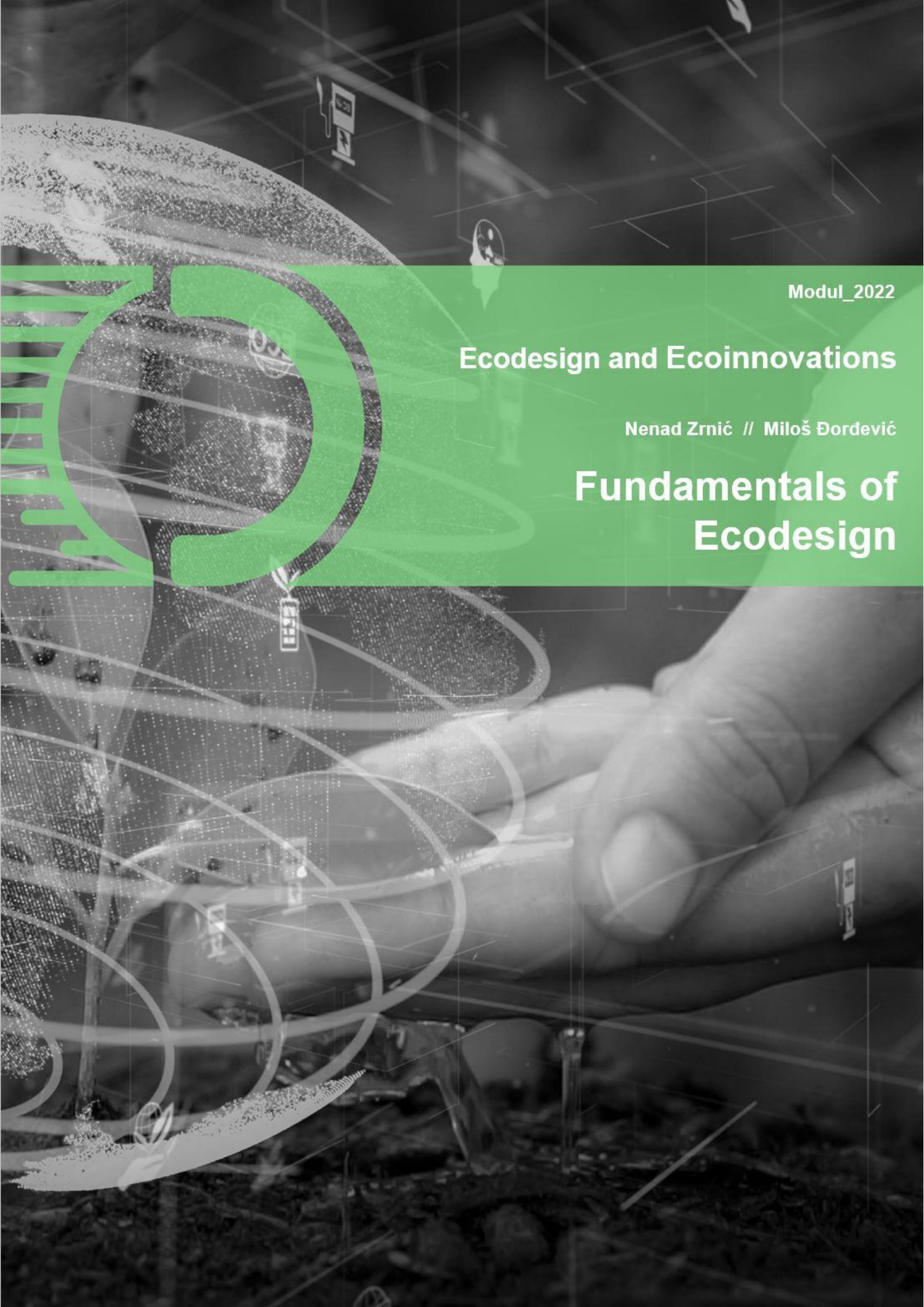


Modul_2022

## Ecodesign and Ecoinnovations

Nenad Zrnić // Miloš Đorđević

# Fundamentals of Ecodesign

Modul_2022.

# Ecodesign and Ecoinnovations

Nenad ZRNIĆ, Miloš ĐORĐEVIĆ

# Fundamentals of Ecodesign

DRIVEN

# TABLE OF CONTENTS

## REASONS FOR INTRODUCING ECODESIGN

Before anything is said about ECODESIGN, the basic questions that arise might look like this:

_What is ECODESIGN?
_Why do we use it?
_Is ECODESIGN necessary?
_What are environmental impacts?
_What is the product life cycle?
_What is an LCA study?
_Design (development) of an Eco or sustainable product?

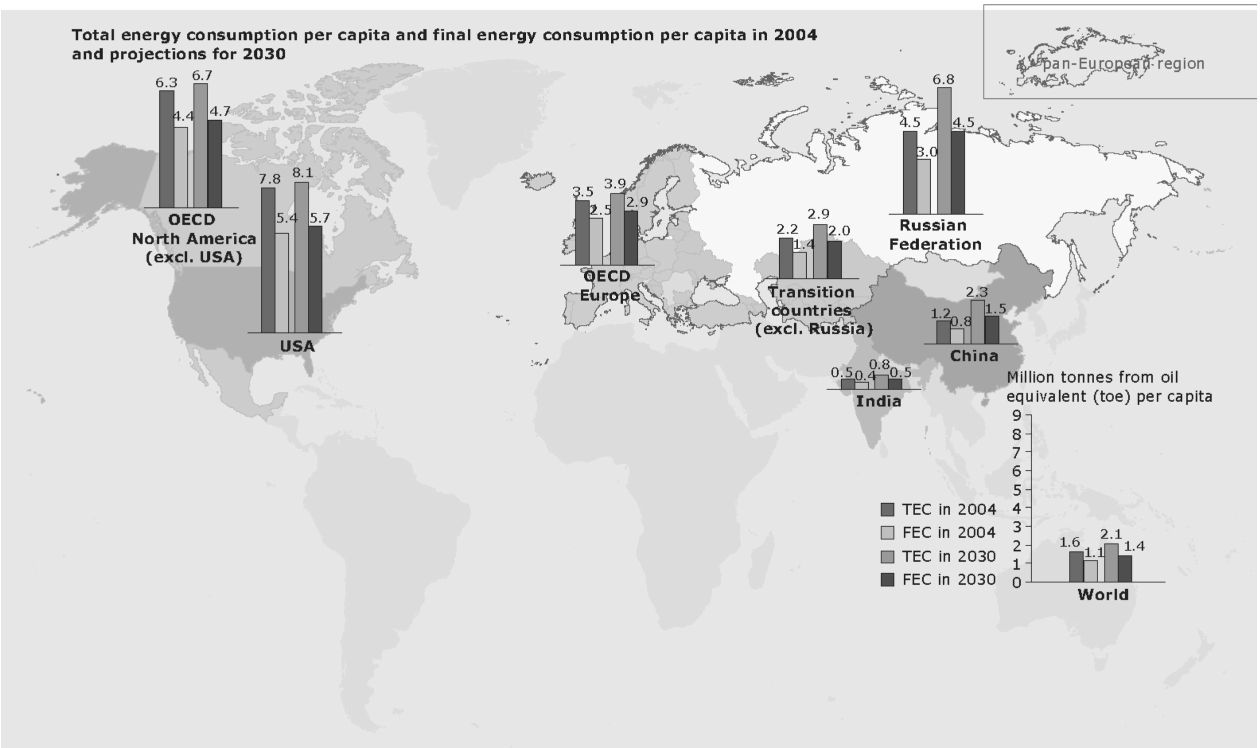
### WHY THE ECODESIGN?

The answer to that question might be:

_20% of the world's population uses 80% of the world's resources,
_resources are available only in limited quantities (energy, raw materials…),
_ECODESIGN helps to reduce the consumption of resources for obtaining products,
_all stages of the product life cycle are considered,
_shifting of the environmental impact from one stage of the life cycle to another is avoided,
_the Earth has become overpopulated, and the demand for energy is increasing.

The average household in the European Union (EU) consumes about 6,000 kWh of electricity per year. The projections for the EU for 2030 are as follows:

_demand for fossil fuels will be higher than ever,
_The EU will be forced to rely more on imports of fossil fuels,
_only 5% of the EU oil needs will be met from domestic sources (oil wells),
_the role of renewable energy will continue to be minor,
_emissions of carbon dioxide ($CO_2$) will continue to rise.




*1. Figure_Total and final energy consumption [Mtoe][1] per capita for 2004 and projections for 2030*
*[Source: World Energy Outlook 2006 OECD[2]/IEA[3] (2006); EEA[4]].*

PRIMARY ENERGY is energy contained in natural resources (e.g. coal, crude oil, sunlight, uranium) and which has not undergone any anthropogenic conversion or transformation [IPCC[5]].

FINAL ENERGY is energy available to the final user (consumer) that is transformed into useful energy (e.g. electricity from a wall outlet) [IPCC].

TOTAL ENERGY is primary energy with the addition of the amount of energy consumed in the electricity generation sector to meet its own energy needs, which is divided into end-user sectors (industrial, commercial and residential sectors) [DOE, Indicators of Energy Intensity in the US - http://intensityindicators.pnl.gov/terms_definitions.stm#economy].

OECD EUROPE**:** Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

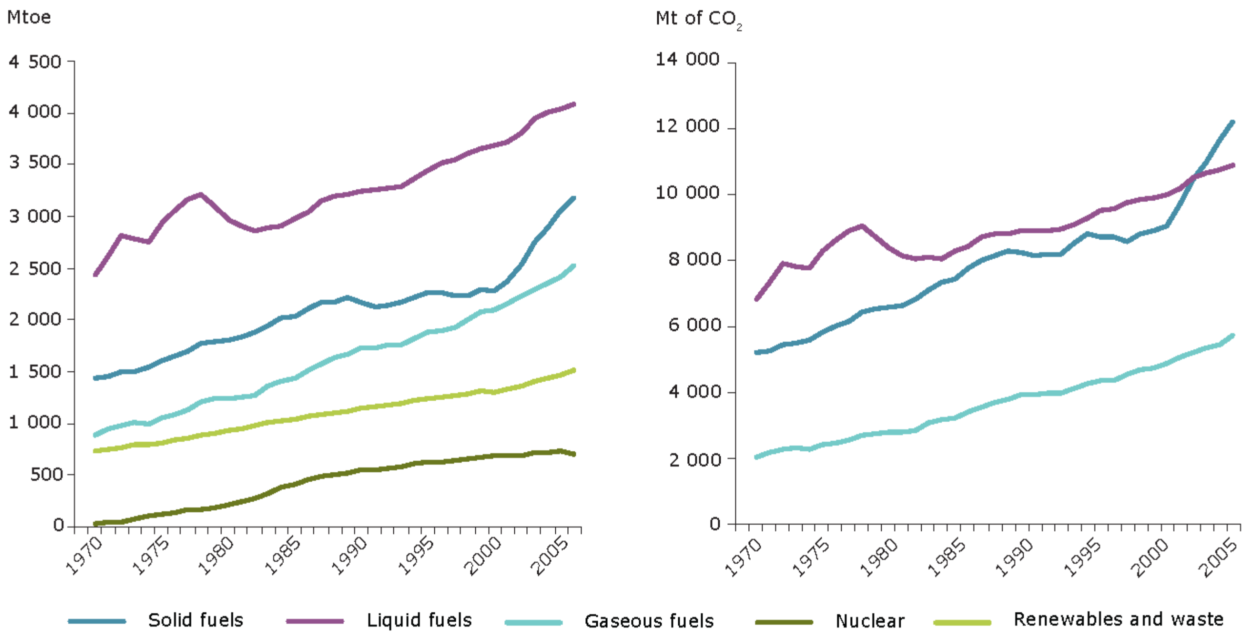
OECD AMERICA**:** Canada, Mexico and the USA.

---

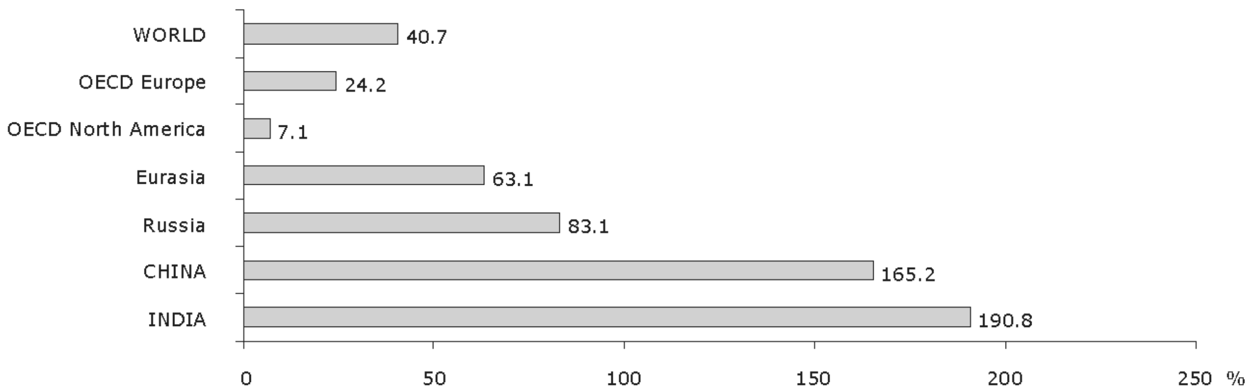
[1] *Mtoe – million tons of oil equivalent,*
[2] *OECD – Organisation for Economic Cooperation and Development,*
[3] *IEA – International Energy Agency,*
[4] *EEA – European Environment Agency, http://www.eea.europa.eu,*
[5] *IPCC – Intergovernmental Panel on Climate Change.*

EURASIA**:** Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Tajikistan, Turkmenistan, Ukraine, Uzbekistan, Albania, Bosnia and Herzegovina, Croatia, Montenegro, FYR Macedonia, Serbia, Bulgaria, Cyprus, Malta, Latvia, Lithuania, Romania, Slovenia, Estonia and Gibraltar.

MIDDLE EAST**:** Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates and Yemen.




*2. Figure_Global primary energy consumption [Mtoe] and $CO_2$ emissions from fossil fuel combustion for the period 1970-2007 [Source: IEA 2009, EEA].*



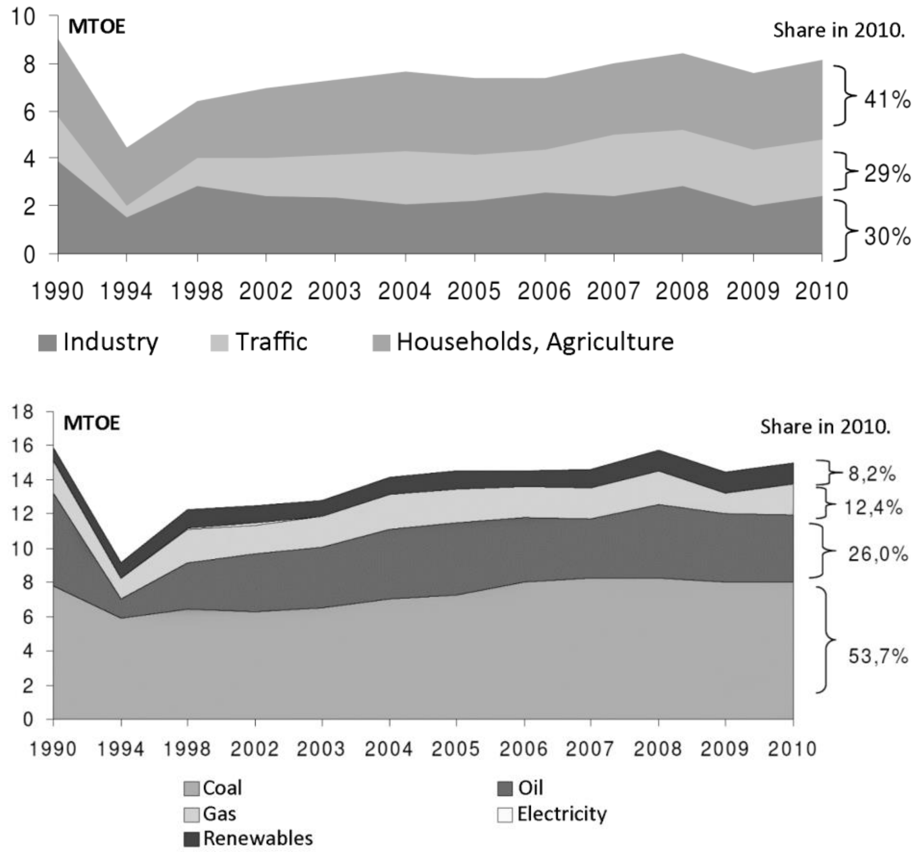

*3. Figure_Projected percentage increase in electricity consumption per capita for 2006-2030 [Source: IEA, EEA, 2009].*

*Table 1: Final energy consumption in [Mtoe] for the period 1990-2008 and final and total energy consumption per capita for 2008 [Source: Eurostat[6], Ameco[7], IEA, EEA, 2011]*

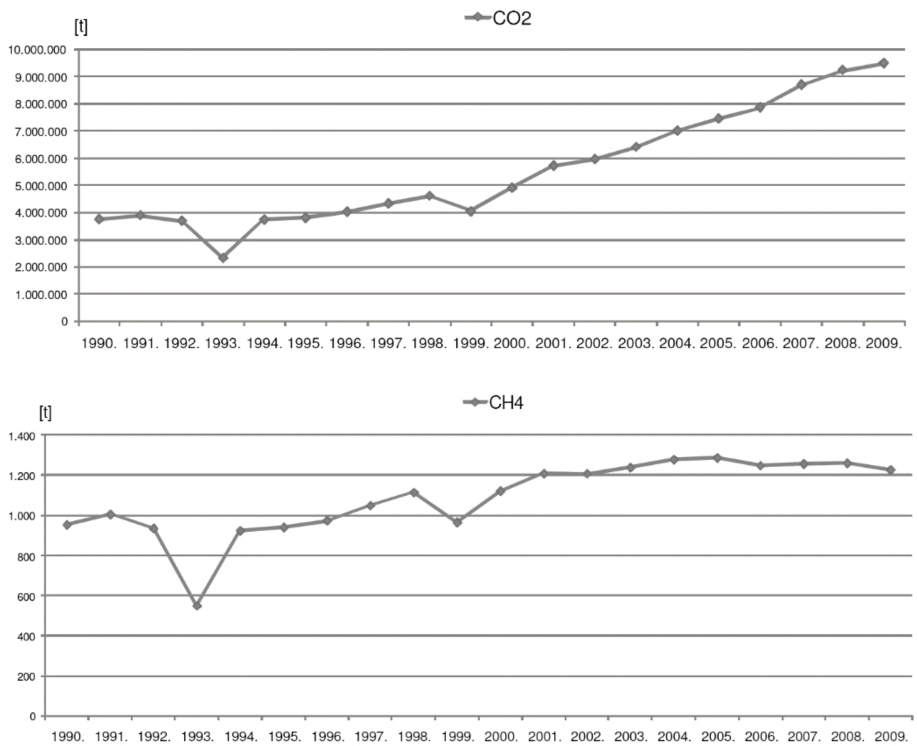
| | **1990** | **1995** | **2000** | **2005** | **2006** | **2007** | **2008** | **Final energy consumption per person in 2008 [Toe/cap][8]** | **Total energy consumption per person in 2008 [Toe/cap]** |
|---|---|---|---|---|---|---|---|---|---|
| EEA | 1,146 | 1,161 | 1,219 | 1,294 | 1,304 | 1,284 | 1,288 | 2.2 | 3.4 |
| EU-27 | 1,071 | 1,078 | 1,123 | 1,189 | 1,193 | 1,171 | 1,175 | 2.3 | 3.6 |
| World | 5,979 | 6,190 | 6,620 | 7,387 | 7,577 | 7,776 | 7,928 | 1.2 | 1.8 |
| Africa | 281 | 312 | 362 | 431 | 442 | 463 | 476 | 0.5 | 0.7 |
| Middle East | 142 | 191 | 226 | 280 | 299 | 319 | 335 | 1.7 | 3.0 |
| China | 650 | 773 | 749 | 1,058 | 1,138 | 1,216 | 1,332 | 1.0 | 1.6 |
| India | 243 | 274 | 299 | 336 | 354 | 371 | 386 | 0.3 | 0.5 |
| Russia | 588 | 433 | 391 | 377 | 389 | 389 | 396 | 2.8 | 4.8 |
| USA | 1,222 | 1,289 | 1,445 | 1,471 | 1,470 | 1,490 | 1,457 | 4.8 | 7.5 |

*4. Figure_In some parts of the world, the night is bright as day – Europe, North Africa, Middle East and part of Asia.*

[6] *Eurostat – statistical office of the European Union,*
[7] *AMECO – Annual Macro-Economic database of the European Commission's Directorate General for Economic and Financial Affairs,*
[8] *Toe/cap – Tons of oil equivalent per capita.*




5. Figure_inal energy consumption by sectors (up), and primary energy consumption by energy products (down) 1990-2010
[Source: Report on the State of the Environment in the Republic of Serbia, 2010]




6. Figure_Total amount of emitted $CO_2$ (up) and $CH_4$ (down) 1990-2009
[Source: Report on the State of the Environment in the Republic of Serbia, 2010].

## NEED FOR ALTERNATIVE ENERGY SOURCES

Combustion of fossil fuels releases gases ($CO_2$, CO, $SO_2$, $NO_X$, etc.) that lead to the occurrence of GLOBAL WARMING phenomena. The effects of global warming are diverse:

_climate changes,
_changes in the ecosystem,
_glacier retreat,
_raising sea level,
_loss of habitats of certain plant and animal species,
_extinction of species that cannot adapt to new climatic conditions,
_etc.

All this requires lifestyle changes, or finding alternative energy sources to replace fossil fuels in the future. Renewable energy sources should be favoured, such as:

_solar power,
_geothermal energy,
_hydropower (water),
_aeolian energy (wind),
_energy from biomass...

## SUSTAINABILITY

THE CONCEPT OF SUSTAINABILITY was first established by the German forester *Hans Carl von Carlowitz* in the 17th century. The growing need for wood and the constant lumbering led to the destruction of forests. He claimed that applying the concept of sustainability can prevent forest destruction by keeping the amount of trees cut in balance with the amount of newly planted trees. Needs for wood must be adapted to this balance or, if this is not possible, new resources should be discovered that can respond to the needs.

The concept of sustainability is also present in industry, especially in product development (sustainable product development).

SUSTAINABLE PRODUCT DEVELOPMENT IS THE LEADING IDEA IN ECODESIGN!

Today, the economy is based on fossil fuels. Every year, new sources of oil and gas are found, but the annual needs for these resources are much higher than what new sources can provide.

Since these sources are not renewable and therefore their stocks are limited, this trend will, in the future, lead to a shortage of these resources. If we want oil and gas to be available to our future generations, we need to reduce consumption, which means changing our way of life, or we need to find some new sources of energy that can replace fossil fuels. Unfortunately, we're still a long way from that!

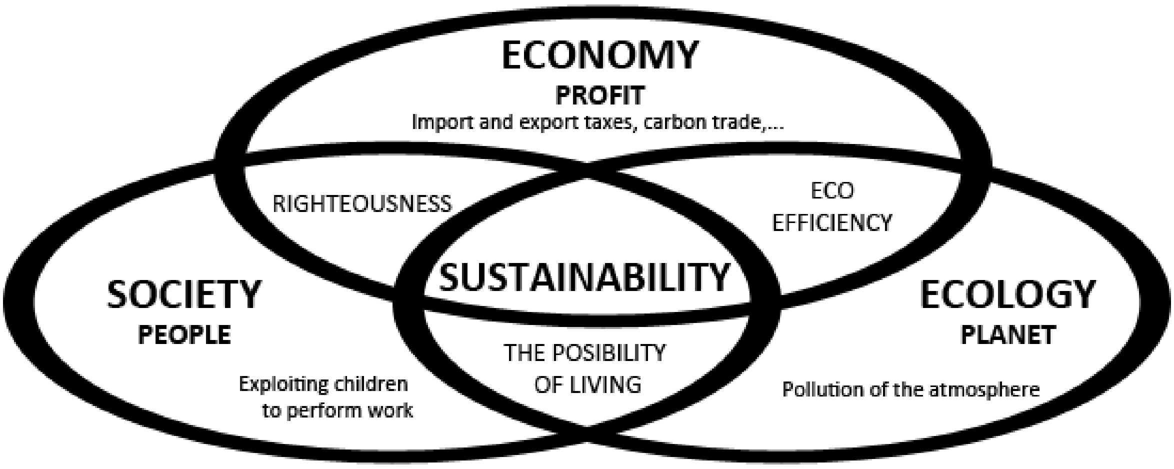
According to the UNITED NATION'S BRUNDTLAND COMMISSION (the World Commission on Environment and Development - WCED), sustainable development is:

“development that meets the needs of the present without compromising the ability of future generations to meet their needs.”

From the DESIGNER'S POINT OF VIEW, the importance of the sustainable development concept is reflected in the creation of products with the use of fewer resources and within their limits of renewal (regeneration).

Sustainability can be understood differently. In the most developed countries of the world (USA, Canada, Japan or the EU) it may present some limitations, such as walking instead of driving a car, less use of air conditioning, less dirty technologies, etc. For people in developing or underdeveloped countries, sustainability can mean “enough food”, “clean drinking water”, “level of education” or “access to information”.

## THREE INTERACTIVE COMPONENTS OF SUSTAINABLE DEVELOPMENT

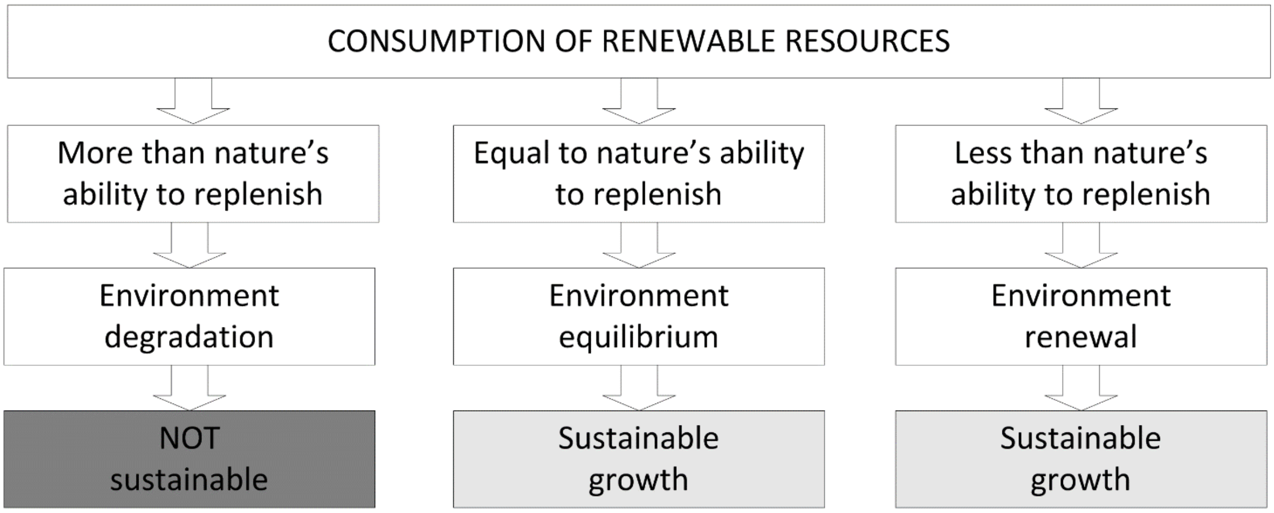



*7. Figure_Sustainability and sustainable development components*

Sustainable development has three components: ECONOMIC, ECOLOGICAL and SOCIAL.

## SUSTAINABLE DEVELOPMENT

The present situation (left branch in fig. 8) must be improved towards sustainable development (central and right branch in fig. 8).




*8. Figure_The concept of sustainable development*

ENVIRONMENTAL DEGRADATION - damage to the local ecosystem or the BIOSPHERE[9] as a whole due to human activity. Vegetation, habitats, soil, water and air are being degraded.

## DEFINITIONS OF ECODESIGN

### WHAT IS ECODESIGN?

ECODESIGN is a process that combines technology and organization in such a way that resources are used efficiently with the least adverse effect on the environment and the greatest benefits for all participants in the chain of creation and use of the product. The application of ECODESIGN enables "smart" use of resources.

### DEFINITION BY EEA, EUROPEAN ENVIRONMENTAL PROTECTION AGENCY:

"The integration of environmental aspects into the product development process, by balancing ecological and economic requirements. ECODESIGN considers environmental aspects at all stages of the product development process, striving for products which make the lowest possible environmental impact throughout the product life cycle".

The term PRODUCT means GOODS (HARDWARE), as well as SERVICES (SOFTWARE).

ECODESIGN can also be defined as the ecological and environmental dimension for every human activity, the design and creation of objects intended for meeting people's needs, the design for a safer future for humanity.

---

[9] *For the term biosphere, see page 9.*

ECODESIGN can be presented as a product design that cares as much about the ecological as the economic effect of that design. ECODESIGN assumes that the contribution of a product to environmental impacts should be considered throughout all stages of its LIFE CYCLE[10].

ECODESIGN strives to use resources in an intelligent way and thus increase the benefits of all stakeholders in the value creation process and, at the same time, to reduce pollution (environmental impact). This should be achieved under fair social conditions.

The following terms are synonyms for ECODESIGN:

_DESIGN FOR ENVIRONMENT
_ENVIRONMENTAL DESIGN
_SUSTAINABLE DESIGN
_GREEN DESIGN
_ECODESIGN
_It is evident, from the previous synonyms, that ECODESIGN represents a symbiosis OF DESIGN AND ECOLOGY.

## MOTIVATION FOR ECODESIGN IMPLEMENTATION

Motivation for ECODESIGN implementation can be divided into three basic groups of reasons, as follows:

ECOLOGICAL REASONS

ECONOMIC REASONS

SOCIAL REASONS

### ECOLOGICAL REASONS:

THE BIOSPHERE represents the sum of all the ecosystems of the planet Earth. We currently use more than 150% of the biosphere's capacity - BIOCAPACITY[11]. To preserve the environment for future generations, consumption of non-renewable resources and ENVIRONMENTAL IMPACTS[12] must be reduced immediately. ECODESIGN represents an effective approach of translating this cycle into reality.

---

[10] *For the term product life cycle, see page 42.*
[11] *Biocapacity is explained in more detail on page 32,*
[12] *Ecological impacts, environmental impacts and environmental effects are synonymous,*

Specific environmental reasons are:

_preserving the environment and resources for future generations,
_the use of non-renewable energy sources must be reduced,
_impacts on the environment must be reduced.

ECONOMIC REASONS:

Specific economic reasons may be as follows:

_the application of ECODESIGN in companies can lead to innovative products, improved quality and optimized functionality,
_creation of new markets and new consumption segments,
_ECODESIGN helps build trust and credibility with STAKEHOLDERS[13] and achieve a better company rating,
_reduced use of materials and energy helps to achieve savings.

SOCIAL REASONS:

Socially acceptable conditions and quality of life, as well as job creation, i.e. factors that ensure social and political stability, can be achieved through the application of ECODESIGN.

Concrete social reasons are:

_socially correct conditions,
_secure employment,
_economic stability,
_political stability.

The idea of ECODESIGN is widespread in various areas of technology: architecture, construction, mechanical engineering, industrial design. Different disciplines use and apply the term ECODESIGN in different ways.

ECODESIGN is primarily oriented towards the development of a (eco-sustainable) product, primarily from an ecological rather than an economic point of view!

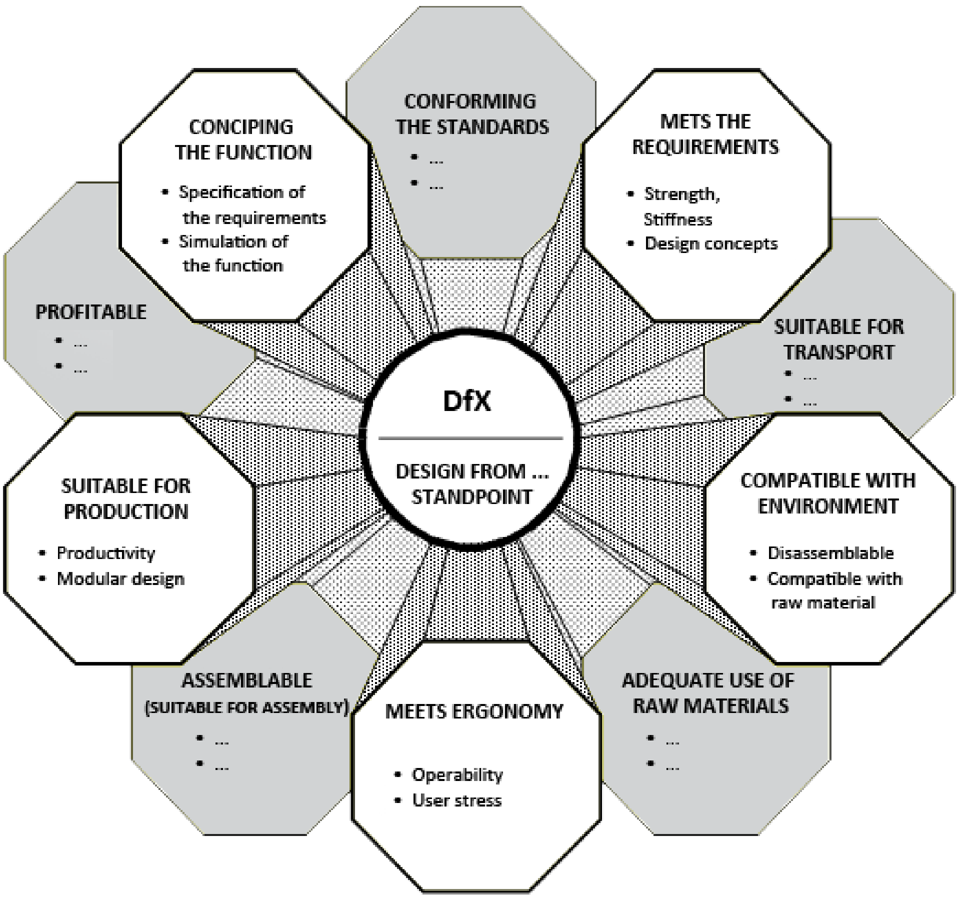
Large companies show interest in the implementation of ECODESIGN, not just because LAWS and DIRECTIVES, such as the Waste Electrical and Electronic Equipment - WEEE Directive or the Restriction of the use of certain Hazardous Substances in electrical and eletronic equipment - RoHS Directive, oblige them to do so. They understood that ECODESIGN is part of the technology of the future; ECODESIGN is considered an investment in technology that allows, among other advantages, great savings on internal costs. Given that engineers working on product development are not necessarily environmental experts, the introduction of ECODESIGN is still a challenge.

[13] *Stakeholders – are a group of people who have interests in something, they can be shareholders, investors, government institutions, etc.*

Practice in product design and development has shown that PRODUCT Life Cycle Thinking - LCT[14] has not yet fully come to life among engineers. The impact of product design on its ENVIRONMENTAL PERFORMANCE, i.e. on its environmental impact, is still unknown to most engineers working on product development.

## DESIGN FOR EXELLENCE
## DESIGN FOR X (DFX)

The design represents a concretization of the product development process. DESIGN FOR EXELLENCE (Design for X – DfX or DFX) is a methodology, i.e. an approach to optimizing a particular aspect of design. The DfX approach is not directly involved in product development, but provides full LOGISTICS for this process. Therefore, this approach is not directly applied to a complete technical system or product, but for some precisely defined characteristic or property. Data and correlations obtained using DfX methods enable the formation of alternatives or iterative approximation to an acceptable solution in the process of product development; in addition, they enable the definition of limitations, which the product or technical system must meet [Ognjanović, 2007].




*9. Figure_Design for exellence; design from the aspect of... (Design for X)*

[14] *For Life Cycle Thinking - LCT, see page 41.*

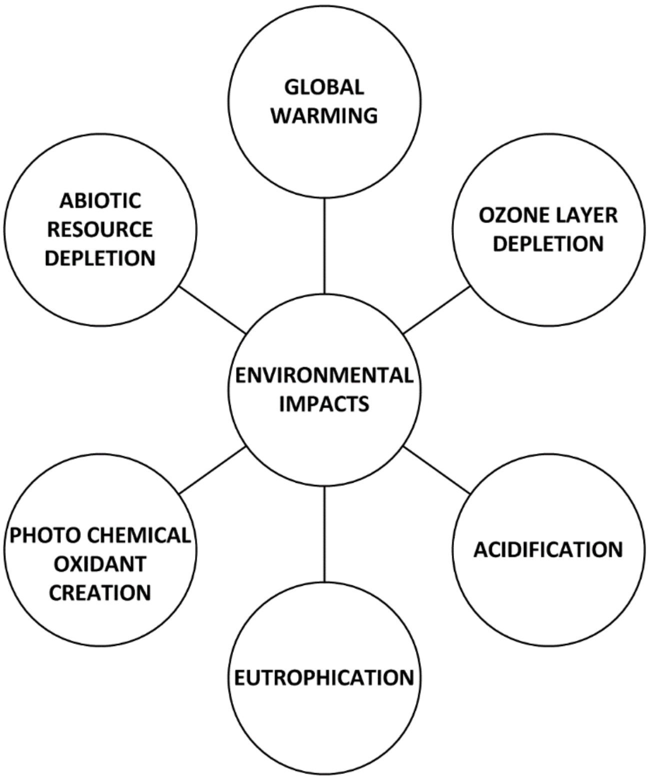
## ENVIRONMENTAL IMPACTS

A few decades ago, the problem of environmental protection arose and people became aware of the great danger of pollution and their responsibility in this regard.

*10. Figure_Different environmental impacts*

Environmental impacts include:

_GLOBAL WARMING,
_CLIMATE CHANGES,
_OZONE DEPLETION,
_PHOTOCHEMICAL SMOG OR PHOTOCHEMICAL OXIDANT CREATION,
_SUMMER SMOG,
_WINTER SMOG,
_HEAVY METALS EMITTED INTO ATMOSPHERE,
_HEAVY METALS DISCHARGED INTO WATER,
_EUTROPHICATION (“ALGAL BLOOMS”),
_LAND USE AND TRANSFORMATION (DEFORESTATION; DESERTIFICATION),
_“FILLING” THE SOIL WITH WASTE,
_PESTICIDES,
_ACIDIFICATION OF THE ENVIRONMENT,
_BIODIVERSITY,
_ECOTOXICITY,
_CARCINOGENS AND SUBSTANCES HARMFUL TO HUMAN HEALTH,
_ABIOTIC RESOURCE DEPLETION.




*11. Figure_The six major categories of environmental impacts – elements that can often be interlinked*

## GLOBAL WARMING – GW:

Changes in the surface-air temperature, referred to as the GLOBAL TEMPERATURE, brought about by the "GREENHOUSE EFFECT" which is induced by the emission of greenhouse gases into the air [EEA,2006].

## OZONE LAYER DEPLETION:

The fragile OZONE SHIELD ($O_3$) which plays a decisive role in stratospheric radiation balance (how much heat from the sun is let in / out of planet) is being damaged by a complex reaction with greenhouse gases. Human made gases such as Chloro-Fluoro Carbons - CFCs are a major contributor to this DEPLETION of the OZONE LAYER [EEA, 2006].

## ACIDIFICATION:

Wet and dry atmospheric fallout which has a very low pH, brought about when water vapor in the atmosphere combines with hydrogen sulphide and nitrous oxide vapors released from burning fossil fuels; the sulphuric and nitric acid in rain, fog, snow, gases and particulate matter. It does not necessarily affect forests /trees by directly attacking them, but can weaken their resistance to pests [Smith & Smith, 2000].

## EUTROPHICATION, "ALGAL BLOOMS":

Increase in nutrients (nitrogen/phosphorous) in fresh or salt water which alters the growth of biological life, in some cases leading to "ALGAL BLOOMS" which upset other life in the local ecosystems.

PHOTOCHEMICAL OXIDANT CREATION OR SMOG - “OZONE ALARM”:

Increase in GROUND LEVEL OZONE (ozone is beneficial in the high atmosphere, but harmful in the immediate atmosphere to mammals and plants as it causes SMOG).

ABIOTIC RESOURCE DEPLETION:

CONSUMPTION OF NON-RENEWABLE RESOURCES e.g. crude oil, coal, iron etc which the word currently relies on for manufacturing and energy production. Unless there are alternatives to the current non-renewable resources, human society cannot sustain its current living standard or life style.

## AIR POLLUTION, GLOBAL WARMING AND CLIMATE CHANGES

*12. Figure_Air pollution and climate impacts*

### AIR POLLUTION

The most common air pollutants are:

_carbon dioxide ($CO_2$),
_carbon monoxide (CO),
_sulfur dioxide ($SO_2$),
_hydrocarbons ($C_XH_Y$),
_nitrogen oxides ($NO_X$),
_ozone ($O_3$),
_particulate matter (PM10 and PM2.5), also known as particle pollution or PM; particles emitted during transport, industrial processes, combustion processes and photochemical reactions.

Adverse effects on the environment due to air pollution most often include:

_global warming (due to $CO_2$, $CN_4$, etc.),
_ozone depletion (due to CFC),
_acid rain (due to $SO_2$),
_effects on human health (due to gases and AEROSOLS[15]).

In developed countries, however, air pollution has been significantly reduced in the last few years, especially due to environmental pollution regulations and control of greenhouse gas emissions. The new concept of hybrid and electric vehicles and transport machines (conventional-electric and electric drive) has the potential to reduce fuel consumption and emissions of harmful gases by up to 90% (Figures 13 and 14).


*13. Figure_Hybrid vehicles: Toyota Prius (left) and “Eco-Bus” (right)*


*14. Figure_Transport machinery:  Hybrid powered forklift (left) and ECO E-RTG electrically powered crane (right)*

[15] *An aerosol is a suspension of fine solid particles or liquid droplets in air or another gas.*

## GREENHOUSE GASES - GHG

There are NATURAL (e.g. methane - $CH_4$, carbon dioxide - $CO_2$, nitrogen oxides - $NO_x$, ozone - $O_3$ and water vapour) and SYNTHETIC (chlorine-fluorocarbons - CFC) gases, which behave as "GREENHOUSE GASES".

### WHAT IS OZONE ($O_3$)?

OZONE is a triatomic oxygen molecule that:

_protects the Earth from excessive radiation in the STRATOSPHERE (15-30 km from the Earth's surface), and
_biologically damage the atmosphere in the lower layers (SMOG, "OZONE ALARM").

## KYOTO PROTOCOL

The Kyoto Protocol is an amendment to the UNFCCC - United Nations Framework Convention on Climate Change, which was held in December 1997 in Kyoto, Japan. The Protocol entered into force on February 16, 2005. So far, 144 countries, including EU countries, have ratified the KYOTO PROTOCOL. The signatory countries of the KYOTO PROTOCOL are obliged to reduce greenhouse gas emissions.

According to the KYOTO PROTOCOL, greenhouse gases include six groups of gases:

_carbon dioxide ($CO_2$),
_methane ($CH_4$),
_nitrogen oxides ($NO_x$),
_hydrofluorocarbons (HFCs),
_perfluorocarbons (PFCs),
_sulfur hexafluoride ($SF_6$).

One natural, very significant greenhouse gas, which is not covered by the protocol, is WATER VAPOUR.

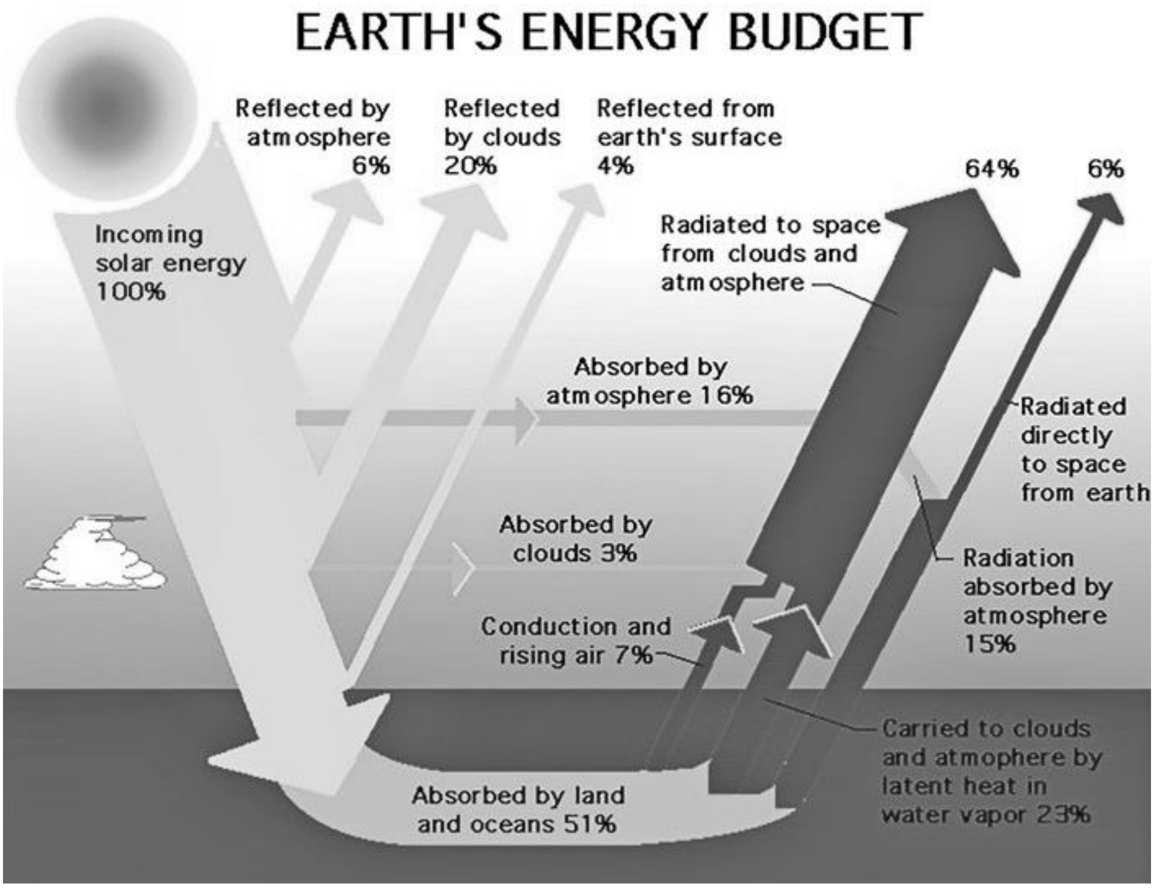
## GREENHOUSE EFFECT

The atmosphere naturally retains and rejects a certain amount of solar energy.

If greenhouse gases didn't trap some of the solar energy, the Earth's temperature would be minus 18 degrees Celsius. With NATURAL greenhouse effect, this temperature would be about 15 °C, and it would be stable.

The greenhouse effect contributes directly to global warming:

_because greenhouse gases are TRANSPARENT TO SHORT-WAVE SOLAR RADIATION, and thus allow penetration of a certain amount of solar heat through Eart'h atmosphere;
_on the other hand, greenhouse gases TRAPP LONGER INFRARED WAVES that the Earth emits into space, making it even harder for the Earth to cool down.



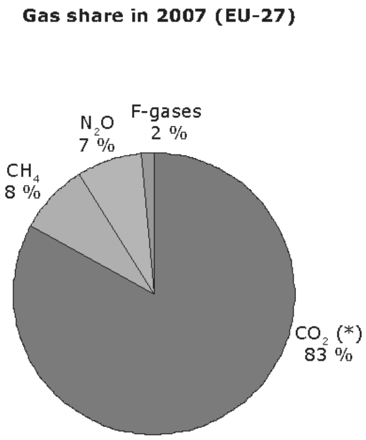

15. Figure_Solar energy balance [Source: NASA, 2005]

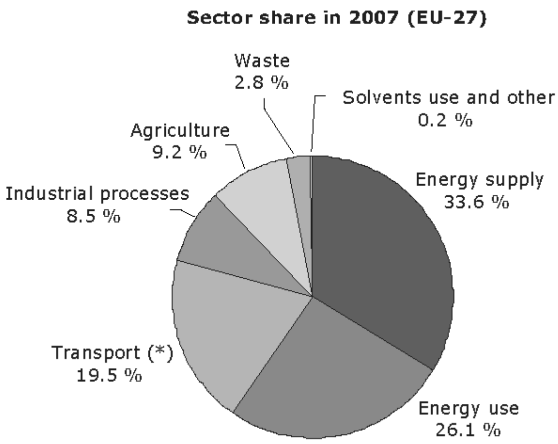
Origin of greenhouse gas emissions**:**

_over the last 20 years, about ¾ of anthropogenic emissions of $CO_2$ into the atmosphere is the result of burning fossil fuels,

_the remaining ¼ of emissions are mainly due to land use and land transformation, primarily deforestation,

_the highest methane emissions ($CH_4$) come from landfill waste decomposition, livestock dung decomposition, farm animal manure, natural gas and oil systems and coal exploitation.

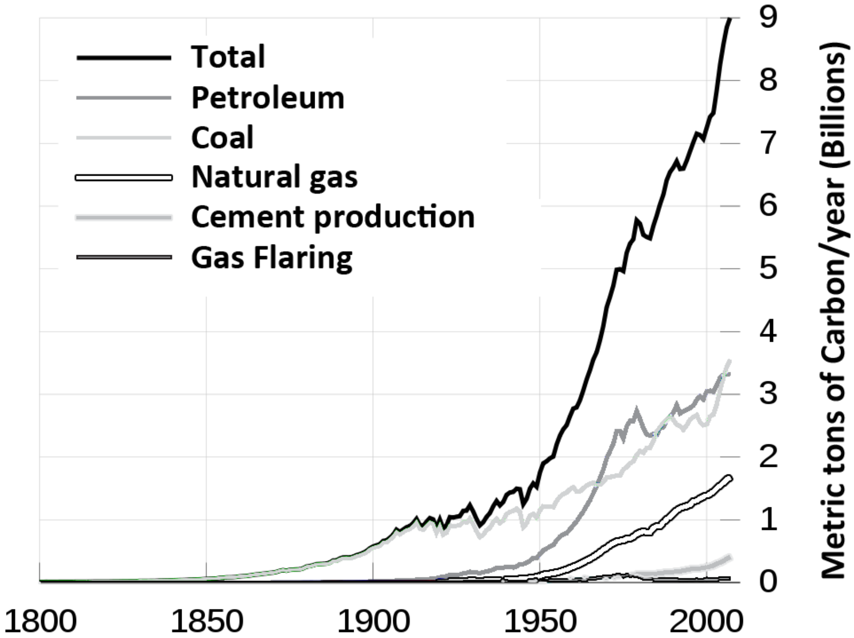



16. Figure_Emissions of greenhouse gases by share of gases and by sector in the EU-27, 2007 [Source: EEA, 2009]

Figure 16 shows the main anthropogenic emitters of greenhouse gases. The mark "*" in Figure 16 indicates that emissions from international water and air transport have not been taken into account, as they are not covered by the Kyoto Protocol. However, if these emissions were taken into account, the share of gas in "greenhouse gases" would increase to 84%, and the share of the transport sector to 24% in total emissions of "greenhouse gases" in the EU-27 region for 2007.

By burning fossil fuels and releasing carbon dioxide into the atmosphere, humans affect the CARBON CYCLE IN NATURE, and thus make the greatest anthropogenic contribution to the "greenhouse effect". On Earth, CARBON exists in limited quantities in deposits of coal, oil and natural gas (fossil fuels), formed over millions of years. Since these deposits cannot be recovered at the rate at which they are consumed, FOSSIL FUELS ARE CONSIDERED NON-RENEWABLE RESOURCES.




*17. Figure_Annual emissions of carbon dioxide at the global level*
*[source: Carbon Dioxide Information Analysis Centre, Flight, D after Marland et al, 2003]*

## OZONE LAYER DEPLETION

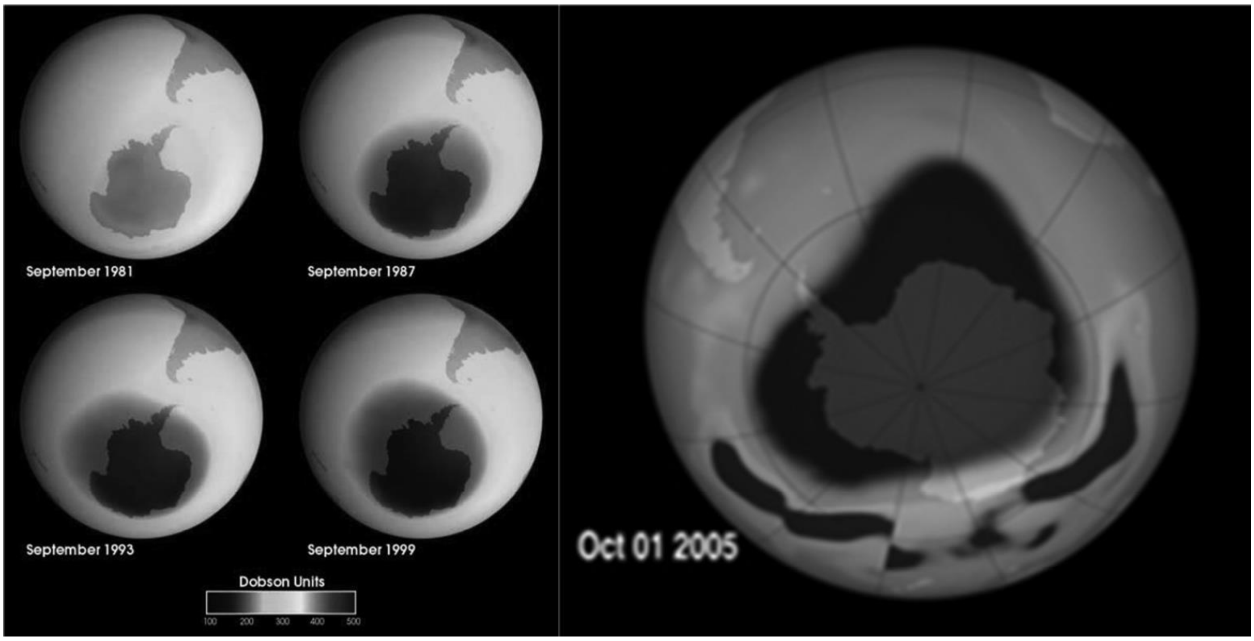
OZONE ($O_3$) is destroyed:

_in reactions with nitric acid ($HNO_3$), which is generated by burning fossil fuels, or
_in reaction with freons (CFCs and HCFCs, used as refrigerants or foams).

Substances controlled by the EC - European Commission - DG ENVIRONMENT DIRECTORATE:

_Chloro-Fluoro Carbons - CFCs,
_Carbon Tetrachloride,
_Methyl Chloroform,

_Halons - HBFCs,
_Hydro-Chloro-Fluoro Carbons - HCFCs,
_Methyl Bromide,
_Brom Chlor Methane - BCM.




*18. Figure_Satellite images of the hole in the ozone layer over Antarctica for 1981, 1987, 1993 and 1999 (left) and 2005 (right) [Source: NASA]*

## SOLAR SPECTRUM AND SIGNIFICANCE OF THE OZONE LAYER

Most of the radiation from the Sun is concentrated on the visible part of the spectrum. It is a narrow of wavelengths from 400 to 700 nm and represents 43% of the total radiation coming from the Sun to Earth. Wavelengths shorter than the visible spectrum (< 400 nm) cover about 7% to 8% of the total radiation, but are very significant, because their energy is very high. This area includes Ultra Violet - UV radiation.

Ultraviolet radiation (UV) is divided into the following wave bands:

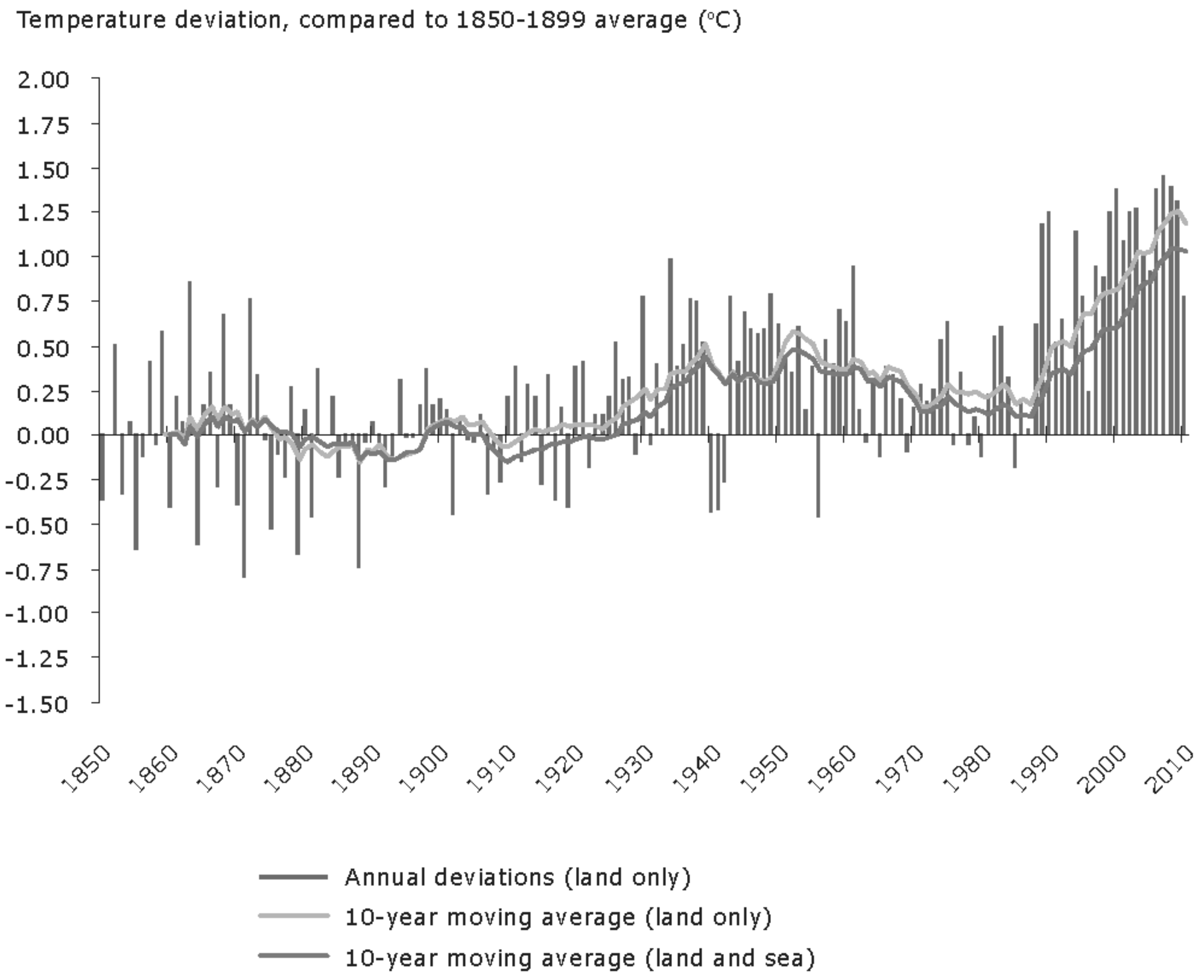
_200 to 280 nm - UV-C radiation,
_280 to 320 nm - UV-B radiation,
_320 to 400 nm - UV-A radiation.

94% of UV-A, 6% of UV-B and 0% of UV-C radiation reaches the Earth's surface.

The absorption of UV radiation in the presence of carbon dioxide is particularly significant, because this gas, since it is heavier than air, is concentrated near the Earth’s surface, so that in these parts of the atmosphere the absorption is greatest. This means that the “greenhouse effects” in the lower parts of the troposphere are the highest.

Global warming affects both the environment and human. There is a wide range of effects of global warming:

_melting of polar ice caps and rising sea and ocean levels,
_impact on agriculture,
_ozone layer depletion (interconnected),
_enhanced frequency and intensity of natural disasters,
_spread of infections,
_retraction of snow cover,
_climate change,
_melting and retreating of glaciers,
_lowering the pH of the ocean (due to the increase in the level of carbon dioxide),
_lost of habitats of some animal species.




*19. Figure_Average temperature increase in Europe (°C) in the period 1850-2010 [source: EEA 2010, Climate Research UNIT - CRU].*

The rise in temperature, Figure 19, is caused by the "greenhouse effect" resulting from greenhouse gas emissions and damage to the ozone layer.

## WATER POLLUTION


*20. Figure_Water pollution and environmental impacts*

Water is considered POLLUTED when any chemical, physical, or biological change in its quality has adverse consequences on any living being who drinks, uses, or lives in that water. Although NATURAL PHENOMENA, such as volcanic eruptions, storms, earthquakes, etc. cause major changes in water quality and ecological status, they ARE NOT CONSIDERED POLLUTION.

The change in the physicochemical properties of water refers to:

_acidity,
_conductivity,
_temperature,
_excessive phosphate and nitrate content (EUTROPHICATION).

### WATER CONTAMINANTS

There are several classes of water contaminants:

_PATHOGENS (bacteria, viruses, protozoa and parasitic worms) that get into sewage and unprocessed waste,
_WASTE THAT CONSUMES OXYGEN (waste decomposed by bacteria with oxygen consumption – when large amounts of these bacteria decompose waste, the amount of oxygen in the water can be reduced, which can lead to the death of some organisms, such as fish),
_WATER-SOLUBLE INORGANIC POLLUTANTS (acids, salts, toxic – heavy metals, chemical waste, fertilizers, sludge, etc.),

_ORGANIC POLLUTANTS (oil, plastics, pesticides, herbicides, insecticides, food residues, wood and logging residues, inadequately stored volatile industrial solutions – VOCs - Volatile Organic Compounds), and other organic compounds that are harmful to humans and all plant and animal species,
_RADIOACTIVE SUBSTANCES AND COMPOUNDS SOLUBLE IN WATER.

The main SOURCES OF WATER POLLUTION are:

_discharge of industrial, chemical waste and by-products,
_discharge of poorly processed or unprocessed sewage,
_washing away spilled oil or petroleum,
_washing away materials from construction sites, farms (sludge, etc.),
_discharge of contaminated and/or hot water in industrial processes,
_acid rain,
_increase in phosphate and nitrate concentration due to the washing off of detergents and fertilizers (EUTROPHICATION),
_leakage from underground reservoirs, which leads to contamination of soil and further to contamination of groundwater reservoirs.

## EUTROPHICATION ("ALGAL BLOOMS")

"ALGAL BLOOMS" is a consequence of water EUTROPHICATION, when, mainly due to human activities, there is overpopulation of water plants, most often algae, which has negative consequences for the aquatic life.

*21. Figure_Eutrophication or "algal blooms"*

EUTROPHICATION begins by bringing fertilizers (usually washed away by rain) into the water from fields and other agro-ecosystems. These fertilizers are rich in phosphates and nitrates, which are, by the way, a limiting factor for flourishing of life in water. With the excess of these salts, plants, especially algae, often begin to flourish. This also increases the number of dead algae, which are then decomposed by SAPROPHYTES (bacteria and fungi that feed on dead organic matter), where oxygen is consumed. The concentration of oxygen in water decreases, and thus suffocation and mass killing of water organisms that consume oxygen for breathing occur. In conditions OF REDUCED OXYGEN CONCENTRATION, or even ANAEROBIC CONDITIONS (when there is no oxygen at all) the decomposition itself will not be complete, so decomposition products are formed that give the water bad taste, unpleasant smell and generally poor quality. Such water cannot be used for drinking and can cause cattle to die if used as a watering hole.

A bigger problem than surface water pollution is GROUNDWATER POLLUTION. Groundwater can travel great distances through underground streams and thus spread pollution.

Another form of water pollution, which occurs in industrial zones, is THERMAL POLLUTION due to the discharge of hot water from nuclear plants and thermal power plants (it can cause the death of water organisms – especially fish).

## POLLUTION (CONTAMINATION) OF SOIL

SOLID WASTE - SW refers to garbage from households, waste and sludge from households and industry.

Municipal Solid Waste - MSW is, in general, biodegradable and recyclable. It is mostly composed of paper (41%) and food residues (21%).

Part of the waste that is TOXIC consists of oil, heavy metals from batteries ($C_d$, $H_g$, $P_b$...) and organic solutions (compounds), to which special attention should be paid, so as not to get into the drinking water and contaminate it. More than 90% of toxic waste is generated by the chemical, oil and metal industries, with dry cleaning shops and petrol stations also contributing to this.

Soil contamination most often occurs as a result of the use of:

_pesticides (e.g. DDT – Dichloro-Diphenyl-Trichloro Ethane),
_herbicides (e.g. AGENT ORANGE - dioxin),
_insecticides.

## DEFORESTATION

22. Figure_Deforestation

DEFORESTATION is the removal of trees from a certain area, without subsequently planting the new trees. This removal may be temporary or permanent, leading to partial or complete eradication of the wood cover. It can be a gradual or rapid process that can occur naturally, anthropogenic, or by a combination of both.

Wide-scale deforestation and impacts on the functioning of essential ecosystems (e.g. the problem of tropical forests of the Amazon highlighted in the media) are of concern. However, smaller-scale deforestation can have an important impact on smaller communities and ecosystems.

Overpopulation of the Earth leads to the deforestation of tropical forests, which leads to large-scale erosion, loss of minerals in the soil and sometimes the FORMATION OF DESERTS (total DESERTIFICATION).

## LAND DEGRADATION AND DESERTIFICATION

23. Figure_Desert at the site of the former Aral Sea, Kazakhstan

DESERT FORMATION (DESERTIFICATION) is land degradation in arid and semi-arid areas resulting from various impacts such as climate change and human activity, as well as irrational water consumption.

LAND DEGRADATION can be reflected in the LOSS OF MINERALS in the soil and the reduction of its quality, as well as in the REDUCTION OF BIODIVERSITY.

## SOIL EROSION

SOIL EROSION is caused by the separation of soil particles and their carrying away by wind (AEOLIAN EROSION) or water (HYDROEROSION).

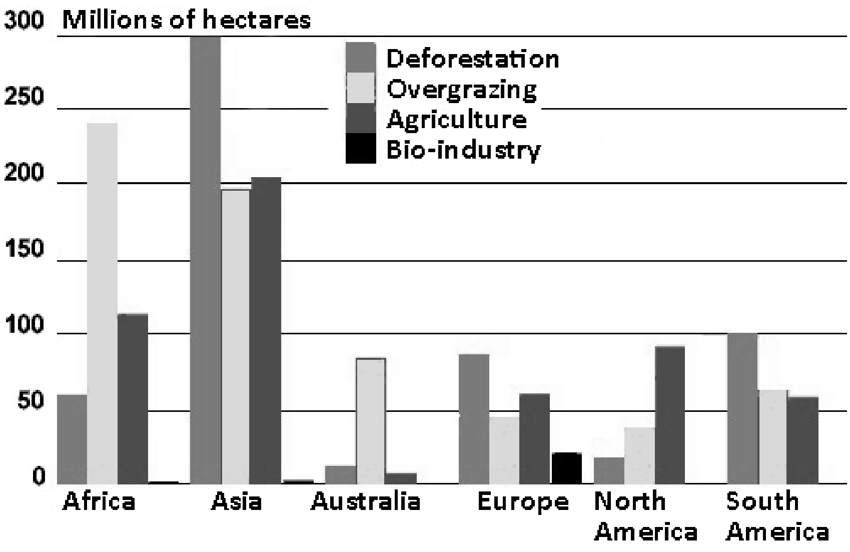
### SOIL EROSION IS CONTRIBUTED BY:

_extreme temperatures,
_precipitation, including acid rain,
_human actions.

### PEOPLE ARE ACCELERATING THIS PROCESS BY:

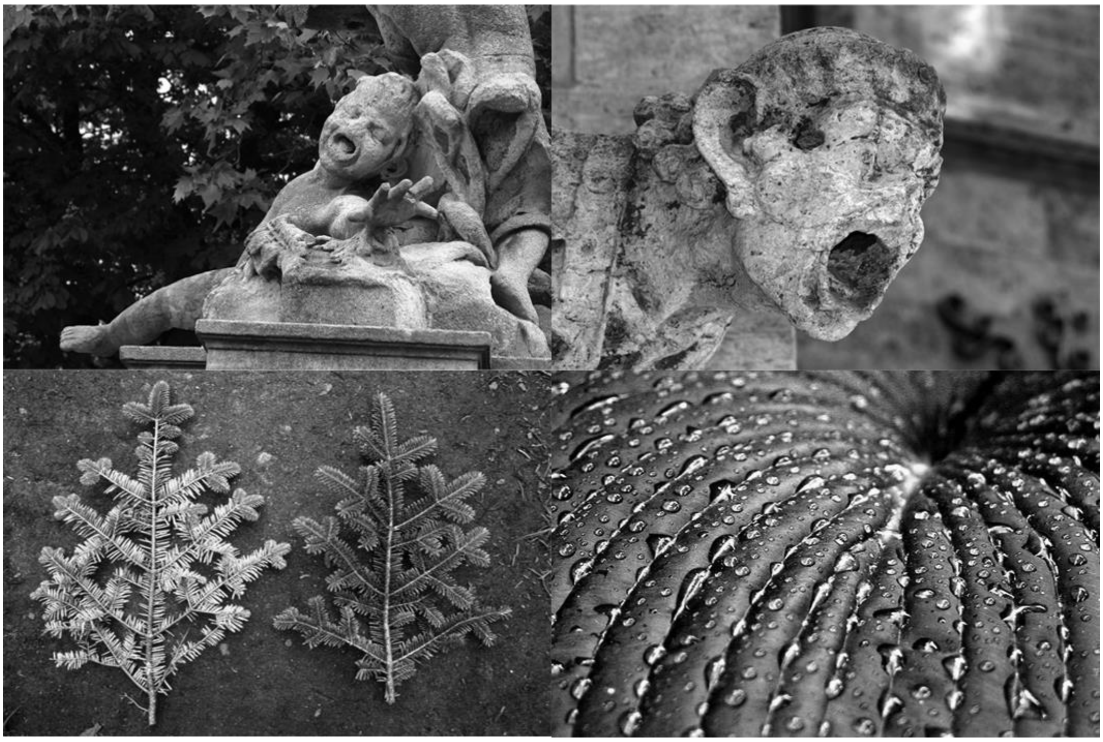
_construction,
_deforestation,
_mining,
_agriculture,
_overgrazing.

Soil erosion (aeolian and hydro) is also affected by LIVESTOCK farming. Cattle brakes the soil with its hooves and thus facilitates its carrying away by wind or water. When the soil is stripped, the level of evaporation increases, by which minerals (salts) reach the surface of the soil (SALINIZATION), thus preventing the growth of plants. The loss of plants leads to a decrease in the amount of moisture in the region, which can lead to climate change and a decrease in precipitation, and so we enter the “vicious circle”.



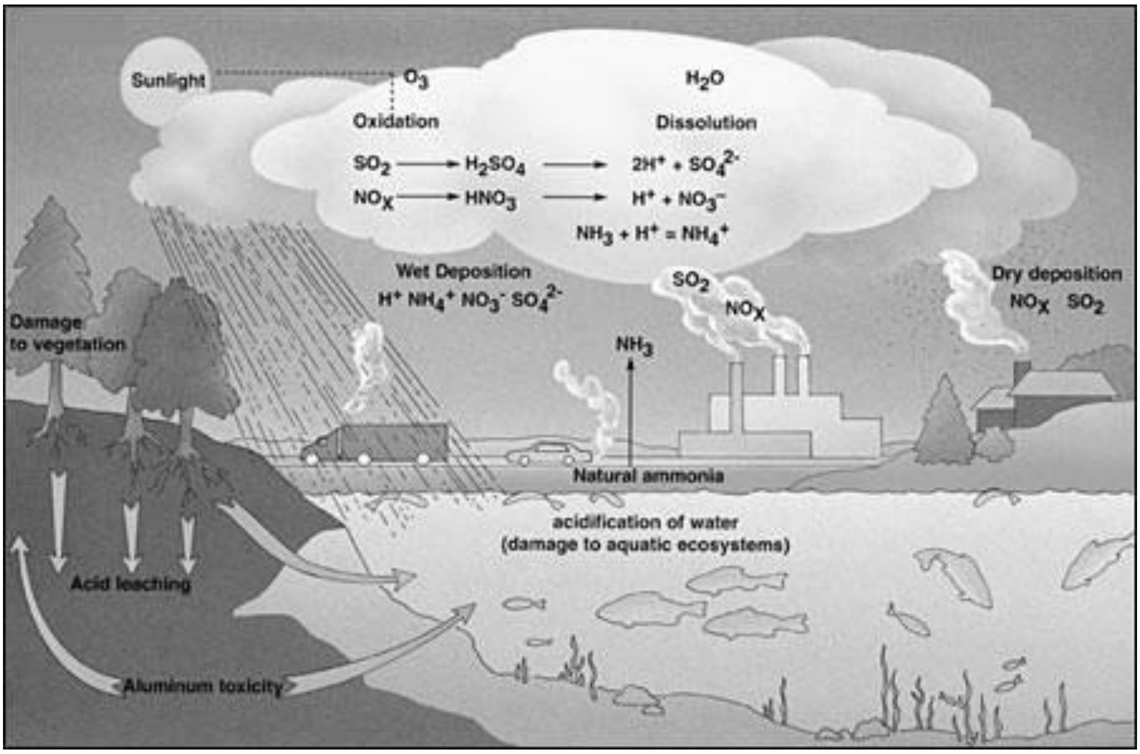

*24. Figure _Soil erosion and desertification*

## ACIDIFICATION OF THE ENVIRONMENT



25. Figure _Effect of acidification on plants and the environment

The effects of acid rain on the living world and man can be devastating. Acidification of water kills all life forms. Buildings made of stone, metal and concrete are also damaged or destroyed.



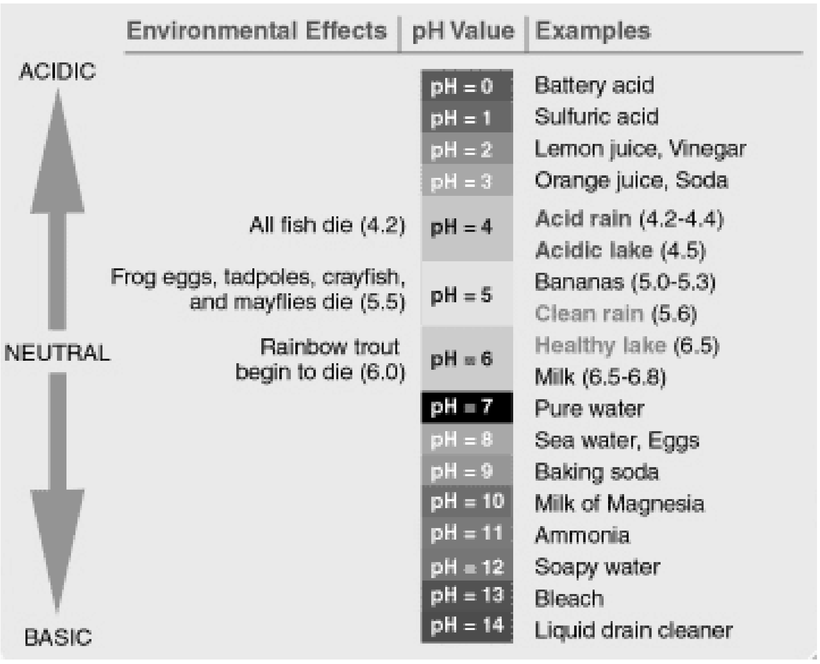

26. Figure_Acidification and its impact on the lake ecosystem

Burning fossil fuels (coal, gasoline, oil), causes emissions of oxides of sulfur, carbon and nitrogen into the atmosphere. These oxides, combined with humidity in the atmosphere, form sulfuric, carbonic and nitric acid. These acids get back to the Earth's surface through ACID RAIN or ACID SNOW, increase soil acidity and disturb the chemical balance of seas, lakes and water streams, Figure 26. Acidification also occurs by deposition of $NO_x$ and $SO_2$ groups from the atmosphere in the form of PARTICLES (DRY DEPOSITION) or through GASES.

When acidifying oceanic ecosystems, atmospheric $CO_2$ dissolves in water and in reaction with it forms carbonic acid ($H_2CO_3$), bicarbonate ($HCO_3^-$) and carbonate ($CO_3^{2-}$) compounds. The ratio of these compounds depends on factors such as sea water temperature and alkalinity. Dissolving $CO_2$ in seawater increases the concentration of hydrogen ions ($H^+$) in the ocean and thus reduces the pH value of the ocean. Changes in the chemical composition of water in the oceans have far-reaching direct and indirect consequences for living organisms and their habitats. One of the most significant consequences of increasing ocean acidity relates to the formation of shells that are built of calcium carbonate ($CaCO_3$). This process is called CALCIFICATION and is very important for the biology and survival of a wide range of marine organisms.

## ACIDITY

In chemistry, pH is the value that expresses the ACIDITY, that is, the ALCALINITY of the environment. The pH scale is logarithmic and has 14 subdivisions (0-14), whereby pure distilled water is said to be pH NEUTRAL with a value of approximately pH = 7.0, at a temperature of 25 °C. For environments with a pH value less than 7.0, we say that they are acidic, and for environments with a pH value greater than 7.0, we say that they are basic/alkaline.




*27. Figure_pH scale and effects of acidity on the environment.*

## REDUCTION OF BIODIVERSITY (DIVERSITY OF FLORA AND FAUNA)

The term BIODIVERSITY means the biological diversity, or diversity of flora and fauna (living organisms) in a given geographical area. Biodiversity is used as a measure of ecosystem health.

*28. Figure_Biodiversity*

The term BIODIVERSITY REDUCTION, means concern about the danger of reduction or even extinction of plant and animal species in different ecosystems.

The reduction of biodiversity is caused by:

_deforestation,
_clearing the land,
_soil, water and air pollution,
_climate change.

*29. Figure_Extinct species: Golden toad - Bufo periglenes (left) and Tasmanian tiger - Thylacinus cynocephalus (right)*

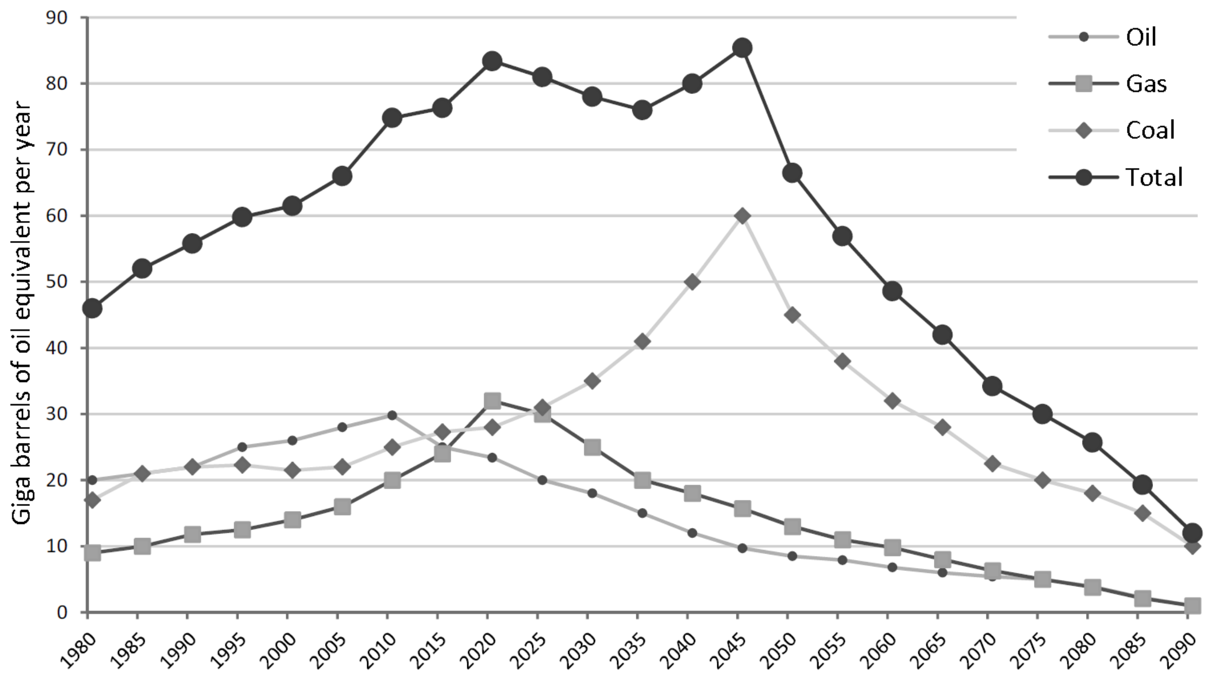
## ABIOTIC RESOURCES DEPLETION

Many of the raw materials we use in production are not renewable (e.g. crude oil, iron ore and other minerals, coal, natural gas...); in addition, the consumption of renewable resources exceeds the nature's ability to replenish (e.g. wood). If the present trend of population growth, industrialization, pollution, food production and resource consumption continues, OUR PLANET'S CAPACITIES WILL BE EXHAUSTED IN THE NEXT 100 YEARS.

*Table 2: Predictions of how long certain resources will last in relation to current demand in the USA and the world [Source: A.Reller,University of Augsburg, T. Graedel, Yale University, 2006]*

| Metal | Demand for resources per US resident [kg] | Residual stocks in relation to world demand [in years] | Residual stocks if world demand equals US demand [in years] |
|---|---|---|---|
| Aluminum | 20.3 | 1027 | 510 |
| Antimony | $92 \cdot 10^{-3}$ | 60 | 13 |
| Copper | 8.1 | 61 | 38 |
| Gold | $0.6 \cdot 10^{-3}$ | 45 | 36 |
| Indium | $0.42 \cdot 10^{-3}$ | 13 | 4 |
| Tin | $139 \cdot 10^{-3}$ | 40 | 17 |
| Nickel | $753 \cdot 10^{-3}$ | 90 | 57 |
| Lead | 5.3 | 42 | 8 |
| Platinum | $0.58 \cdot 10^{-3}$ | 360 | 42 |
| Silver | $20 \cdot 10^{-3}$ | 29 | 9 |
| Tantalum | $2 \cdot 10^{-3}$ | 116 | 20 |
| Uranium | $76 \cdot 10^{-3}$ | 59 | 19 |
| Phosphorus | $107 \cdot 10^{-3}$ | 354 | 142 |
| Zinc | 4.5 | 46 | 34 |

In order to conserve natural resources, we need to take into account the use of renewable resources, recycle as much as we are able, find and develop alternative energy sources, or in other words, think and act "GREEN".




*30. Figure_World production of oil, coal and gas[16]*

## EXAMPLE OF A CASE STUDY

**Global warming:**
- Production of electricity to manufacture the product,
- Production of electricity to run the fridge during use.

**Air pollution:**
- Emissions from manufacturing aluminum, steel, plastics,
- Emissions from electricity production.

**Reducing biodiversity:**
Destroying forests and other biotopes in order to:
- harvest timber for cardboard packaging,
- extract oil for plastics,
- dig for bauxite to produce Al ...

**Water pollution:**
- Waste from electricity production (cooling towers).

**Resource depletion:**
- Iron ore,
- Bauxite (aluminum),
- Oil,
- Natural gas etc.

**Ozone depletion:**
- HSFCs used as refrigerant,
- Blowing agent for foam insulation.

**Land degradation:**
- Mixing of iron ore for steel,
- Extracting oil,
- Digging for bauxite,
- Landfills if not recycled.

**Solid waste:**
- Waste from manufacturing,
- Waste from extracting materials (sterile),
- Waste from energy production,
- Component disposal at the EoL.

*31. Figure_Ecological footprint of a refrigerator*

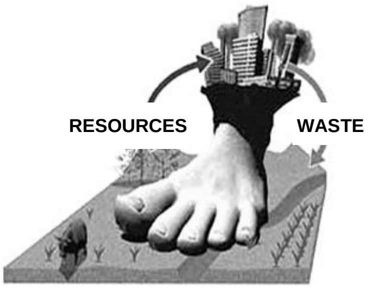
[16] *1 barrel = 158.984 litres; Source: http://en.wikipedia.org/w/index.php?oldid=486550941.*

## ECOLOGICAL FOOTPRINT

Irrational exploitation of natural resources (wood, oil, coal, minerals, etc.), together with large quantities of toxic substances that we throw into water and emit into the atmosphere or the soil, disturb the natural balance. Each product contributes to environmental degradation at every stage of its life cycle, leaving behind a characteristic ECOLOGICAL FOOTPRINT[17], which extends beyond national borders and long after the end of the product's life.

### ECOLOGICAL FOOTPRINT:

_calculates how much productive land and sea is needed to provide the resources, such as energy, water and raw materials, we use in our everyday lives,
_calculates the emissions generated from the oil, coal and gas we burn,
_determines how much land, air and/or water is required to absorb our waste.



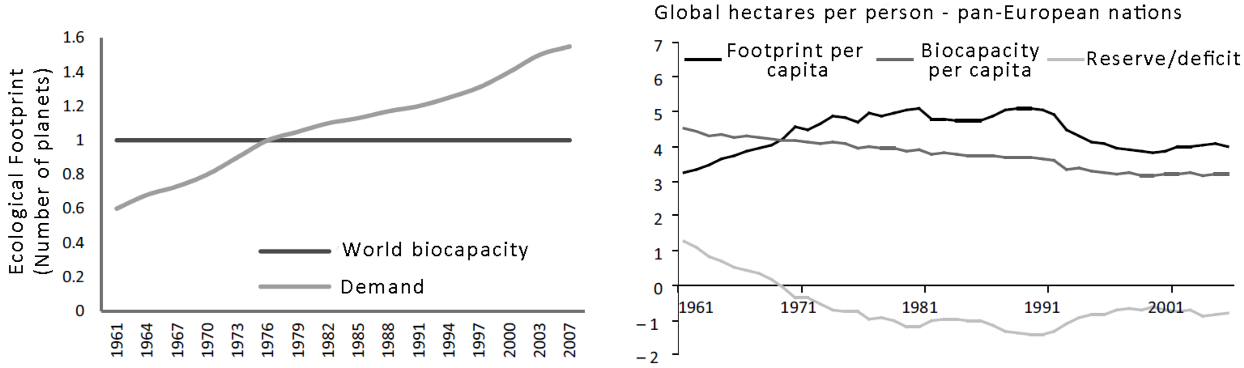

THE ECOLOGICAL FOOTPRINT can be calculated for an INDIVIDUAL, a GROUP or a PRODUCT, and is reflected in consumption per one person (group or product), i.e. in the level of resource consumption.

So, the ECOLOGICAL FOOTPRINT is the sum of all the environmental impacts of a product throughout its life cycle.

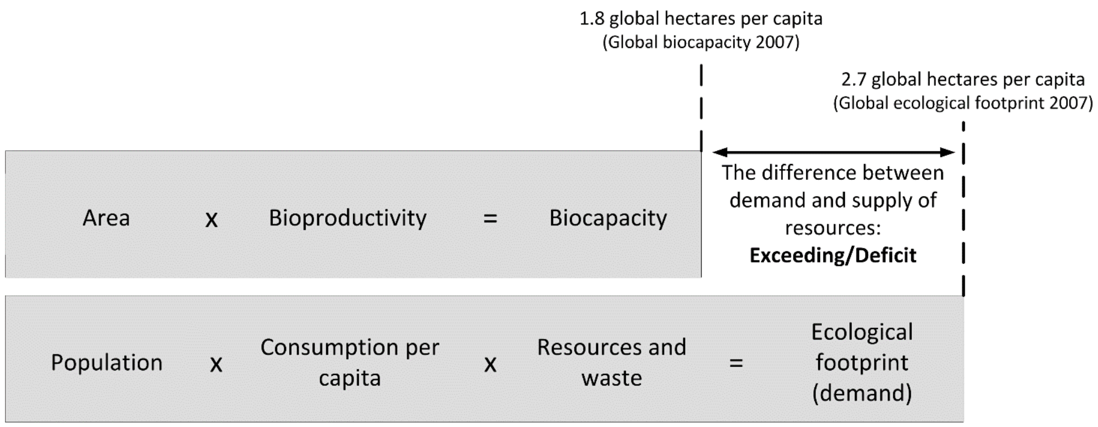
*Table 3: Global ecological footprint and biocapacity over time in global hectares per person [Source: Global Footprint Network, 2009., www.footprintnet-work.org/atlas]*

| | 1961 | 1965 | 1970 | 1975 | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2007 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Global population [in trillions] | 3.1 | 3.3 | 3.7 | 4.1 | 4.4 | 4.8 | 5.3 | 5.7 | 6.1 | 6.5 | 6.7 |
| Ecological Footprint | 2.4 | 2.5 | 2.8 | 2.8 | 2.8 | 2.6 | 2.7 | 2.6 | 2.5 | 2.7 | 2.7 |
| Biocapacity | 3.7 | 3.5 | 3.1 | 2.9 | 2.6 | 2.4 | 2.3 | 2.1 | 2.0 | 1.8 | 1.8 |
| Ratio of ecological footprint to biocapacity | 0.63 | 0.73 | 0.88 | 0.97 | 1.06 | 1.07 | 1.18 | 1.24 | 1.29 | 1.45 | 1.51 |

[17] *The ecological footprint also represents a simplified method of LCA study.*




*32. Figure_Global ecological footprint and biocapacity(left); ratio of biocapacity, demand and ecological footprint (right)*




*33. Figure_Parameters that determine how much the ecological footprint exceeds the biocapacity [Source: Global Footprint Network, 2009, www.footprintnetwork.org/atlas]*

*Table 4: Ten countries with the largest ecological footprint [Source: "Ranking America", 2009]*

| | Country | Global hectares per person |
|---|---|---|
| 1. | Luxembourg | 10.2 |
| 2. | United Arab Emirates | 9.5 |
| 3. | USA | 9.4 |
| 4. | Kuwait | 8.9 |
| 5. | Denmark | 8.0 |
| 6. | Australia | 7.8 |
| 7. | New Zealand | 7.7 |
| 8. | Iceland | 7.4 |
| 9. | Canada | 7.1 |
| 10. | Norway | 6.9 |

The BIOCAPACITY of the Earth is always constant. Mankind consumed 65% in 1961, 120% in 1990, 125% in 1995, and today over 150% of the Earth's biocapacity, and this percentage is increasing by the day. It won't be long before we need the resources of two planets of the Earth to meet our needs.

The DEMAND[18] for resources represents the needs of the human population at the global level. The supply of resources varies from year to year in relation to the management of ecosystems and their degradation (deforestation, etc.), depending on the needs of agriculture (irrigation, use of artificial fertilizers), climate and various other factors.

## RAW MATERIALS


*34. Figure _Products made of different raw materials*

### ANY PRODUCTION OF GOODS REQUIRES:

_raw materials,
_installations, equipment, tools, technology,
_human mental and physical activity and work.

Raw materials are very important for the production process.

Natural resources can be:

_RENEWABLE - where raw materials can be restored in a very short period of time, such as forests,
_NON-RENEWABLE - where raw materials are either in limited quantities, as some ores, or take a very long period of time to form, as crude oil.

[18] *When it comes to energy needs, raw materials and other resources, terms such as needs, demand or requirements are synonyms and will continue to be used equally,*

## SELECTION OF MATERIALS

The first step in the design of each product is the choice of materials. It is a complex process, because the choice of materials determines the durability of the product, whether it can be recycled or not, and many other things. A designer can minimize the impact on the environment significantly by proper selection of materials. The pursuit of a sustainable product imposes a transition to renewable resources in many areas. Seeds (sunflower, edible oil) can be a source for obtaining plastics, soybeans can be a source for less harmful paints and coatings, glue or ink for the printer. From the manufacturer's point of view, in many cases there is no difference in quality (physical or chemical) between materials coming from renewable resources, or those from limited resources (e.g. aluminum, glass, paper). Therefore, many different materials can meet design specifications. This does not mean, of course, that plastic should not be used, but it should be reused (e.g. for food packaging).

*35. Figure_Example of the use of recycled materials in the production of new products: lamp made of glass bottle (left), pen holder made of plastic bottle (center) and book cover made of keyboard (right)*

Product life begins with the acquisition of materials. One of the ecodesign rules says that the designer should use as few materials as possible, and only those materials, if possible, that come from renewable sources, because the sources on the Earth are generally non-renewable. The impact of materials on the environment as part of the product life cycle begins with their extraction or harvesting and continues with processing, transport and final transformation into a product. The impact of the material on the environment depends primarily on its source, e.g. recycled aluminum affects the environment much less than the primary one. It is not possible to establish a clear hierarchy of the impact of materials on the environment, because materials are assessed according to several criteria, e.g. their source, processing methods, impact on energy efficiency, durability and recyclability.

The typical classification of materials divides them into NATURAL and ARTIFICIAL. Natural materials can be found in nature and they are wood, stone, coal, bones, corals, cotton, silk, fur, natural rubber, wool... If natural materials are transformed by physical or chemical processes, they become artificial materials, e.g. cement is obtained by burning limestone.

The dilemma that exists is: should natural or artificial material be chosen for the product?

RECOMMENDATION: IT IS BETTER TO CHOOSE NATURAL MATERIALS THAN SYNTHETIC ONES.

Materials used in ECO PRODUCTS:

_should come from renewable/sustainable sources,
_their impact on the environment during extraction, transport and processing should be minimal,
_they must not be hazardous for people and the environment (both as a product and as a waste),
_must be 100% recyclable.

Wood is considered an ENVIRONMENTALLY FRIENDLY raw material, because it grows in nature and the traditional process of wood transformation does not lead to major pollution. However, apart from a few exceptions, it cannot be said that wood is recycled. However, as a waste, wood is not harmful to the environment because it is BIODEGRADABLE[19].

## IMPACT OF MATERIALS ON THE ENVIRONMENT

### TOXICITY

There are 30,000 anthropogenic chemicals, which are often related to the production of materials. The best example of the hazardous nature of the production of chemicals is the city of BHOPAL in India, i.e. an accident that occurred in 1984, when methyl isocyanate killed about 4,000 people and affected tens of thousands more [Wikipedia, Bhopal_disaster]. Then there are POPs (Persistent Organic Pollutants), DDT, PCBs. ASBESTOS was once considered a magical material, while today it is known to be carcinogenic, and there are various other worrying chemicals and materials.

[19] *Biodegradability refers to the ability of a material to decompose after interactions with biological elements.*

## RoHS DIRECTIVE

The materials PROHIBITED by the RoHS directive (Restriction of the use of certain Hazardous Substances in electrical and electronic equipment - 2002/95/EC) are:

_Hg – mercury,
_Pb – lead,
_Cd – cadmium,
_$Cr^{6+}$ – hexavalent chromium,
_PBB – polybrominated biphenyls,
_PBDE – polybrominated diphenyl ethers.

## MATERIALS PROHIBITED/RESTRICTED FOR USE IN THE EUROPEAN UNION

Certain materials are prohibited or restricted for use in the EU. Among them are:

_benzene,
_asbestos and asbestos fibres,
_polychlorine biphenyls (PCBs) and polychlorine triphenyls (PCTs),
_carcinogens, lead carbonates and sulphates, mercury and arsenic compounds,
_pentachlorophenol and its compounds (PCP),
_cadmium (Cd),
_ugilec 121, ugilec 141 i DBBT,
_various flammable substances,
_hexachlor ethane,
_CMR - carcinogenic, mutagenic, or toxic for reproduction,
_chlorine solutions, carcinogens, mutagens and teratogens,
_batteries and accumulators with Pb, Hg, Cd,
_short-chain chlorinated paraffins (SCCPs),
_nitrogenous dyeing agents (nitro dyes and varnishes),
_Penta BDE, Octa BDE.

## MATERIALS FROM THE ASPECT OF RECYCLABILITY

*Table 5: Recyclability of certain materials*
*[Source: CES EduPack 2006, Granta Design Limited, Cambridge, UK]*

| Material | | Recyclability |
|---|---|---|
| Ceramics and glass | Concrete | no |
| | Brick | no |
| | Silica glass | yes |
| | Soda lime glass | yes |
| | Alumina | no |
| | Aluminum nitride | no |
| | Silicon | no |
| | Silicon carbide | no |

| | | |
|---|---|---|
| Metals and alloys | Cast iron | yes |
| | Gray iron | yes |
| | High carbon steel | yes |
| | Low-alloy steel | yes |
| | Low carbon steel | yes |
| | Medium carbon steel | yes |
| | Stainless steel | yes |
| | Aluminum alloys | yes |
| | Cast bronze | yes |
| | Lead and tin alloy for soldering | yes |
| | Cast magnesium AM20 | yes |
| | Cast nickel-beryllium alloy | yes |
| | Titanium alpha alloy | yes |
| | Tungsten alloys | yes |
| | Alloys of zinc and aluminium | yes |
| Hybrids: composites, foams and natural materials | Carbon Fibre Reinforced Composites (CFRP) | no |
| | Polyester and glass fibre composites (GFRP) | no |
| | Flexible polymer foams | no |
| | Solid polymer foams | yes |
| | Bamboo | no |
| | Cork | no |
| | Wood | no |
| Polymers and elastomers | Butyl rubber | no |
| | EVA | yes |
| | Polyisopropene (IR) | no |
| | Natural rubber (NR) | no |
| | Polychloroprene, Neoprene (CR ) | no |
| | Polyurethane (eiPU) | yes |
| | Silicone elastomers | no |
| | Acrylonitrile butadiene styrene - ABS (filled with aluminum) | yes |
| | Cellulose polymers (CA) | yes |
| | Ionomer (I) | yes |
| | Aromatic polyamides - PA (Polyamides, Nylons) | yes |
| | Polycarbonate, carbon-filled - PC | yes |
| | Polyether ether ketone, glass-filled - PEEK | yes |
| | Polyethylene, glass-filled - PE | yes |
| | Polyethylene terephthalate - PET carbon-filled | yes |
| | Polymethyl methacrylate (Acrylic) - PMMA | yes |
| | Polyoxy methylene (Acetal) - POM mineral-filled | yes |
| | Polypropylene, carbon-filled – PP | yes |
| | Polystyrene, glass-filled – PS | yes |
| | Polyurethane – tpPUR | yes |
| | Polyvinyl chloride – tpPVC | yes |
| | PTFE, glass-filled | yes |
| | Epoxides | no |
| | Phenols | no |
| | Polyester | no |

## DISCUSSION REGARDING MATERIALS

The selection of raw materials is the main activity of the designer in the so-called EMBODIMENT[20] design phase.

It is therefore necessary to focus on:

_material reduction,
_eliminate the application of toxic materials,
_preserve raw materials by their adequate use and reduction of wastes, replace rare and expensive materials, i.e. reduce their use, with various other materials,
_recycle materials by reusing or reprocessing them, recycle components, modules assemblies, or entire products,
_focus on the use of materials that do not require significant energy for their processing,
_reduce the number of components, i.e. strive for simplicity of the product as much as possible, which is one of the basic rules of product design and development.

## ECO PROCESSES

Design plays a key role in the product lifecycle, while the process itself is is used to follow current market needs or new ideas, or it may be part of the company's strategic development plan. It starts with production planning and ends at the end of the life of the product. To facilitate REPROCESSING or RECONDITIONING (bringing the product back to a certain state),[21] designers can apply special measures during the product design and manufacturing process (DfX approach[22] and use of "SMART" materials). Options apply to RECYCLING capabilities at all stages of the design process. "CLEAN" TECHNOLOGIES are of particular importance when designing ECO PRODUCTS[23].

ECOLOGICAL PROCESSES are also known as "CLEAN TECHNOLOGIES". The manufacturing process is closely related to the selection of materials. A good and efficient process depends on the quality of the design. Reducing the number of components and/or different materials, as well as a simpler design or assembly process are some of the ways to achieve optimal processes.

### A CLEAN TECHNOLOGICAL PROCESS IS ONE THAT:

_avoids (minimizes) waste generation,
_minimizes toxic emissions,
_ensures efficient use of energy.

---

[20] *Embodiment design is a stage in product design where the shape and dimensions of the product are developed,*
[21] *See note on page 42,*
[22] *For DfX approach see page 11,*
[23] *See page 40.*

## TECHNOLOGICAL PROCESSES AND "CLEAN" TECHNOLOGIES

The impact on the environment during the last stage can be reduced by careful selection of materials and processes. This concerns both the team of designers and the previously presented activities.

Design for Manufacture - DfM[24] is an important limitation of the design process, because together with Design for Environment - DfE, "CLEAN" MANUFACTURING, and "CLEAN" TECHNOLOGIES, it can minimize pollution and contribute to long-term sustainable development. We need to focus on pollution prevention at the earliest stage of product development. Achievement of "CLEANER" PRODUCTION is achieved on three levels:

_minimise waste, energy consumption within the process of operating unit,
_modify technology to use the same materials but more efficiently and with less energy,
_redesign the process completely and change input material(s).

The definition of "CLEAN" production under the United Nations Environment Programme (UNEP) reads:

"A conceptual and procedural approach to production that demands that all phases of the life cycle of a product or of a process should be addressed with the objective of prevention or minimization of short- and long-term risks to human health and to the environment."

"CLEAN" PRODUCTION focuses on the reduction of pollutant emissions, and introduces pollution prevention requirements, which must be considered throughout the life cycle, i.e. covers the entire supply chain of materials and energy in the production process.

### "CLEAN" TECHNOLOGY IS ALSO DEFINED AS:

"A means of providing a human benefit which, overall, uses less resources and causes less environmental damage than alternative means with which it is economically competitive."

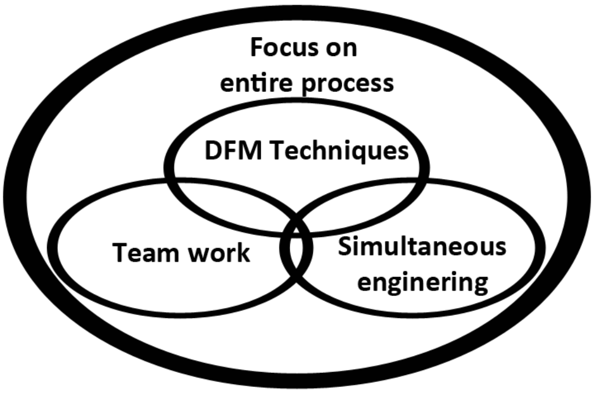
The definition of "CLEAN" TECHNOLOGY includes two elements that go beyond the definition of "CLEAN" PRODUCTION, namely:

_"CLEAN" TECHNOLOGY concentrates not only on products or processes, but on the BENEFIT THE PRODUCT OR PROCESS PROVIDES. This focus on MEETING HUMAN NEEDS rather than providing material artefacts links Clean Technology explicitly to Sustainable Development.
_another new element is the idea OF ECONOMIC EFFICIENCY, i.e. efficient use of resources that can be deployed anywhere.

---

[24] *See DfX approach on page 11.*

"CLEAN" TECHNOLOGY implies improvement through redesigning the product or process or rethinking the way the service is delivered. "CLEAN" TECHNOLOGY is more a WAY OF THINKING than a set of "heavy" technologies.




*36. Figure_Elements of the design for manufacture*

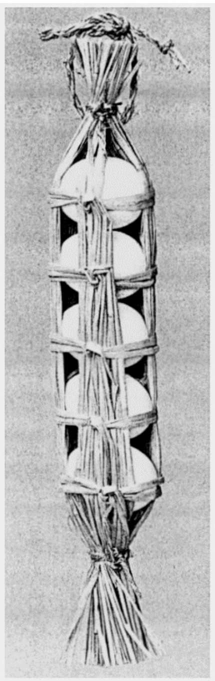
## ECO PRODUCT

THERE IS NO PRODUCT THAT DOES NOT HARM THE ENVIRONMENT AT ALL.

An ECO PRODUCT is such a product that harms the environment to a satisfactory level.

An ECO PRODUCT must:

_minimally harm the environment during raw materials extraction phase, production phase, use phase, or as waste,
_use a minimum of materials and energy throughout its life cycle,
_use recycled materials and enable the continuity of the recycling process,
_not produce large quantities of waste, due to overpacking or too short LIFESPAN[25],
_not use materials from sources at risk of extinction (animals, plants or matter),
_not entail violent actions towards animals,
_not produce any risks to human and animal health.



*37. Figure_Eco packaging of eggs*

[25] *See note on page 47.*

## LYFE CYCLE THINKING - KEY TO THE APPLICATION OF ECODESIGN

As already stated, the application of ECODESIGN is primarily oriented towards the development of an (eco-sustainable) product. In addition, ECODESIGN is a challenge for engineers, because engineers involved in product development are most often not experts in environmental issues.

Life Cycle Thinking - LCT is a "*HOLISTIC (systemic) consideration of environmental impact, caused by the product during its life cycle phases.*"

### THINKING:

When you think about product quality:

_What do you take into consideration?
_What qualities of the product do you assess before purchasing it?
_What qualities of the product attracts you?

By holding two products in our hands, we sometimes think that a heavier one is at the same time better:

- ✓ Why is that?
- ✓ Is it because we think that the heavier product contains "better" materials (for example metal instead of plastic)?
- ✓ Is it because we think that just because it's heavier, the product lasts longer?
- ✓ Is it because we consider plastic "cheaper" or "weak"?
- ✓ In addition to the material the product is made of, its performance and appearance (aesthetics) are two important parameters that are taken into account when purchasing the product. Sometimes we're willing to spend a lot of money just because we're attracted by appearance. When you intend to buy a product, the price is another important factor for making a decision.

### ANOTHER POINT OF VIEW:

- ✓ Have you ever considered assessing a product from the standpoint of protecting the human environment?
- ✓ Have you ever thought about how this product affects the environment?
- ✓ Have you thought about how much negative impact this product will cause for the rest of its life cycle?
- ✓ Have you ever thought of taking the environmental performance of a product as a selection criterion?

Imagine you want to buy a regular office chair:

- ✓ Can you imagine that this product can produce toxic waste (although, of course, it does not contain any toxic material)?
- ✓ Has it ever occurred to you that the use of air conditioning in your car contributes to global warming?

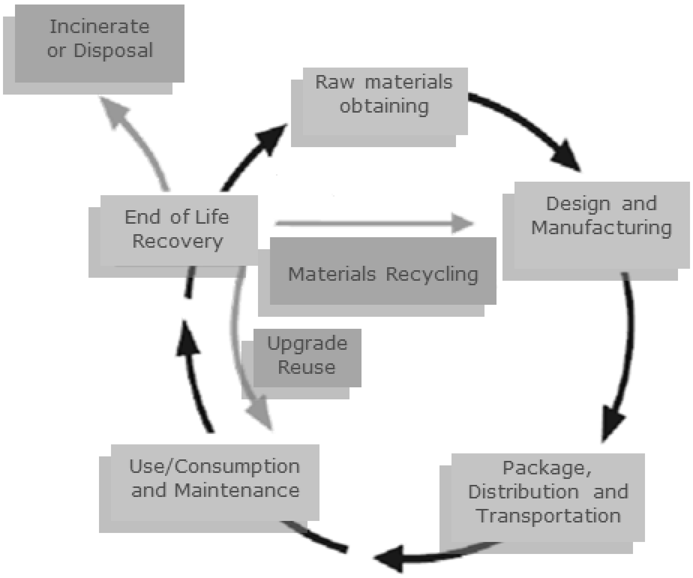
- ✓ Did you know that regular jeans travel 50,000 miles around the world before they reach the store where you buy them?
- ✓ Can you imagine that more than 14,000 kg of material and an additional 30,000 litres of water are needed to produce your PC?

Maybe you're not close to this kind of thinking?

This is because you have probably only thought about the use phase of the product, where you are directly "faced" with the product and are in contact with it. But that product went through several different stages, before you could buy it in the store, and it will go through a few more after you put it away. All these stages affect man's environment.

## THE LIFE CYCLE OF A PRODUCT

The product undergoes successive and interconnected stages that are potentially environmentally hazardous. These stages (phases) are called LIFE CYCLE OF A PRODUCT, because the life of a product starts from *"collection of raw materials, through production, transport and use, to final disposal (according to ISO 14040: 1997 – 5 phases of the product life cycle)."*




*38. Figure_Life cycle of a product*[26]

RAW MATERIALS are obtained by extraction or harvesting, i.e. natural resources are converted into raw materials, e.g. bauxite to aluminium, iron to steel, oil to plastic, sand to glass, etc.

THE MANUFACTURE includes the design of the product and its development according to the product specifications. Based on the production documentation (lists of

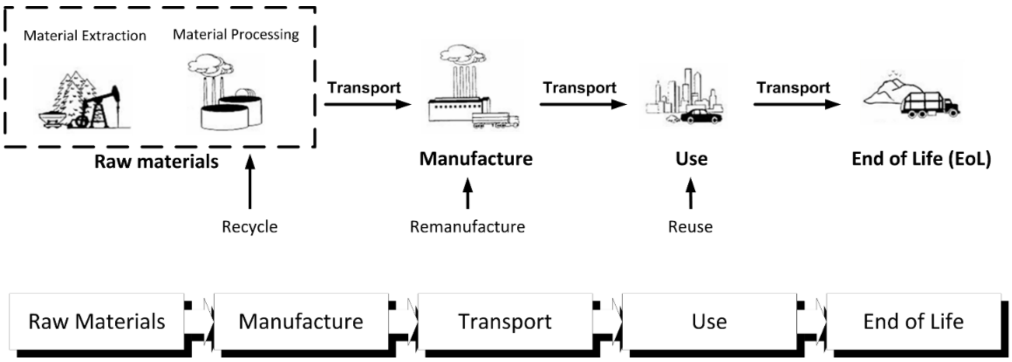
[26] *Reuse, upgrade, reconditioning, remanufacture, reprocessing and recycling are all "product rebirth" processes.*

requirements, drawings and 3D models, etc.) the raw materials are transformed into a product by means of specific processes (casting, forging, thermoforming, etc.). In all these transformation processes, additional materials are used (oxygen and acetylene are used in joining parts by welding).

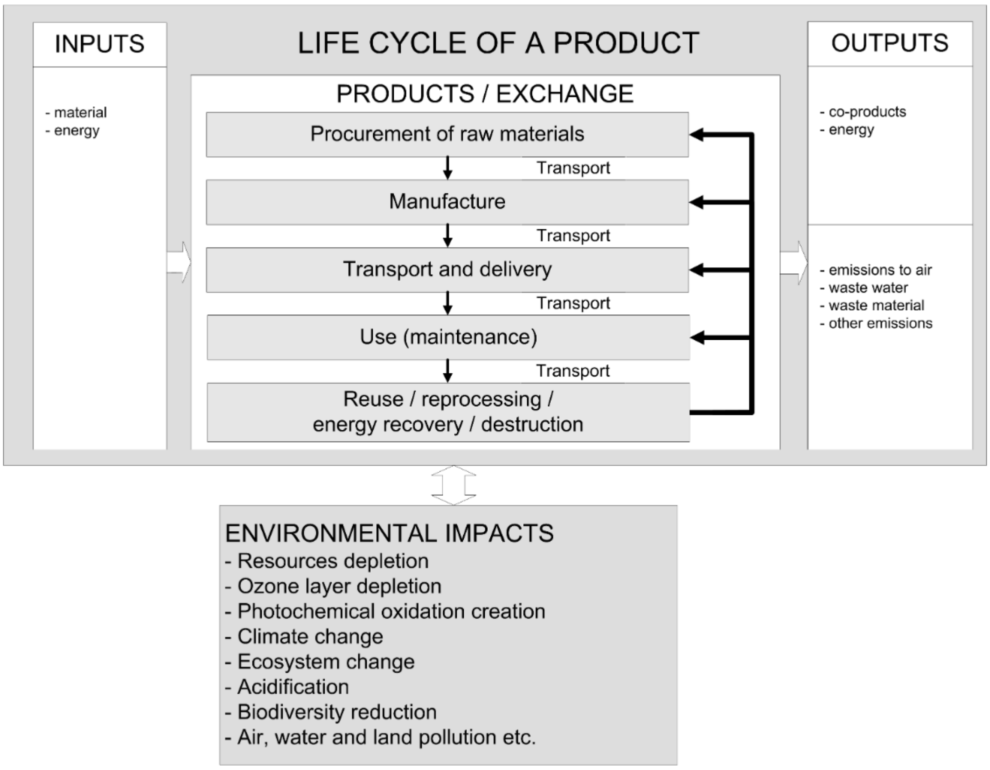
DISTRIBUTION is the next step, after the production and packaging of the product. The product is transported from the manufacturer to the client/consumer. Some products do not go directly to the consumer, but through multiple intermediaries.

The USE of the product may also include maintenance and repairs that extend its useful life.

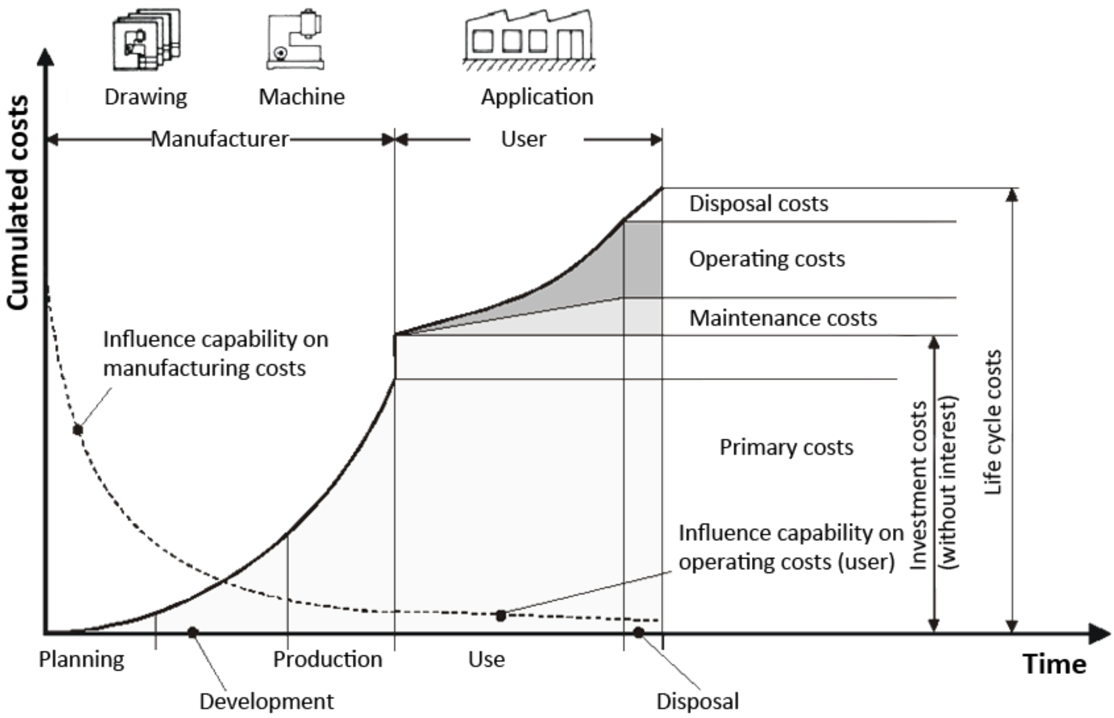
The END OF LIFE of a product occurs when it can no longer be used for a variety of reasons. Then it is either DISPOSED OF or RESTORED in order to be REUSED or RECYCLED.



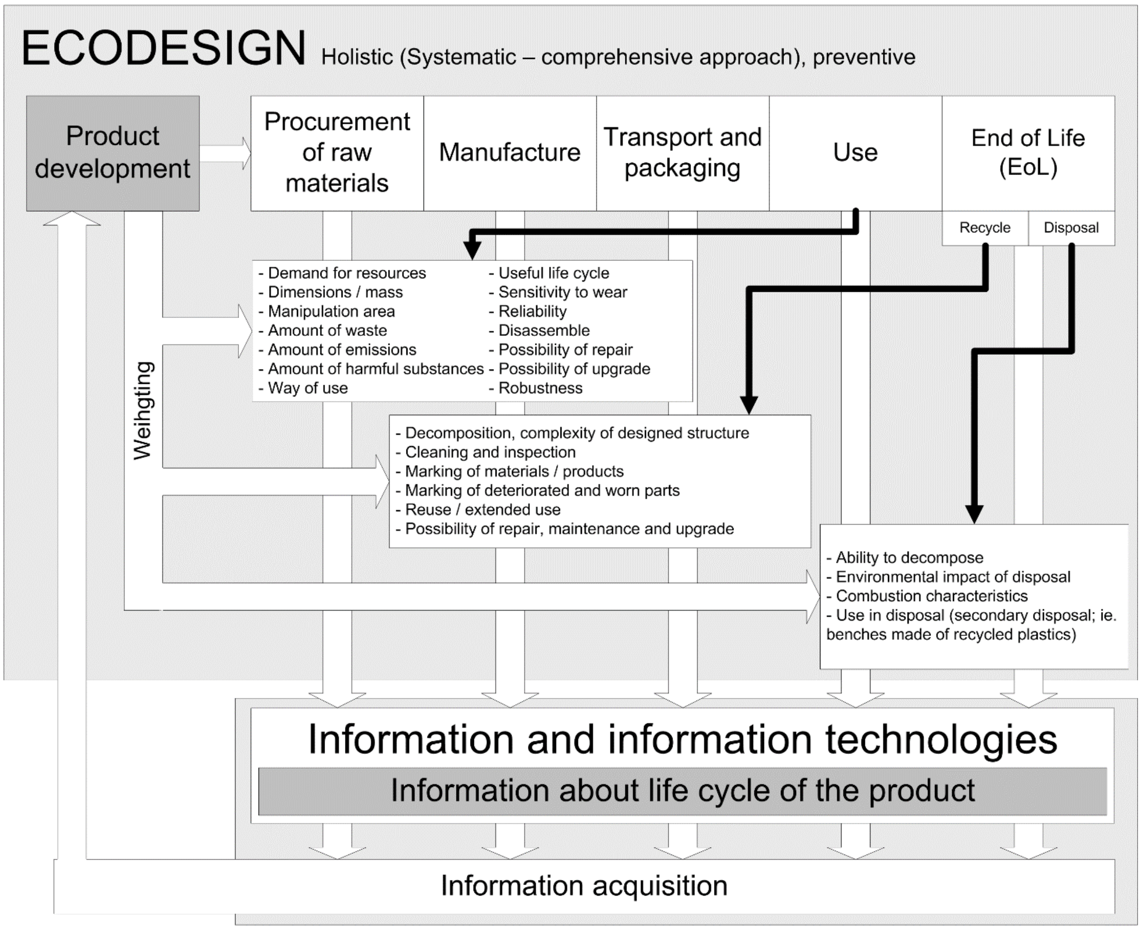

*39. Figure_Successive phases of the product life cycle and their simplified overview according to ISO 14000*




*40. Figure_Product life cycle and environment interaction chart*




*41. Figure_Product life cycle costs [Source: Workshop "State of the Art in Design Science", Editor: M. Ognjanović, TEMPUS project JEP 40069, "Design in Mechanical Engineering", Belgrade, XI 2006]*




*42. Figure_Holistic approach to product development*

## RAW MATERIALS PHASE

In order to make any product, different materials are required! Imagine one of your household appliances, like a washing machine. Various materials were used in the production of the same, such as, among others, metals (steel sheets), glass or plastic. Do you know how these materials were obtained, how they were EXTRACTED and what processes are needed for this? Our interest must start, for example, from the point of extraction of iron ore for the production of steel, or the point of extraction of crude oil for the production of plastics. RAW MATERIALS are processed into materials that are further used in production. If we want to go deeper into the analysis, we also need to take into account all the energy needed for extraction and processing of raw materials. Analyzing even more deeply, the change (transformation) of the land that occurs by digging and extracting raw materials should also be taken into account.

### WHAT TYPES OF ENERGY ARE THERE AND HOW ARE THEY OBTAINED?

Take, for example, electricity: electricity can be obtained from hydroelectric power plants, solar power plants or wind turbines, etc. Most of the available electricity was obtained from thermal power plants using fossil fuels (coal or gas - non-renewable energy sources) or from nuclear power plants. Nuclear power plants make nuclear waste that is still difficult to handle. Combustion of fossil fuels generates combustion co-products such as ash, carbon dioxide ($CO_2$) and methane ($CH_4$). Carbon dioxide and methane are Green House Gases - GHG. The existence of a large amount of these gases in the atmosphere is the cause of a phenomenon called Global Warming - GW! Any production needs energy, and therefore energy production is necessary, mainly from fossil fuels! We all know that fossil fuel supplies are limited. With the growth of industrialization, the need for fossil fuels and resources has also grown, so it won't be long before we need the resources of the two planets of the Earth to meet our needs!

## MANUFACTURING PHASE

When the materials are extracted, they can be processed into parts and components during the PRODUCTION PROCESS. These components can be assembled into a final product. When making a product, we need tools and machine equipment (machine tools). Machines and tools use electricity. In addition, ADDITIONAL MATERIALS are required, such as chemical substances, coolants, glue or water. If we look a little more closely, we should also consider all the energy needed for lighting, heating or cooling the factory. This is so-called ADDITIONAL ENERGY or OVERHEAD ENERGY. Experience shows that additional energy can grow up to 200% of the total energy needed for production. All the energy required for the transport of components and parts (internal transport) must also be taken into account.

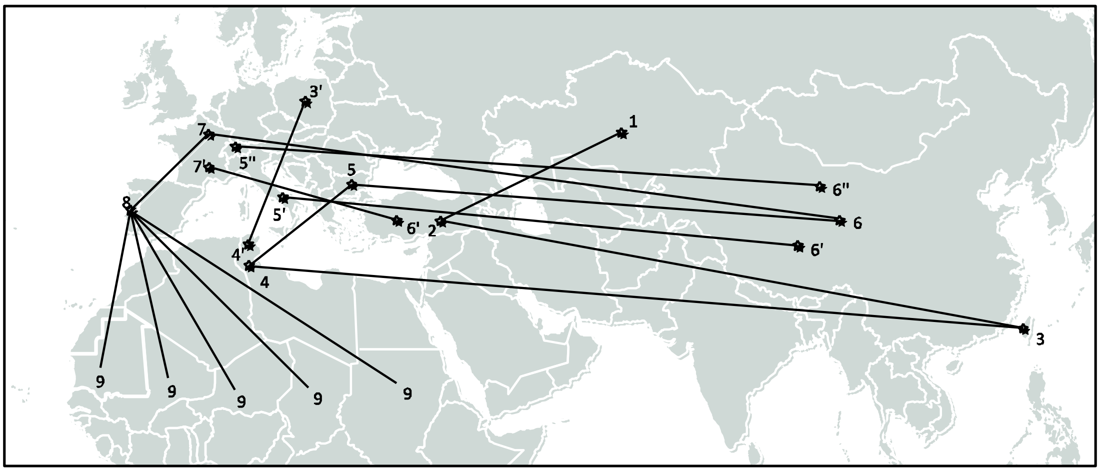
## DISTRIBUTION PHASE (TRANSPORTATION AND PACKAGING)

The final product is PACKED and DELIVERED to the customer or consumer (retail). Depending on the type of TRANSPORT (airplane, ship, train or truck), different energy consumption and gas emissions occur. However, this is not all about transport. So far, transport needed for the distribution of products has been considered. In a more detailed analysis, transport between different suppliers and the factory must also be taken into account. These may be suppliers of materials as well as suppliers of finished parts and components, etc.

Let's go back to those jeans that were mentioned earlier. Usually, jeans travel about 50,000 km (the Earth's circumference is 40,000 km) before consumers in Europe can buy them. The question arises, what does this "trip around the world" consist of (Figure 43)? Consider that cotton, needed to produce jeans, is grown in Kazakhstan (1). Cotton is harvested and sent to Turkey (2) to produce yarn. Weaving is carried out in Taiwan (3). The paint required for textile painting comes from Poland (3'), and painting itself is done in Tunisia (4). In Bulgaria (5), textiles are softened by various processes. Buttons, imported from Italy (5'), as well as lining imported from Switzerland (5''), are sewn in China (6). In France (7), the surface of textiles is cleaned with pumice stone imported from Turkey (6'). The trousers are then sent to Portugal (8) where the *"Made in Portugal"* label is sewn onto them. From Portugal, jeans are distributed throughout Europe for sale. Just try to imagine the enormous amount of energy needed to transport between all these countries and the amount of gases emitted!

**Note: Combustion of 1 litre of fuel produces about 2.5 kg of $CO_2$!**

About 45% of used jeans are distributed to Africa (9) after use as second hand goods.




*43. Figure_"Trip around the world" of regular jeans…*

## USE PHASE

In order to work properly, the product may require energy or secondary (additional) materials, such as e.g. lubricants, water or refrigerants. During the USE PHASE, the product must perform its function.

Consequently, the LIFE OF A PRODUCT is the time during which the product performs its function correctly.

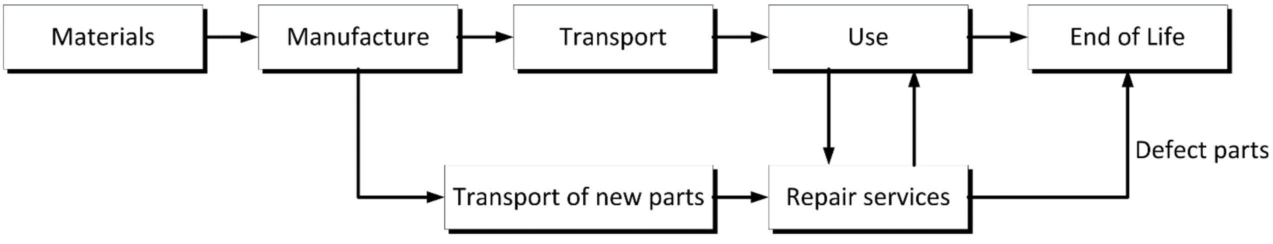
Most consumers deals with a product during this phase. Some environmental impacts at this stage may cause discomfort for the user. Imagine products, e.g. household appliances, that produce high noise and vibration when in use. Also, imagine products that need batteries to work. In addition to the fact that batteries cause a lot of pollution after the end of their life, users of such products have to spend a lot of money to buy batteries. In the case of battery-operated products, it is clear that by reducing the need for batteries, we also reduce the negative environmental impact and the costs of using the product.

The impacts on the human environment, as well as the costs, depend on the BEHAVIOR OF THE USER, i.e. on how the user "USES" the product. Imagine a washing machine that only works half-loaded; the amount of water and electricity required can be the same as when the machine is fully loaded. However, the output, i.e. the amount of washed clothes is only half of the capacity. This means that the price per one wash cycle and the relative impact on the environment (in relation to the output) is twice as high.

The designer, however, has no influence on how the product will be used. All he can do is provide a design that prevents inadequate use of the product. In the use phase, there is an interaction between the user and the product. Usually this interaction stops when the product is no longer working properly and is disposed of (thrown away) by the user. The product then enters a new phase called END-OF-LIFE[27].

## MAINTENANCE AND REPAIR SERVICES

THE REPAIR CYCLE delays the onset of the end-of-life phase of the product. Parts and components of the product may be repaired several times and reused. Defective parts, those that are irreparable, broken or worn, must be replaced by new ones. These new parts must first be manufactured, then transported and distributed, before being used in the repair cycle. Defective, i.e. replaced parts have reached the end-of-life phase. However, when some defective parts cannot be repaired or are not economically worth changing, the product finally reaches the end-of-life phase.




*44. Figure_Repair cycle chart [Source: Wimmer, 2007]*

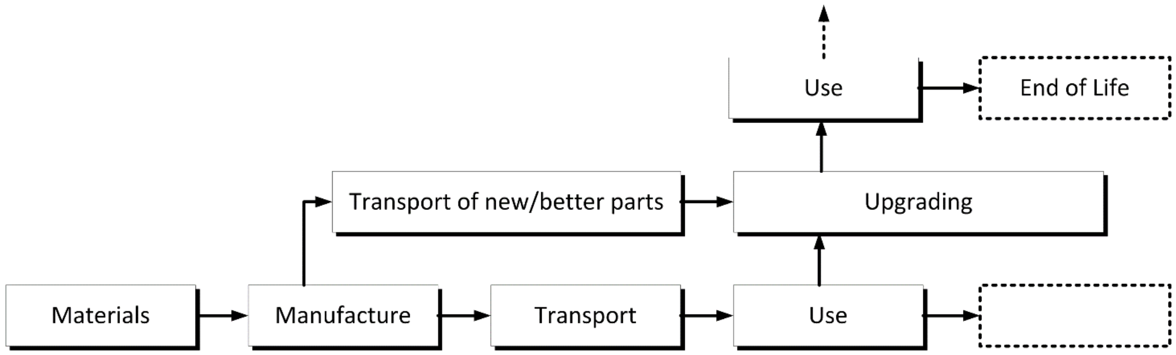
[27] *A distinction should be made between the life cycle of a product, which consists of all the phases through which the product undergoes from the extraction of raw materials it consists of to the final disposal at a landfill, and the life span, or service life of the product, which is practically reduced to the phase of use, i.e. the period of proper functioning of the product. The life span, i.e. the service life of the product ends when it stops to meet its purpose.*

## UPGRADE

The product is inspected in the maintenance and repair cycle. In addition to maintenance and repair of parts, the goal is to improve and optimize the functionality of the product. Products with a modular structure can be upgraded more easily. UPGRADE - QUALITY IMPROVEMENT delays the end-of-life phase of the product.

Imagine a personal computer (PC): by changing its components, part by part (e.g. RAM, hard disk or graphics card), the performance and functionality of the computer are improved; the computer use phase is extended.

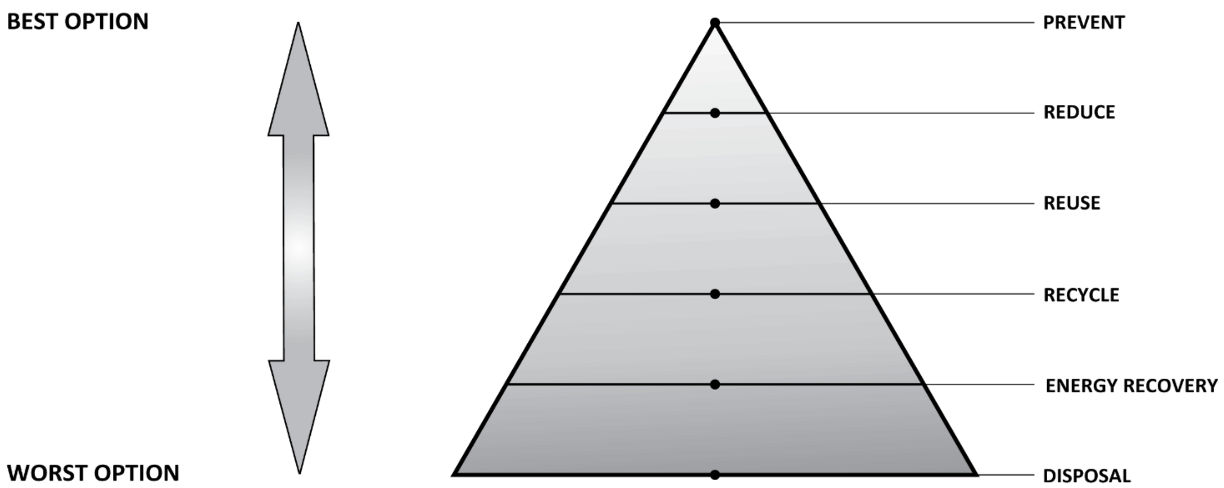
The different phases of the product life cycle, are not only linear sequences but also contain different cycles and loops.




45. Figure_Quality improvement cycle - Upgrade [Source: Wimmer, 2007]

## END-OF-LIFE PHASE - EoL

There are several different ways of treating the product and its parts after THE END OF ITS LIFE (EoL), i.e. when the product is no longer usable and becomes waste. For example: the product may be DISASSEMBLED, components and parts may be REUSED, and used materials may enter the RECYCLING cycle. The following figure shows the hierarchy of procedures for the case of integrated waste management.




46. Figure_Prevention pyramid in waste management

## WASTE MANAGEMENT, SOLID WASTE MANAGEMENT - SWM

When the product reaches the end of its life, it becomes waste. There are several WASTE MANAGEMENT options:

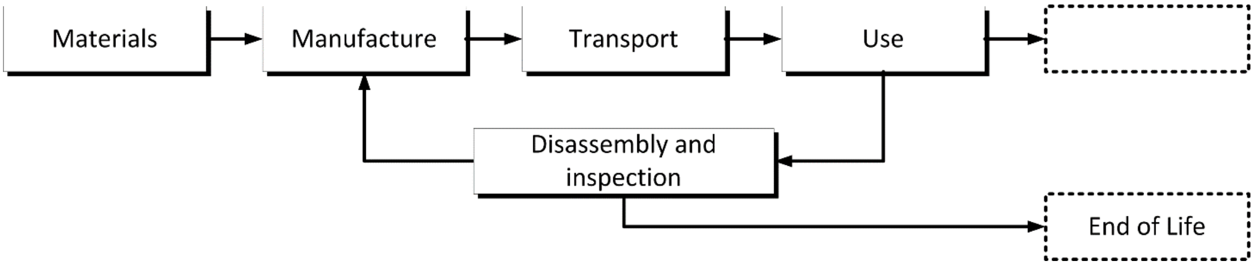
_reuse
_remanufacture
_recycling
_incineration (biological or thermal treatment of waste)
_landfill

Note: the last option is the most unfavorable, and the first three options represent a resurgence of the product[28].

When designing a product, the following priorities should be considered: DURABILITY, UPGRADE, REUSE, RECYCLING, ENERGY RECOVERY AND DISPOSAL. This means that the designer should first develop the extended-life product and then try to model the product structure so that it can be improved. REUSE represents the highest level of regeneration, whether the product is used for the same purpose or not. Then there is UPGRADE, REMANUFACTURE and RECYCLING. If none of the above is possible, the last option is to INCINERATE the waste in order to at least restore some of the energy. In the event that this last option is not achievable, the waste IS DISPOSED OF AT A LANDFILL, which must be well insulated in order not to harm the environment (soil, air, groundwater pollution).

## REMANUFACTURE, REPROCESSING

In this cycle, the product is DISASSEMBLED after use into parts and components. These parts and components are INSPECTED and REPAIRED if necessary. The parts thus checked and repaired shall be returned to their original use. Parts and components, which cannot be repaired and reused, end their service life. These parts may enter the recycling cycle.




*47. Figure_Reversed cycle of manufacture [Source: Wimmer, 2007]*

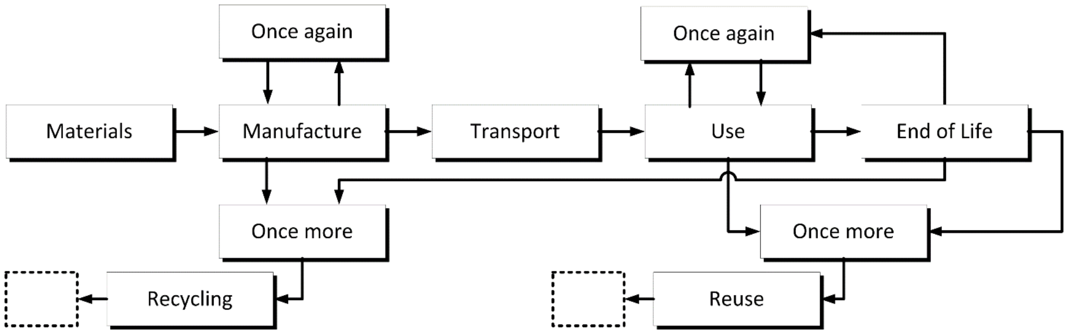
[28] *See note on page 42.*

## RECYCLE, RECYCLABILITY

RECYCLING is the restoration of useful materials in discarded products. The difference between RECYCLING and REUSE is that RECYCLING INVOLVES DESTRUCTION OF THE PRODUCT STRUCTURE, while REUSE means that the product, or its components, are reintroduced into use WITHOUT DESTROYING THE STRUCTURE.

Theoretically, any man-made product can be recycled (metals, glass, cardboard, paper, as well as most plastics). However, the level of restoration may differ. Product recycling assumes a system that is capable of collecting and disassembling products, restoring and classifying materials. As can be seen in Figure 48 (RECOMMENDATIONS OF VDI 2243), waste collected during the production, use and end-of-life phases, as well as defective parts and even the entire product can be fed into the recycling cycle.

In general, there IS A CLOSED-LOOP and OPEN-LOOP RECYCLING.




*48. Figure_Recycling cycle [Source: Wimmer, 2007]*

In A CLOSED-LOOP RECYCLING, recycling materials are collected from a single product system, recycled and returned to the production cycle of the same product system. This intention should be assessed from an economic as well as an environmental point of view, given that processes, which must be applied in a closed-loop recycling, can cause re-pollution of the human environment.

In OPEN-LOOP RECYCLING, materials from one product system are recycled and then used in other product systems.

There are several well-established recycling cycles, such as the existing recycling cycles for glass, metal, paper and some plastics, for example PET - packaging.

### RECYCLABILITY:

### PRODUCT COMPONENTS CAN BE RECYCLED:

_if recycling is the best option,
_if the environmental impact of recycling is insignificant in relation to non-recycled products,
_if there are no blended materials, including adhesives,
_if the design allows disassembly,
_if materials can be identified.

POLYMATERIALS, MULTI-MATERIALS or COMPLEX materials are those materials that contain two or more materials from which the product is made (materials in layers, such as multilayer food packaging films).

## PRODUCT TYPES

Products can be classified into several types, according to the phase of their life cycle in which the products impact the environment the most. These types are:

_TYPE A: Raw material intensive product
_TYPE B: Manufacture intensive product
_TYPE C: Transport intensive product
_TYPE D: Use intensive product
_TYPE E: EoL (disposal) intensive product

## HISTORY OF ECODESIGN

The term ECOLOGY itself derives from the greek words OIKOS, meaning HOUSE or HOME and the word LOGOS, meaning SCIENCE, so ECOLOGICAL DESIGN or ECODESIGN would be ecology-related design or designing.

### EARLY '70s:

The first steps are being taken in the field of recycling, in developed countries and large cities. They are primarily recycling steel, plastic, copper, lead, aluminum, glass, paper, cardboard, artificial and natural fibres (cotton). Quantity, “quality” and the cost of waste become a problem to think about. This period is characterized by:

_collection of products out of use and their introduction into the production process as raw materials (REPROCESSING),
_increased costs of raw materials, especially after the major oil crisis,
_lower prices of recycled materials.

### MID '80s:

Issues arise relating to the environment and are becoming more and more burning (e.g. THE OZONE LAYER DEPLETION). It was concluded that RECYCLING IS NOT THE SAME AS “ENVIRONMENTALLY FRIENDLY”. Attention is paid to the conservation of natural resources and the choice of materials from the aspect of the environment and production methods. Environmentally friendly products are created and harmful emissions are analyzed.

## EARLY '90s - CONCEPTS OF SUSTAINABILITY AND SUSTAINABLE DEVELOPMENT:

In the early 1990s, there was a necessity for long-term evaluation of the products and effects of production: LIFE CYCLE ASSESSMENT (LCA). Analysis of obtaining raw materials, production, distribution, use and final disposal of the product is performed. A series of successive stages through which the product passes are called the product life cycle ("PRODUCT LIFE") - from "birth (design and production), to the final end of its life" (known as "CRADLE-TO-GRAVE"). REUSE or UPGRADE, as well as its RECYCLING of the product, has enabled the extension of its life and led to the CONCEPT OF LIFE CYCLE ASSESSMENT – LCA. Product Life Cycle Assessment deals with the analysis and evaluation of the environmental impact of a product at each stage of its life cycle. Thus, the designer knows and is aware of the consequences of his/her work on the environment at the time the product is just a concept.

## INTERNATIONAL ENVIRONMENTAL PROTECTION CONVENTIONS

_1985 – Vienna Convention for the Protection of the Ozone Layer,
_1991 – Basel Convention, which dealt with the control of the transport of hazardous waste and its elimination beyond national borders,
_1992 – United Nations Framework Convention on Climate Change - Rio de Janeiro, Brazil
_1997 – Montreal Protocol, which dealt with ozone depleting substances,
_2001 – Convention on Persistent Organic Pollutants (POPs), signed in Stockholm...

## STANDARDS AND LEGISLATION
## ISO 14000 AND EU DIRECTIVES

In the EU, ECODESIGN-related normative frameworks are incorporated in a wide range of environmental protection areas:

_Waste Management – WM & Solid Waste Management - SWM,
_electronic and electrical equipment (WEEE),
_restriction of the use of certain hazardous substances (RoHS),
_industrial machines,
_telecommunications and radio equipment,
_liability for damaged products,
_product safety, etc.

In the early 90s, ISO organization created certain regulations (ISO 14000).

Below is an overview of most of the major DIRECTIVES. Some directives and legislation will be dealt with in more detail later. According to THE WASTE CONSORTIUM AND SUSTAINABLE URBAN ENVIRONMENT AGENDA [EPSRC, 2008], major EU directives are:

_Waste Framework Directive (2006/12/EC),
_Waste Oil Directive (75/439/EEC),
_Groundwater Directive (80/68/EEC),
_Sewage Sludge Directive (86/278/EEC),
_Batteries & Accumulators Directive (91/157/EEC),
_Hazardous Waste Directive (91/689/EEC),
_Packaging and Packaging Waste Directive (94/62/EC),
_Integrated Pollution Prevention and Control Directive (96/61/EC),
_Landfill Directive (99/31/EC),
_End Of Life Vehicles (ELV) Directive (2000/53/EC),
_Incineration of Waste (2000/76/EC),
_directive on the prohibition (reduction) of the use of certain harmful substances in electrical and electronic equipment - Restriction of Hazardous Substances (RoHS) Directive (2002/95/EC),
_Waste Electrical and Electronic Equipment (WEEE) Directive (2002/96/EC),
_Ozone Depleting Substances (ODS) Directive,
_Animal By-products Regulations (1774/2002),
_Management of Waste from Extraction Industries Directive (2006/21/EC),
_Proposed Framework for the Setting of Eco-design Requirements for Energy-using Products (EUP) Directive, which is replaced by the Energy-related Products (ErP) Directive 2009/125/EC .

## ECO LABELING

### LABEL

"LABEL is an item used to identify something or someone, as a small piece of paper or cloth attached to an article to designate its origin, owner, contents, use, or destination" . [www.freedictionary.com]

The LABEL is also a marking that should provide the consumer with information about the subject product – a ONE-WAY CHANNEL OF COMMUNICATION BETWEEN THE PRODUCER AND THE CONSUMER.


49. Figure_Various labels and Eco labels

## ECO-LABELS

ECO-LABELS are used to help the consumer determine the environmental performance of the product. However, there is also a constant increase in FRAUDULENT ECO-LABELS[29] on the market, which arouse consumer suspicion and harm honest producers.

### EUROPEAN UNION ECOLOGICAL SYMBOL

50. Figure_“Flower” – EU Eco-label

[29] *See page* 64.

The EUROPEAN UNION ECOLOGICAL SYMBOL is a “FLOWER” with 12 blue, five-pointed stars, surrounding the capital letter “Є”. The flower is designed to encourage products and services that are more environmentally friendly and to help consumers recognize these products.

## EMAS

*51. Figure _EMAS label*

EMAS requires the organizations to improve their performance in relation to environmental protection, by using less raw materials, consuming less energy and producing less waste. All these steps help preserve the environment, reducing harmful impacts, and making companies more economically competitive.

## DESCRIPTIVE AND PROMOTIONAL LABELING

### LABELING CAN BE DESCRIPTIVE OR PROMOTIONAL (ADVERTISING).

Examples of descriptive inscriptions are: “MADE OF 100% RECYCLED PAPER”, “100% RECYCLABLE”, while “ENVIRONMENTALLY FRIENDLY” is an advertising inscription.

## ECO-LABEL “BLUE ANGEL”<br>“DER BLAUE ENGEL”

The first country to develop an Eco-labelling programme was Germany (in 1977). The label called “BLUE ANGEL” (“DER BLAUE ENGEL”) was designed as an instrument of ecological campaign, which was supposed to balance the market and highlight the positive qualities of products and services on a voluntary basis. “Blue Angel” promotes care for the environment, as well as consumer protection. Therefore, it is awarded to products and services that individually contribute to ecology in general, and that also meet high standards of professional health and safety and convenience for use. Economical use of raw materials, production methods, use, lifespan and disposal - all these factors are marked as very significant.


*52. Figure_"Blue Angel", the first Eco-Label*

## COEXISTENCE OF ECO PROGRAMS

Multiple ECO PROGRAMS can coexist in one country. For example, there are two competitive programs in the US: "GREEN CROSS" and "GREEN SEAL".

### "GREEN SEAL" ECO PROGRAM

In order to carry the "GREEN SEAL" label, the company must present the entire life cycle of the product. The "Green Seal" program and standards have been developed with the input of public opinion. These standards apply to many, extremely different products, such as: paper, motor oils, light bulbs, detergents, paints, toilet paper, etc.

*53. Figure_"Green Seal" label*

The standards established by the "Green Seal" program include the analysis of the entire product life cycle and cover the following areas, among others:

_production plant – factory,
_production process,
_materials used in the production process,
_performances of the product,
_energy efficiency of the product,
_noise level,
_packaging,
_product labelling,
_advertising material,

_product installations and auxiliary material,
_disposal of products and/or recyclability...

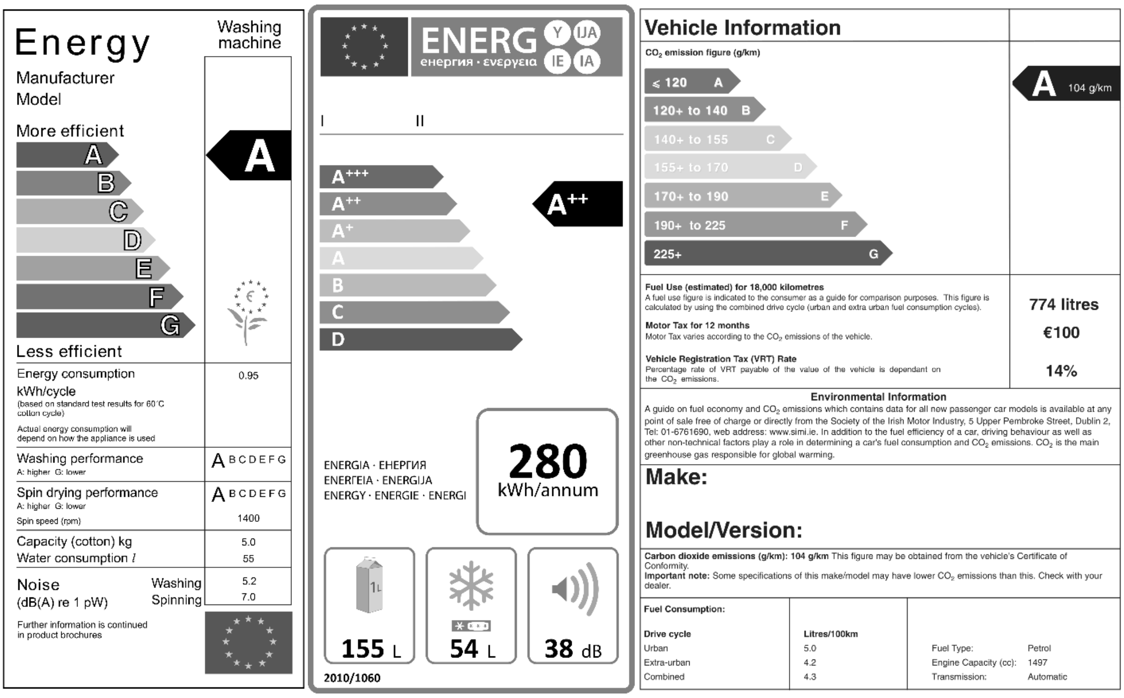
## OTHER ECO PROGRAMS

The Eco-label in Canada: "ENVIRONMENTAL CHOICE". The Eco program in Sweden, Norway and Finland carries a "GREEN SWAN" ("NORDIC SWAN") label. A similar label exists, for example, in the Republic of Korea.


*54. Figure_Canadian, Nordic and Korean Eco programs*

## EU ENERGY LABEL

According to the EU Directive 92/75/EC (and several others), most of the "major home appliances", bulb packagings and vehicles must have the clearly indicated EU ENERGY LABEL[30] when they are displayed for sale or rent.




*55. Figure_EU energy efficiency labels for washing machines (left), refrigerators (centre) and vehicles (right)*

[30] *For more information, see : http://en.wikipedia.org/wiki/European_Union_energy_label.*

ENERGY EFFICIENCY is classified into 7 CLASSES (A-G, where A is the most efficient and G is the most inefficient). The label also provides other useful information about the product, which makes the choice easier for the consumer.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A | B | C | D | E | F | G | Class |
| <0.19 | <0.23 | <0.27 | <0.31 | <0.35 | <0.39 | >0.39 | Energy efficiency index |

*56. Figure_Energy efficiency scale of washing machines: energy efficiency class and energy efficiency index*

For washing machines, the “ENERGY EFFICIENCY SCALE” is calculated for cotton washing at 60 °C (140 °F) with the maximum amount of laundry in the drum (usually 6 kg). The ENERGY EFFICIENCY (ECONOMY) INDEX (coefficient) is given in kWh per kilogram of laundry washed [kWh/kg].

The energy label shall contain information on:

_total consumption per cycle,
_washing performance - class A-G,
_drying performance - class A-G,
_maximum spin speed,
_maximum capacity in kg,
_water consumption per cycle in litres,
_noise in washing and drying cycles dB(A).

Since 2010, a new type of labels has been in use where PICTOGRAMS have replaced words (Figure 55 in the middle), so that a product with the same label can be sold in several countries. Also, the energy efficiency classes were extended to classes $A^{+}$, $A^{++}$ and $A^{+++}$, and the aforementioned directive was replaced by a new one (2010/30/EU), which entered into force on July 31, 2011.

## CLASSIFICATION OF ECO-LABELS

International Organization for Standardization - ISO classifies Eco-labels into THREE TYPES (TYPE I, II, III), and has developed a set of standards to determine how companies should present their labels to consumers.

## TYPE I ECO-LABEL

*Table 6: Some of the national Eco programs and the spectrum of areas and products they cover [Source: Wimmer, 2007]*

| Name | Blue Angel | Nordic Swan | NF Environment | EU Flower | Eco Mark |
|---|---|---|---|---|---|
| Label | | | | | |
| Country | Germany | Nordic countries | France | EU | Japan |
| Application | Products made of recycled plastic, wood, recycled paper, paper, textiles, vehicles, construction machinery, paint for low **$CO_2$** emissions walls, oils and biodegradable lubricants, reusable packages, photo-voltage products | Rechargeable batteries, household electrical appliances, textiles, detergents, buildings and decorative products, household chemistry, domestic heating, automobiles, machinery, office equipment and products, paper and pulp products, services | Refrigerators and vehicles, garbage bags, paints and colors, interior decoration profiles, office and home furnishings | Vehicles, household and garden equipment, lubricants, clothing, household electrical appliances, textiles, articles of wood and paper, cleaning products | Office equipment, copiers, printers and inks therefor, solar hot water supply, water saving equipment, dissolved and reused wood products, textiles, buildings, recycled materials products |

With this label, the third party defines the standards for certification, monitors the inspection of the product and grants permission to use its label for the product that meets its standards.

Swedish label “TCO’99”, USA - “EPA ENERGY STAR” program and Japanese “PC GREEN LABEL AND ECO MARK” are Eco labels for computer monitors and represent TYPE I ECO LABELS.

THE “EPA ENERGY STAR” program was developed with the aim of promoting a voluntary partnership between office equipment manufacturers in order to save energy and preserve the environment.

The Japanese “PC GREEN LABEL AND ECO MARK” refers to office equipment and household appliances.

“TCO’99” sets standards for office equipment from the point of view of safety, visual ergonomics, energy consumption, propagation of electric and magnetic fields and recycling.

57. Figure_Type I Exo label: American (left), Japanese (centre) and Swedish (right)

## TYPE II ECO-LABEL

For this label, the manufacturer does not ask permission from a third party, but makes a “SELF-DECLARED ENVIRONMENTAL CLAIM”. These claims fall under the ISO 14021 standard, which defines the basis of statements to establish that there are no exaggerations and inaccurate facts in them. ISO 14021 does not permitt expressions such as:

_environmentally sound,
_environmentally friendly,
_clean,
_green,
_nature friendly,
_ozone friendly...

A clearly designated labelled environmental aspect (impact) is required. Expressions in widespread use include:

_content of recycling material used in the product,
_reduced amount of resources,
_reduced amount of energy,
_recovered energy,
_reduction of waste...

58. Figure_Example of Type II Eco-labels in the furniture industry

TYPE III ECO-LABEL - ECOLOGICAL PRODUCT DECLARATION (EPD)

In this case, the environmental impact during the entire life cycle of the product is given quantitatively, so that consumers can evaluate it themselves. Environmental impacts are reflected in:

_global warming potential - greenhouse gases (GWP),
_ozone-depleting gases (ODS),
_Acidification Potential – AP,
_Photochemical-Oxidant Creation Potential - POCP,
_Eutrophication Potential - oxygen consumption - (EP).

*Table 7: Comparison of different types of environmental labels and declarations [Source: Wimmer, 2007]*

| Item | Type I | Type II | Type III |
|---|---|---|---|
| Name | Eco labeling | Self-declared environmental claim | Environmental Product Declaration |
| Target audience | Retail consumer | Retail consumer | Industrial / Retail consumer |
| Communication method | Environmental label | Text and symbols | Environmental profile data sheet |
| Scope | Entire life cycle | Single aspect* | Entire life cycle |
| Criteria | Yes** | None | None |
| Use of LCA | No | No | Yes |
| Practitioner | Third party | First party | Third / First party |
| Effort of procedure | High | Moderate | High |
| Governing body | Eco-labelling body | Consumer bureau | Accreditation body |

* A specific aspect of a life cycle or a single environmental attribute

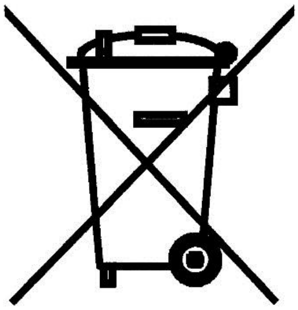
** Environmental and functional product criteria

This type of eco-labels consists of four parts:

_product description,
_inventory of materials throughout the life cycle of the product – inventory data,
_scientifically verified impact categories,
_certificate.

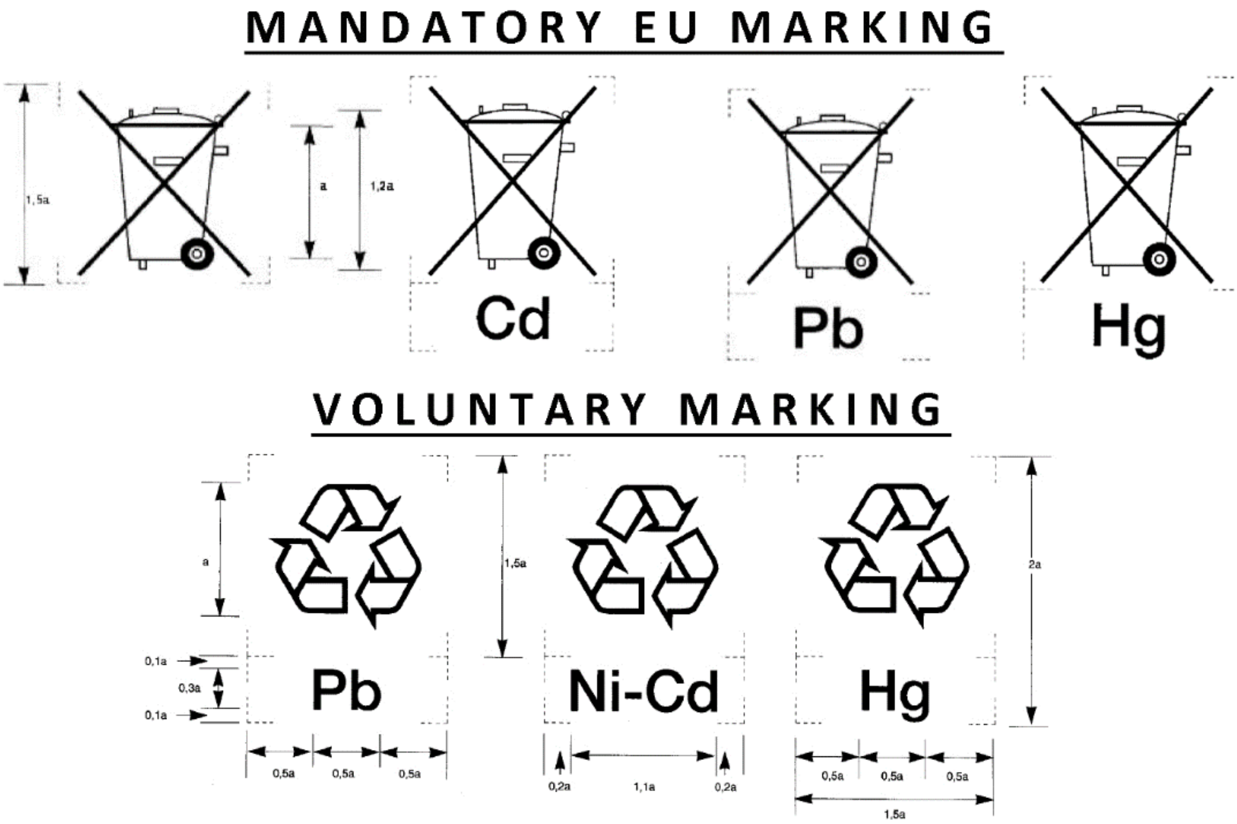
## LABELS OF SOME OF THE EU DIRECTIVES

THE CROSSED OUT BUCKET SYMBOL means the obligation to take the product at the end of its life to a designated place intended for the collection (disposal) of such products. It MUST NOT BE DISPOSED OFF as other type of waste in a regular waste bin. Very often this place can be the store where the product was purchased. If the PRODUCT IS TOO SMALL to be imprinted with the symbol mentioned above, then the SYMBOL SHALL BE PRINTED ON THE PACKAGING, THE INSTRUCTION MANUAL AND/OR THE WARRANTY. For medical devices, this symbol must be printed on the package.



*59. Figure_Symbol for special waste collection*

## LABELLING OF BATTERIES CONTAINING MERCURY, CADMIUM AND LEAD



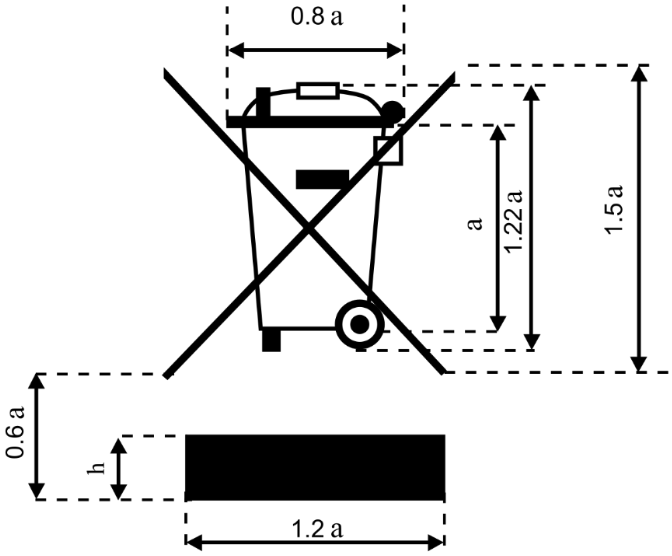

*60. Figure_Mandatory and voluntary labelling of batteries containing mercury, cadmium and lead*

The EU Directive 93/86/EEC requires the labelling of batteries containing mercury ($H_g$), cadmium ($C_d$) and lead ($P_b$).

## WEEE DIRECTIVE

The WEEE DIRECTIVE (2002/96/EC) requires manufacturers of electrical and electronic goods to label their products, as of July 13, 2005, in the manner shown in Figure 61. The EU legislators' objectives were as follows:

_manufacturers must be recognizable, otherwise there would be no individual liability of the manufacturer,
_historical waste must be distinguished from non-historical waste in order to ensure a difference in value,
_waste electrical and electronic equipment should be prevented from entering municipal waste streams.




*61. Figure_Symbol for special collection of WEEE (WEEE directive)*

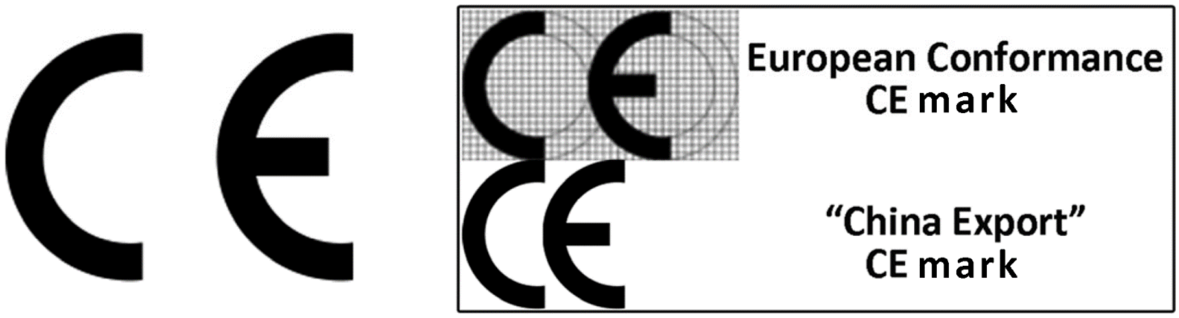
## RoHS DIRECTIVE

According to the RoHS Directive (2002/95/EC), the use of 6 types of substances (Hg, Cd, Pb, $Cr^{6+}$, PBDE, PBB) is prohibited, and products that meet the requirements of the Directive and do not contain these substances are awarded the RoHS COMPLIANT label.


*62. Figure_Different labels which designate meeting of the RoHS Directive requirements - "RoHS COMPLIANT"*

## “CE” MARKING

The “CE” marking is awarded to products that meet the EU directive for Energy-using Products, 2005/32/EC (EuP). In addition to this most significant directive, products bearing this label must meet about 25 other EU directives. This label guarantees that the product has met EU safety, health and environmental requirements.




*63. Figure_“CE” marking (left) and distinction from false (and non-existent) “China Export” marking (right)*

## END-OF-LIFE VEHICLES DIRECTIVE - ELV

According to THE VEHICLES DIRECTIVE (ELV – End of Life Vehicles, 2000/53/EC), vehicle manufacturers must guarantee that their vehicles are manufactured in such a way that the required level of reuse, recovery and recyclability can be achieved. These levels are given in Table 8 and refer to the percentage of the total mass of the vehicle.

*Table 8: Target reuse, recovery and degree of recyclability of end-of-life vehicles according to the ELV Directive, by average vehicle mass and the deadline for achieving the target [Source: Wimmer, 2007]*

| Deadline | january 1, 2006 | January 2015 |
|---|---|---|
| Reuse and recovery | 85% | 95% |
| Reuse and recycling | 80% | 85% |

Vehicle manufacturers should CODE the MATERIALS of parts according to standards in cooperation with manufacturers of materials and equipment, in order to enable identification of components and materials suitable for recycling. The labelling of plastics is closely related to this (see p. 72).


*64. Figure_Labelling of materials and parts in the automotive industry*

## LABELLING OF DANGEROUS SUBSTANCES

According to Directive 67/548/EEC and ANNEX IV THERETO, HAZARDOUS SUBSTANCES AND COMPOUNDS are classified and labelled according to their physico-chemical, toxicological and ecotoxicological properties. These are substances that pose a risk in normal use and application. The symbol, information on the origin and type of material, notes and safety recommendations shall be written in BOLD, BLACK LETTERS IN A RECTANGULAR YELLOW TABLE.


*65. Figure_Warning table (safety recommendation)*

THE SKULL AND CROSSBONES REPRESENT A UNIVERSAL SYMBOL FOR TOXIC SUBSTANCES.

*66. Figure_Universal symbol for toxic substances*

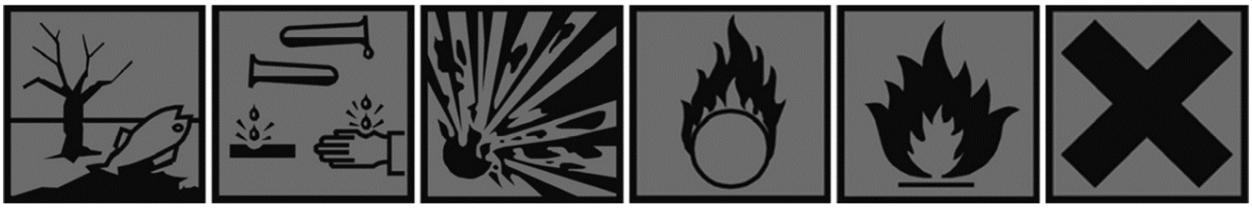
FLAMMABLE SUBSTANCES are substances that will ignite and continue to burn when brought into contact with an ignition source.

General ignition sources are: open flames, hot surfaces, static electricity, smoking material, cutting and welding operations, radiant heat, heat due to friction, electrical and mechanical sparking (due to friction), spontaneous combustion (self-ignition), and thermal products of chemical reactions.

CORROSIVE SUBSTANCES can dissolve other materials such as metal and can destroy living tissues.

EXPLOSIVE SUBSTANCES explode when combined with other substances or when exposed to heat.

Classification, packaging, labelling and advertising of chemicals and certain products in accordance with EU directives 67/548/EEC and 99/45/EC (DSD/DPD system[31]) are shown in Figure 67.



*67. Figure_Symbols for substances harmful to the environment, corrosive, explosive, oxidizing, flammable and harmful or irritating substances (respectively)*

Classification, packaging, labelling and advertising of chemicals and certain products IN ACCORDANCE WITH THE GLOBALLY HARMONIZED CLASSIFICATION AND LABELLING SYSTEM of the UN harmonized with EU regulation 1272/2008 (GHS system) are shown in Figure 68.

*68. Figure_Symbols for explosive, flammable and oxidizing substances, pressurised gases, corrosive, toxic and substances harmful for the respiratory system and nature (respectively)*

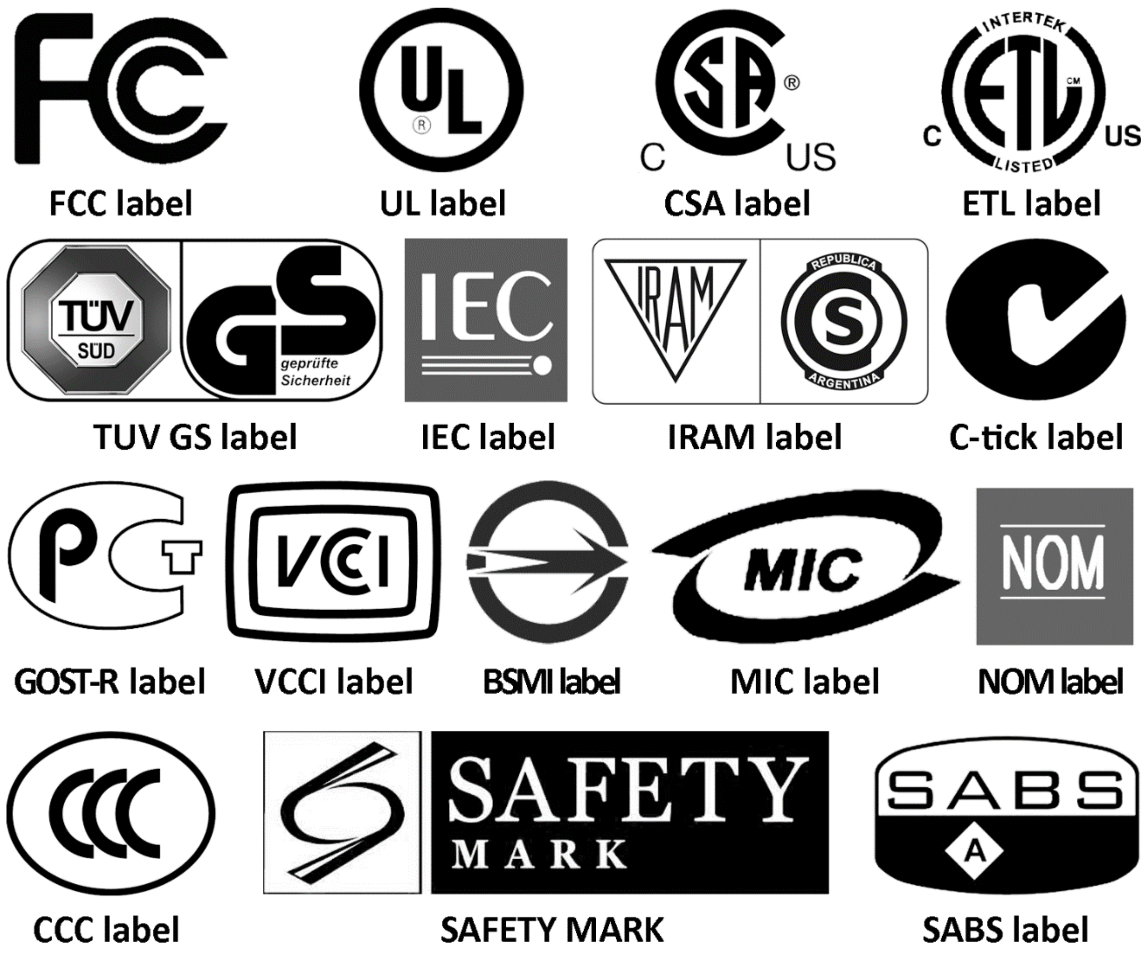
ODS – Ozone Depleting Substances include refrigerants (e.g. CFCs, HCFCs), dry cleaning agents (carbon tertrachloride) and melting agents for foams (rigid and flexible PU foam, expanded polystyrene). In some cases (e.g. with refrigerants), it is difficult to find alternative materials that would have a more favourable effect on the environment. In those situations one should try to find alternative technologies and processes, or present other solutions.

[31] *For DSD/DPD and GHS system and other information related to chemicals, see the web presentation of the Agency for Chemicals of RS (http://www.shema.gov.rs)*

*Table 9: Hazardous substances and compounds*

| Physico-chemical properties | Toxicological properties | Specific impacts on the man | | Environmental impacts |
|---|---|---|---|---|
| Explosive – "E" | Very toxic – "$T^{+}$" | Carcinogens category 1 or 2 | "$T^{+}$" or "Carc" | Harmful to the environment – "N" |
| Oxidizing – "O" | Toxic – "T" | Carcinogens category 3 | "$X_n$" or "Carc" | |
| Extremely flammable – "$F^{+}$" | Harmful – "$X_n$" | Mutagens category 1 or 2 | "Mut" | |
| Easily flammable – "F" | Corrosive – "C" | Mutagens category 3 | "$X_n$" or "Mut 3" | |
| Flammable | Irritating – "$X_i$" | Toxic for reproduction category 1 or 2 | "$T^{+}$" or "Repr." | |
| | | Toxic for reproduction category 3 | "$X_n$" or "Repr. 3" | |

## LABELS OF ELECTRICAL AND ELECTRONIC EQUIPMENT – EEE




69. Figure_Some of the EEE marks [Percept Technology Labs, 2012] (hereinafter these marks will be dealt with respectively)

All commercial electronic devices (unintended radio frequency emitters) sold in the USA are regulated by the Federal Communications Commission - FCC, if:

_contain clocks or oscillators,
_operate at frequencies higher than 9 kHz, and
_use digital technology.

Products that meet the FCC are divided into two categories:

1. CLASS A - a device intended for use in an industrial or commercial environment and not intended for home or residential use.
2. CLASS B - a device for home or residential use, such as computers, calculators, printers, electronic games...

UL label is a registered certificate of "UNDERWRITERS LABORATORIES INC.", as an independent, non-profit organization for testing, product safety and certification. The UL label is one of the most recognizable, accepted and verified labels in the world. cUL label is the UL label for Canada. It complies with the Canadian Safety Requirements. This label designates computers and computer equipment, vending machines, alarm systems, lighting systems and many other types of electronic products.

CSA label means that the product is certified to meet U.S. and Canadian standards, including applicable UL, ANSI, ASME, ASTM, ASSE, CSA and NSF.

cETLus – ETL LISTED label (INTERTEK ETL label) is the legal equivalent of UL and CSA LISTED labels in the USA and Canada. The product carrying the ETL LISTED label has been found to meet the minimum requirements of the prescribed product safety standards.

The GS label shows that the product meets the German standards for safe operation of the equipment. The TUV GS label is a voluntary mark in Germany, which refers to products that have been tested for safe operation. The GS label applies only to final products and can only be assigned by the ZENTRALSTELLE DER LÄNDER FÜR SICHERHEIT-ZLS (CENTRAL OFFICE OF SAFETY OF THE GERMAN STATES). The GS label (Geprüfte Sicherheit, meaning the tested safety in operation) is a label for electrical products, such as office equipment, home and industrial equipment, and is widely accepted in Europe.

CB TEST REPORT is a standardized report in an item-by-item format, in relation to the applicable IEC (International Electrotechnical Commission) STANDARD. The report provides a clear and unambiguous result of all necessary tests, measurements, verifications, inspections and validations. It also contains photographs, schemes, sketches and product descriptions. The CB TEST REPORT must be paired with the CB TEST CERTIFICATE to be considered valid.

Argentina has a binding law - Resolution 92/98 - which applies to electrical and electronic equipment and is implemented through a mandatory certification system by accredited organizations. IRAM (Instituto Argentino de Normalizacion) is the national certification body in Argentina. EEE that meets the Argentine requirements validated by IRAM must bear an S-MARK, a mandatory Argentine safety mark.

Australian Communications Authority - ACA and the Radio Spectrum Management Group - RSM of New Zealand harmonized the laws and formed them into C-TICK LABEL, whose requirements should be met by a product. All electrical and electronic equipment products intended for the Australian and New Zealand markets shall meet the requirements of the applicable standards. In order for the product to enter the market, it must be tested in accordance with the appropriate standards by a registered laboratory.

The GOST-R label is a mandatory certificate (permit) which all electrical products delivered to Russia must bear. The GOST-R certificate is issued according to the technical evaluation of the product to ensure compliance with Russian safety regulations. It is valid for 1-3 years. The GOST-R certificate can be issued for:

_the goods to be delivered (issued and valid only for the given shipment),
_serial production (issued for 1-3 years and valid for all goods delivered in that period)

The GOST-R certificate covers a wide range of products:

_consumer products, such as food, textiles, cosmetics and toys,
_mechanical and electrical goods,
_industrial equipment for food, chemicals, oil and gas, construction and other industries.

Products which are not subject to mandatory certification according to Russian laws, can be voluntarily labeled.

VCCI label (Voluntary Control Council for Interference by Information Technology Equipment) pertains to Information Technology Equipment - ITE, sold in Japan. Products with the VCCI label are of high quality. Manufacturers must become members of VCCI for their products to bear the VCCI label.

Most electronic products for the Taiwanese market must be approved by the Taiwanese Bureau of Standards, Metrology and Inspection - BSMI and must comply with Chinese National Standards - CNS. This includes information technology products, consumer electronics (including home applications), power tools, office equipment and a wide range of industrial products.

All electronic products intended for the South Korean market must comply with two labels according to Korean regulations. Manufacturers are required to have the product safety mark Kc and EMC and/or MIC (Ministry of Information and Communications) for EMC (Electromagnetic Compatibility) and/or TELECOM marks on their products in order to sell them on the South Korean market.

The Mexican government requires that all electronic products be tested for safe operation in Mexico, and accordingly marked with the mandatory NOM label (Normality of Mexico).

Only test reports approved by SINALP (Sistema Nacional de Acreditamieno de Laboratorios de Pruebas), NATIONAL SYSTEM FOR ACCREDITATION OF LABORATORY TESTS, are accepted.

The CCC label (China Compulsory Certification mark) is required for a wide range of products sold in China. The list of products includes 19 product groups and a total of 132 product categories.

The PSB label is awarded by Singapore's Productivity and Standards Board – PSB. PSB requires all registered and controlled goods to be marked with a SAFETY MARK. Granting of authorisation and registration is valid for a period of three years, after which it must be renewed.

SABS is a security scheme for electronic and electrical goods implemented by the South African Bureau of Standards - SABS, as the agency of the South African government. SABS approval can be obtained based on product testing in a recognized laboratory. The label is not necessary for the checked goods.

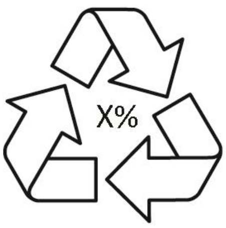
## MATERIAL LABELS

### THE MOBIUS LOOP SYMBOL INDICATES THAT THE PRODUCT IS RECYCLABLE, NOT RECYCLED.

*70. Figure_Mobius Loop symbol*

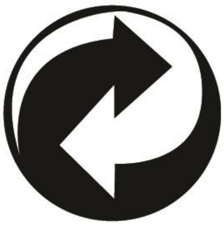
The meaning of the MOBIUS LOOP symbol is not precisely defined. Generally speaking, it is considered an international symbol for recycling and its use is on a voluntary basis.

The MOBIUS LOOP SYMBOL WITH PERCENTAGE shows that the material can be recycled, and the "X" in the symbol shows the PERCENTAGE OF RECYCLED CONTENT.




*71. Figure_Mobius Loop symbol with percentage of recycled content*

THE GREEN DOT label DOES NOT NECESSARILY MEAN that the packaging is recyclable. It is a symbol used on packaging in many European countries and means that the MANUFACTURER HAS MADE A CONTRIBUTION TO THE RECYCLING OF PACKAGING.



72. Figure_The Green Dot symbol

When marking PAPER, MOBIUS LOOP is used as an international symbol for recycled paper. Also, THE GREEN DOT label is used for recycled paper. In order to receive the label of the National Association of Paper Merchants mark - NAPM, the paper or cardboard must be made up of a minimum of 75% of the original old paper and/or wood fibres, without milled waste fibres. Another symbol, often used on paper and cardboard packages, is the RESY symbol for recycling. This symbol guarantees that the packaging with this symbol is recyclable and will be accepted by the paper (cardboard) recycler.


73. Figure_Labels for recycled paper/cardboard: (a) international symbol for recycled paper – Mobius Loop, (b) The Green Dot symbol, (c) NAPM symbol and (d) RESY symbol for recyclable paper/cardboard packaging

Forest Stewardship Council logo designates products containing WOOD from a sustainable forest, which is independently certified in accordance with the rules of FSC A.C.


74. Figure_Label for tree grown on the plantation

The COMPOSTABLE symbol is relatively new and refers to BIODEGRADABLE plastic packagings. The symbol indicates that the packaging has been tested and suitable for disposal in order to create compost (fertilizer).


*75. Figure_Label for biodegradable material*

The SOIL ASSOCIATION symbol is a nationally independent quality mark (EU provision no. 2092/91) for ORGANICALLY GROWN FOOD and other products, such as compost. The symbol is awarded to farmers, food processors, distributors, traders and industrial producers, who meet the standards prescribed by the SOIL ASSOCIATION. This label protects consumers from fraud and protects manufacturers from competition that does not meet the given standards.


*76. Figure_Soil Association symbol for organically grown food and compost*

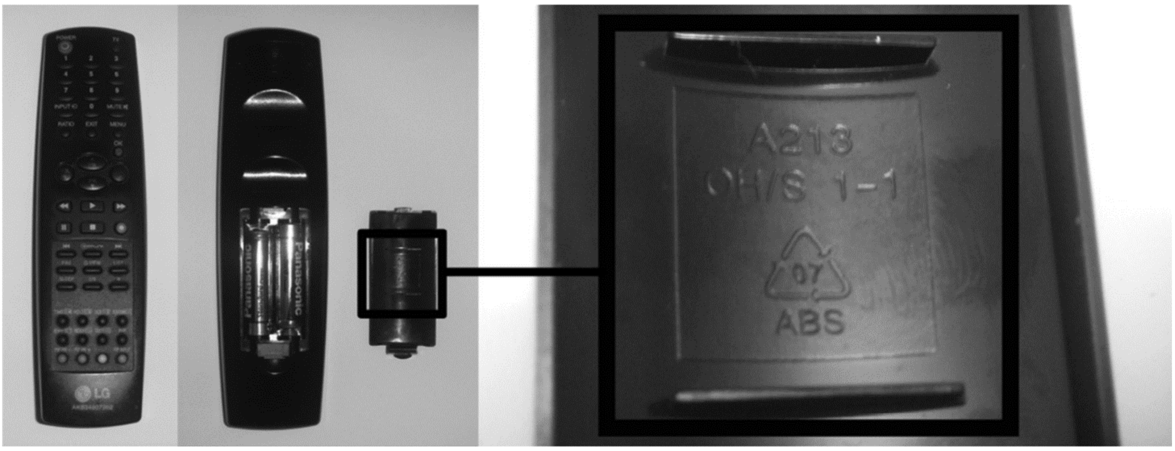
For simplified separation and disassembly, PLASTICS bear special marks. They are classified into 7 CATEGORIES and denoted by numbers from 1 to 7 within the simplified MOBIUS LOOP, whereby the type of the given plastic is written at the bottom of the mark:

_PETE or PET – polyethylene terephthalate,
_HDPE – high density polyethylene,
_V – vinyl and polyvinyl chloride (PVC),
_LDPE – low density polyethylene,
_PP – polypropylene,
_PS – polystyrene,
_OTHER – other plastics.

This is of particular importance in the automotive industry, as mentioned earlier.


*77. Figure_Plastics marking*

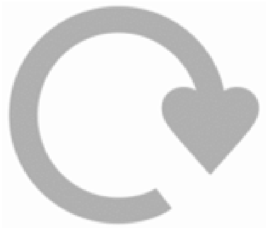
LABELS on plastic ARE most often IMPRINTED, OR ENGRAVED INTO MOLDS and thus made together with the part that is produced. The labels themselves are usually placed in such a way that they DO NOT DISTURB THE AESTHETICS of the product (e.g. on the inside of the remote control cover, on the inside of the computer housing cover, on the bottom of the plastic cup, etc.)




*78. Figure_Plastics labeling on the example of the remote control*


*79. Figure_Glass labeling*

The label for GLASS recycling is shown in Figure 79 - top, left. In addition to this label, labels containing the letter GL below the MOBIUS LOOP are very often used, with numeric mark inside it (Figure 79 – top, right). In the same Figure, in the lower row, the labels for separate collection of glass of different colours, mixed glass and glass panels (e.g. window glasses) are shown. In the lower left corner of each of the labels, shown on the lower part of Figure 79, the RECYCLE NOW symbol appears, which is designed to motivate people to recycle. The circularity of the arrow represents sustainability in recycling, and the arrow itself, in the shape of a heart, symbolizes that nature “feels good” when we recycle.



80. Figure_Recycle Now symbol

The symbol for RECYCLABLE ALUMINUM, i.e. ALUMINUM RECYCLING, can be placed in/on the aluminum recycling facility. The containers for collecting aluminum cans bear the MET label.


81. Figure_Labels for aluminum and aluminum foil recycling

The symbol for RECYCLABLE STEEL or IRON may be placed in/on the steel recycling facility.


82. Figure_Labels for steel and iron recycling

The TIDYMAN symbol has nothing to do with recycling, but encourages you to be a conscientious citizen, who takes adequate care of his/her waste. Indicates that waste is carefully and seriously disposed of and not littered.

83. Figure_Tidyman mark

## CONCLUSION

### ABOUT THE DESIGNER ROLE

ECODESIGN is a tool in the hands of designers that helps them achieve the goal of protecting the environment and prevent further environmental damage.

The implementation of the DfX approach in ECODESIGN leads to special engineering areas and methods, such as:

_Design for Manufacture – DfM
_Design for Assembly and Disassembly - DfA, DfD,
_Design for Recycling - DfR,
_Design for Environment protection - DfE.

The role of ECODESIGN is to develop a product that is made of recycled materials, uses fewer resources during manufacture, transport and use, and that can be collected, reused, upgraded and easily disassembled to recycle the materials from which it is made.

Design has the power to discover, invent, innovate and use new materials, new energy sources, such as SOLAR CELLS, WIND TURBINES, GEOTHERMAL STATIONS, BIOMASS...

Ecodesign does not tend to diverge from its basic intention to create objects that meet the needs of mankind!

### IS ECODESIGN NECESSARY?

ECODESIGN is a new way of thinking in design. It is even more significant because designers do not think about this aspect when designing meaningless (stupid) and useless products, and non-renewable resources are used to obtain such products.


*84. Figure_Useless product: Nail polish dryer!?*

For this reason, ECODESIGN should be understood and approached with the conviction that it is a GENERALLY USEFUL THING, and not only because of the necessity to comply with legal regulations.



85. Figure_Motorized ice cream cone (left), a plate with instructions on how to return to Earth in case you are abducted by aliens, or otherwise found in space (top right) and a waffle set in the form of a typewriter (bottom right)

86. Figure_Toilet paper holder (left) and protector that prevents hair from falling into the food (right)

## REFERENCES AND LITERATURE


[1] Anca Bârsan, Lucian Bârsan: *Ecodesign for Sustainable Development, Volume 1 - Fundamentals*, Transilvania University of Brasov, Romania, 2007.

[2] Richard Morris: Ecodesign for Sustainable Development, Volume 2 - Product Life Cycle Assessment, University of Brighton, UK, 2007.

[3] Maria Paralika: Ecodesign for Sustainable Development, Volume 3 - Product Recycling Technologies, T.E.I. of Athens, Greece, 2007.

[4] Wolfgang Wimmer: Ecodesign for Sustainable Development, Volume 4 - Product Development, Vienna University of Technology, Austria, 2007.

[5] Wimmer, W, Züst, R., Ecodesign PILOT - Product - Investigation -, Learning - and Optimization - Tool for Sustainable Product Development, Kluwer Academic Publishers, Dordrecht, The Netherlands, 2003.

[6] Wimmer, W., Zuest, R., Lee, K., Ecodesign Implementation - A Systematic Guidance on Integrating Environmental Considerations into Product Development, Netherlands: Springer Verlag, 2004.

[7] Carlo Vezzoli, Ezio Manzini: *Design for Environmental Sustainability,* Springer-Verlag, London, 2008.

[8] Ostad A. Ghorabi Hesamedin: *Ecodesign - Sustainable Product Development*, Vienna University of Technnology, Institute for Engineering Design, Ecodesign Research, 2006.

[9] Ministry of Housing, Spatial Planning and the Environment (VROM) and Centre of Environment Science - Laiden University (CML), VROM & CML, 2001: *Life cycle assessment. An operational guide to the ISO standards*, *Final report*, May 2001.

[10] Tchobanoglous, G., Theisen, H., Vigil, S.: *Integrated Solid Waste Management: Engineering Principles and Management Issues*, ISBN: 9780070632370, pp. 992, McGraw-Hill, 1993.

[11] Kalpakjian, S., Schmid, S.: *Manufacturing Engineering and Technology*, $5^{th}$ edition, Upper Saddle River: Pearson Education, 2006.

[12] Gerhard Pahl, Wolfgang Beitz, Ken Wallace: *Engineerin Design: A Systematic Approach*, Springer, 1996.

[13] Joenson, G.: LCA – a tool for measuring environmental performance, UK: Pira International, 1996.

[14] Curran, A. C.: *Environmental Life-Cycle Assessment*, New York: McGraw-Hill, 1996.

[15] Wenzel, H., Hauschild, M., Alting, L.: Environmental Assessment of Products, Vol. 1: Methodology, tools and case studies in product development, "Chapman & Hall", London, UK, 1997.

[16] Goedkoop, M. & Spriensma, R.: The Eco-indicator 99. A damage oriented method for life cycle impact assessment. Volume I: Methodology report. Volume II: Methodology annex. VROM report 1999/36, 2001.

[17] Thrane, M., Schmidt, J.: *Life Cycle Assessment- Chapter 4A*, Published in: Environmental Planning and Management – Tools for Sustainable Development. Red. Kørnov L., H. Lund and A. Remmen, Department of Development and Planning, Aalborg University, 2004, http://www.plan.aau.dk/~thrane/Publications/Personal%20publications.htm (accessed 01.2007).

[18] Koshiken Tiia, Hybrid *RTG*: *Lowering emissions at container yard*, "Konecranes", 2008.

[19] Stahlbock Robert, Voß Stefan: *Operations research at container terminals*, OR Spectrum, Springer-Verlag 2007.

[20] Tatjana Kandikjan, *Lecture excerpts*, Industrial Design, University of St. Cyril and Methodius, Faculty of Mechanical Engineering, Skopje, Macedonia, 2006.

[21] Andrija Vujičić: Assessment of the life cycle of machines and devices of interrupted transport, Master's thesis, University of Belgrade, FME, 2010.

[22] Darko Batina: *Recycling of electrical and electronic equipment*, M.Sc. paper, University of Belgrade, FME, 2012.

[23] Konstantin Nešović: Rubber recycling methods and technical-economic cost-effectiveness analysis, M.Sc. paper, University of Belgrade, FME, 2012.

[24] Zoran Petković, Davor Ostrić: *Metal Constructions in Machine Building 1*, FME, Belgrade, 1996.

[25] Zoran Petković: Metal Constructions in Machine Building 2, FME, Belgrade, 2005.

[26] Milosav Ognjanović: *Machine Development and Design*, FME, Belgrade, 2007.

[27] Milosav Ognjanović: *Machine Elements*, FME, Belgrade, 2011.

[28] Workshop "State of the Art in Design Science", Editor: M. Ognjanović, TEMPUS project JEP 40 069, “Design in Mechanical Engineering”, Belgrade, XI 2006.

[29] Radovanović Milan R.: *Fuels*, FME, University of Belgrade, 1994.

[30] Smith, R. L., Smith, T. M.: *Elements of Ecology*, 4th edition, San Francisco: Benjamin/Cummings Science Publishing, 2000.

[31] Schumann, W.: *Der neue BLV Steine- und Mineralienfuehrer*, 4th edition, Muenchen, Germany: BLV Verlagsgesellschaft, 1994.

[32] Schumann, W.: *Handbook of Rocks, Minerals & Gemstones*, Boston: Houghton Mifflin Company, 1994.

[33] Gray, C. and Jones, D.: *An investigation into the feasibility and rationale for incorporating active disassembly into a domestic electronic product*, Research Study Commissioned by the Electronic Product Producer to Inform Product Development, "Wax RDC", Farnham, 2008.

[34] Heijungs Reinout: Environmental Life Cycle Assessment of Products, Background - October 1992, B&G, TNO - CML, The Netherlands, 1992.

[35] Heijungs Reinout: Environmental Life Cycle Assessment of Products, Guide - October 1992, B&G, TNO - CML, The Netherlands, 1992.

[36] Wenzel, H.: *Ecodesign strategy - the interaction between the environmental specialist and the designer*, Workshop "Eco-design of electronic products" - report, Kista, Stockholm, (05/2005) http://www.greenpack.org/results/Docs/ecodesign_strategy.pdf, 2000.

[37] Marcus Hesse, Jean-Paul Rodrigue: *The transport geography of logistics and freight distribution*, Journal of Transport Geography, Volume 12, pp. 171-184, 2004.

[38] Kölble Christoph: *New technologies increase efficiency in intermodal transport*, Conference paper STRC 2004, 4th Swiss Transport Research Conference, Monte Verità/Ascona, March 25-26. 2004, http://www.strc.ch/pdf_2004/Koelble_ Efficiency_STRC_2004.pdf.

[39] Simons, D., Mason, R.: *Lean and Green: "Doing More With Less",* Efficient Consumer Response (ECR) Journal, Volume 3, No. 1 Spring 2003.

[40] Ongmongkolkul, A., Nielsen, P.H.: *Life Cycle Assessment of Paperboard Packaging in Thailand*, Asian Institute of Technology, 2002, http://www.howproductsimpact.net/box/ (accessed 08.08.2006.).

[41] Chien-Yung Lai, Chin-Hung Hsu, Hui-Ming Kuo: An Empirical Study of Constructing a Dynamic Mining and Forecasting System for the Life Cycle Assessment-based Green Supply Chain, WSEAS Transactions on Systems, Issue 4, Volume 11, E-ISSN: 2224-2678, pp. 129-139, April 2012.

[42] Đorđević, M., Batina, D., Zrnić, N., Jerman, B., Hladnik, J.: *Modeling energy usage patterns of a PC and ways of improving it's energy efficiency*, Proceedings of the XX International Conference on Material Handling, Constructions and Logistics - MHCL'12, University of Belgrade, Faculty of Mechanical Engineering, ISBN: 978-86-7083-763-8, pp. 319-324, 3-5 October, Belgrade, Serbia, 2012.

[43] Ivan Gržetić: *Global Warming and Kyoto Protocol*, University of Belgrade, Faculty of Chemistry, http://helix.chem.bg.ac.rs/~grzetic/predavanja/Osnovi%20hemije%20atmosfere%20i%20zagadjivaci%20vazduha/GLOBALNO%20ZAGREVANJE%20I%20KJOTO%20PROTOKOL.pdf

[44] Roger Bedard: *Overview of US Ocean Wave and Current Energy: Resourece, Technology, Environmental and Business Issues and Barriers*, EPRI - Electric Power Research Institute, 2007, http://oceanenergy.epri.com/attachments/ocean/reports/EWTEC_Bedard_Sep_11.pdf.

[45] John Dyson: *33 ways to save energy*, Reader's Digest, Serbia, July 2009, pages 96-100, www.rdsrbija.com.

[46] *GaBi Education - Handbook for Life Cycle Assessment* (LCA) *- Using the GaBi Education Software Package*, *GaBi* Software, "PE International", University of Stuttgart, Chair of Building Physics (LBP), Life Cycle Engineering (GaBi), 2010.

[47] Environmental Protection Agency: *Report on the State of the Environment in the Republic of Serbia for 2009*, Republic of Serbia, Ministry of Environment and Spatial Planning, Belgrade, 2010.

[48] Environmental Protection Agency: *Report on the State of the Environment in the Republic of Serbia for 2010*, Republic of Serbia, Ministry of Environment, Mining and Spatial Planning, Belgrade, 2011. Ministry of Environment, Mining and Spatial Planning of the Republic of Serbia, *Law on Waste Management*, 2010, “Official Gazette of RS” no. 36/09 and 88/10.

[49] Dejan Lekić: *Framework for reporting in the field of environmental protection in the Republic of Serbia*, Ministry of Environment, Mining and Spatial Planning of the Republic of Serbia, Environmental Protection Agency, www.emc-project.gov.rs/en/media/public/presentations/sepa-lekic.

[50] ETRMA - European Tyre and Rubber Manufacturers' Association: *End of life tyres - A valuable resource with growing potential*, 2010 edition, http://www.etrma.org/public/activitieseofltelts.asp.

[51] IPCC SRREN, 2011 - Intergovernmental Panel on Climate Change, Working Group III - Mitigation of Climate Change: *Special Report on Renewable Energy Sources and Climate Change Mitigation*, final release, Abu Dhabi, United Arab Emirates, 5-8th May 2011.

[52] IPCC - Intergovernmental Panel on Climate Change: *Special Report on Carbon Dioxide Capture and Storage* (CCS -Carbon Capture and Storage), 2005.

[53] United Nations ESCAP - Economic and Social Commission for Asia and the Pacific: *Eco-efficiency Indicators: Measuring Resource-use Efficiency and the*

*Impact of Economic Activities on the Environment*, United Nations, 2009, www.unescap.org/esd.

[54] The Waste Consortium, EPSRC Sustainable Urban Environment Programme: *Strategies and Technologies for Sustainable Urban Waste Management*, Symposium, April 21, 2008, London, Proffesor William Powrie, Principal Investigator, http://www.suwic.group.shef.ac.uk/SUE%20Waste.html.

[55] Worldwatch institute, 2005: *Renewables 2005 Global Status Report*, Washington DC.

[56] Ministry of Environment, Mining and Spatial Planning of the Republic of Serbia: *Law on Packaging and Packaging Waste*, 2009, “Official Gazette of RS”, No. 36/09.

[57] Ministry of Environment, Mining and Spatial Planning of the Republic of Serbia: *Waste*, 2012, http://www.ekoplan.gov.rs/src/02-Otpad-224-document.htm.

[58] Government of the Republic of Serbia: *Waste Management Strategy for 2010-2019*, “Official Gazette of the REPUBLIC OF SERBIA” no. 36/09, 55/05, 71/05 - corrigendum, 101/07 and 65/08 http://www.srbija.gov.rs/vesti/dokumenti_sekcija.php?id=45678.

[59] TU Vienna , Institute for Engineering Design - ECODESIGN: *ECODESIGN Information platform*, www.ecodesign.at.

[60] TU Vienna, Institute for Engineering Design - ECODESIGN: *ECODESIGN PILOT's Assistant*, http://www.ecodesign.at/assist/assistent?lang=en.

[61] TU Vienna , Institute for Engineering Design - ECODESIGN: *ECODESIGN PILOT,* http://www.ecodesign.at/pilot/ONLINE/ENGLISH/.

[62] TU Vienna , Institute for Engineering Design - ECODESIGN: *EEG PILOT,* http://www.ecodesign.at/pilot/eeg/ENGLISH/INDEX.HTM.

[63] Table of classes of material with EcoDesign Assistant, http://www.ecodesign.at/pilot/ONLINE/ENGLISH/ASSIST/classes.html.

[64] "PRé (PRoduct ecology) Consultants", http://www.pre.nl/.

[65] "PRé (PRoduct ecology) Consultants", *ECO-it*, http://www.pre.nl/eco-it/default.htm.

[66] CES EduPack 2005, "Granta Design Limited", Cambridge, UK, Granta Design 2005.

[67] CES EduPack 2006, "Granta Design Limited", Cambridge, UK, Granta Design 2006.

[68] EEA - European Environment Agency, http://www.eea.europa.eu.

[69] EUROSTAT - Statistical office of the European Union, http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home.

[70] AMECO - Annual Macro-Economic database of the European Commission's Directorate General for Economic and Financial Affairs, http://ec.europa.eu/economy_finance/db_indicators/ameco/zipped_en.htm.

[71] European Commision (EC): *Energy Efficiency - Eco-design of Energy-Related Products*, http://ec.europa.eu/energy/efficiency/ecodesign/eco_design_en.htm.

[72] IEA - International Energy Agency, http://www.iea.org/.

[73] IPCC - Intergovernmental Panel on Climate Change, http://www.ipcc.ch/.

[74] EPA - US Environmental Protection Agency, http://www.epa.gov/.

[75] EPA - US Environmental Protection Agency, http://www.epa.gov/oms/climate/420f05001.htm.

[76] Environmental Protection Agency of RS: *Waste classification*, Ministry of Environment and Spatial Planning, www.sepa.gov.rs.

[77] Ministry of Natural Resources, Mining and Spatial Planning of the Republic of Serbia: *What is the Ecolabel of the Republic of Serbia?,* http://www.ekoplan.gov.rs/src/Sta-je-to-Eko-znak-Republike-Srbije--1467-c101-content.htm.

[78] Republic of Serbia, Agency for Chemicals, http://www.shema.gov.rs

[79] DOE: *Indicators of Energy Intensity in the United States*, http://intensityindicators.pnl.gov/terms_definitions.stm#economy].

[80] "Global Footprint Network", 2009, www.footprintnetwork.org/atlas

[81] "Ranking America", 2009: *Top Ten Countries by Ecological Footprint*, http://rankingamerica.wordpress.com/2009/07/11/the-u-s-ranks-3rd-in-ecological-footprint/.

[82] NASA, 2005: *The Earth's Energy Budget*, http://asd-www.larc.nasa.gov/erbe/components2.gif.

[83] Flight, D. , 2006: *Fossil Fuel* [online] http://en.wikipedia.org/wiki/Fossil_fuel, (accessed 12-04-06) after Marland, G., Boden, T.A. & Andres, R.J., 2003, *Global, Regional and National $CO_2$ Emission Trends: a Compendium of Data on Global Change*, [online] Carbon Dioxide Information Analysis Centre, US Department of Energy, http://cdiac.esd.ornl.gov/trends/emis/tre_glob.htm.

[84] A.Reller,University of Augsburg, T. Graedel, Yale University: *How long will it last ?*, 2006, http://www.infographicsblog.com/wp-content/uploads/2009/10/how-long-will-materials-last.jpg.

[85] Environment, Health and Safety Online - EHSO, 2010: *Battery Recycling and Disposal Guide for Households*, http://ehso.com/ehshome/batteries.php.

[86] Virtual Chembook: *pH Scale*, http://www.elmhurst.edu/~chm/vchembook/184ph.html

[87] ESA - Ecological Society of America: *Biodiversity*, 1997, http://www.esa.org/education_diversity/pdfDocs/biodiversity.pdf.

[88] Alison Knight: *Hidden Histories: the story of sustainable design*, ProQuest Discovery Guides, 2009, http://www.csa.com/discoveryguides/design/review.pdf.

[89] APM terminals, Port of Rotterdam, Maritime Journal, Mercator Media, 2012.

[90] UNEP - United Nations Environment Programme, http://www.unep.org.

[91] Jefferey, S.: *What is Globalisation?*, The Guardian Newspaper, UK, October 31, 2002.

[92] Mallenbaker ,2006: Corporate Social Responsibility: News and Resources. Companies in Crisis: What NOT To Do When It All Goes Wrong, http://www.mallenbaker.net/csr/CSRfiles/crisis03.html (accessed 10-05-06).

[93] Office of National Statistics, 2002: *Greenhouse gas emissions from transport*, http://www.statistics.gov.uk/downloads/theme_environment/transport_report.pdf (accessed 12-05-06).

[94] Department for Transport, London, http://www.dft.gov.uk/.

[95] Department for Transport, 2003: *Reducing the Environmental Impact of Distribution: Transco National Logistics. Good Practice Case Study, 2001*, http://www.freightbestpractice.org.uk/imagebank/GPCS2101.pdf (accessed 05-05-06).

[96] "Seacell", 2006: *Benefits*, http://www.seacell.info/benefits.htm (accessed 13-05-06).

[97] Transport Intelligence, 2006: *Global Air Cargo 2006: Market Reports*, http://www.transportintelligence.com/market_d.asp?ProductID=195 (accessed 14-05-05).

[98] Jennie Price, WRAP, cited in Packaging magazine, 2006, Waste and Resources Action Programme, 2006: *Questions & Answers,* http://www.wrap.org.uk/waste_minimisation/retailer_initiative_innovation_fund/questions_answers/index.html (accessed 15-05-05).

[99] WRAP - Waste and Resources Action Programme, 2012: *Retail supply chain - waste prevention guidance,* http://www.wrap.org.uk/content/retail-supply-chain-waste-prevention-guidance.

[100] BBC News, June 15th, 2004: *Action Urged on China's Environment*, http://news.bbc.co.uk/1/hi/world/asia-pacific/3805883.stm (accessed 25-04-06).

[101] "Gridcore Systems International": *About the Unique Gridcore Product, Specification Sheet*, http://www.pixelwindow.com/gridcore/specif.html.

[102] DSD/DPD and GHS system, Agency for Chemicals of RS, http://www.shema.gov.rs

[103] IEC - International Electrotechnical Commission, http://www.iec.ch/.

[104] www.freedictionary.com

[105] SETAC - Society of Environmental Toxicology and Chemistry, http://www.setac.org/.

[106] *Environmental Product Declaration Steelcase*, 2004, "Think", Office Chair, Strasbourg, France.

[107] "Earthshift, Inc.", Building pathways to sustainability, 2011: *SimaPro Impact Assessment Methods* http://www.earthshift.com/software/simapro/impact-assessment-methods.

[108] "IVAM" - Research and consultancy on sustainability, IVAM LCA DATA 4, http://www.ivam.uva.nl/index.php?id=164&L=1&L=1.

[109] Ecodesign Web, Loughborough University, 2005, http://ecodesign.lboro.ac.uk/index.php?section=72.

[110] Table overview of energy consumption in transport, http://www.infra.kth.se/fms/pdf/appendix_transport.pdf]

[111] CRSES - Centre for Renewable and Sustainable Energy Studies: *Wave Energy Convertors*, http://www.crses.sun.ac.za/oen/images/pdf/WaveEnergyConvertors.pdf.

[112] Kyle Sherer: *Energy Island: Unlocking the potential of the ocean as a renewable power source*, "Ecogizmo", 2008, http://www.gizmag.com/energy-island-otec/8714/.

[113] Online Materials Information Resource - MatWeb, "MatWeb, LLC" http://www.matweb.com/.

[114] BPF - British Plastics Federation, http://www.bpf.co.uk/.

[115] "Autodesk": *Autodesk Simulation Moldflow*, 2012, http://usa.autodesk.com/moldflow/.

[116] "Dieflow Consulting": *Dieflow*, 2008, http://www.dieflow.com/index.html.

[117] "Rao Design International, Inc.", *Blow Molds*, 2002, www.raodesign.com/raoproducts.htm.

[118] "DOMPet & DOMPlast": *Orodja/gravure*, http://www.dompet-sp.si/orodja.htm.

[119] E-recycling: *Recycling of electrical and electronic waste*, "JUGO-IMPEX E.E.R. D.O.O.", 2010, www.ereciklaza.com.

[120] Minnesota Pollution Control Agency, www.reduce.org.

[121] TFOT - The Future of Things: *Adaptive Aerodynamics using Smart Materials*, http://thefutureofthings.com/news/18/adaptive-erodynamics-using-smart-materials.html.

[122] "TWI LTD", Granta Park, Great Abington, Cambridge, CB21 6AL, United Kingdom, 2012, http://www.twi.co.uk.

[123] Explainthatstuff!: *Shape memory alloys*, http://www.explainthatstuff.com/how-shape-memory-works.html.

[124] Key to Metals database: *Applications of Shape Memory Alloys in the medical field,* http://www.keytometals.com/page.aspx?ID=CheckArticle&site=ktn&NM=212.

[125] Blog, chrisbemis.com, Advanced Materials, Science, http://chrisbemis.com/blog/topic/advanced-materials.

[126] "Plastigi NV", Belgium, http://www.plastigi.be/eng/welkom.asp.

[127] "Dornob", Design Ideas Daily: *Flat-Pack Mobile Home: The Swiss Army Knife of Apartments*, http://dornob.com/flat-pack-mobile-home-the-swiss-army-knife-of-apartments/.

[128] "Komar Industries, Inc.", Global Innovators in Engineered Waste and Processing Systems, 2012, http://www.komarindustries.com/.

[129] TFL - Transport For London, http://www.tfl.gov.uk/.

[130] "Toyota", 2012, http://www.toyota.com/prius/.

[131] "Transport Inteligence": *Global Air Cargo 2006*, http://www.transportintelligence.com/market-reports/report-oldlink/195/.

[132] WCN Publishing, Northbank House, 5 Bridge Street, Leatherhead, Surrey KT22 8BL, England: *World Cargo News Online*, http://www.worldcargonews.com/htm/n20050405.548544.htm.

[133] CITYBIKE WIEN - das Gratis-Stadtrad in Wien, http://www.citybikewien.at/.

[134] "SSI Shredding System, Inc.", 2012, http://www.ssiworld.com.

[135] Knowles, Tim (04-04-05): *Tesco: Shelf-Ready of Else*, Food Manufacture: The Information Resource for Food and Drink, http://www.foodmanufacture.co.uk/news/fullstory.php/aid/1349/Tesco:_shelf-_ready_or_else_.html.

[136] "Tetra Pak", http://www.tetrapak.com/Pages/default.aspx.

[137] Guardian.co.uk: *Biofuels data: US corn production and use for fuel ethanol*, Jan. 22nd 2010, © 2011 "Guardian News and Media Limited", http://www.guardian.co.uk/environment/datablog/2010/jan/22/us-corn-production-biofuel-ethanol (accessed 29-8-2011).

[138] Jerry Garrett: *Corn Ethanol: Biofuel or Biofraud ?*, 2007, © 2011 "The New York Times Company", http://wheels.blogs.nytimes.com/2007/09/24/corn-ethanol-biofuel-or-biofraud/ (accessed 29-8-2011).

[139] "Percept Technology Labs": *Global Certification*, 2012, Percept Technology Labs © 2012, http://percept.com/global-certification.html (accessed 23-8-2012).

[140] www.dotpackaging.com/features/environment/fenv004.shtml.

[141] Wikipedia: United Nation's Brundtland Commision - The World Commision on Environment and Development – WCED, http://en.wikipedia.org/wiki/Brundtland_Commission.

[142] Wikipedia, http://en.wikipedia.org/w/index.php?oldid=486550941.

[143] Wikipedia, http://en.wikipedia.org/wiki/Deadweight_tonnage.

[144] Wikipedia, http://en.wikipedia.org/wiki/Feet_(unit_of_length).

[145] Wikipedia, http://en.wikipedia.org/wiki/Twenty-foot_equivalent_unit.

[146] Wikipedia, http://en.wikipedia.org/wiki/European_Union_energy_label.

[147] Wikipedia, http://en.wikipedia.org/wiki/List_of_environmental_issues.

[148] Wikipedia, http://en.wikipedia.org/wiki/PH.

[149] Wikipedia, http://en.wikipedia.org/wiki/Tonne_of_oil_equivalent.

[150] Wikipedia, http://en.wikipedia.org/wiki/Ocean_acidification.

[151] Wikipedia, http://en.wikipedia.org/wiki/Sustainable_energy.

[152] Wikipedia, http://en.wikipedia.org/wiki/Wind_Energy.

[153] Wwikipedia, http://en.wikipedia.org/wiki/Photo-voltaic_cells.

[154] Wikipedia, http://en.wikipedia.org/wiki/Photo_voltaic.

[155] Wikipedia, http://en.wikipedia.org/wiki/Solar_thermal_collector.

[156] Wikipedia, http://en.wikipedia.org/wiki/Solar_water_heating.

[157] Wikipedia, http://en.wikipedia.org/wiki/Biomass.

[158] Wikipedia, http://en.wikipedia.org/wiki/Biofuel.

[159] Wikipedia, http://en.wikipedia.org/wiki/Geothermal_energy.

[160] Wikipedia, http://en.wikipedia.org/wiki/Textile.

[161] Wikipedia, http://en.wikipedia.org/wiki/Iron.

[162] Wikipedia, http://en.wikipedia.org/wiki/Steel.

[163] Wikipedia, http://en.wikipedia.org/wiki/Aluminium.

[164] Wikipedia, http://en.wikipedia.org/wiki/Bauxite.

[165] Wikipedia, http://en.wikipedia.org/wiki/Copper.

[166] Wikipedia, http://en.wikipedia.org/wiki/Magnesium.

[167] Wikipedia, http://en.wikipedia.org/wiki/Manganese.

[168] Wikipedia, http://en.wikipedia.org/wiki/Zinc.

[169] Wikipedia, http://en.wikipedia.org/wiki/Lead.

[170] Wikipedia, http://en.wikipedia.org/wiki/Ceramics.

[171] Wikipedia, http://en.wikipedia.org/wiki/Glass.

[172] Wikipedia, http://en.wikipedia.org/wiki/Polymer.

[173] Wikipedia, http://en.wikipedia.org/wiki/Rubber.

[174] Wikipedia, http://en.wikipedia.org/wiki/Hybrid_materials.

[175] Wikipedia, http://en.wikipedia.org/wiki/ROHS.

[176] Wikipedia, http://en.wikipedia.org/wiki/Materials_science.

[177] Wikipedia, http://en.wikipedia.org/wiki/Osmotic_power.

[178] Wikipedia, http://en.wikipedia.org/wiki/OTEC.

[179] Wikipedia, http://en.wikipedia.org/wiki/Manufacturing.

[180] Wikipedia, http://en.wikipedia.org/wiki/Design_for_manufacturability.

[181] Wikipedia, http://en.wikipedia.org/wiki/Design_for_assembly.

[182] Wikipedia, http://en.wikipedia.org/wiki/Fordism.

[183] Wikipedia, http://en.wikipedia.org/wiki/Modular_design.

[184] Wikipedia, http://en.wikipedia.org/wiki/Tripple_bottom_line.

[185] Wikipedia, http://en.wikipedia.org/wiki/Natural_capital.

[186] Wikipedia, http://en.wikipedia.org/wiki/Bhopal_disaster.

[187] Wikipedia, http://en.wikipedia.org/wiki/Efficient_energy_use.

[188] Wikipedia, http://en.wikipedia.org/wiki/Energy_saving_lamp.

[189] Wikipedia, http://en.wikipedia.org/wiki/Fuel_efficiency.

[190] Wikipedia, http://en.wikipedia.org/wiki/Eco-Design_of_Energy-Using_ Products_Directive.

[191] Wikipedia, http://en.wikipedia.org/wiki/Restriction_of_Hazardous_Sub stances_Directive.

[192] Wikipedia, http://en.wikipedia.org/wiki/Waste_Electrical_and_Electro nic_Equipment_Directive.

[193] Youtube: *Jacques Fresco Utopia,* http://www.youtube.com/watch? v=BpyBwPQNyVU.

[194] Youtube, "Cameron Art Museum": *Winning Ideas: Selected Product Designs 2008*, http://www.youtube.com/watch?v=Jb2A1sO2XQA&feature=related.

[195] Youtube, "Indiamartvideos", *Plastic Bag Manufacturing Video*, http://www.youtube.com/watch?v=Nr7Dih_KCA4&feature=related.

[196] Youtube: *Eco-Friendly Packaging*, http://www.youtube.com/watch? v=_9Fuo0iv0pI.

[197] Youtube: *Very Eco Friendly Packaging*, http://www.youtube.com/watch? v=ypnQ7LEfRv0&feature=related.

[198] Youtube: *Sustainable Planet*, http://www.youtube.com/watch?v=vge67xmNirc.

[199] Youtube, John Cooney with Citizens for Global Solutions*: Neglected Sky*, Winner of the Environment Award in the 5th Annual Media That Matters Film Festival, 2009, http://www.youtube.com/watch?v=I9tCenQh3Rw.

[200] Youtube, Leyla Acaroglu, "EcoInnovators": *Why Do We Need Ecodesign ? Sustainability Challenges*, http://www.youtube.com/watch?v=EMasgfo1BdA.

[201] Youtube, "The secret Life of Things": *Sustainability animation - Life Cycle Pscycle-ology*, http://www.youtube.com/watch?v=OKyrB2Jn2Zs.

[202] Youtube, "DigInfo", 2007: *Ocean Thermal Energy Conversion System*, http://www.youtube.com/watch?v=aQmfRNzLNQs&feature=related.

[203] Youtube, Dominic Michaelis, University of Southampton: *Energy Island*, 2008, http://www.youtube.com/watch?v=OrzY6cs9Jic&feature=player_embedded.

[204] Youtube, "Tech Trends": *Energy Island*, 2008, http://www.youtube.com/watch?v=LPWiQskY1VM&feature=related.

[205] Youtube, "Alstom Power": *Wind Turbine - Alstom Pure Torque - a design for higher reliability*, http://www.youtube.com/watch?v=pi9F-sOhqtY.

[206] Youtube, "XRGI": *Electricity from all kinds of renewable sources*, http://www.youtube.com/watch?v=NaLBvHYYyUA&feature=related.

[207] Youtube: *Stirling Dish 500MW solar power plant*, http://www.youtube.com/watch?v=OTQ4cFn5sXs&feature=related.

[208] Youtube: *Wave Energy Device*, http://www.youtube.com/watch?v=tt_lqFyc6Co&feature=related.

[209] Youtube, "Pelamis": *Giant Sea Snake Renewable Electricity Generation*, http://www.youtube.com/watch?v=mcTNkoyvLFs&feature=related.

[210] Youtube, "Tidal Energy Pty Ltd" and the Davidson-Hill Venturi Turbine: *Tidal Energy Pty Ltd and the Davidson-Hill Venturi Turbine*, http://www.youtube.com/watch?v=4Iq-h4ShZ8s&feature=related.

[211] Youtube, "Optiline™": *SIMCRO OPTILINE™ - design for ease of manufacture and assembly*, http://www.youtube.com/watch?v=P7UxgOns-Xo.

[212] Youtube: *Design for Assembly Optimisation*, http://www.youtube.com/watch?v=PcHzFKLokuE&feature=related.

[213] Youtube, "NCC Automated Systems, Inc.": *Solar Conveyor - Glass Panel Handling Features*, http://www.youtube.com/watch?v=TYjpoQZasPw.

Modul_2022.

# Ecodesign and Ecoinnovations

Nenad ZRNIĆ, Miloš ĐORĐEVIĆ

# Fundamentals of Ecodesign

ISBN

Financial support was provided by the DRIVEN project (Grant agreement No. 2020-1-SK01-KA203-078349) under Erasmus+ Call 2020 Round 1 KA2 - Cooperation for innovation and the exchange of good practices.