MESTRADO INTEGRADO EM ENGENHARIA DA ENERGIA E DO AMBIENTE

Biomass on Earth-General Concepts

Aula N 1

Doutor Santino Di Berardino

Santino.diberardino@lneg.pt

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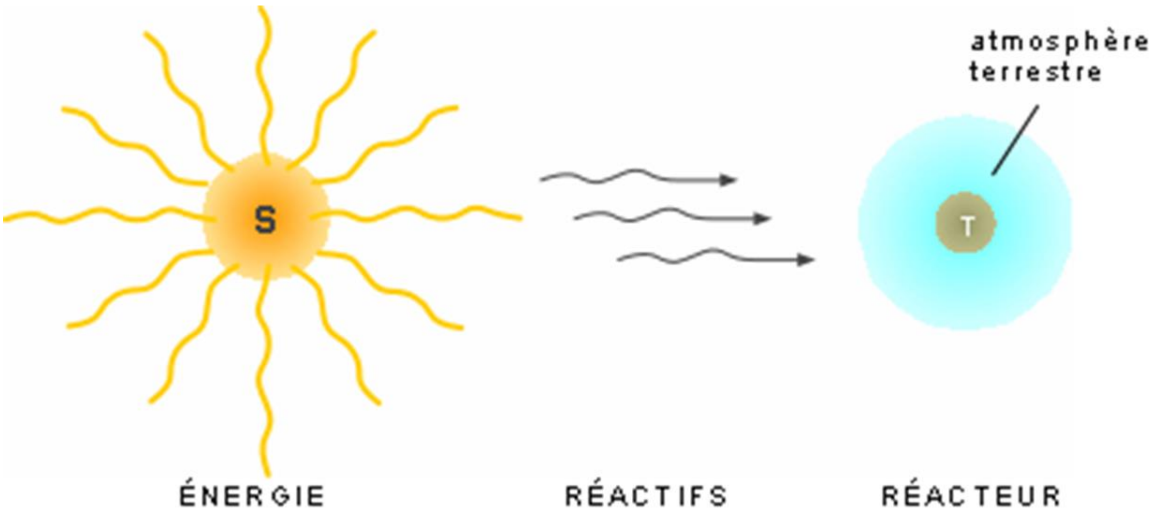
BIOENERGY - ENERGY FROM THE SUN

Life on earth depends on the Sun. But it is a virtually closed system in terms of matter



Solar energy, available in the form of radiation to the earth's surface, exceeds 11,000 times the energy currently needed by mankind.

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Origin of Life on Earth - Early Theories

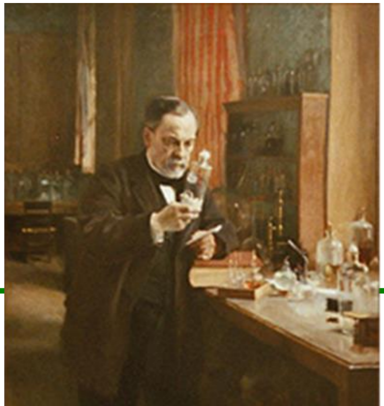
- At the end of the 19th century, several German scientists, including Liebig, Richter and Helmholtz, tried to explain the appearance of life on Earth with the hypothesis that it had been brought from another part of the universe in the form of resistant spores in meteorites - **Cosmozoic theory** .
- The presence of organic matter in meteorites found on Earth has been used as an argument in favor of this theory, which does not invalidate the possibility of terrestrial contamination after the fall of the meteorite.
- The existence of organic molecules in space, such as formaldehyde, ethyl alcohol and some amino acids, has already been proven. However, these molecules appear to form spontaneously without biological intervention.

Panspermia Theories

- o The Swedish physicist **Arrhenius** proposed a theory according to which life would have originated in spores driven by light energy, coming in a "wave" of outer space. He called this theory **Panspermia** (seeds everywhere). These ideas have now fallen into disrepute due to the radiation of space, the heating of the entrance into the atmosphere, etc.
  In the 1980s, Crick (one of the discoverers of the DNA structure) and Orgel suggested a theory of ***directed Panspermia***, in which the initial agent of life on Earth would have arisen from the multiplication in the primitive ocean of microorganisms carried on a ship unmanned space, launched by any very advanced civilization.
- None of these theories truly advances the clarification of the fundamental question: **How did life come about?**

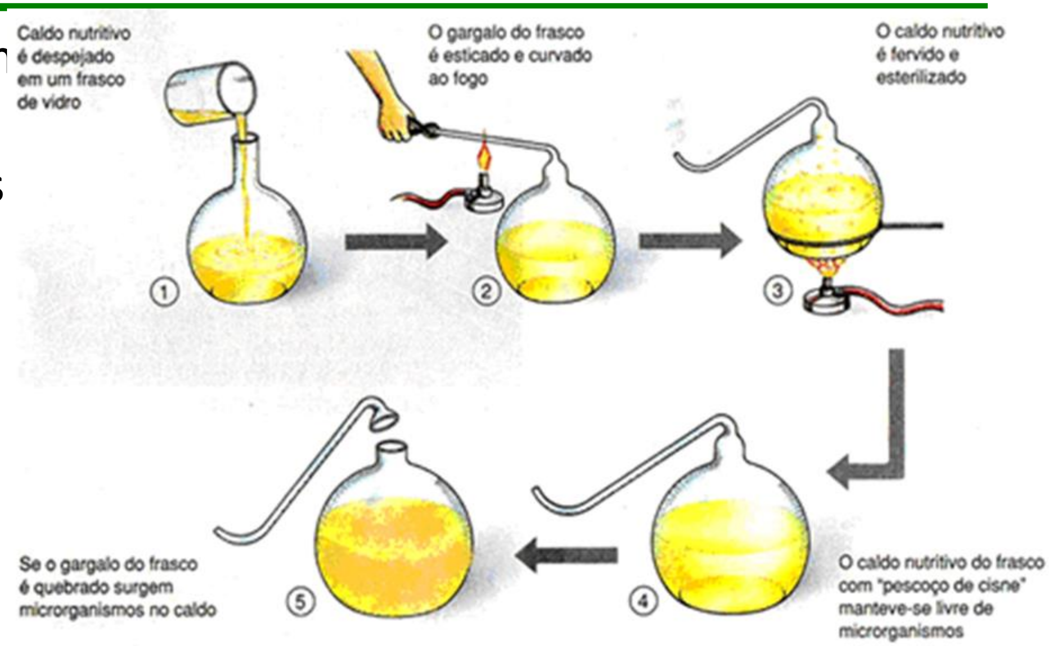
Theory of biogenesis - Louis Pasteur

- The theory of biogenesis, which considers that living beings originated and evolved from other living beings, was proven by the French scientist **Louis Pasteur** (1822 - 1895), around 1860.
- **Abiogenesis theory**, based on the belief that living things spontaneously originated from decomposing organic materials or from non-organic materials, was **eliminated**.



Swan's Experience (Pasteur)

- The absence of microorganisms in the swan-necked flasks kept intact and their presence in flasks whose "neck" had been broken show that the air contains microorganisms, which develop by coming in contact with the nutrient and sterile liquid of the balloon.



- In the intact flask, the microorganisms can not reach the nutrient and sterile liquid, because they are trapped in the "filter" formed by the water droplets that appear on the neck of the flask during cooling

Heterotrophic Theory

- The age of our planet is estimated at 4.5-5 billion years and it is assumed that life appeared much later, about 2.5-3 billion years, when the Earth's crust was formed by the cooling of the Earth. Planet. The appearance of life on earth does not yet have completely exhaustive explanations.
- In 1936 the Russian **Alexander Oparin** launched a revolutionary theory that organic molecules of living beings would have gradually evolved from simple molecular organizations: **Heterotrophic Theory.**
- According to this theory, the atmosphere of primitive Earth 3 billion years ago was devoid of **oxygen** (O_2) and **Nitrogen** (N_2) and was composed of inorganic gases such as **methane** (CH_4), carbon dioxide (CO_2) **ammonia** (NH_3), **hydrogen** (H_2) and **water vapors** (H_2O).

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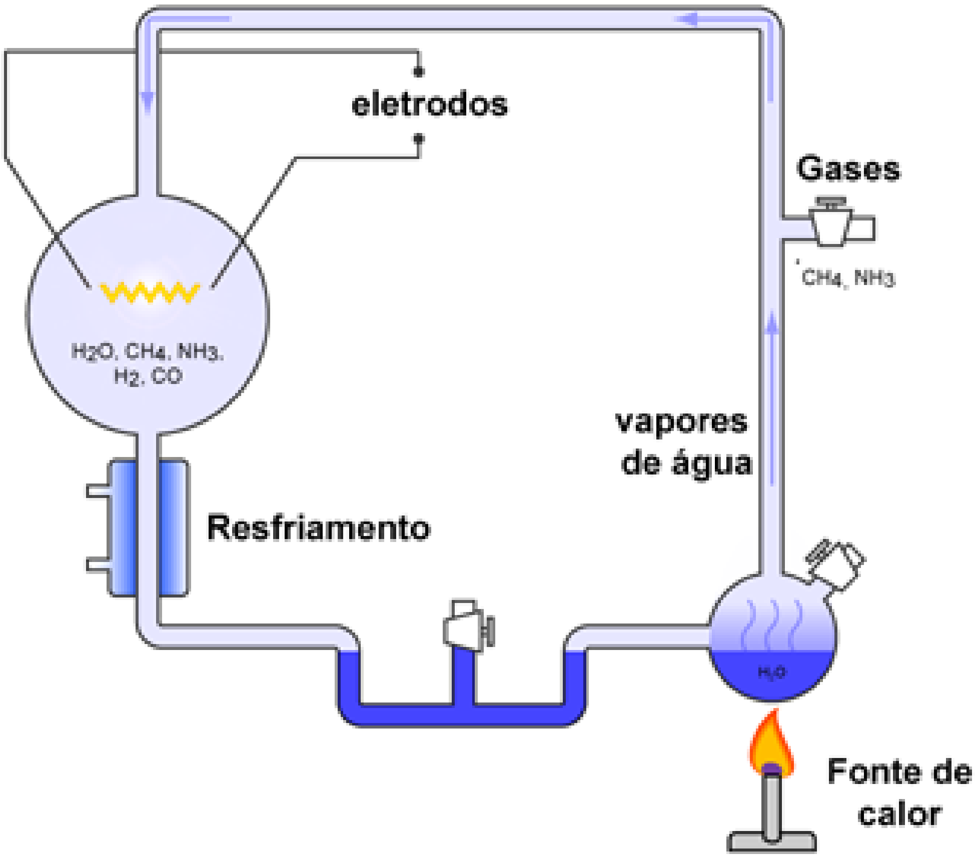
Evidence for heterotrophic theory

- Oparin could not prove his hypothesis. But, in the 1950s, scientists **Harold Urey and Stanley Miller**, conducted an experiment in the laboratory. They placed in a glass flask a primitive atmosphere full of gases discharged from volcanic eruptions (water vapor (H_2O), methane gas (CH_4), carbon dioxide (CO_2), Hydrogen (H_2), ammonia (NH_3) which subjected them to heating and electric shock with a high-voltage electric spark.
- After a certain time, they were able to artificially **produce several amino acid molecules** that showed the **appearance of amino acid molecules inside the balloon**, which accumulated in the U-tube.
- They **proved the Oparine theory**

Miller Experiment



Training Mechanisms in the Earth

- There was no oxygen, there was no protective layer of **ozone** (O_3), and the surface of the planet was bombarded, so that in addition to visible light, by ultraviolet rays, the temperature was quite high.
- For millions of years methane and ammonia would have combined into organic compounds of increasing complexity, by reactions, triggered by ultraviolet rays, heat from volcanoes, electric discharges from the atmosphere, etc., acting on the **reducing atmosphere**, giving rise to amino acids, which were floating in the atmosphere.
  With the humidity saturation of the atmosphere, the rains began to occur. The amino acids were dragged into the soil and subjected to prolonged heating, the amino acids merging with each other, forming proteins.

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Training mechanisms

- These multiple and varied organic compounds would have accumulated in primitive lakes and seas (the primitive ocean) for 2 billion years, forming a "**protein soup**" in the warm waters of the primitive seas, becoming progressively more complex, coacervate structures, which would have constituted the first sub-vital groups and, in successive stages, would have transformed into heterotrophic microorganisms.
- The proteins dissolved in water formed colloids that interpenetrated and originated the **coacervates**, which included molecules of nucleoproteínas. Then, they were organized into droplets delimited by lipoprotein membrane. The first cells appeared.

Evolution mechanisms

- These pioneer cells were very simple and did not yet have an enzymatic device capable of performing photosynthesis. They were therefore heterotrophic. Only later did the more evolved autotrophic cells arise. And this allowed the appearance of the beings of aerobic respiration.
- **Coacervates** can not be considered living organisms. However, its spherical organization was made of proteins and double layer of lipids that separated an internal medium from an external medium, that is, it resembled a cytoplasmic membrane. These artificial structures were called protobionts or microspheres, protocells, micelles, liposomes and coacervates.

The origin of life

- Given the complexity of the structures and mechanisms of regulation of autotrophic microorganisms, it is assumed that **the first living beings would have been heterotrophic**, which fed on organic substances not of autotrophic origin but derived from the abiogenic synthesis referred to.
- In the absence of photosynthesis, oxygen in the soil was scarce and most of the **microorganisms were anaerobic**, fed by organic molecules of non-biological origin. Its growth may have led to impoverishment of the nutrients in the medium, the growth rate was greater than the synthesis of M. O.
- Some microorganisms may have started to make their own nutrients, synthesizing the organic matter using light and a pigment that must have appeared in them, **chlorophyll**.

The origin of life

- At first these microorganisms must have been autotrophic during the day and heterotrophic at night, and the process evolved until the decomposition phase of the water, in hydrogen that combined with the carbon and giving rise to the production of oxygen that was released into the atmosphere .
- With the progressive appearance of this compound in the atmosphere, the conditions for important biological evolution were created, as the aerobic respiration (oxidation) reactions produce much more energy than the anaerobic ones, being thus available for the development of the complex structures of the terrestrial species and developed the world of plants, animals and decomposers that is now known.

Arrival of man and his evolution

- Modern Man **(Herectus**) arose about 2 million years ago.
- Until year 12000 AC lived of plants and hunting - their number was <5 million
- **12,000 years ago, an evolution took place**: it learned **agriculture** and took root. He is **no longer nomadic**. There is a house and **the women have it** !!!
- In the year 6000 BC were 20 million
- In year 0 about 200 million

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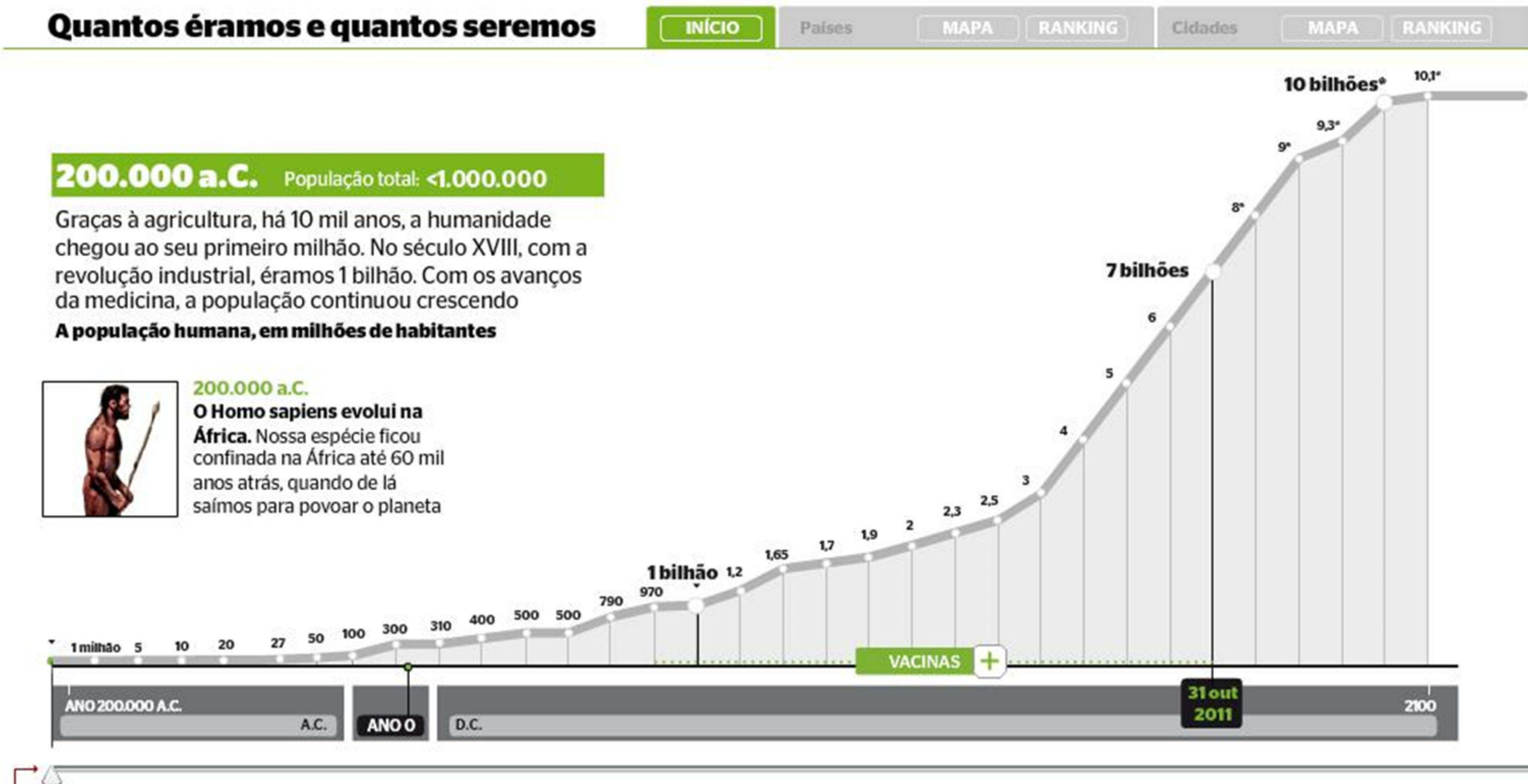
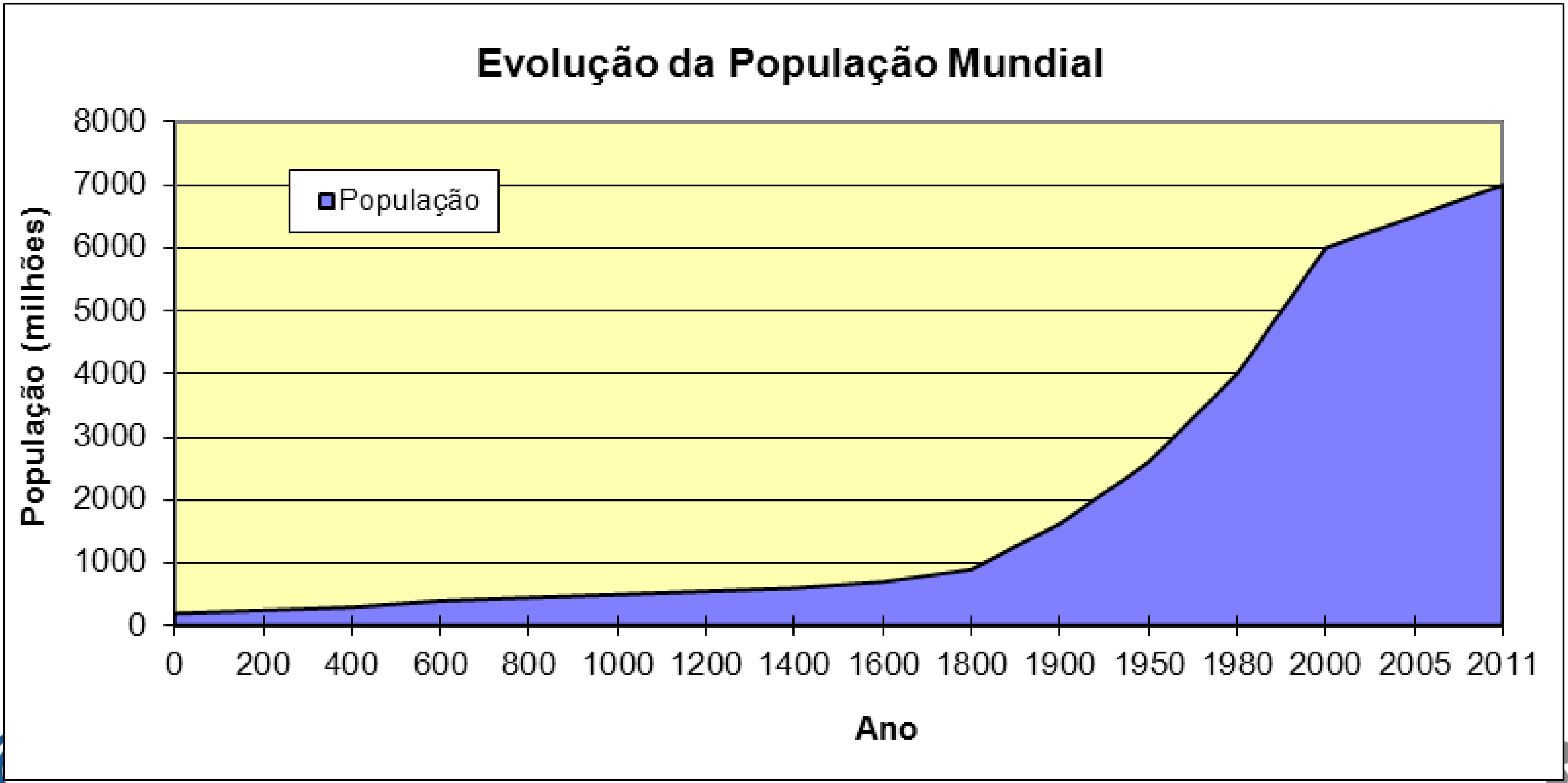
Evolution of the world population



Evolution of the world population

- From year O to 1800 evolves gradually
- Then there is an exponential growth



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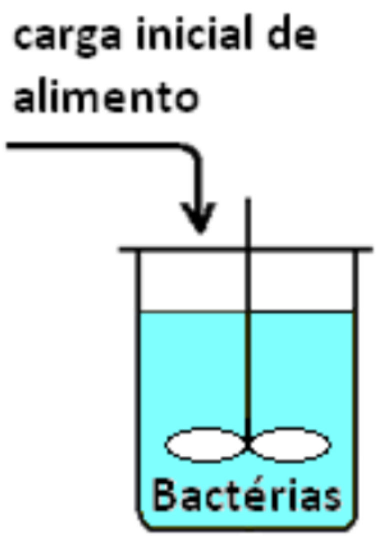
Biological growth of a bacterial community

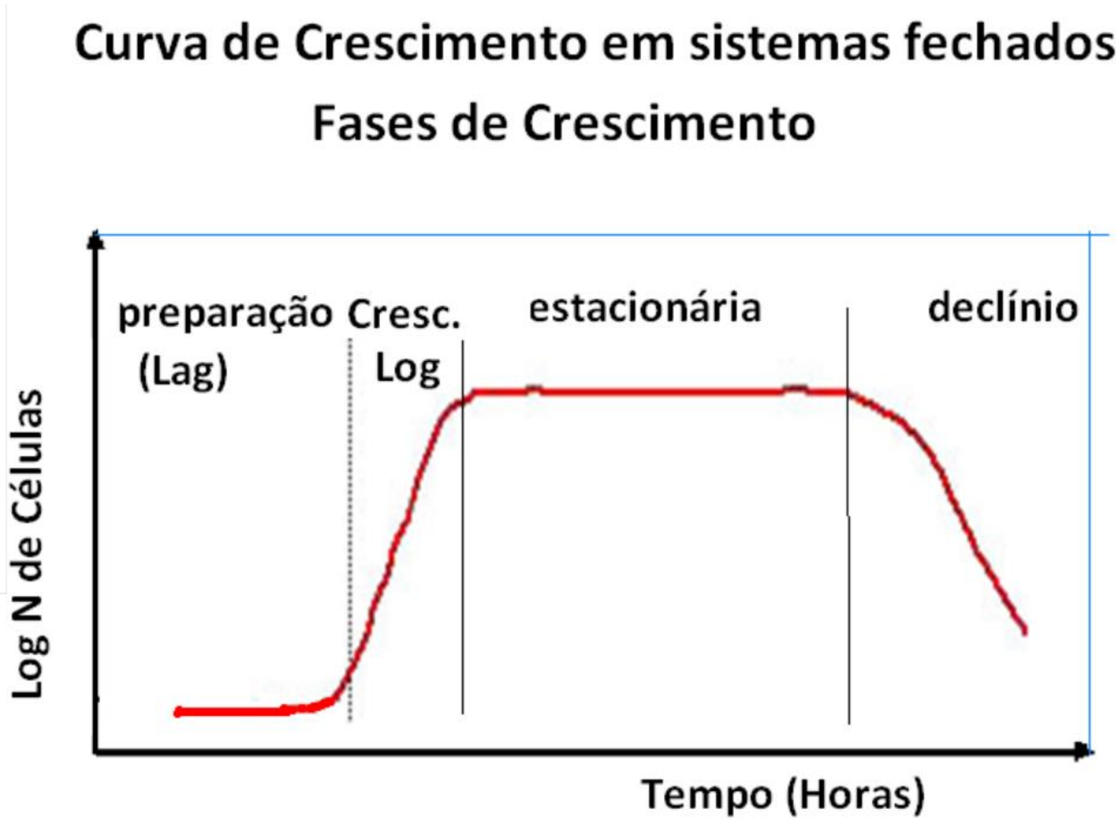
- It occurs the multiplication of the number of individuals and the decrease of the food.
- Bacterial growth is due to an increase in the number of cells in a population. Bacteria divide by binary fission, a process in which a parental cell divides to form two new cells identical to those that gave rise to them.
- Bacteria have **exponential growth** when food is abundant and the growth rate corresponds to the variation of the number of cells or the cell mass per unit of time.

Growth curve

- The typical growth cycle of a species in a closed reactor with abundant initial food is divided into four phases: lag phase, exponential or log phase, stationary phase and phase of death or decline.



$$\frac{dX}{dT} = \mu X$$



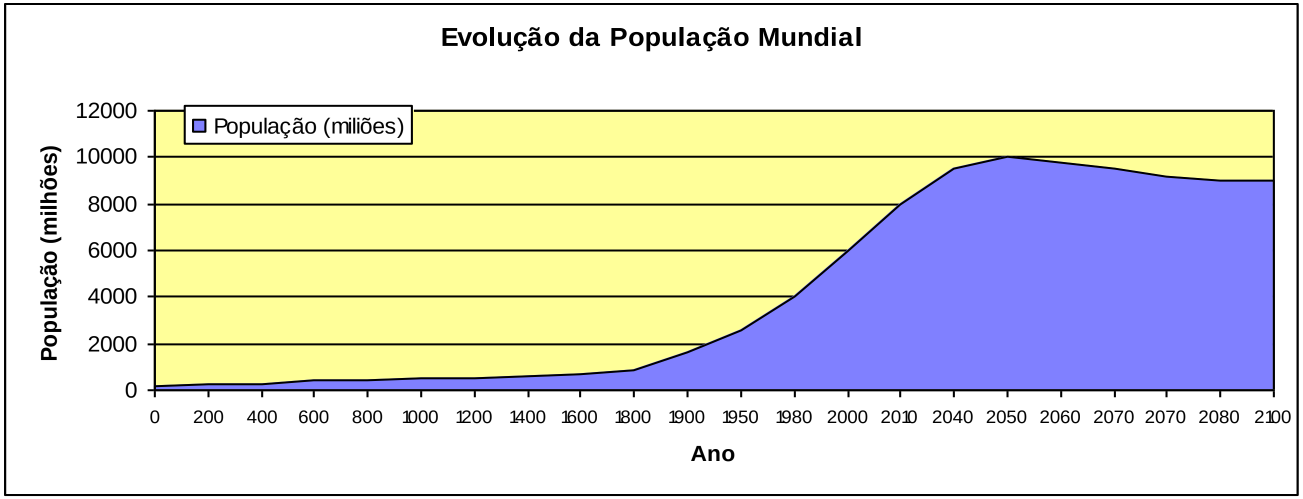
The phases

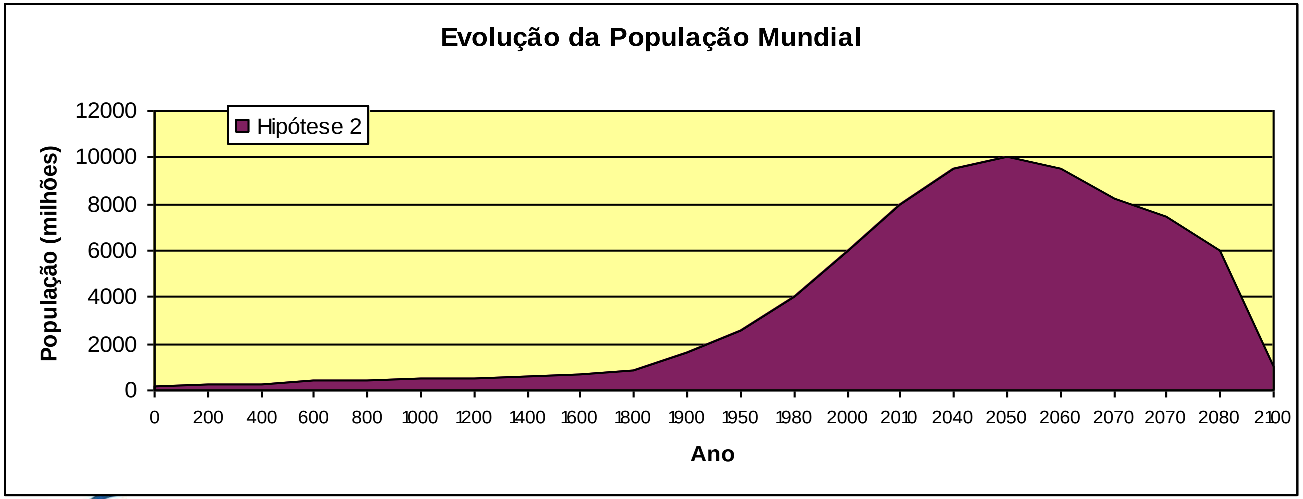
- Phase lag is characterized by a period of insignificant growth; Adaptation of the population in half.
- Log phase, exponential growth; Food is plentiful and available.
- Stationary phase: the number of dividing cells is proportional to those that die.
- Decline phase, in which the number of cells dying is greater than the one that divides.

Evolution of population on earth

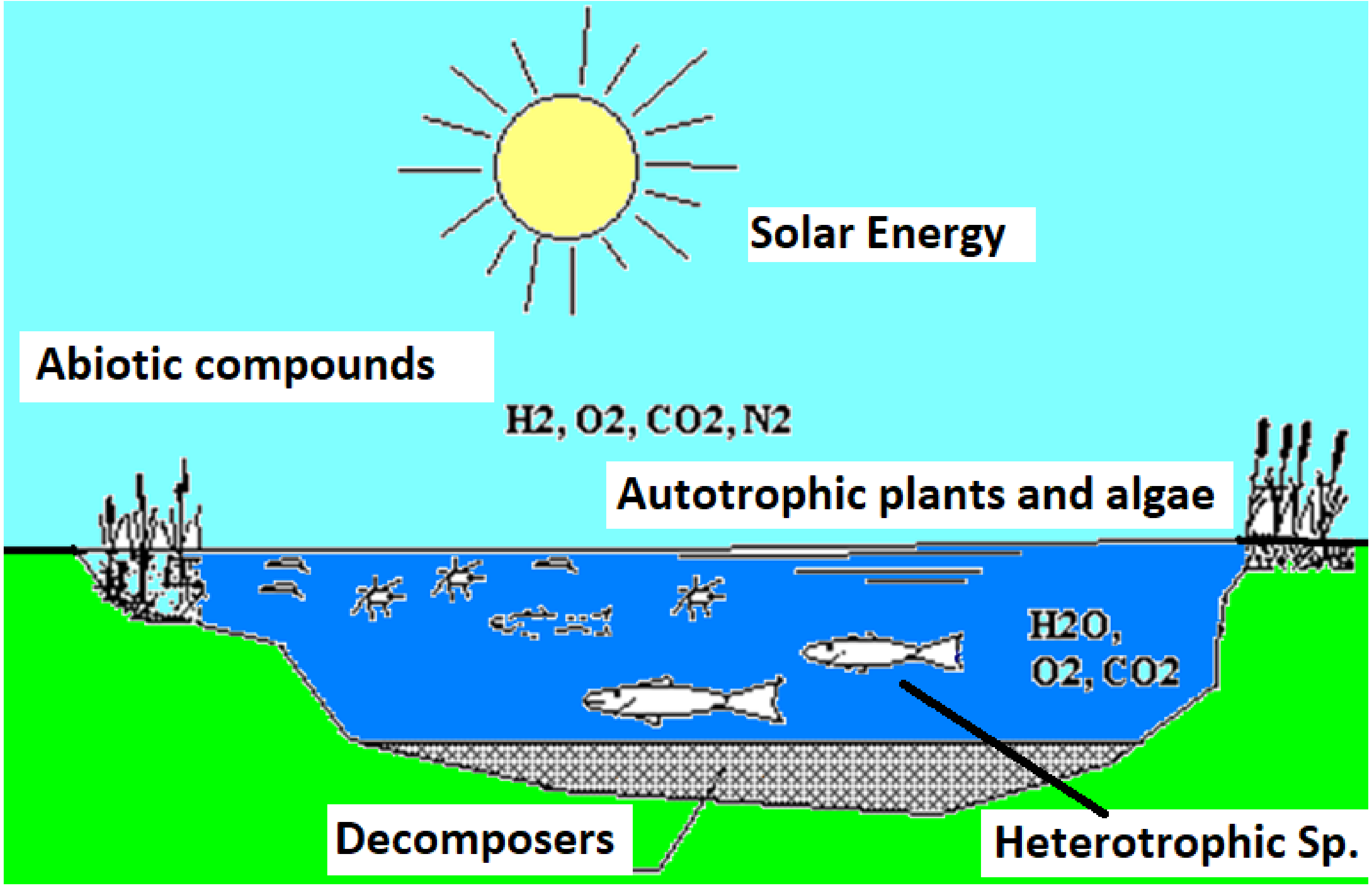
- The evolution of population on land is much more complex than that of a bacterial population in a closed reactor.
- However there are two similar predicted evolution models.

Models of evolution of the world population





Ecologic sistem



Ecologic sistem

- **<u>Abiotic substances</u>**, basic organic and inorganic compounds of the environment;
- **<u>Producers</u>**, **<u>autotrophic organisms</u>**, mostly green plants and algae. They make food from simple inorganic substances;
- **<u>Consumers, heterotrophic organisms</u>** (animals), which ingest other organisms or particles of organic matter;
- **<u>Decomposers</u>**, **<u>heterotrophic organisms</u>**, mostly bacteria and fungi, that break down the complex substances of dead protoplasms, absorb part of decomposed products and release substances that are simple and usable by producers.

classification

- **Primary Biomass**: all the biomass formed by the autotrophic beings (Algae, plants, wastes and forestry).
- **Secondary biomass:** it is produced by heterotrophic (herbivore) beings that feed on the primary biomass (meat of animals and their dejections, etc.)
- **Tertiary biomass:** it is produced by those who feed on the secondary (carnivorous, man, industrial waste etc.)

Role of the diet In The world Balance

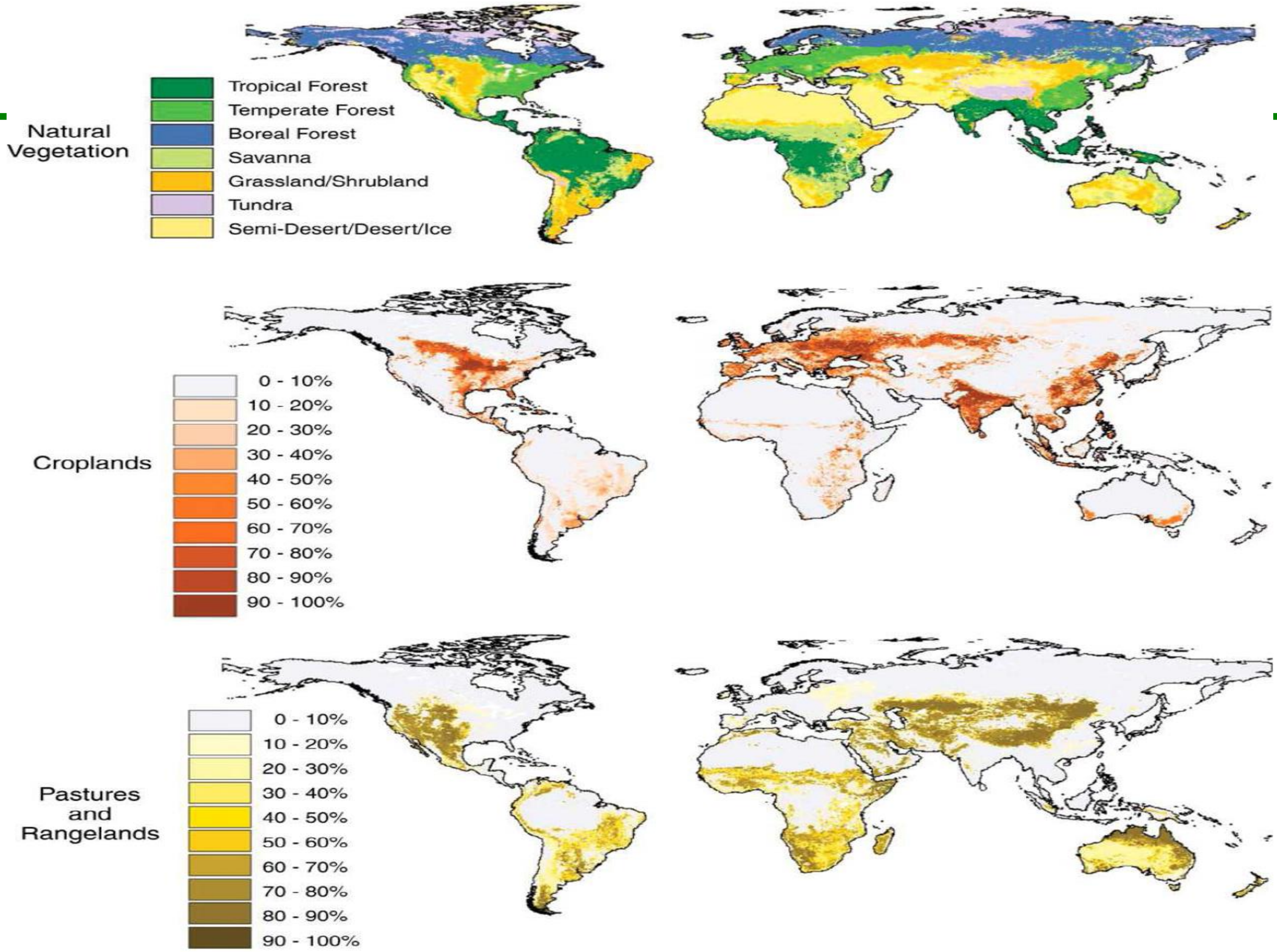
- **Biomass is used for food**
- Man is **HETEROTROPHIC** and need **Biomass for FOOD**
- The diet has a significant role in the energy and food balance of the world. Comparing the global food requirements for three diets, we can see:
- **vegetarian:** 2388 kcal cap-1 day-1; 166 kcal cap-1 day-1 of animal products;
- **moderate**: 2548 kcal cap-1 day -1; 554 kcal cap-1 day-1 of animal products;
- **Strong:** 2746 kcal cap-1 day-1; 1160 kcal cap-1 day-1 of animal products.

Wolf J., Bindraban P.S., Luijten J.C., Vleeshouwers L.M.: Exploratory study on the land area required for global food supply and the potential global production of bioenergy. (2003) "Agricultural Systems", Vol. 76, 841-861.

Food consumption

- For a world population in 1998 of $5.9 \cdot 10^9$ inhabitants) and the estimated population in the year 2050 of $9.37 \cdot 10^9$ hab), the cereals equivalent 10^9 tons dry weight per an. Food consumption results in: *Adaptado de Wolf et al.)*

Type of diet	Diet Vegetarian		Quality Diet (Moderate)		Strong Diet	
Year	1998	2050	1998	2050	1998	2050
Food Needs [10^9tTS ·Year-1]	2,8	4,45	5,17	8,21	9,05	14,36



Worldwide extent of human land-use and land-cover change Published by AAAS: **J. A. Foley et al., Science 309, 570 -574 (2005)**

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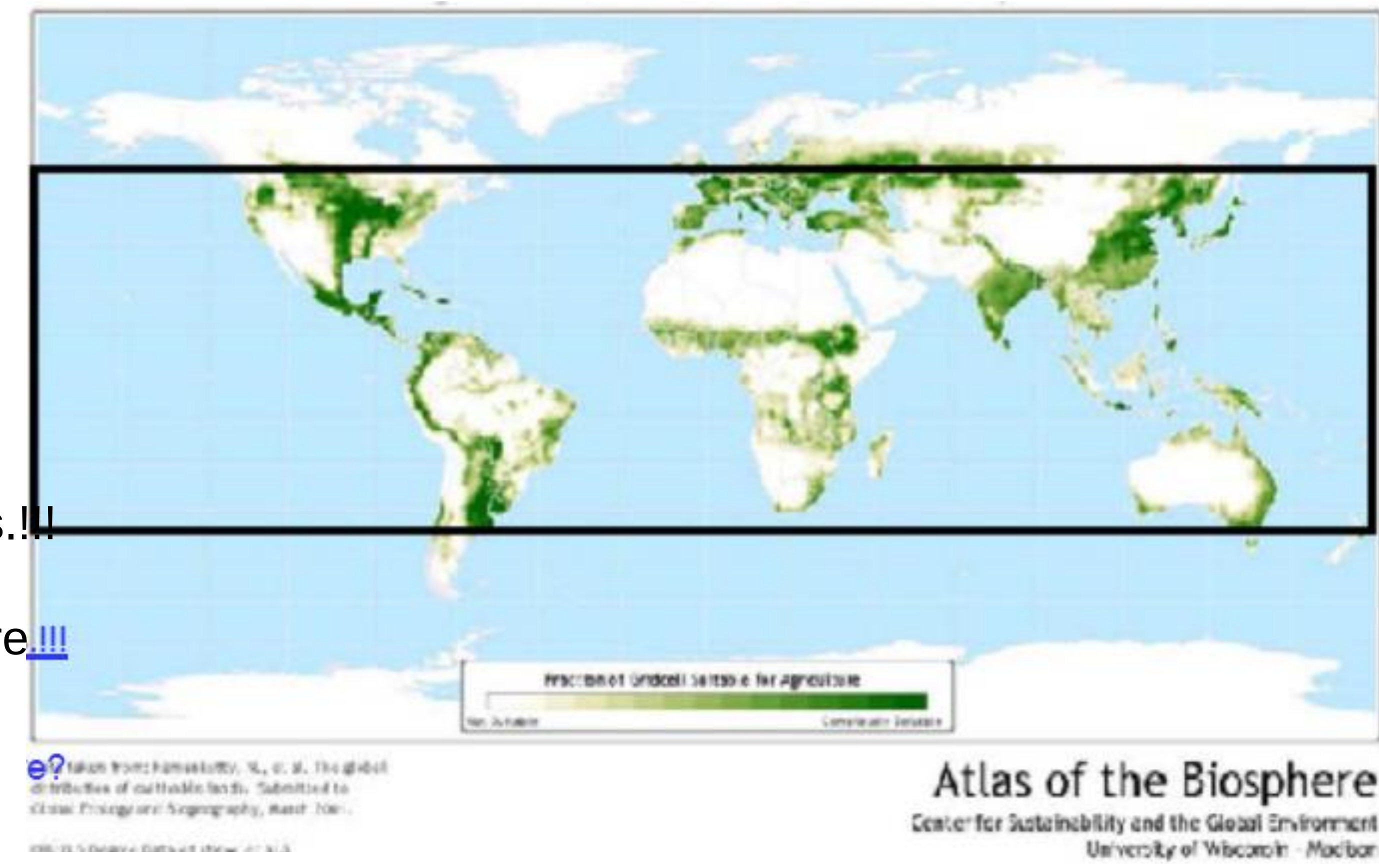
Vast Areas of the Globe Are Not Suitable for High Levels of Terrestrial Agriculture

a. Crop lands
-green area
b. Pasturelands
- partly green areas
c. Rain forests and Forests - no go!!!
d. Deserts areas
algal productions
Solar-biofuels refineries.!!!
e. More actions now -
What are we waiting fore.!!!



But could be used for algal culture.

National Renewable Energy Laboratory

Forecast energy consumption

Toital Forecast energy consume	Estimated value PJ/ano	Source
Total energy need year of 2050	1 000 000	Sanders J.: Biorefinery, the bridge between Agriculture and Chemistry. Workshop: Energy crops & Bioenergy.
Total energy demand year of 2050	1 300 000	Shell's World Energy Scenario

Both the forecast methods shows great energy demand in future. Will be bioenergy able for it ?

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World energy scenarios – Future goals

No.	Bioenergy potentials -terrestrial	Predicted value	Source
1.	Non collected straw (50%)	75 000 PJ/year	Sanders J.: Biorefinery, the bridge between Agriculture and Chemistry. Wageningen University and Researchcenter. Workshop: Energy crops & Bioenergy.
2.	Collected waste processing (50%)	45 000 PJ/year	
3.	Forest/pastures (50%)	150 000 PJ/year	
4.	10% of arable land – World Wide (20tTS/ha)	51 000 PJ/y	Holm-Nielsen J.B., Madsen M., Popiel P.O.: Predicted energy crop potentials for biogas/bioenergy. Worldwide – regions – EU25. AAUE/SDU. Workshop: Energy crops & Bioenergy.
5.	20% of arable land – World Wide (20tTS/ha)	101 000 PJ/y	
6.	30% of arable land – World Wide (20tTS/ha)	152 000 PJ/y	
Sum: 1+2+3+5		371 000 PJ/year	

the potential of collected straw, forest/pasture and a portion of arable land is much less than consume.

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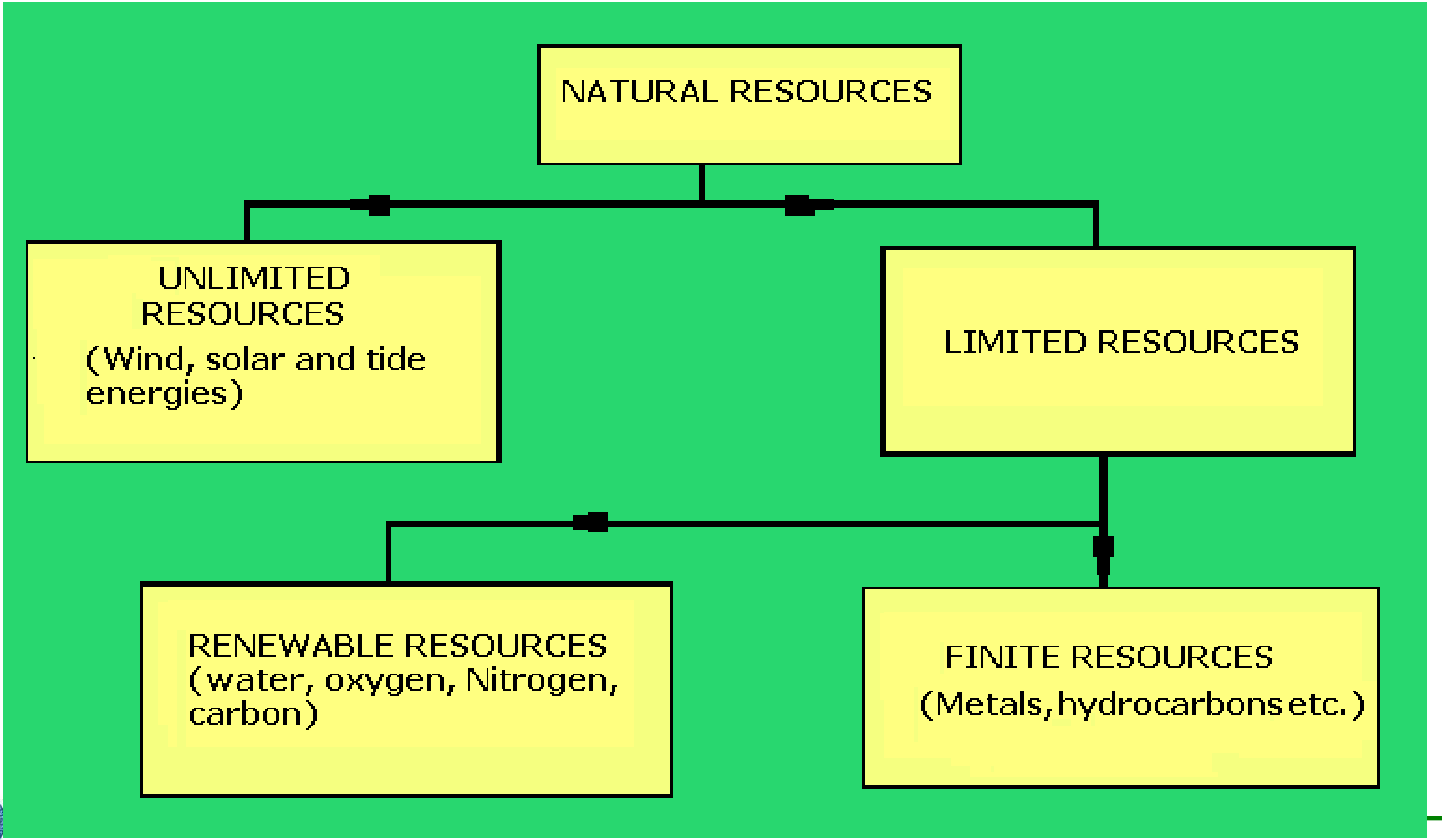
Natural resources - Classification

- Some resources (water, carbon, nitrogen, oxygen etc. are **naturally renovated by the ecological system** (by cycles). Pollution is affecting the capacity of natural cycles.
- Other resources are finite and will disappear.
- Sustainable growth occurs when the velocity of using the resources (finite and renewable) is lower or equal to the velocity of production or regeneration of the same resources.
- Recycling is a way to reduce the use of natural resources being an important tool for sustainability.

Resources evaluation



Hydrologic and Oxygen Cycles

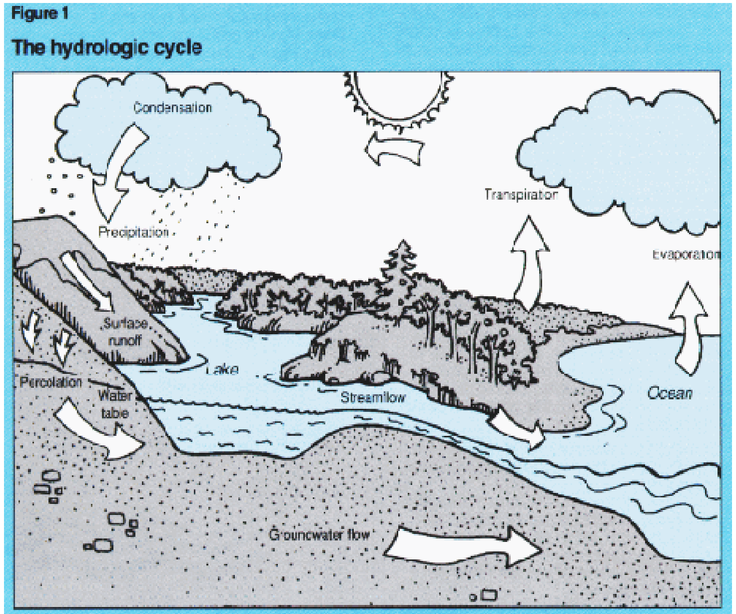
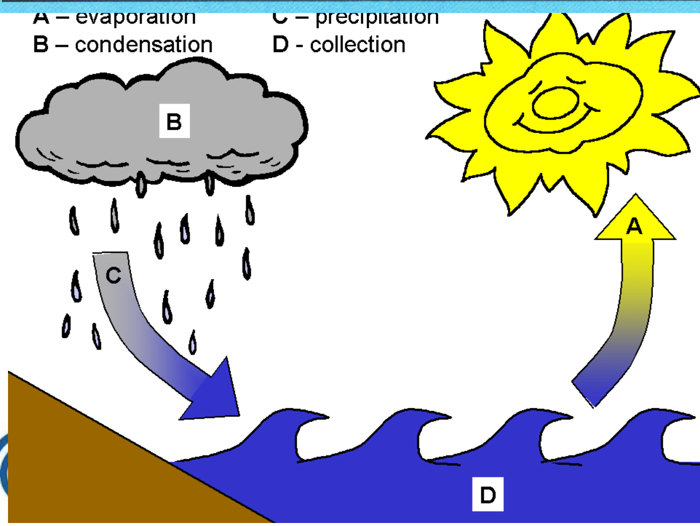
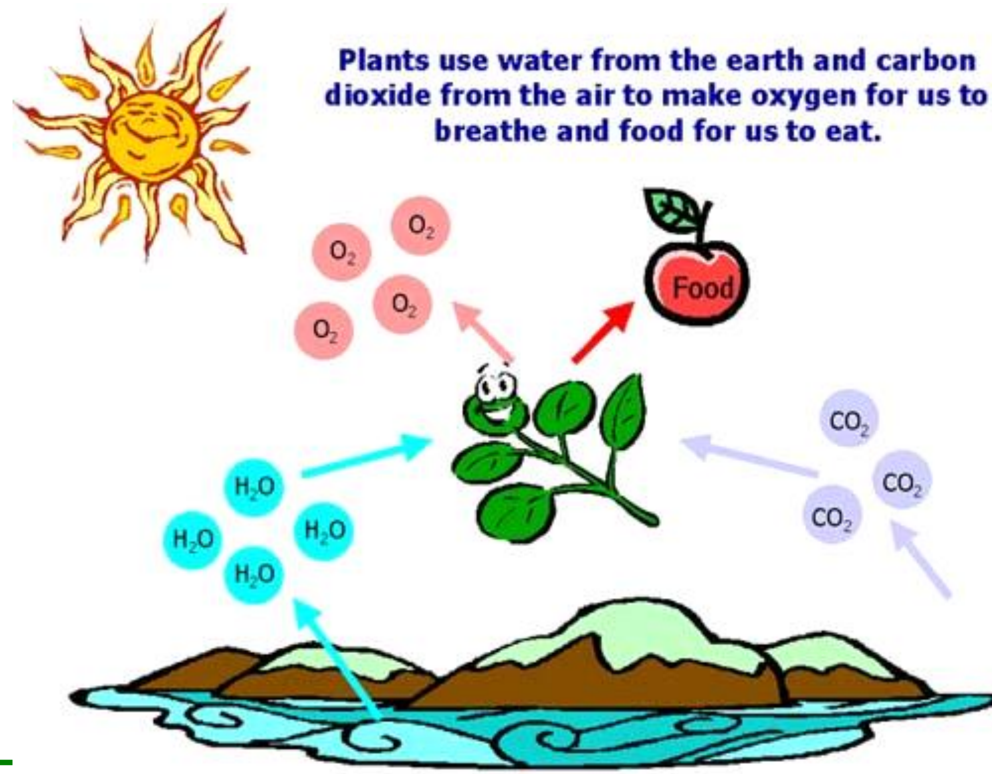


Figure 1
The hydrologic cycle

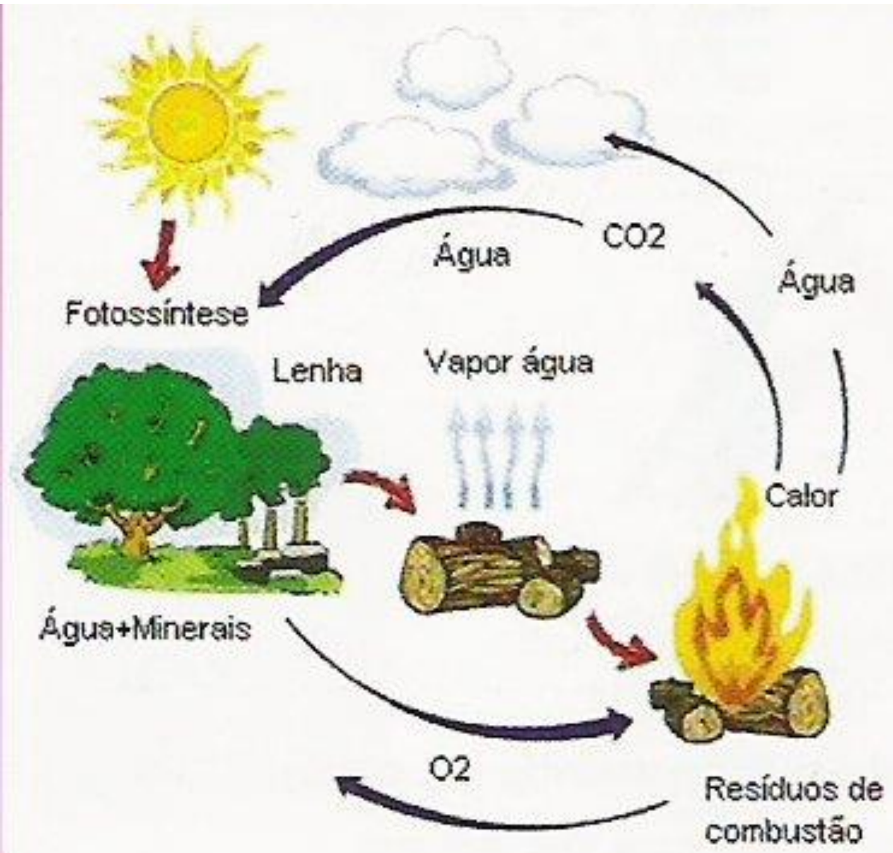


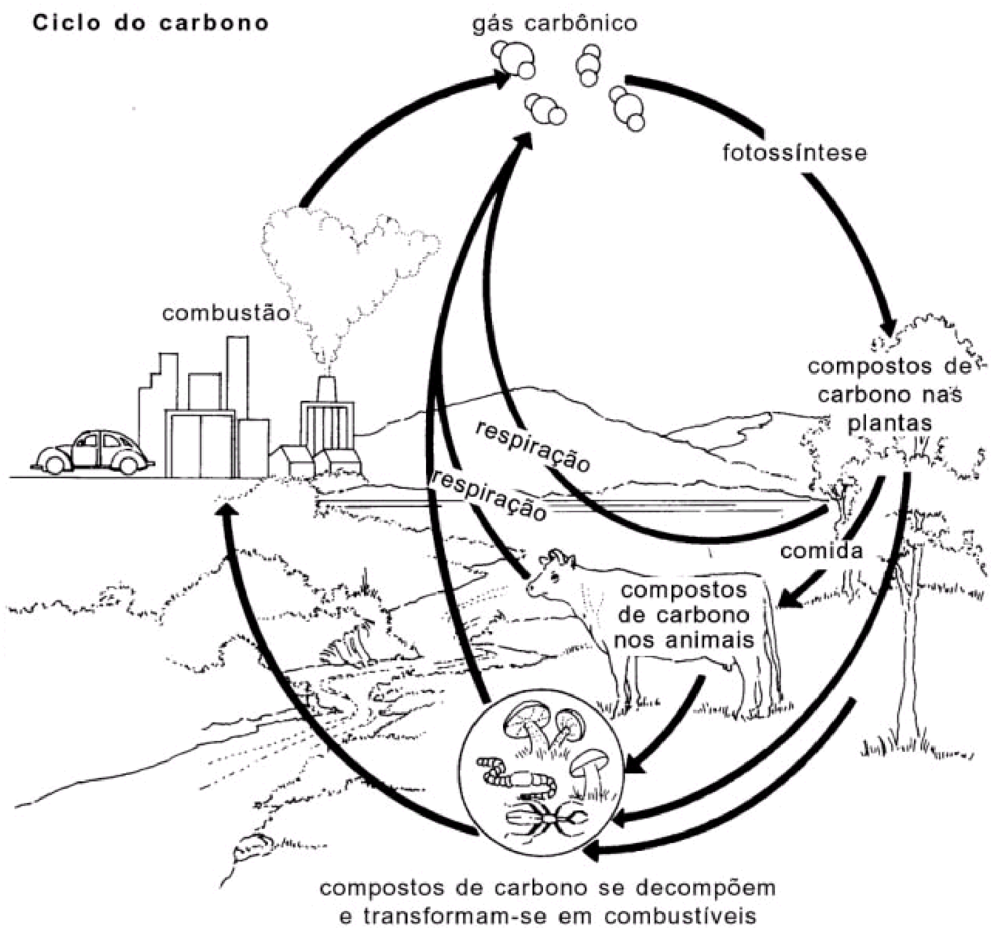
The Cycles renovate the Water and oxygen



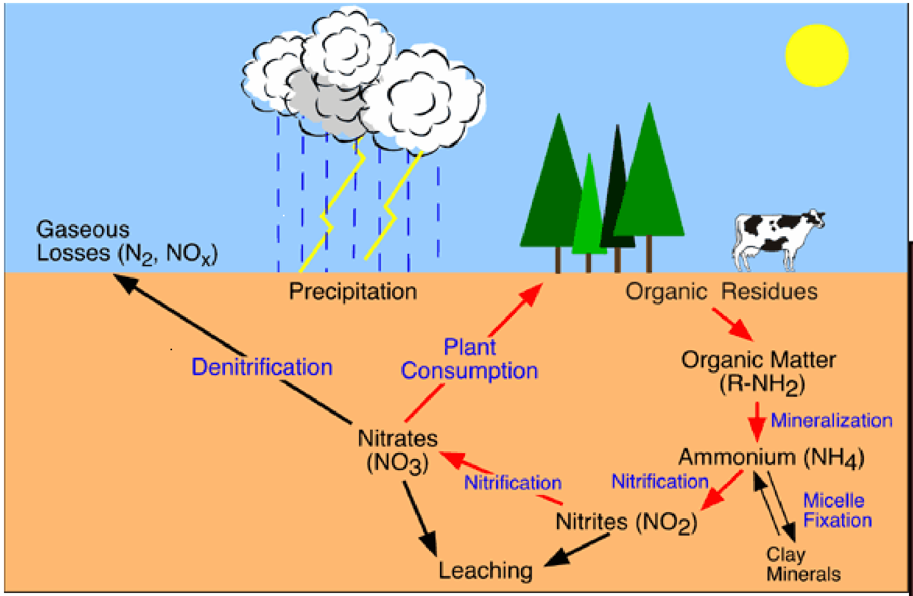
Carbon Cycle

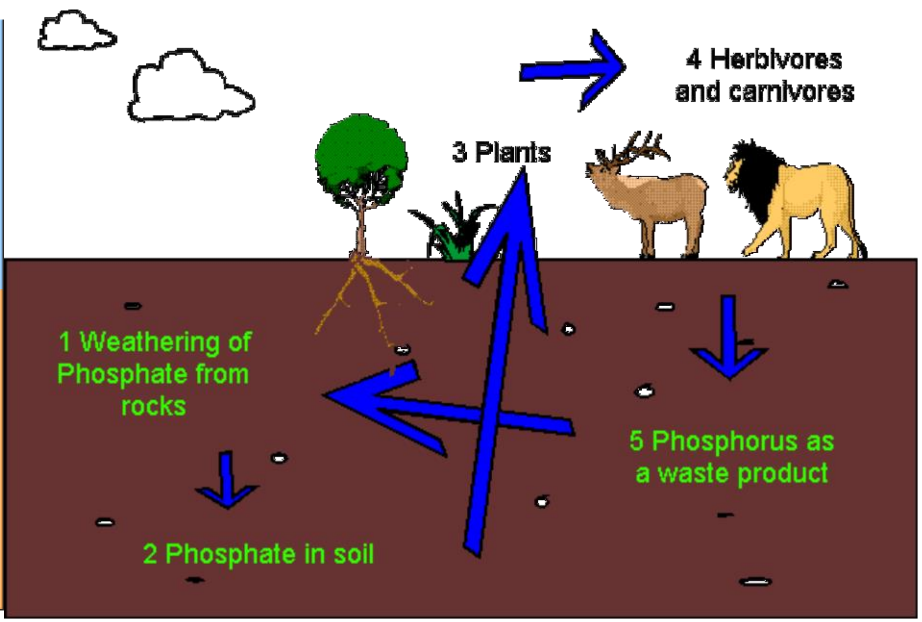
Nature Eliminates CO_2





Nitrogen and Phophorus Cycles





Dynamic concept

- Sustainability depends on the **rate of consumption of renewable resources**.
- sustainable growth occurs when the natural renewable resources are used **slower** than it can be naturally renovated, **by the cycles**.
- This avoids long term environmental degradation, allowing capability to sustain human life.

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
- **<u>But these wastes can be a resourse</u>**

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.

The Environmental problem

- The historical model of the development of present rich societies was based on:
- technologies that were concerned with increasing production, to the detriment of environmental protection, strong and negative pressure on the environment.
- The environmental factor only emerged as a concern of society when symptoms of degradation of natural resources became evident.
- Environmental damage is caused by the industrial processes involved in resource extraction and pollution induced in the transformation process.
- All resources exploited and generated in an economic system end sooner or later in the form of emissions and waste.
- All productive processes involve the use of resources, and determine unavoidable implications on nature, which has limited self-regenerating abilities.

Sustainable Growth

- It essentially involves shifting our economies and societies to a new development model in which the various components are fully integrated into evolutionary processes, rather than being treated separately and sequentially.
- Sustainable development is in direct correlation with the availability of renewable resources and limited resources, with balanced growth, when the speed of resource utilization is less than or equal to the speed of regeneration or production of these resources.
- Current use of resources, especially the most critical and scarce resources, is thus the main factor in environmental damage and its reduction is the key to achieving effective environmental protection and preserving stocks for future generations.
- The concept of sustainable growth was promoted during the "Eart Summit", which took place from June 3 to 14, 1992 in Rio de Janeiro.

Brundtland Commission on Environment and Development

Coined and defined in 1987 by the **Norwegian Prime Minister Gro Harlem Brundtland** the meaning of the term "Sustainable Development" as: Strategies and actions that have the objective that meets the needs and aspirations of the present **without compromising** the ability of future generations to meet their own needs" (United Nations, 1987).

Sustainability Model

- Sustainability concerns the entire evolution of life on earth and is the confluence of three main constituent elements:

Economy	Environment	Society

- “Sustainability is a path of continuous improvement, wherein the products and services required by the society are delivered with progressively less negative impact upon Earth” (as defined by AIChE Institute for Sustainability in 1995) (Schuster D., 2010).

Sustainability in practice

- The ‘sustainability’ concept and its associated forms are today widely embedded in all the fields of human activities: processing industry, energy, environmental field, city planning, including wastewater and waste management.
- The goal is the promotion of new green society

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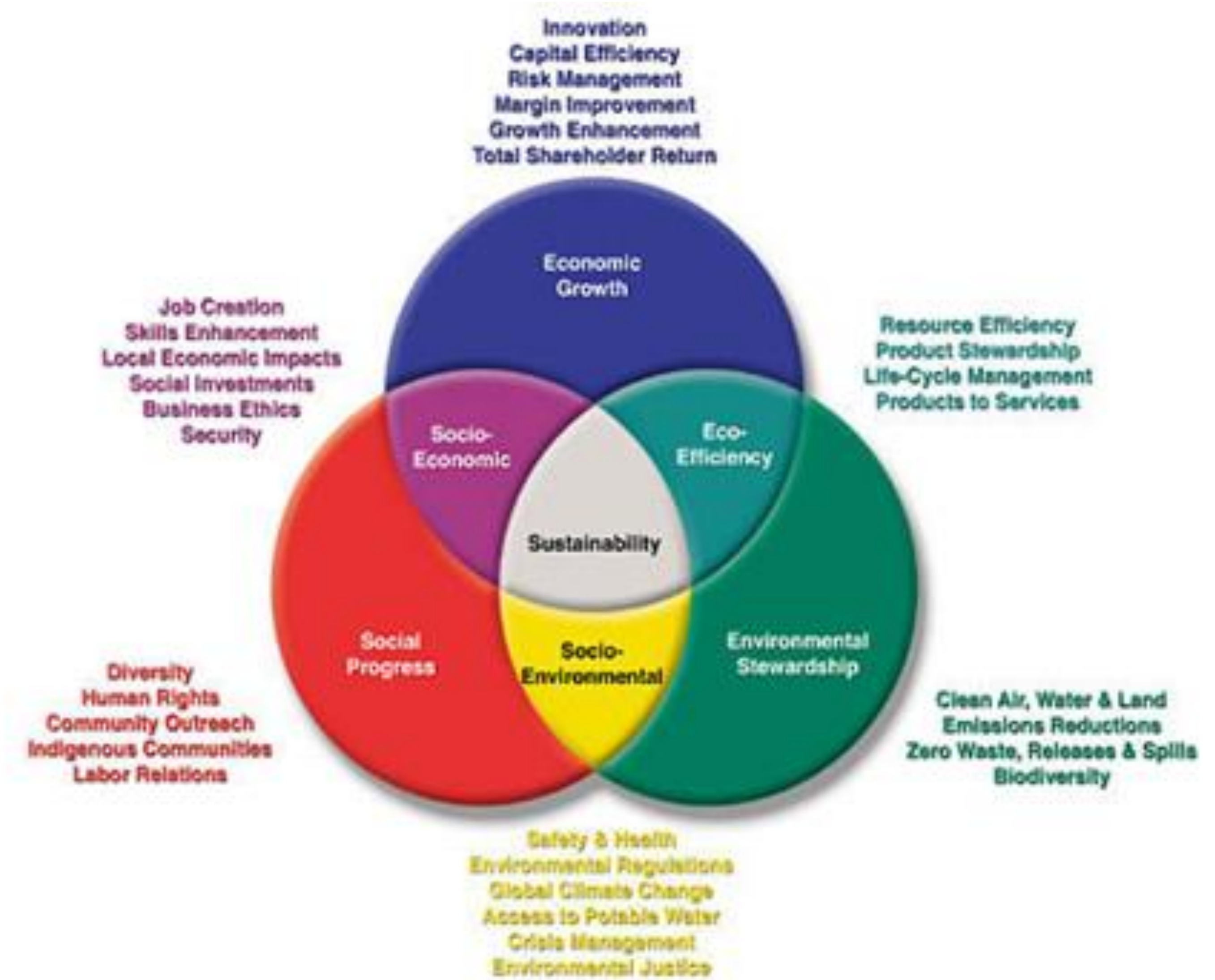
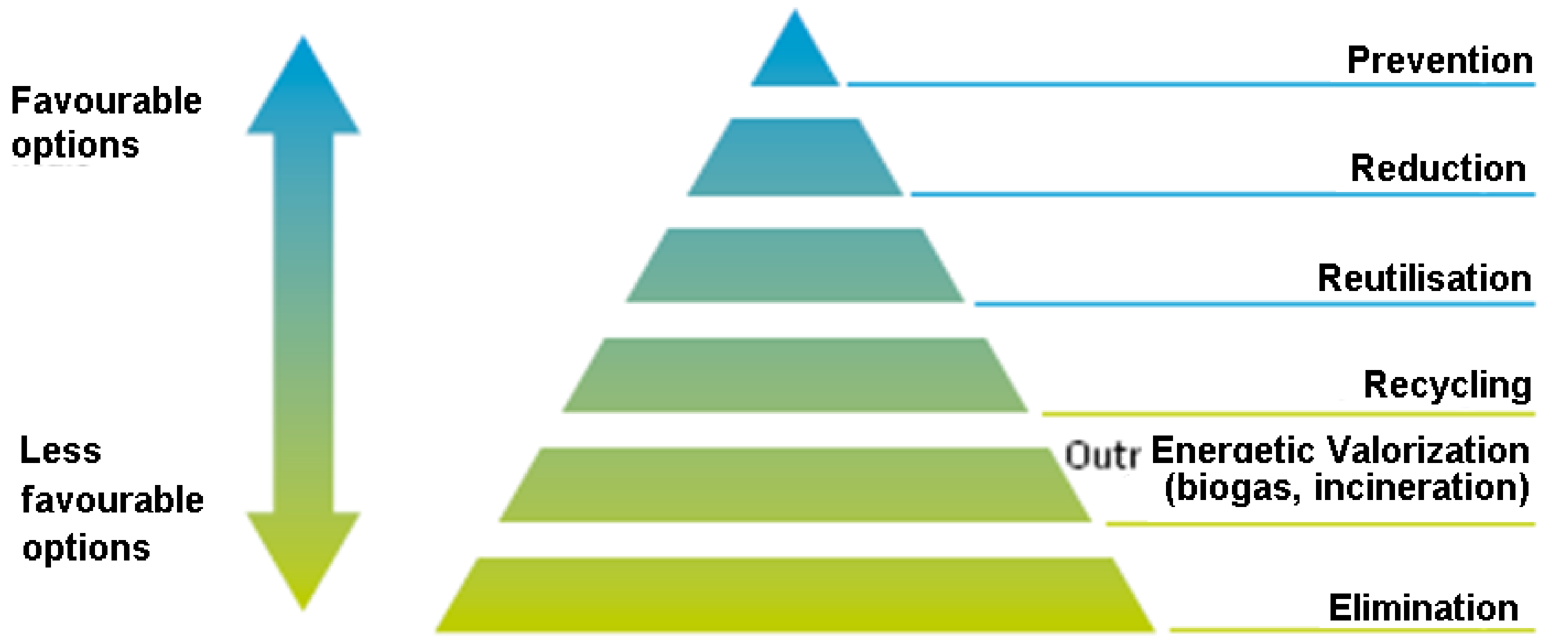
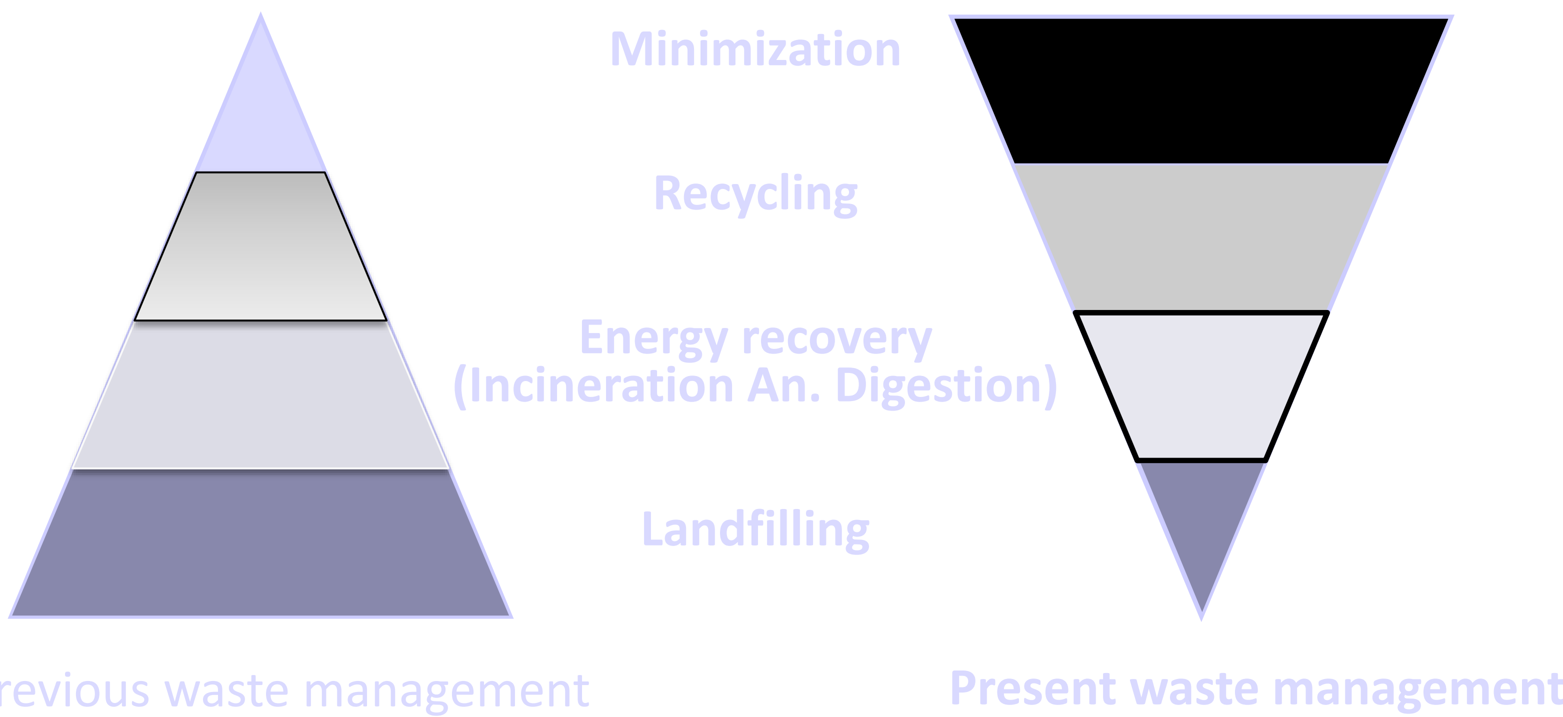
Sustainability Model (from Shuster 2012)



Hierarquie of options in Solid Waste management



The waste management priority list



Evolution of Environmental Awareness

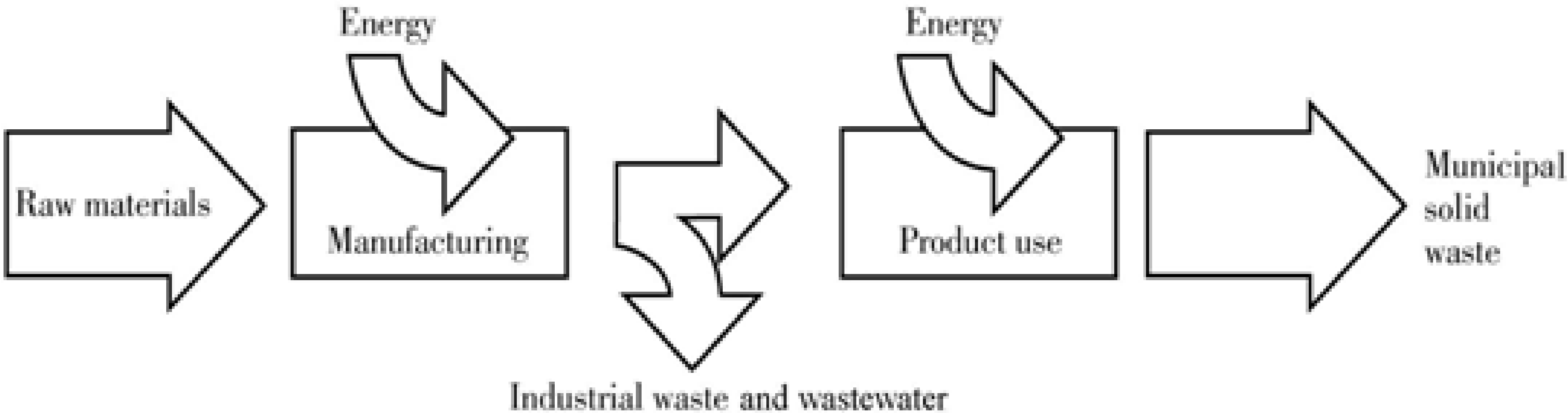
(Adapted from Weatherley, 2013)

Decade	Industry technologic approach - Environmental Awareness
Pre-1980	End of pipe solutions, Cleaning of Waste Gas, Waste Water and Contaminated Soil. Dispersion Compliance Avoidance of Prosecution Minimum Expenditure Operation at the legal boundaries.
1980's and 1990's	Awareness extends beyond Pollution Prevention by treatment. Public concerns at climate change and resource depletion. Rebalancing of views on economic growth. Significant environmental impacts recognised. Emergence of stronger legislative frameworks – Emergence of business and "green" ethics. Emergence of biotechnology.
2000	Production Integrated Clean Technology, Emission Reduction in Energy and Process Technology
2010	Sustainable Production, Resources, Efficient Production, Utilization of Products, Recovery

Technologies for sustainability - At manufacturing level

- The idea of **industrial ecology** was proposed by Davitaya, in 1977, who stated an analogy relating industrial systems to natural systems: "**Nature operates without any waste products. What is rejected by some organisms provides food for others**;
- The organization of industry on this principle-with the waste products of some branches of industry providing raw material for others-means in effect using natural processes as a model, for in them the resolution of all arising contradictions is the motive force of progress" (Grdzelishvili and Sathre, 2006).

Conventional Linear Perspective of Materials Flow (Thomas and Callan (2007)

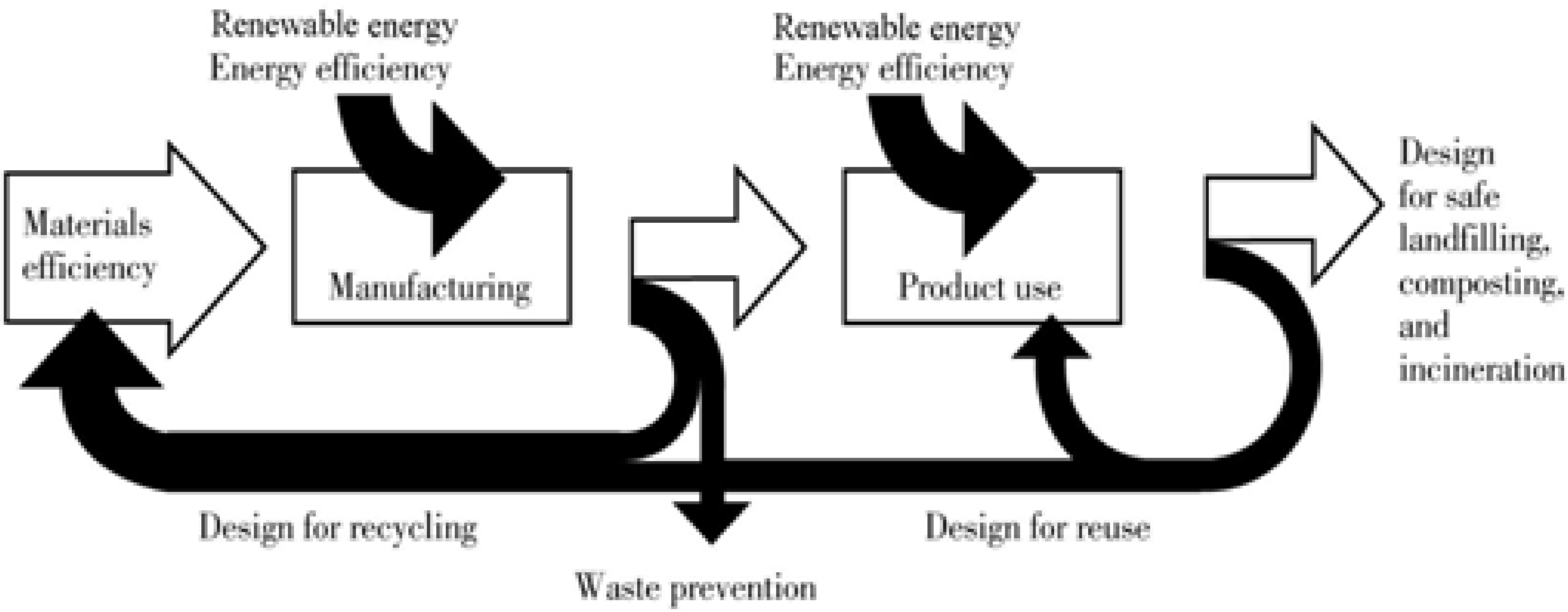


The conventional flow industrial process is modified to Cyclical or Closed Materials Flow: Cradle to Cradle, which assumes that materials run in a circular pattern in a closed system, allowing residuals to be returned to the production process.

Closed System of Materials Flow

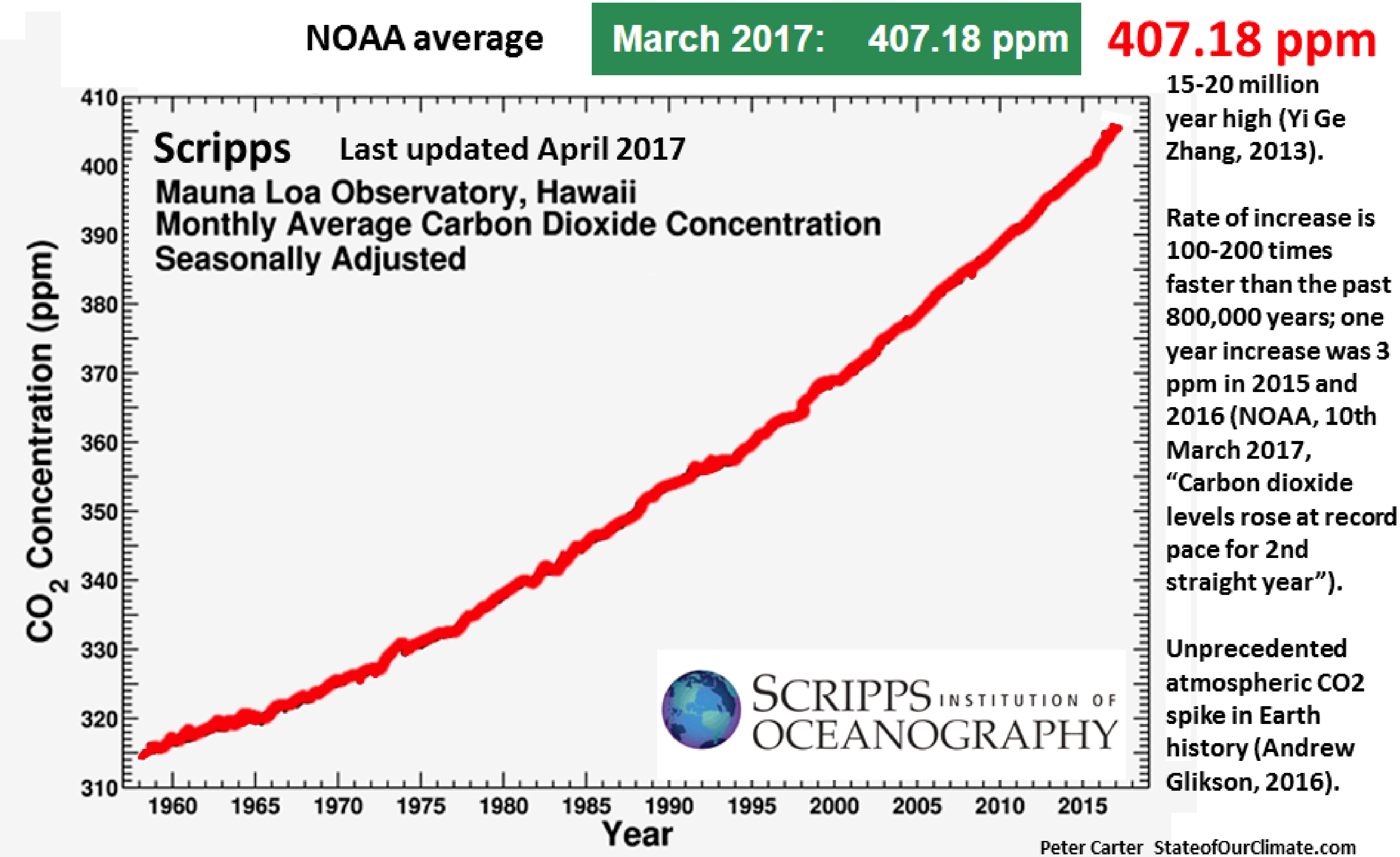
(Thomas and Callan (2007)

Industrial Ecosystems represent a closed system of manufacturing, whereby the wastes of one process are reused as inputs in another.



CO_2 Atmospheric is growing-fossil fuel use

Accelerating Atmospheric CO2 Concentration April 2017



15-20 million year high (Yi Ge Zhang, 2013).

Rate of increase is 100-200 times faster than the past 800,000 years; one year increase was 3 ppm in 2015 and 2016 (NOAA, 10th March 2017, “Carbon dioxide levels rose at record pace for 2nd straight year”).

Unprecedented atmospheric CO2 spike in Earth history (Andrew Glikson, 2016).

Peter Carter StateofOurClimate.com

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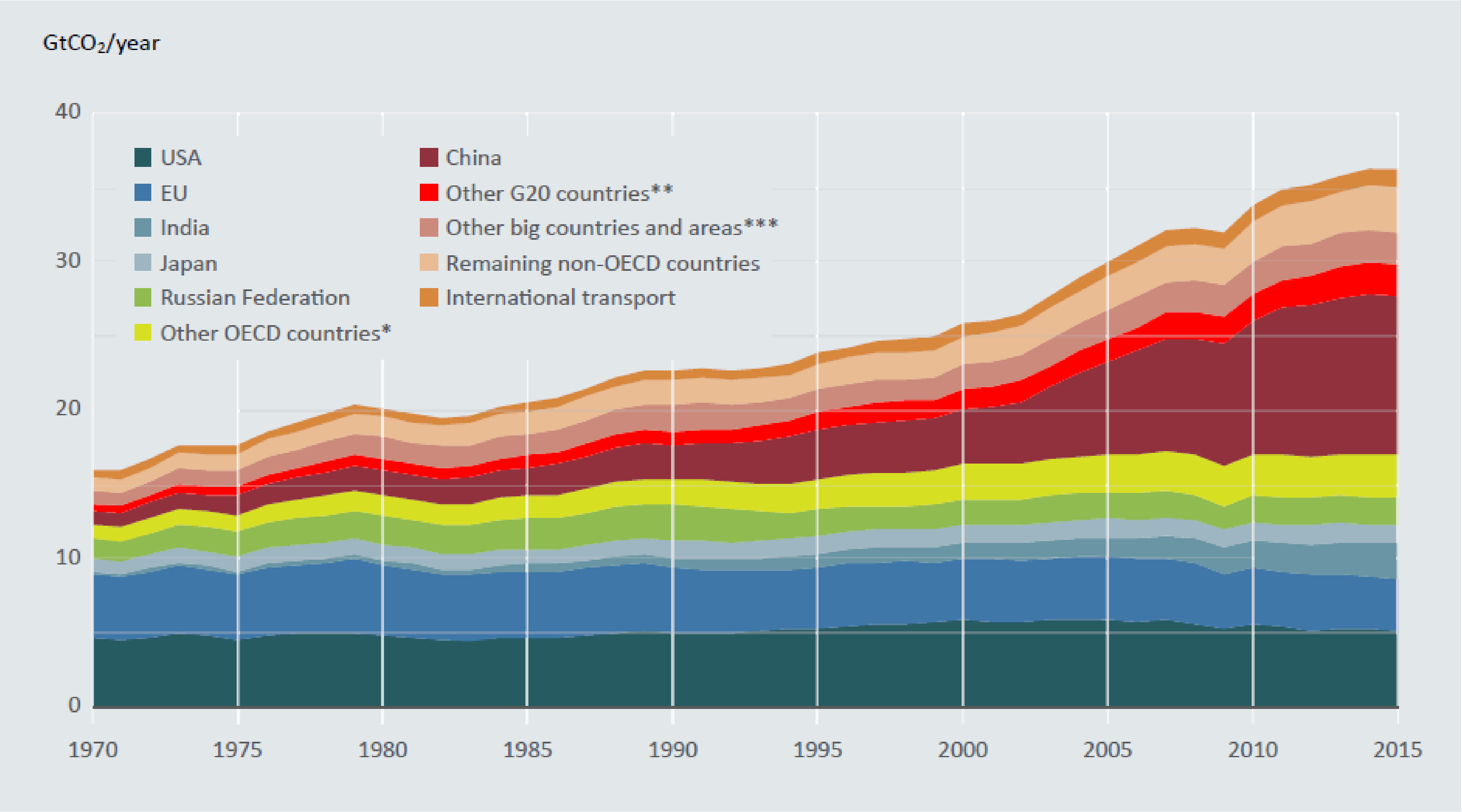
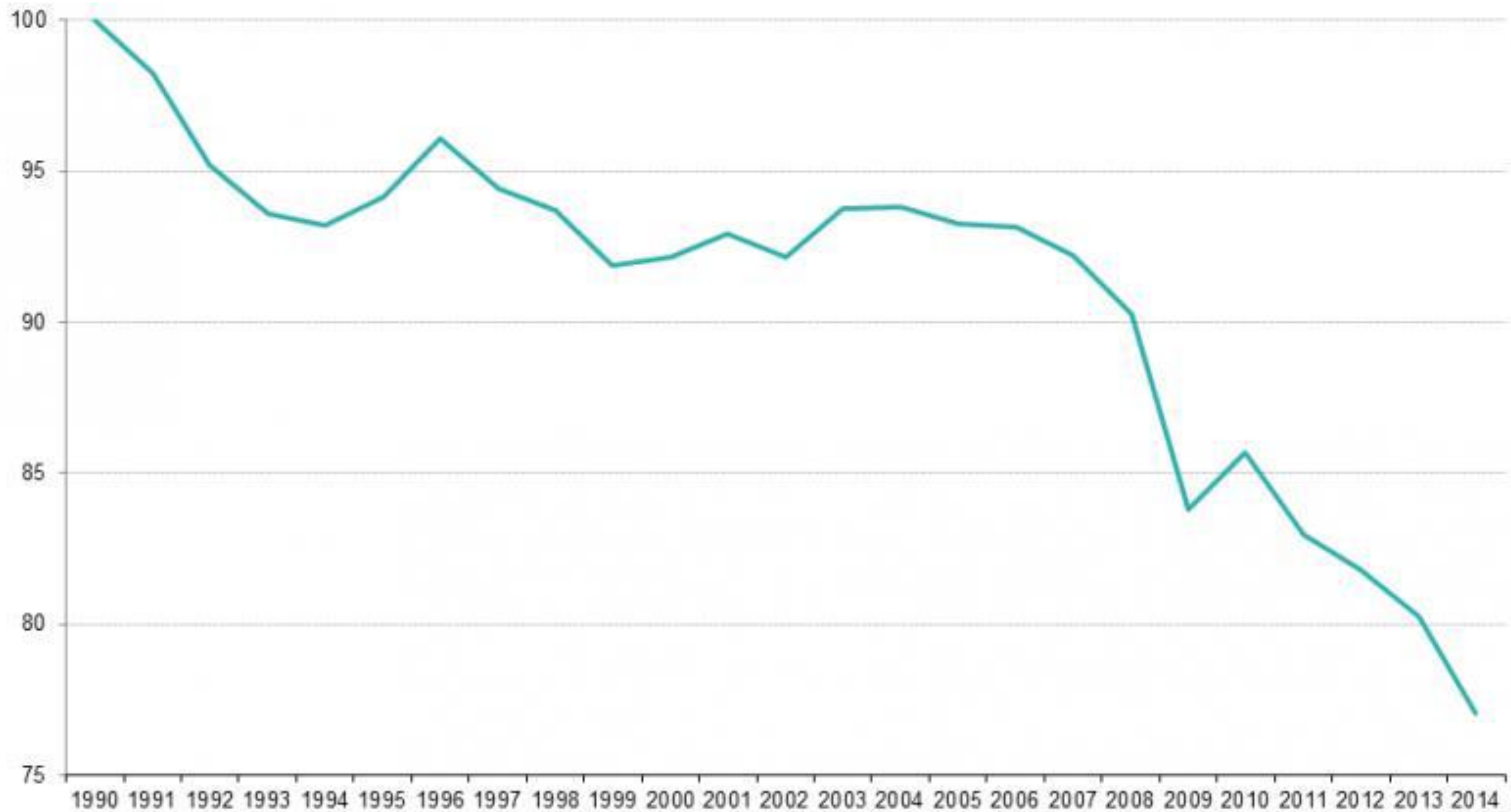
CO2 Emissions in atmosphere

Figure ES1: Carbon dioxide emissions from fossil-fuel use and industry.



* Other OECD countries include Australia; Canada; Mexico; Republic of Korea and Turkey.
** Other G20 countries include Argentina; Brazil; Indonesia; Saudi Arabia; South Africa and Turkey.
*** Other big countries and areas include Egypt; Iran; Kazakhstan; Malaysia; Nigeria; Taiwan, Province of China; Thailand and Ukraine.

In EU emissions are decreasing



What is really meant by CO2-neutral?

- As carbon dioxide is often fixed in plants for years or even decades, they are referred and as CO2 sinks. They play an important role in the earth's climatic balance.
- Fossil raw materials are CO2 sinks too, albeit ones that have existed for millions of years.
- When raw materials containing carbon are used for energy purposes, they combine
- with oxygen and produce carbon dioxide which is considered to be one of the main causes of the greenhouse effect.
- However this is also the case when plants are not used and rot.
- Whereas in nature growth and decomposition are in balance, the concentration of CO2 in the atmosphere is constant and the CO2 cycle is closed, fossil raw materials are no longer bound into this cycle.
- When they are used for energy production, the CO2 concentration in the atmosphere rises and the greenhouse effect is exacerbated.

Climate Strategies and Targets

KYOTO PROTOCOLL

1° Commitment Period (2008 - 2012)

5% cut in GHG compared to 1990 levels

Target for the EU countries under «burden-sharing»	
EU	**-8%**
Portugal	+27%
Italy	-6,5%
Germany	-21%

2° Commitment Period (2013 – 2020): *"Doha Amendment to the Kyoto Protocol"*

18% cut in GHG compared to 1990 levels

Europe strategies

«EUROPE 2020 STRATEGY» (2010)

Employment, Innovation, Education, Poverty Reduction and **Climate/Energy**

2020 climate & energy package

- 20% cut in **greenhouse gas** emissions (from 1990 levels)
- 20% of EU energy from **renewables**
- 20% improvement in **energy efficiency**

Portugal: Country Report: European Semester 2016, European Commision		
GHG	1% cut in 2020 compared to 2005	it is expected that the target will be achieved: -25% in 2020
RENEWABLES	+31%	on track to reach its 31% target in 2020
ENERGY EFFICIENCY	25% reduction of final energy consumption in 2020	on track to reach its 2020 energy efficiency target.

2050 Low carbon Economy

2050 Low-Carbon Economy

PARIS AGREEMENT (2015): Efforts to limit the temperature increase to 1.5°C above pre-industrial levels, below the 2°C strarting point.

EU was the first major economy to submit its intended contribution to the new agreement in March 2015.

ENERGY ROADMAP 2050 suggests that:

By 2050, the EU should cut greenhouse gas emissions to **80%** below 1990 levels

Milestones to achieve this:

1. 40% EMISSION CUTS BY 2030 (*Framework for Climate and Energy*)
2. 60% EMISSION CUTS BY 2040

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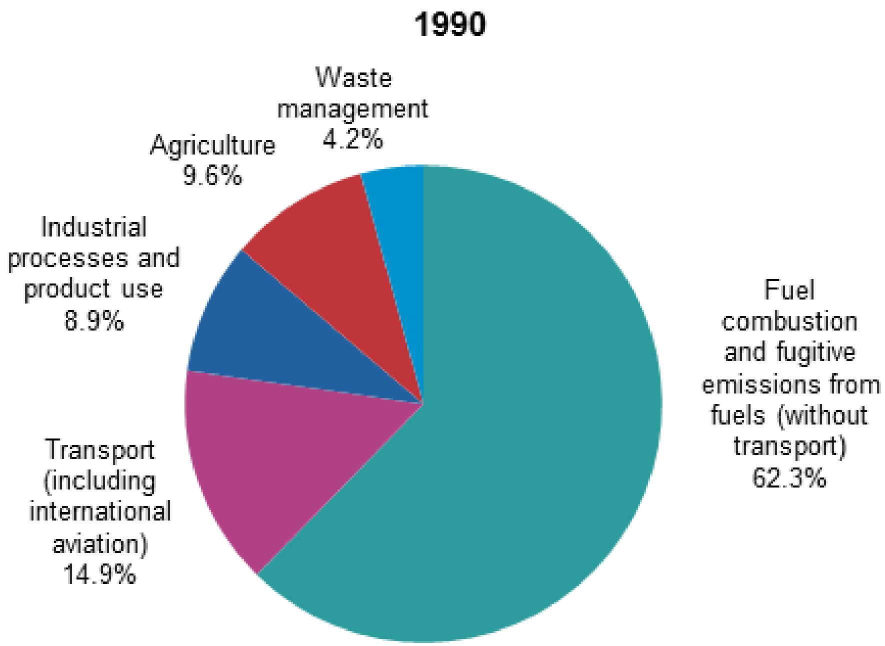
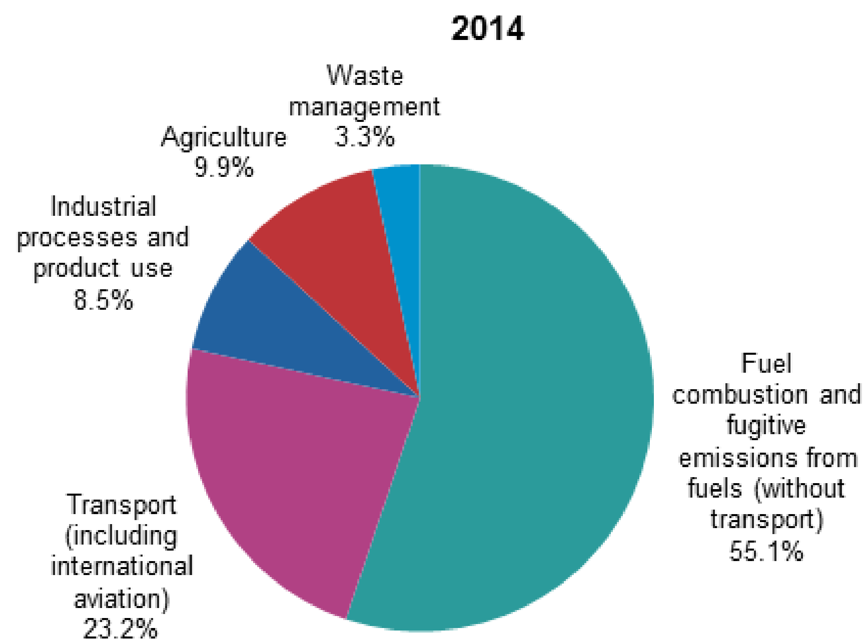
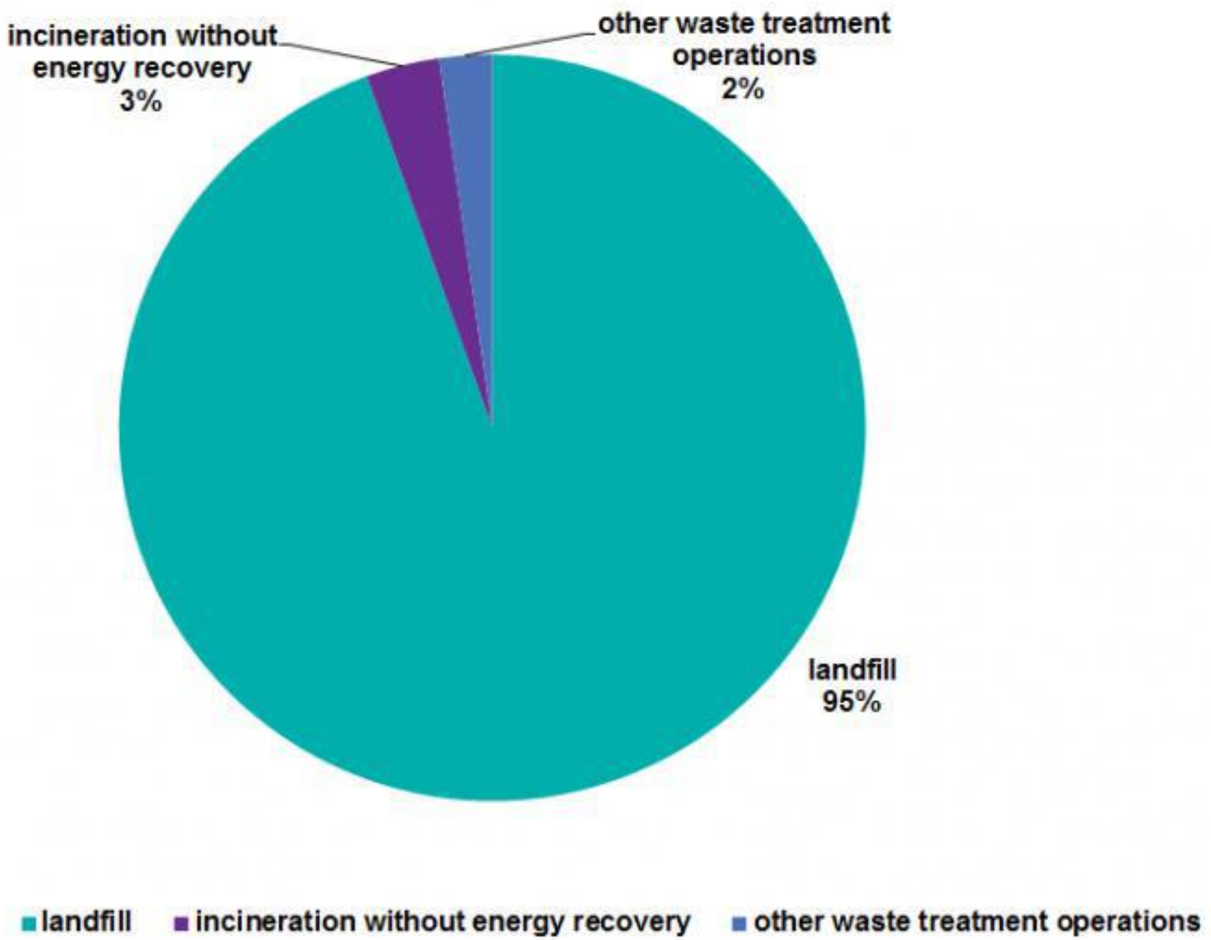
Wastes are not the main source of EU emissions





Greenhouse gas emissions from Waste Management



Estimated share of three waste disposal operations in GHG emissions (2011)- Source: EEA Greenhouse gas data viewer, March 2014

Waste sector-emissions

- waste sector reduce GHG emissions through 2 main activities:
- 1. Avoiding the use of primary materials for manufacturing through waste avoidance
- and material recovery (i.e. the GHG emissions associated with the use of primary materials –energy-related – are avoided)
- 2. Producing energy that substitutes or replaces energy derived from fossil fuels (i.e. the emissions arising from the use of waste as a source of energy are generally lower than those produced from fossil fuels).
- Depending on which GHG accounting convention is used, the waste sector is capable of generating a net GHG benefit through waste avoidance, material recovery, and energy recovery.

Manufacture of synthetic fertilisers:GHGs released

- **1. 413** kg CO_2 per kg synthetic N,
- 0.5-3 kg CO_2 per kg synthetic P,
- 0.4-1.5 kg CO_2 per kg synthetic K (ROU 2006, Boldrin 2009).
- Substitution of fertiliser with composted waste applied to land saves around **8 kg CO2-e per ton**.
- The net climate impact of both open and enclosed composting systems in Europe are savings of **around 35 kg CO2-e per tonne** of wet organic waste input (Smith et al 2001, Boldrin et al 2009), taking into consideration fertiliser and peat substitution, and carbon storage in soil.

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The future is in our hand

BIOGAS be a tool to

-Economic GlobalCrises

- Climate change

- Local Energy supply

-Sustainable agriculture

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