the strong renewable energy and energy efficiency penetration on the EU's primary energy demand (PRIMES modelling results)

Biomass utilisation



Perspective

BIOMASS SOURCE	APPLICATION
•Forest residues •Woody agricultural waste •Arable agricultural wastes •Waste from forest industries •Wastes from agr-industries •Energy crops	•Domestic applications •Centralized heating networks •Industrial thermal applications •Electrical applications
•Agricultural waste •Biodegradable waste from industrial plants •Sludge from treatment plants	BIOGAS

historical use of biomass

- **TRADITIONAL ENERGY RESOURCES**

  Firewood

- **INDUSTRIAL MATERIAL**

Agricultural and industrial machinery

Furniture

Transport machinery

- **ENERGY RESOURCES**

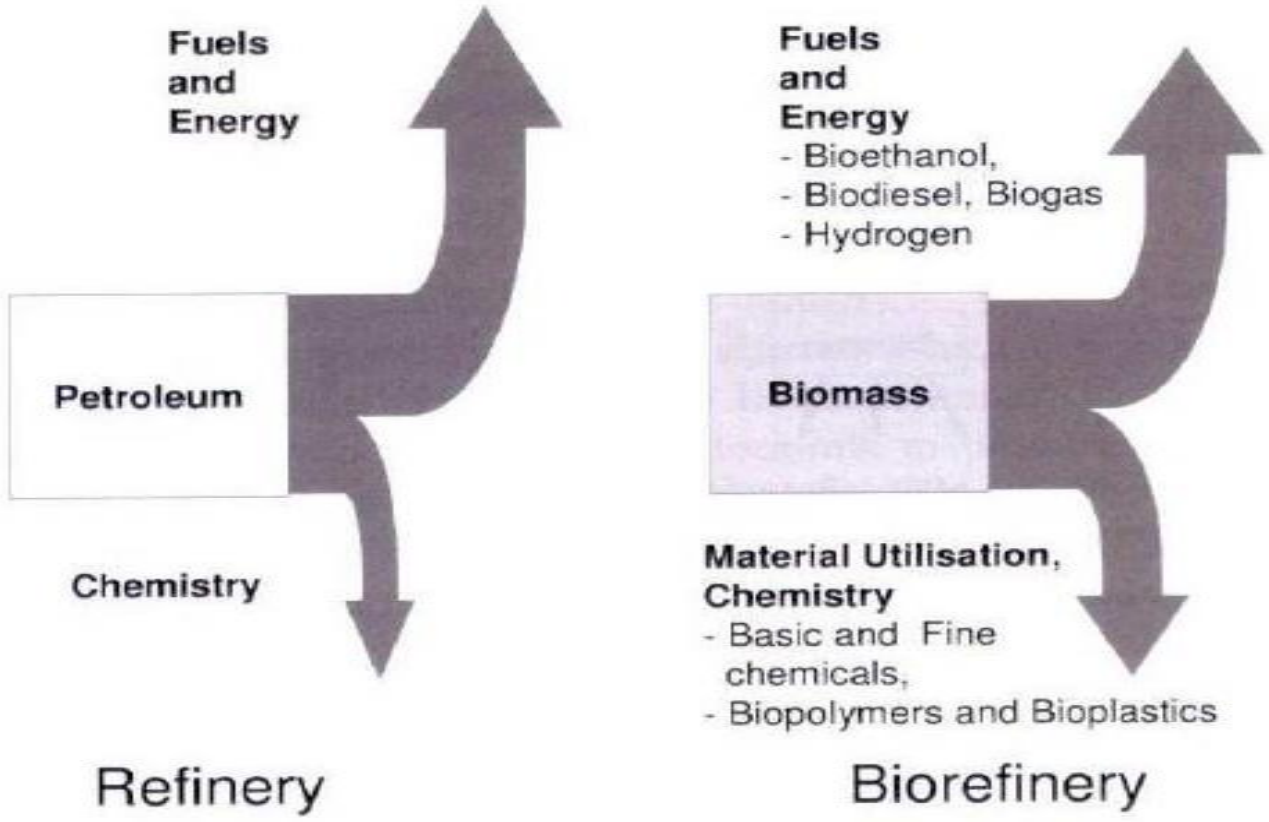
  Thermal energy

  Electricity generation

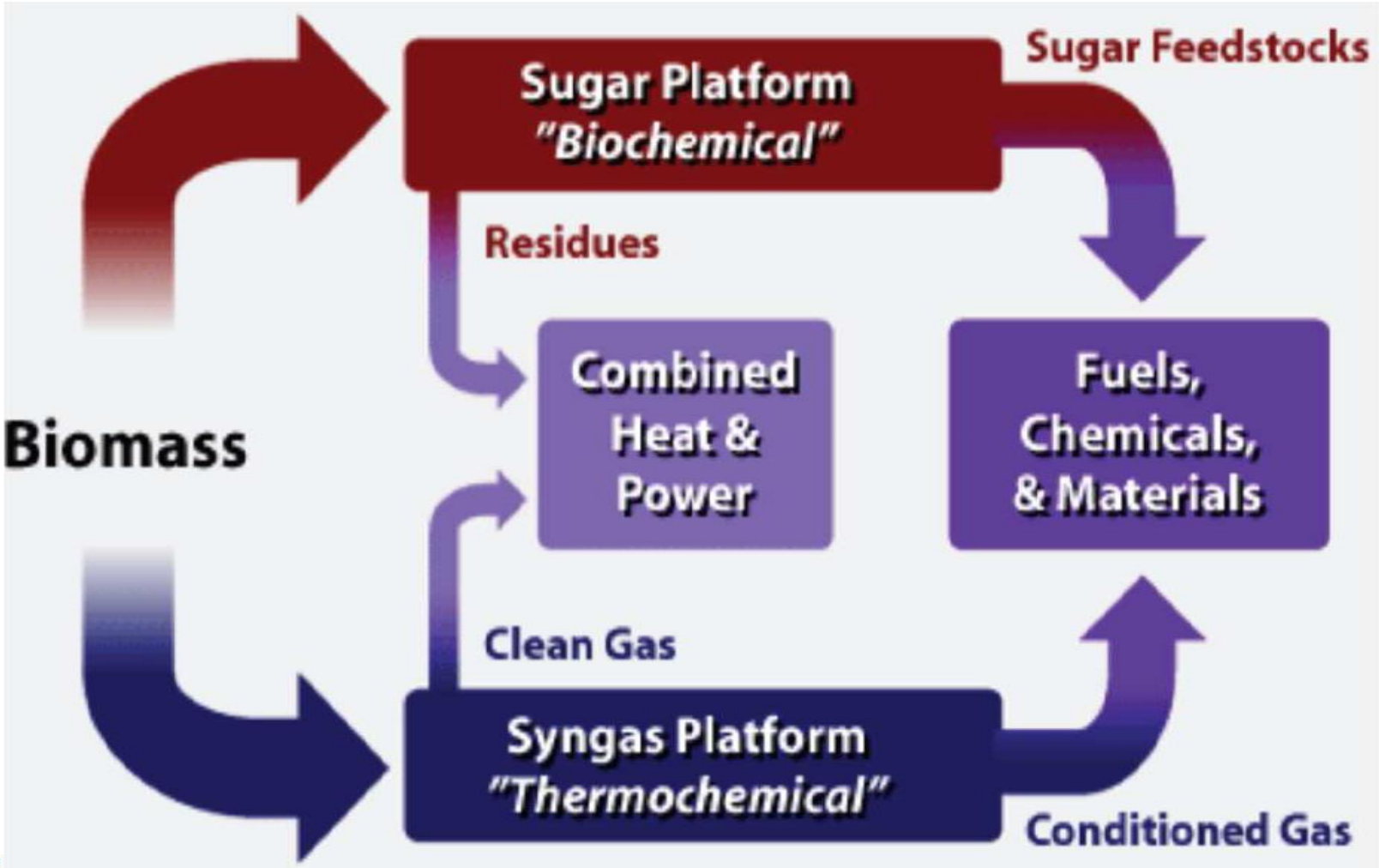
  Biogas and Biofuels

Comparison oil refinery vs biorefinery

- **Comparison of the basic principles of an oil refinery and a biorefinery(Kamm et al. 2006)**



Two-platform biorefinery concept



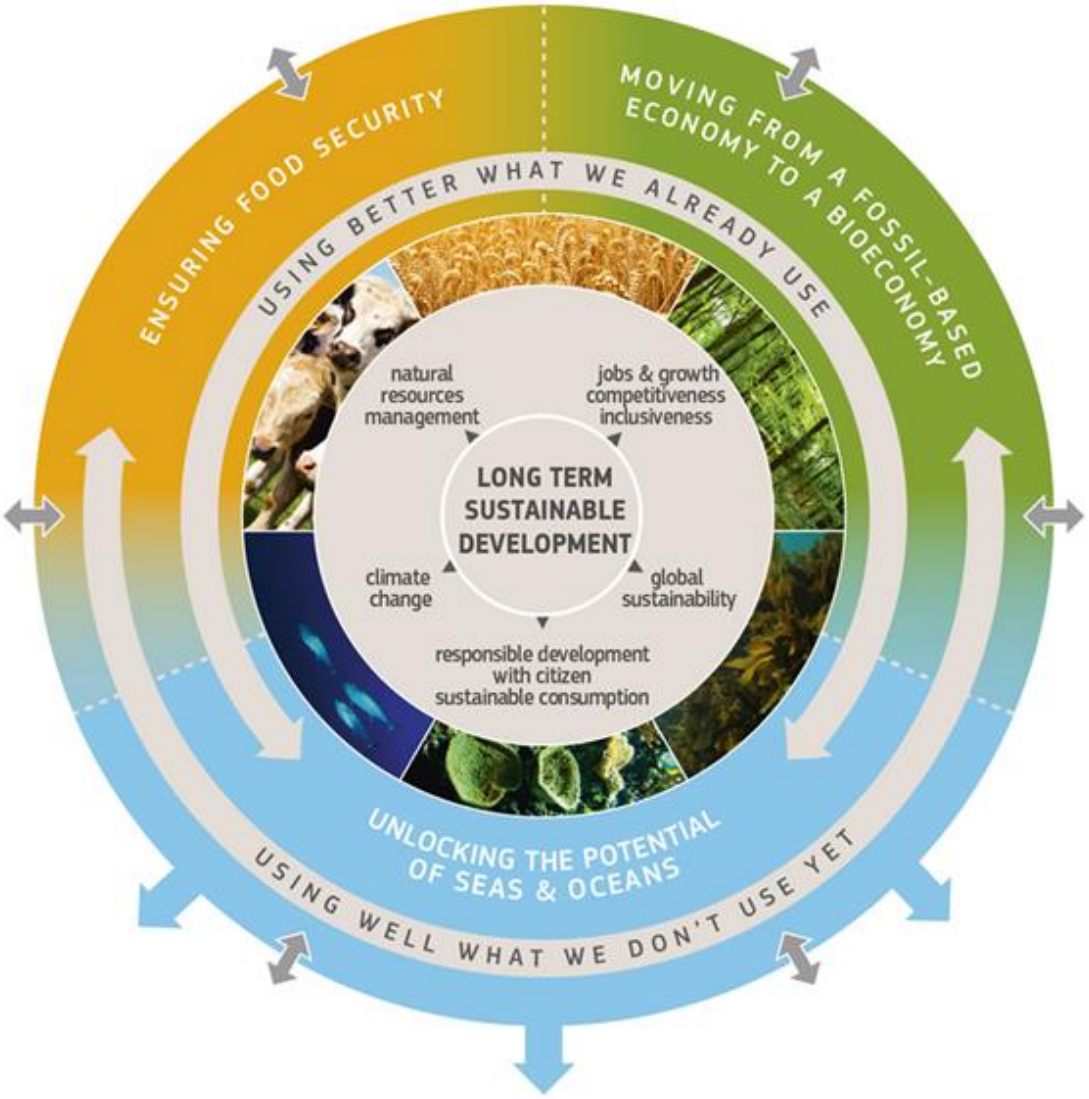
Source: NREL 2006, Biomass Programm, DOE/US]

A Bioeconomy for Europe

On 13 February 2012, the European Commission adopted a strategy for **«Innovating for Sustainable Growth: A Bioeconomy for Europe».**
This strategy proposes a comprehensive approach to address the ecological, environmental, energy, food supply and natural resource challenges that Europe and indeed the world are facing already today and it will be revised in 2017.

[1] ." Source: "Innovating for Sustainable Growth - A Bioeconomy for Europe" (2012).

Bioeconomy a strategy for Europe



Biomass based economy

This lay-out sintetize the biomass valorisation chain.

Biorefinary

GREEN ECONOMY=GREEN CHEMISTRY + BIOENERGY