15 May. 2014

Important facts and data presented in lecture course "Ecology and Sustainable Development" providing the knowledge base for the examination

Please note: Figures which should be known for the test are marked in red!

Part 1 - Ecology and Ecosystems:

Biology and the environment:

- Protein production is directed by the nucleic acids deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).
- The DNA contains all the hereditary information.
- Regions of the DNA which perform the particular coding functions are called „genes".
- The genome is the whole set of genes of an organism and is divided into chromosomes.
- Cells are the smallest unit of life that can function independently.
- Prokaryotes are single cell organisms like bacteria.
- The first living things on Earth were prokaryotes which developed 3.5 billion years ago.
- Animals, plants, fungi have eukariotic cells.
- Eukariotes generally have many different cells.
- Different cells perform different functions. Cells of the same function form tissues and tissues make up organs.
- The potential energy of chemical substances is the energy the held in the bonds between the atoms. Breaking down larger molecules through a chemical reaction releases this potential energy as heat or kinetic energy.
- An **ecozone** is the largest scale biogeographic division of the earth's surface based on the historic and evolutionary distribution patterns of plants and animals. List a few ecozones.
- A **biome** is a climatically and geographically defined area of ecologically similar communities of plants, animals, and soil organisms. There are terrestrial and aquatic biomes.

- Ecosystem services are "fundamental life-support services upon which human civilization depends".
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  Biosphere:

  - The biosphere is postulated to have evolved at least some 3.5 billion years ago.
  - The **lithosphere** is the solid outermost shell of a rocky planet and is fragmented into tectonic plates, which move independently relative to one another. This movement of lithospheric plates is described as plate tectonics and can lead to earthquakes, tsunamis….
  - The maximum density of water is at 4C:
    - Cold water sinks to the bottom of water bodies and creates circulation and supply of nutrients and oxygen for living species.
    - Ice floats on water protecting lower layers from freezing.

- Chemical compounds dissolved in water determine the acidity of water.
- Acidity is expressed as a pH value. pH = - log [H+]. The pH scale comprises 14 orders of magnitude. Some substances make water acidic (pH<7), others basic (pH>7).
- The **Earth's hydrosphere** consists of water in all forms: the oceans, inland seas, lakes, and rivers; rain; underground water; ice (as in glaciers and snow); and atmospheric water vapor (as in clouds).
- The abundance of water on Earth is a unique feature that distinguishes our "Blue Planet" from others in the solar system. Approximately 70.8 percent (97% of it being sea water and 3% fresh water) of the Earth is covered by water and only 29.2 percent is landmass.
- The most recent withdrawal of the ice sheets occurred only 10,000 years ago leading to an interglacial period known as the Holocene.
- The water cycle describes the methods of transport for water in the hydrosphere.
- Oceans comprise 97% of the planet's water. Source of the vast majority of water vapor that condenses and falls as rain or snow.
- The tremendous heat capacity of the oceans moderates the planet's climate, and its absorption of gases affects the composition of the atmosphere.
- Oceans show strong movements of water masses which are vital for regional climate.
- Top 10 m surface zone of oceans absorbs 80 % of solar energy. In this „photic zone“ practically all of the oceans primary production of biomass by phytoplankton takes place. Phytoplankton is the first step in the food chain and source of all life in the oceans.
- Ocean water contains on the average ca 3,5 % salt. The salt content arises from permanent transport of salts from land masses through rivers and atmospheric deposition. The salt content increases the density of water and influences the ocean currents, like the gulf stream.
- Sea water contains dissolved gases, like oxygen produced by photosynthetic processes of plants, and carbon dioxide, mainly from exchange processes with the atmosphere.
- The earth‘s ocean is composed of huge river-like flows driven by density differences, heating and cooling, gravity and wind.
- Gulf Stream: Largely driven by the global thermohaline Circulation. Powerful, warm, and swift Atlantic ocean current that originates in the Gulf of Mexico, exits through the Strait of Florida, and follows the eastern coastlines of the United States and Newfoundland before crossing the Atlantic Ocean. At about 30°W, 40°N, it splits in two, with the northern stream crossing to northern Europe and the southern stream recirculating off West Africa.
- **The atmosphere** protects life on Earth by absorbing ultraviolet solar radiation and reducing temperature extremes between day and night.
- Atmospheric pressure is a direct result of the total weight of the air above the point at which the pressure is measured. Atmospheric pressure decreases with height.
- Approximately 3.3 billion years ago the formation of the earth's present atmosphere started. The cyanobacteria were the first oxygen-producing species through photosynthesis based on the consumption of carbon dioxide leading to the formation of organic molecules. Photosynthesising plants would later evolve and continue releasing oxygen and sequestering carbon dioxide. The increase in oxygen in the atmosphere enabled the evolution of species using cellular respiration consuming O_2 and building materials of living matter, like proteins.
- Atmospheric circulation refers to large scale movement of air, and the means (together with the smaller ocean circulation) by which heat is distributed on the surface of the Earth.

- The major driving force of atmospheric circulation is solar heating, which on average is largest near the equator and smallest at the poles.
- The atmospheric circulation transports energy polewards, thus reducing the resulting equator-to-pole temperature contrast.
- The Hadley cell is a circulation pattern that dominates the tropical atmosphere, with rising motion near the equator, poleward flow 10-15 kilometers above the surface, descending motion in the subtropics, and equatorward flow near the surface. In the tropical zone the hot air picks up lots of moisture from the surface, cools when rising and releases much of the moisture in form of rain in the tropical zone. As the air flows towards the pole it is exposed to further cooling and therefore sinks to the ground as dry air, warms during sinking due to compression leading to a warm arid climate in these zones. The air then flows back to the tropical zone due to pressure differences.
- Near the tropopause, as the air moves polewards in the Hadley cell, it is turned eastward by the Coriolis force creating the subtropical jet streams that flow from west to east „Westerlies“). Analogously, near the surface, the equatorward return flow is rotated to the west. These surface winds, with both an equatorward and a westward component, are referred to as the trade winds.
- The large-scale structure of the atmospheric circulation varies from year to year, but the basic structure remains fairly constant.
- However, individual weather systems - midlatitude depressions, or tropical convective cells - occur "randomly", and it is accepted that weather cannot be predicted beyond a fairly short limit: about ten days in practice.
- Nonetheless, the average of these systems, the climate, is quite stable.

Biogeochemical cycles:

- The most important biogeochemical cycles are: The carbon cycle. The nitrogen cycle. The phosphorus cycle. The oxygen cycle
- The **carbon cycle** is the biogeochemical cycle by which carbon is exchanged between the biosphere, geosphere, hydrosphere, and atmosphere of the Earth. The cycle is usually thought of as four major reservoirs of carbon interconnected by pathways of exchange.
- The major carbon reservoirs are:
  - the atmosphere,
  - the terrestrial biosphere (which usually includes freshwater systems and non-living organic material, such as soil carbon),
  - the oceans (which includes dissolved inorganic carbon and living and non-living marine biota),
  - the sediments (which includes fossil fuels).
- The ocean contains the largest active pool of carbon near the surface of the Earth (38.000 Gto).
- Carbon exists in the Earth's atmosphere primarily as the gas carbon dioxide (CO_2). Although it is a very small part of the atmosphere overall (approximately 0.04% on a molar basis, though rising), it plays an important role in supporting life.
- Carbon exists in the biosphere as living species (plants, animals) largely consisting of organic carbon compounds (carbohydrates, celluloses, proteins…..) and of inorganic carbonates (e.g. shells of animals).
- Carbon exists in the lithosphere as inorganic carbonate rocks and as carbon rich deposits of dead organic matter (coal, oil, natural gas).
- Carbon exists in the hydrosphere as dissolved carbon dioxide, suspended carbonates, dead organic matter.

- Carbon is an essential part of life on Earth. It plays an important role in the structure, biochemistry, and nutrition of all living cells.
- Organic compounds are produced from CO_2 by autotroph organisms through the process of photosynthesis. The energy required for this process comes from solar radiation.
- The most important autotrophs for the carbon cycle are trees in forests on land and phytoplankton in the Earth's oceans.
- Carbon is transferred within the biosphere as heterotrophs feed on other organisms or their parts (e.g. fruits).
- Phytoplankton are the autotrophic component of plankton. Size usually less than 0,1 mm. Through photosynthesis, phytoplankton are responsible for about half of the oxygen produced in the Earth's atmosphere.
- Carbon uptake from the atmosphere:
  - Photosynthesis: When the sun is shining, plants perform photosynthesis to convert carbon dioxide into carbohydrates, releasing oxygen in the process. Chlorophyll is vital for photosynthesis, which allows plants to obtain energy from light. Chlorophyll molecules absorb light and transfer that light energy to the cells. Photosynthesis follows the reaction $6CO_2 + 6H_2O + h\nu \rightarrow C_6H_{12}O_6$ (glucose) $+ 6O_2$.
  - Inorganic processes: At the surface of the oceans carbon dioxide is readily exchanged with the atmosphere and dissolved in the water. This carbon exchange becomes important in controlling pH in the ocean and can also vary as a source or sink for carbon.
- Carbon release back into the atmosphere**:**
  - Respiration performed by animals: involves the breaking down of glucose (or other organic molecules) into carbon dioxide and water.
  - Decay of animal and plant matter: Fungi and bacteria break down the carbon compounds in dead animals and plants and convert the carbon to carbon dioxide if oxygen is present, or methane if not.
  - Combustion of organic material: produces carbon dioxide (and other compounds, like water vapor). Burning fossil fuels such as coal, petroleum products, natural gas or biomass releases carbon that has been stored in the geosphere for millions of years.
  - Outgasing from oceans: At the surface of the oceans where the water becomes warmer, dissolved carbon dioxide is released back into the atmosphere.
  - Volcanic eruptions: release primarily water vapor, carbon dioxide and sulfu dioxide.
- The **nitrogen cycle** is the biogeochemical cycle that describes the transformations of nitrogen and nitrogen-containing compounds in nature. Earth's atmosphere is about 78% nitrogen, making it the largest pool of nitrogen. Nitrogen is essential for many biological processes; and is crucial for any life here on Earth. It is in all amino acids, is incorporated into proteins, and is present in the bases that make up nucleic acids, such as DNA and RNA.
- Uptake of gaseous nitrogen from atmosphere:
  - Nitrogen fixation: conversion of gaseous nitrogen into forms usable by living organisms is done by bacteria.
  - Assimilation: Most plants can absorb nitrate or ammonium ions from the soil via their root hairs.
- Fertilizers: Compounds given to plants to promote growth; they are usually applied through the soil for uptake by plant roots. Fertilizers can be organic (composed of organic matter), or inorganic (made of simple, inorganic chemicals or minerals). They

can be naturally occurring compounds such as peat or mineral deposits, or manufactured through natural processes (such as composting) or chemical processes (such as the Haber-Bosch process). Fertilizers typically provide the plant nutrients (the major ones being nitrogen, phosphorus, and potassium).

- In the Haber-Bosch Process developed 1910 ammonia (NH_3) is produced through a high temperature/high pressure reaction between hydrogen (from natural gas) and atmospheric nitrogen. NH_3 is used to produce nitrogen fertilizer, mostly in the form ammonium nitrate and urea. The Haber-Bosch process now produces 100 million tons of nitrogen fertilisers per year. That fertilizer is responsible for sustaining one-third of the Earth's population, but overfertilisation is considered a severe environmental problem.
- Release of nitrogen into the atmosphere:
  - NO_x: Fossil fuel combustion has contributed to a 6 or 7 fold increase in NO_x flux to the atmosphere. NO_x actively alters atmospheric chemistry, and is a precursor of tropospheric (lower atmosphere) ozone production, which contributes to smog, acid rain, and increases nitrogen inputs to ecosystems.
  - N_2O: The use of fertilizers on a global scale emits significant quantities of this green house gas into the atmosphere.
  - NH_3: Concentration in the atmosphere has tripled mainly as the result of increased use of fertilisers. It reacts in the atmosphere with NO_x and SO_2/SO_3 forming ammonium nitrate and sulfate as an aerosol. These are components of acid precitation.
- **Phosphorous:** Key component of all living matter (cell membranes) and molecules vital for life, like DNA, RNA. Primary uptake in food chain of water soluble phosphorus by plants, then transfer upwards.
- Supply of phosphorus to waters and soil:
  - Excretion of waste and decomposition of the compounds. Waste water is a major source of phosphorus (also due to detergents).
  - Input through fertilisation in agriculture. Oversupply of waters with phosphorus contributes to eutrophication.
- **Oxygen:** constitutes 20.9% of the volume of air.
- Free oxygen also occurs in solution in the world's water bodies. The increased solubility of O_2 at lower temperatures has important implications for ocean life, as polar oceans support a much higher density of life due to their higher oxygen content. Polluted water may have reduced amounts of O_2 in it, depleted by decaying algae and other biomaterials (eutrophication).
- Sources of oxygen: The main source of oxygen within the biosphere and atmosphere is photosynthesis. Photosynthesizing organisms include the plant life of the land areas as well as the phytoplankton of the oceans. Green algae and cyanobacteria in marine environments provide about 70% of the free oxygen produced on earth and the rest is produced by terrestrial plants.
- Oxygen consumption from the atmosphere: The main way oxygen is lost from the atmosphere is via respiration, mechanisms in which animal life and bacteria consume oxygen and release carbon dioxide. The reaction for aerobic respiration is essentially the reverse of photosynthesis and is simplified as: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 2880\ kJ{\cdot}mol\text{-}1$. In vertebrates, O_2 is diffused through membranes in the lungs and into red blood cells (erythrocytes).Erythrocytes consist mainly of hemoglobin.

Ecosystem dynamics:

- Within the ecosystem, species are connected by food chains or food webs: Energy from the sun, captured by primary producers via photosynthesis, flows upward through the chain to primary consumers (herbivores), and then to and secondary consumers (carnivores and omnivores), before ultimately being lost to the system as waste heat. On average, only 10% of the organism's energy is passed on to its predator. The other 90% is used for the organisms life processes or is lost as heat to the environment.
- Directly linked to this are pyramids of numbers, which show that as the chain is travelled along, the number of consumers at each level drops very significantly, so that a single top consumer (e.g. a Polar Bear) will be supported by literally millions of separate producers (e.g. Phytoplankton).
- A food web extends the *food chain* concept from a simple linear pathway to a complex network of interactions. Food sources of most species in an ecosystem are very diverse, resulting in a complex *web* of relationships.
- An ecosystem(s) is unstable when the load capacity is overrun and is especially unstable when a population has overconsumers.
- The productivity of ecosystems is estimated by comparing three types of land-based ecosystems and the total of aquatic ecosystems: The forests (1/3 of the Earth's land area) contain dense biomasses and are very productive. The total production of the world's forests corresponds to half of the primary production. Savannas, meadows, and marshes (1/3 of the Earth's land area) contain less dense biomasses, but are productive. Represent the major part of what humans depend on for food. Extreme ecosystems in the areas with more extreme climates -- deserts and semi-deserts, tundra, alpine meadows, and steppes -- (1/3 of the Earth's land area) have very sparse biomasses and low productivity. Finally, the marine and fresh water ecosystems (3/4 of Earth's surface) contain very sparse biomasses (except coastal zones).
- Major abiotic factors affecting the species in a given ecosystem are:
  - Water, which is an essential element to life and a milieu.
  - Air, which provides mainly oxygen and carbon dioxide to living species and allows the dissemination of pollen and spores.
  - Soil, at the same time source of nutriment and physical support.
  - Temperature, which should not exceed certain extremes, even if tolerance to heat is significant for some species.
  - Light, which provides energy to the ecosystem through photosynthesis.
- Biotic factors affecting the species in a given ecosystem ar**e:** Relations within a population: co-operation or competition.
- Some examples of <u>global</u> ecological crises are:
  - Permian-Triassic extinction event 250 million of years ago.
  - Cretaceous–Tertiary extinction event 65 million years ago.
- Some examples of an ecological crises with <u>local and regional</u> impact are:
  - The Exxon Valdez oil spill off the coast of Alaska in 1989.
  - The nuclear meltdown at Chernobyl.
  - The overconsumption of natural resources under conditions of abundance as happened at the Easter Island.

Part 2- Ecosystem functions:

Biodiversity:

- Biodiversity is the variation of life forms within a given ecosystem, biome or for the entire Earth. It is richer in the tropics. As one approaches polar regions one generally finds fewer species. Flora and fauna diversity depends on climate, altitude, soils and the presence of other species.
- The IUCN Red List contains now more than 16.000 threatened species. IUCN is the International Union for the Conservation of Nature and Natural Resources.
- Benefits of Biodiversity: There are a multitude of benefits of biodiversity such as:
  - resistance to diseases and catastrophes,
  - provision of food and drink, medicines, industrial products,
  - ecosystem services,
  - technology models, leisure,
  - cultural and aesthetic value.
- Recent reductions of biodiversity:
  - Extinction of many bird species on remote islands after discovery and introduction of foreign species by man starting 500 years ago.
  - Industrialisation and change of land use beginning in the 19th century.
  - Habitat fragmentation as a consequence of land use changes, like converting forests into agricultural land.
- Numbers of species:
  - 300.000 plants,
  - 1,2 million animals (including ca 1 million insects)
- The conservation of biological diversity has become a global concern and is addressed in the **Convention on Biological Diversity,** which is an international treaty of 1992 (Rio) with main goals: conservation of biodiversity, sustainable use of its components and fair sharing of such resources.

Acid rain:

- Acid rain is rain or any other form of precipitation (snow, fog, dew) that is unusually acidic (pH<5).
- Acid rain is mostly caused by human emissions of gaseous sulfur and nitrogen compounds (NO_x, SO_2) which react in the atmosphere to produce acids: mainly HNO_3, H_2SO_4
- Main sources:
  - burning of fossil fuels (coal, oil, gas) in power plants
  - waste incineration and industrial production plants
  - diesel and gasoline vehicles and ships
  - Acid rain has harmful effects on aquatic animals, plants and buildings.
- Industrial acid rain is a substantial problem in China, Eastern Europe, Russia and areas down-wind from them. These areas all burn sulfur-containing coal to generate heat and electricity.
- Adverse effects of acid rain in surface waters: damage to fish and other aquatic animals.
- Adverse effects of acid rain on forests and other vegetation: Acid rain can slow the growth of vulnerable forests and cause leaves and needles to turn brown and fall off.
- Technical solutions to reduce emission of acid gases:

  - Coal-burning power plants use flue gas desulphurisation (FGD) to remove sulphur-containing gases from their stack gases.
  - Automobile emissions control with catalytic converters reduce emissions of nitrogen oxides from motor vehicles.

Chemicals:

- A chemical substance is a material with a definite chemical composition. Presently 52 million chemical compounds are known and registered by Chemical Abstracts Services (USA). More than 100.000 different chemical compounds are regularly produced by industry and enter the environmental system.
- The most important chemical substances in relation to pollution of the environment are:
  - fertilisers,
  - plant protection chemicals (pesticides, herbicides…..),
  - detergents,
  - waste materials from human consumption and industrial processes,
  - pharmaceuticals.
- All chemical compounds in actual use have been tested for toxicity, registered at a proper authority (e.g. the US Food and Drug Administration – FDA, EU National Competent Authorities, or the European Chemicals Agency).
- The US registry of the FDA contains 150.000 entries with some 5.000 classified as somehow toxic.
- Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH): covers the production and use of chemical substances in the EU with the aim to achieve an enhanced protection of human health and the environment.

Pesticides:

- The most important classes of pesticides are:
  - bactericides for the control of bacteria,
  - fungicides for the control of fungi,
  - herbicides for the control of weeds,
  - insecticides for the control of insects.
- United Nations Food and Agriculture Organization (FAO) adopted an International Code of Conduct on the Distribution and Use of Pesticides in 1985 to create voluntary standards of pesticide regulation for different countries. The United Nations Codex Alimentarius Commission seeks to create uniform standards for maximum levels of pesticide residues among participating countries.
- In the European Union an extensive legislative framework is in place controlling the use of pesticides in food and feed.
- Environmental effects: Use of pesticides can have unintended effects on the environment. Over 98% of sprayed insecticides and 95% of herbicides reach a destination other than their target species. Many of the chemicals used in pesticides are persistent soil contaminants and eventually enter the water systems resp. food chain.
- The European Union also regulates maximum concentrations of pesticides in water: The Maximum Residue Limit (MRL) for ground and drinking water is typically 0,1 microgram per liter.

POPs:

- Persistent organic pollutants: compounds that resist degradation and thus remain in the environment for years. POPs are frequently halogenated, usually with chlorine. Their lipid solubility results in the ability to bioaccumulate in the fatty tissues of living organisms.
- Bioaccumulation of fat soluble persistent organic pollutants in the food chain can lead to a concentration enrichment of factor 10.000.000.
- Some POPs have been banned like Polychlorinated biphenyls (PCBs), DDT, polycyclic aromatic hydrocarbons (PAHs), like Benzo-A-Pyrene while others continue to be used.
- Chlorofluorocarbons reduce concentration of stratospheric ozone, create the „ozone hole“ and are therefore responsible that the more UVB-radiation (270 – 315 nm) reaches the surface of the earth which significantly enhances the risk for skin cancer.
- Montreal Protocols of 1987 and 1990 completely phasing out CFC production by 2000.
- Ozone layer seems to remain stable now.

Part 3 - SD concept:

Milestones in the evolution:

- Public awareness of environmental pollution was first raised massively in 1962 by **Rachel Carson** through her battle against the uncontrolled use of pesticides in agricultural production in the USA for which she coined the term „biocides“.
- **Dennis Meadows “The Limits to Growth - A Report of the Club of Rome’s Project on the Predicament of Mankind” 1972:** “If the world's consumption patterns and population growth continue at the same high rates of the time, the earth will strike its limits within a century.”
- **“Decoupling”:** A Key Element of Sustainable Development, means decoupling of resource use from economic growth and decoupling of environmental impact from resource use.
- **Establishment of the United Nations Environment Programme (UNEP) in 1972:** to coordinate the United Nations environmental activities, to assist developing countries in implementing environmentally sound policies and to encourage sustainable development through sound environmental practices.
- UN-WCED commissioned report **“Our Common Future”** in 1983, published in 1987 (“Brundtland Report”) it provided for a definition of Sustainable Development: „*Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*“
- **1988:** The World Meteorological Organization and the UNEP established the **Intergovernmental Panel on Climate Change (IPCC).** IPCC is the scientific body tasked to evaluate the risk of climate change caused by human activity. Main activity of the IPCC is publishing special reports on topics relevant to the implementation of the UN Framework Convention on Climate Change (UNFCCC), which is an international treaty to combat global warming.
- **1992: United Nations Conference on Environment and Development** (“Earth Summit”) 5 important documents produced:
  - The Rio Declaration on Environment ad Development.
  - Agenda 21: a document of 40 chapters outlining the main tasks to be carried out for the achievement of sustainable development.

- The Forest Principles on the sustainable management of Forests.
- The Framework Convention on Climate Change (UNFCCC).
- The Convention of Biological Diversity (UNCBD).
- The Convention to Combat Desertification (UNCCD).

- **2000: Establishment of the Millennium Development Goals** at the Millennium Summit held at the UN Headquarters in New York. The **Millennium Development Goals** are eight goals that 189 United Nations member states have agreed to try to achieve by the year 2015:
  - Eradicate extreme poverty and hunger.
  - Achieve universal primary education.
  - Promote gender equality and empower women.
  - Reduce child mortality. Improve maternal health.
  - Combat HIV/AIDS, malaria, and other diseases.
  - Ensure environmental sustainability.
  - Develop a global partnership for development.

Policies in theEuropean Union:

- Major EU policy actions:
  - 1973: First Environmental Action Programme of EC.
  - 1997: Single European Act (Amsterdam) placed environmental protection on equal footing with economic growth and free trade.
  - 2001 Gothenburg European Council Decision establishing EU Sustainable Development Policy: *Integration of environmental considerations into all Community policies.*
  - 2002 Communication of European Commission "Towards a Global Partnership for Sustainable Development" COM(2002)82: *Commitment of the EU to promoting sustainable development on a global level.*
  - *2008: The Climate and Energy Package: A series of Directives to combat climate change.*
- Since 1970 ca 250 pieces of EU legislation have been produced and 7 Environmental Action Programmes established: Basis for the current policy guidelines of the European Union.
- The Lisbon Agenda of 2005: Economic Growth, Social Equilibrium, Environmental Quality are the 3 pillars of Sustainable Development which is the Guiding Principle for the European Union.

Part 4 - Environmental pollution:

Air:

- **Major sources for air pollutants:**
  - Emissions from industry (production plants, power plants, waste incineration)
  - Traffic (road, shipping)
  - Small scale heating
- **Major EU legislation on air pollution:**
  - Euro Emission Standards for Road Vehicles1970 – ….
  - Integrated Pollution Prevention and Control Directive 1996 and 2008
  - National Emission Ceilings Directive 2001
  - Thematic Strategy on Clean Air for Europe 2005
  - Air Quality Directives 1996 – 2008

- **National Emissions Ceiling Directive:**
  - The directive requires all Member States to report information annually concerning emissions and projections for four main air pollutants:
    nitrogen oxides (NO_X), non-methane volatile organic compounds (NMVOC), sulphur dioxide (SO_2) and ammonia (NH_3). To help protect human health and the environment, the NECD sets pollutant-specific and legally binding emission ceilings for each of these pollutants and for each country, which must be met by 2010. The ceilings set in the NECD were designed to reduce such adverse impacts by an agreed amount.
- Emissions of major air pollutants have been significantly reduced due to the environmental protection activities of the EU.
  - Largest reduction for SO_2/SO_3 due to industrial abatement measures and elimination of sulfur from diesel and gasoline.
  - Large reduction of NMVOCs (Non-Methane VOCs) and NO_X due to industrial abatement measures and introduction of catalysts for cars.
- **Major air pollutants**:
  - Particulate Matter (PM_{10}, $PM_{2,5}$),
  - Ozone (O_3),
  - Nitrogen dioxide (NO_2),
  - Sulphur dioxide (SO_2)
- **Major reasons for still enhanced regional exposure of population:**
  - SO_2: power stations (coal, oil); transport using sulphur-containing fuel (esp. shipping)
  - PM_{10}: dust from road traffic (minerals); vehicle emissions (carbon); small scale heating (carbon); regional transport of air pollutants (secondary particulate matter); industrial emissions
  - $PM_{2,5}$: vehicle emissions (carbon); small scale heating (carbon); regional transport of air pollutants (secondary particulate matter)
  - O_3 : road vehicle and ship emissions (VOCs and NO_x); high UV radiation
  - NO_2: road vehicle and ship emissions
- **Transport** responsible for emissions of CO_2, Particulate Matter, SO_2 (shipping), NO_x + VOCs (forming ozone).
- Transport accounts for roughly 30 % of the energy consumption and of the GHG emissions. Transport in many regions now the major source for air pollution.
- Major mitigation measures for air pollutions from traffic: Establishment of more stringent emission limits for road vehicles in EU Directives (EURO 5, EURO 6, EURO 7….., EURO V, EUROVI….); catalytic converters (CO, $NO_{x,}$ VOCs) and particle traps (PM); limits for fuel consumption for a fleet of a producer:
  CO_2 (max 130g CO_2/km)
- Large disparities in transport costs: Road: 20 EUR, Rail: 60 EUR (for 1000 ton.km), Ship: < 10 EUR.
- Evironmental Quality of Megacities: extremely high air pollution in developing countries and emerging economies

Water:

Water Pollution:

- Water pollution is a large set of adverse effects upon water bodies such as lakes, rivers, oceans, and groundwater caused by human activities.
- Water pollution has many causes, the most important being:
    - Industrial waste water discharges: heavy metals, organic toxins and oils. Now largely eliminated in EU, USA, Japan. Still a major problem in emerging economies and developing countries.
    - Agricultural effluents: pesticides, herbicides leading to ground water pollution, nutrients from fertilisation leading to eutrophication, manure leading to bacterial contamination.
    - Human waste water discharge, unprocessed or processed in sewage plants: nitrates and phosphates leading to eutrophication and bacterial contamination.
    - Oil discharges: oil spills due to accidents with tankers or in drilling or release of hydrocarbons due to intentional cleaning of oil tanks at the open sea.
    - Excessive warming of surface waters due to discharges of heated cooling water of thermal and nuclear power stations leading to a depletion of oxygen.
- **Eutrophication:**
- high primary productivity due to a high nutrient input (particularly phosphorus and nitrogen) into water. A eutrophic lake is subject to excessive alga blooms, resulting in murky water and poor water quality. The bottom waters of such lakes are commonly deficient in oxygen; thus, such lakes commonly lack those fish species.
- A widely-used measure of eutrophication is the determination algal and cyanobacterial biomass from the chlorophyll concentration.
- An oligotrophic lake is a lake with low primary productivity, the result of low nutrient content. These lakes normally have very clear waters, some even with drinking-water quality. The bottom waters of such lakes typically have ample oxygen; thus, such lakes often support many fish species.
- Major sources for eutrophication: waste water and agriculture.
- **Pathogens:**c
- an produce waterborne diseases in either human or animal hosts: Contaminated drinking water, used in the preparation of food, can be the source of foodborne disease through consumption of the same microorganisms.
- According to the World Health Organization, diarrheal disease is responsible for the 4% of the total daily global burden of disease largely attributable to unsafe water supply, sanitation and hygiene, and mostly concentrated in children in developing countries.
- **Chemical water pollution:**
    - Heavy metals including acid mine drainage,
    - chemical waste as industrial by products,
    - fertilizers, in runoff from agriculture including nitrates and phosphates.
- **Some important organic water pollutants are:**
    - insecticides and herbicides (a huge range of organohalide and other chemicals),
    - VOCs (volatile organic compounds), such as industrial solvents, from improper storage, petroleum hydrocarbons including fuels (gasoline, diesel, jet fuels, and fuel oils) and lubricants (motor oil),
    - detergents,
    - various chemical compounds found in personal hygiene and cosmetic products,
    - agropharmaceuticals,
    - human medicines…..

- **General Problems of water pollution in Europe:**
  - 20 % of all European surface water bodies seriously threatened by pollution (nitrate and pesticides).
  - Widespread acidification of lakes in Northern Europe.
  - European seas threatened by eutrophication.
  - Coastal zones under heavy pressure.
  - Occasionally poor bathing water quality.
  - Frequent oil discharges on open seas.
  - Wide-spread over-consumption of water, particularly in the South of Europe.
- Water Framework Directive (WFD) 2000/60/EC: Integrated impact-based river basin management. Ecosystem approach: Holistic assessment of surface water status. Major objective: "good surface water status" by 2015.
- Coastal Zones are subject to strong anthropogenic pressures:
  - freshwater inputs rich in pollutants,
  - population growth in coastal areas,
  - fish and shellfish farming (500.000 tons of molluscs annually),
  - tourism
- Ecosystem functioning disruptions in coastal zones: anoxic crises, algal blooms, etc.
- Concentrations of phosphorus in European rivers and lakes decreased during the 1990s, reflecting the improvement in waste water treatment. The decrease was not sufficient to halt eutrophication. Nitrate concentrations in Europe's groundwaters have remained constant and are high in some regions, threatening drinking water abstractions. Main reason is the increased use of fertilisers in agriculture.
- Waste Water Treatment:
  - Primary: removal of solid materials.
  - Secondary: biological treatment.
  - Tertiary: chemical treatment
- Agriculture is the main source of nutrients (and other chemicals) to surface waters leading to eutrophication and groundwater pollution. Use of nitrogen fertilisers has increased 10-fold in EU during last 50 years!
- The quality of water at designated bathing beaches in Europe (coastal and inland) has improved throughout the 1990s and early 2000s. In 2003, 97% of coastal bathing waters and 92% of inland bathing waters complied with the mandatory standards.

Soil:

- Soil performs a number of key environmental, social and economic functions that are vital for life:
  - Plants and crops depend on soil for the supply of water, nutrients and as a medium for growing.
  - Soil stores, filters, buffers and transforms substances that are introduced into the environment, crucial in protecting water supplies and regulating greenhouse gases.
  - Soil is a provider of raw materials.
  - Soil is a fundamental component of our landscape and cultural heritage.
  - List a few soil functions.
- Land use in the EU: 36 % forest, 47 % agricultural area, 17 % other use
- Soil problems:
  - Soil erosion by water and by wind.
  - Southern Europe soils often have a reduced organic carbon content.

- The Boreal region has the biggest carbon stocks on earth. Threat of loss of methane by global warming.
- Soil contamination arises from the rupture of underground storage tanks, application of pesticides, percolation of contaminated surface water to subsurface strata, leaching of wastes from landfills or direct discharge of industrial wastes to the soil.
- The most common chemicals involved are petroleum hydrocarbons, solvents, pesticides, lead and other heavy metals.
- The concern over soil contamination stems primarily from health risks: contamination of water, crops, feed and food.
- There are an estimated 150.000 contaminated sites within the European Union, many of these in the new Member States of the former Soviet block.
- Waste deposits:
    - Each European produces on average 500 kg waste per year.
    - Waste deposition is one of the largest impacts on soil.
- A number of adverse effects can occur from landfill operations:
    - contamination of groundwater and/or aquifers by leakage
    - outgassing of methane (green house gas) from decaying organic wastes
    - harbouring of disease vectors such as rats and flies
    - simple nuisance problems (e.g. dust, odour).
- Mitigation of landfill waste problems:
    - waste reduction and recycling
    - incineration and pyrolysis
    - composting and mechanical biological treatment
    - banning of disposal of untreated waste in landfills (AT, DE, CH)

Part 5 - Natural resources:

Trends in global resource consumption:

- The last century has been characterised by a steeply rising consumption of natural resources and energy. Up to now there is no significant change in the global consumption trend.
- Drivers of increased resource (and energy) use:
    - Population numbers
    - “Development” in the sense of transition from an agrarian to an industrial regime:
    - Person in industrial regime uses 3-5x more energy and natural resources than a person in an agrarian regime.
    - Rising income (GDP)
- The ecological footprint is a measure of human demand on the Earth's ecosystems. It compares human demand with planet Earth's ecological capacity to regenerate. It represents the amount of biologically productive land and sea area needed to regenerate the resources a human population consumes and to absorb and render harmless the corresponding waste.
- Resource capacity of the world already exceeded.
- European countries, USA, Japan enjoy a high level of human development – but at the cost of a large ecological footprint. African and many Asian countries have a very low footprint, but face urgent needs to improve access to basic services (health, education, potable water).

Forest – from deforestation to desertification:

- Nowadays about 30 % of the earth‘s surface are covered by forests.
- Human-caused deforestation and the degradation of forest habitat is continuing primarily due to:
  - expansion of agriculture (with often slash and burn practices),
  - urban sprawl,
  - illegal logging,
  - over harvest of fuel wood,
  - mining, and petroleum exploration.
- Carbon uptake in EU forests = 10% of EU emissions
- Forest fires destroy every year several hundred thousand hectares of forests in the South of Europe.
- In the world's tropical rainforests destruction is most pronounced at the current time: One fifth of the world's tropical rainforest was destroyed between 1960 and 1990.
- Rainforests account for around 5 % of the Earth’s land surface and are home to above 50 % of the estimated number of vegetal and animal species. They regulate climate at local and global levels and provide resources to some 1.4 billion people who are among the poorest.
- Loss of forests and woodlands in Africa was 16% between 1975 and 2000
- Impact of deforestation on the environment:
  - Reduction of biodiversity.
  - Reduction of the landscape's capacity to intercept, retain and transport precipitation.
  - Reduction of amount of water in the soil and groundwater.
  - Deforested areas become sources of surface water runoff which can lead to flash flooding.
  - Enhancement of green house gas emissions due to burning of forests and release of organic carbon from soil.
  - Land degradation, drying of the soil layers, eventually desertification.
- The primary reasons for desertification are:
  - overgrazing,
  - overcultivation,
  - incorrect irigation methods,
  - deforestation,
  - overdrafting of groundwater,
  - increased soil salinity,
  - global climate change.
- The transition zones between deserts and the normal vegetation zones (desert fringes) have fragile, delicately balanced ecosystems. In these marginal areas human activity may stress the ecosystem beyond its tolerance limit, resulting in degradation of the land.
- Globally 10 – 20 % of the drylands are deserted.

Crops and food:

- In the fertile-half moon the neolithic revolution based on the introduction of agriculture started 10.000 years ago. The eight so-called Neolithic founder crops of agriculture appear: wheat, barley, peas, lentils, bitter vetch, chick peas and flax.

- When people lived on hunting and gathering 1000 ha of land were needed to support 1 person.
- Due to introduction of agricultural practices (traditional agriculture only 100 ha needed to support 1 person.
- With industrialised agriculture this area was reduced to 10 ha.
- Present day industrialised agriculture based on large scale landscape, heavy use of fertilisers – less than 1 ha needed to support 1 person.
- General changes introduced by human evolution on land:
  - Deforestation: forest area decreased substantially over the centuries, natural forest replaced by "industrial forests" in many areas (low resistance to pests and diseases, storms…), impact on water storage capacity of land, biodiversity….
  - Draining of wetlands: wetland areas strongly reduced and their functions diminished (water reservoirs, productive biotopes, filtering and de-nitrification, landscape value).
  - Expansion of infrastructures: cities, communication infrastructure (transport), industries and industrial infrastructure
- Until the first Industrial Revolution, the vast majority of the human population labored in agriculture. Since the 1940s, agriculture has dramatically increased its productivity, due to increased mechanization and the use of petrochemical derived pesticides and fertilizers. Modernisation of agriculture has allowed the world population to double over the last 50 years.
- Nowadays 36 percent of the world's workers are employed in agriculture, but agricultural production accounts for less than five percent of the gross world product.
- Area of arable land is still slightly increasing due to draining of wetlands, irrigation and deforestation. But area used for cereals is decreasing due to increase in meat production.
- Areas needed for crops and meat production:
  - 1 kg of vegetable 1 m^2
  - 1 kg of beef 250 m^2
- Meat makes up only ca 5 % of the global food production – but takes 2/3 of the agricultural land. Meat has only a slightly higher energy content than crops.
- Meat, butter and cheese have a particularly high footprint. To produce 1 kg of beef more than 40 kg of feed (e.g. cereals, grass...) and 15.000 liters of water are needed
- Global agricultural production: ca 3.000 million tons annually cereals and vegetables, ca 400 million tons meat and fish
- Globally only 12 % of land surface usable for agriculture and only 2,5 % high value farmland.
- Arable land per capita decreasing due to population growth, but the agricultural yield can be increased: now 70% in industrialised countries, 20% in developing countries.
- Agriculture accounts for 70% of the global consumption of freshwater water. Globally 40% of crops are produced in irrigated fields.
- Over-extraction of water already now a very severe problem for dry regions in Africa and Asia! By 2030 2 billion people will be affected by severe water shortage.
- Lake Chad has shrunk to 10% of its original size since the 1960s.
- Food prices have sharply risen during the last decades due to population growth, higher living standards combined with higher demands for meat, production of heavily subsidised energy crops….
- Genetic modification of seed material allows to produce plants with new properties:
  - Enhanced resistance against insects (Bt-maize).
  - Enhanced resistance against efficient broad band pesticides (RoundupReady Soy).

  - Improved nutrient content.
  - Higher drought resistance.
  - Higher salt resistance.
- Global share of the most important GM crops (2009/2010):
  - Soy 77%
  - Maize 26%
  - Cotton 49%
  - Rapeseed 21%
- European Commission Report on GMO Biosafety (2010):
  - Reports on 130 research projects covering a period of more than 25 years and involving 500 research groups:
  - GMOs are not *per se* more risky than plants obtained with conventional breeding technologies.
- EU tried to ban imports of GM food and feed into the EU, but lost the WTO case: Only labelling acceptable.
- However many open questions remain:
  - Dependence on large industry ?
  - Pollination of non-GM plants ?
  - Development of resistance of pests ?
- The Doha Development Round:
  - Concerns the renewal of the WTO Agreement on Agriculture to accommodate the interests of the developing countries.
  - The most significant differences are between industrialised nations led by the European Union (EU), the United States (USA), and Japan and the major developing countries led and represented mainly by Brazil, China, India, South Korea, and South Africa.
  - The industrialised countries are pushed to open their markets for agricultural products from developing countries by reducing import barriers („Doha Agenda“).
  - Developing countries also demand that Europe abolishes its high export subsidies for agricultural products, which together with the internal production subsidies distort competition in these countries and drive local farming out of business.
  - „Bali package“ of 2013: provisions for lowering import tariffs and agricultural subsidies, with the intention of making it easier for developing countries to trade with the developed world in global markets. Developed countries would abolish hard import quotas on agricultural products from the developing world and instead would only be allowed to charge tariffs on amount of agricultural imports exceeding specific limits.

Fish stocks::

- There exist 14 fish species which are important for the foodsupply of the humans.
- Worldwide about 100 million people live directly from fishing because it´s their only source for protein.
- Global fish catch rose from 20 million tons in 1950s to 90 million tons in the 1980s due to the use of new technologies for commercial fishing, radar detection of fish swarms, trawling, purse sein....
- Since then the global catches have remained about constant due to a strong increase of Chinese fishing activities and a much larger outreach of fishing fleets.
- Fish catches of certain species and in specific regions have dramatically decreased due to reduction of the fish stocks: e.g. North Atlantic cod, salmon, tuna

- The "United Nations Convention on the Law of the Sea" treaty deals with aspects of overfishing and grants coastal states exclusive fishing rights for a 200 mile zone. All coastal states to ensure that the maintenance of living resources in their exclusive economic zones is not endangered by over-exploitation
- Aquaculture production: 60 million tons (in comparison: fish catches are 90 million tons).
- 30 years from now 80% of the fish consumed could come from aquaculture.

Global food supply in 2050:

- To supply the 10 billion people with food in 2050 a doubling of global food production is necessary, *but* available agricultural land per inhabitant now 0,25 ha, and only 0,15 ha in 2050.

Minerals and metals:

- In Europe ca 30 million cars, 100 million mobile phones and 20 million tv sets become obsolete each year.
- Each person in a highly developed region produces more than 500 kg of waste per year.
- The EU has set recycling goals between 50 and 85% for household waste, electrical and electronic waste, demolition materials, end of life vehicles and packaging

Fossil Fuels:

- Global energy consumption will more than double till 2050 and energy related CO_2 emissions will rise from 34 Gto/yr in 2011 to 62 Gto/year by 2050 according to OECD/IEA analysis unless a technology change occurs.
- Primary energy consumption per capita and year (2008):
  - World average: 21 MWh
  - North America: 87 MWh
  - EU-27: 40 MWh
  - China: 18 MWh
  - Latin America: 14 MWh
  - Africa: 8 MWh
  - India: 6 MWh
- Shares in global total energy production (2010):
  - oil 32 %,
  - coal 27 %,
  - gas 21 %,
  - biomass and waste 10 %,
  - nuclear 6 %,
  - hydropower 2,5 %,
  - geothermal, wind, solar 1,5 %
- Total energy production and consumption rate now 500 EJ and 1000 EJ in 2050.
- 80 % of the present global energy production is from fossil fuels.
- Only 16 % of energy comes from renewable sources
- Estimated Fossil Fuel Reserves:
- Oil: 50% of the global known conventional reserves now consumed, further resources of same magnitude, plus ca 3x the amount consumed as „unconvential resources“ (oil sands)

- Natural gas: 30% of the global known conventional reserves now consumed, further resources of roughly double the amount consumed by now, plus ca 10-20x the amount consumed as „unconvential resources“ (shale gas)
- Coal: nearly unlimited supply
- Uranium: practically unlimited supply
- Future technologies must support the reduction in consumption of natural resources, be climate relevant, be affordable for different regions of the world.

Part 6 - Climate Change:

- The “Keeling curve” shows the increase of atmospheric concentrations of CO_2 which roughly matches the amount of fossil fuels burned per year.
- Since the beginning of industrialization 240 Gto carbon (nearly 900 Gto CO_2) have accumulated in the atmosphere.
- Major sources of CO_2 are fossil fuel consumption and cement production (total 365 Gto carbon) and land use change - mainly biomass burning (total 60 Gto carbon)
- Major sinks are uptake by oceans and by plants (photosynthesis)
- The concentrations of Green House Gases CO_2, N_2O and CH_4 increased from 280 to 430 ppm CO_2eq (weighted sum of all GHGs).
- Green House Gas emissions have strongly enhanced the natural warming having led to an overall increase of the global mean temperature by 0,9C.
- CO_2 changes during last 400.000 years: Changes in the Earth's orbit around the sun, known as Milankovitch cycles, are believed to be main reason for the large oscillations, but the industrial revolution has caused a fast and dramatic rise in CO_2 concentrations of the atmosphere.
- The main factors influencing average global temperatures on earth and consequently climate are:
  - changes in the Earth’s orbit around the Sun known as Milankovitch cycles, and
  - the concentrations of the green house gases (carbon dioxide, methane, nitrous oxides) and of particulates in the atmosphere,
- Total GHG emissions (2011): global 34 Gto/yr CO_2, 50 Gto/yr CO_2eq
- Per capita GHG-emissions (2011): USA 17,2 tons CO_2, EU 7,5 tons CO_2, China 7,2 tons CO_2, India 1,6 tons CO_2
- Main sectors for GHG emissions are:
  - energy production (electricity, heating....)
  - transport
  - agriculture
  - industrial processes
  - waste burning and decomposition
- Emission rates still to go up between 3 and 5% annually.
- Total amount of emitted CO_2 during each subsequent 15-year period strongly increasing.
- Asia is becoming the largest emitter of CO_2.
- Under baseline scenarios (IPCC RCP8,5 scenario) annual CO_2 emissions will rise to 90 Gto by 2100.
- Earth absorbs 70 % of radiation it receives from the sun. 30 % is reflected. Absorbed radiation is re-emitted. GHGs absorb reflected radiation and re-emit a fraction back to the land surface.
- Total natural absorption and reflection of earth is 342 W/m^2.

- Carbon dioxide, methane, nitrogen dioxide, halocarbons, tropospheric ozone and black carbon on snow fields have a warming effect.
- Stratospheric ozone, aerosols and cloud albedo have a cooling effect.
- **Total anthropogenic RF increasing:**
  - **2013:** 1,1- 3,3 W m^{-2}
  - **2050:** 3.0–4.8 W m^{-2}
  - **2100:** 2.7–8.4 W m^{-2}.
- Accurate prediction of temperature rise extremely difficult due to complexity of the system.
- **Temperature Evolution till 2100 for 2 Scenarios:**
  - RCP8,5 (BAU): temperature increase from now 3,7°C (range 2,6 - 4,8°C)
  - RCP2,6 (optimal stabilisation of climate): temperature increase from now 1°C (range 0,3 -1,7°C)
- (Possible) impacts of Climate Change:
  - Warming of Mediterranean Sea and oceans
  - Strong retreat of Alpine and other glaciers.
  - Reduction of Northern hemisphere snow cover.
  - Melting of permafrost areas with potential release of methane (forcing factor 23 x of CO_2) possibly leading to a non-linear accelerated warming.
  - Increased seasonal melting of the Greenland ice
  - Reduction of the Arctic sea ice: Loss of Arctic sea ice already now 40%. Loss will continue for all scenarios. BAU scenario: Arctic ice gone by 2080.
  - Number of warm days and heat waves increasing: health effects for older people, reduced agricultural yield
  - Possible increase of number and strength of extreme weather events.
  - Under BAU scenario average global sea level rise till 2100 is 0.45 to 0.81 m (RCP8.5, *medium confidence).*By 2300 sea level rise could reach 1 to 3 m (*medium confidence).*
  - By 2050, water availability is projected to decrease by 10-30% over some dry regions at mid-latitudes and in the dry tropics.
  - Possibly disturbance of monsoon cycles.
- European Climate Change Programmes I and II: aim at reducing risk of global warming by mitigation and adaptation efforts and have the vision to limit global warming to 2°C corresponding to maximum 450 ppm CO_{2equ}
- Kyoto Protocol (1997, in force since 2005): Commitment to reduce GHG emissions by 5% (EU 8%) below 1990 levels till 2012. Only 13% of the global GHG emissions affected by the Kyoto Protocol, but important first step.
- Global mitigation scenario: To stabilise the GHG concentrations at 450 ppm CO_2e a global emission reduction of 50 % by 2050 is required (rel. 1990). Industrialised countries must start reduction immediately with goals -30 % by 2020 and -85 %
- **Preparation of a post-2012 climate change policy: Goal: Limitation of further global temperature increase to 2 °C compared to pre-industrial times.**
  - ➢ **EU GHG emission reduction targets:** minus 20% in EU till 2020 below 1990 levels
  - ➢ **Technical measures:**
    - o Reduction of primary energy use (20% compared to projections made in 2007): industrial processing and manufacturing, lightning, heating, transport.
    - o Development of Carbon Capture and Storage (CCS) for fossil fuel power plants.
    - o Increase of renewable energies (20% of total energy market – now 13%), including decarbonisation of transport (10% biofuels from sustainable production).

- **Implementation measures in EU:**
    - Emissions Trading System (EU ETS) covering 11.000 installations emitting together 50% of the EU GHGs with significantly restricted number of certificates.
    - Effort Sharing Decision which defines an aggregate reduction target for the non-ETS sector of 10% (compared to 2005).
    - Strategic Energy Technology Plan (SET-Plan)
- **Preparation of a post-2020 climate change policy with targets for 2030:**
- ➢ **Preliminary GHG emission reduction targets:**
    - minus 40% by 2030 (compared to 1990) – according to "2050 Low carbon Economy Roadmap"
    - Increase of renewable energies to 27% of total energy market
    - Fundamental issues for a new 2030 framework for climate and energy policies: Types, nature and level of specific targets? Targets at EU, national or sectorial level? Legally binding?
    - Serious concerns about the competitiveness of energy intensive industries in Europe (chemicals, refining, pulp and paper, steel....) – account for 20% of industrial production and 25% of employment. Energy costs in the USA are 1/3 of Europe!
    - Due to diverging views on targets the European Commission has proposed NOT to set (binding) targets in Jan. 2014 – decision by EP and Council?
- EU-28 are responsible for only 10% of the global GHG emissions.
- **Post-Kyoto Roadmap for global action:**
- **UN Climate Change Conferences 2007-2012:**
- ➢ **Key issues to be solved:**
    - Burden sharing between industrialised and developing countries (incl. China, India).
    - Compensation for halting deforestation to countries with tropical rain forests (e.g. Brazil, Indonesia).
    - Financial support to the least developed countries for climate change adaptation (mainly Africa).
- ➢ **Major results:**
    - Commitment of 82 countries which together are responsible for 80 % of the green house gas emissions to implement national action plans for mitigation.
    - Agreement of 50 % global reduction by 2050 and consensus that industrialised countries would reduce by 80% till 2050.
    - Agreement on halting deforestation, a.o. with financing by industrialised states.
    - Agreement to provide by 2020 annually 100 billion $ for adaptation in least developed countries ("Green Climate Fund").
    - Agreement to set up a renewed Kyoto-Protocol in effect till 2020.
- **Results achieved so far:**
    - Up to now no legally binding international treaty, only "declarations of intent".
    - Europe is the pioneer, but efforts in other countries are insufficient to achieve any reduction.
    - Global GHG emissions are still increasing by 3-5% each year.
    - The global energy mix has not been significantly altered (32% oil, 27% coal, 21% gas, 10% biomass and waste, 6% nuclear, 2,5% hydro, 1,5% wind and solar energy).
    - More than 1.200 coal fired power plants are proposed for construction.
    - Subsidies for mining of fossil fuel have not been reduced.
    - Fossil fuels are expected to maintain their dominant position in the global energy mix beyond 2030. Hence between 2000 and 2030, CO_2 emissions from

energy use are projected to grow 45 to 110% over that period, particularly in developing regions (non-Annex I regions). *(Source EEA 2013).*
  - First political priority is now again the economy (growth, jobs, "balanced" budgets...).
  - Adaptation seems to become more important than mitigation.
- **Alternative pathways:**
  - There is a growing disconnect between the trajectory that the world is on and one that is consistent with a 2°C climate goal. As the 450 (ppm CO_2eq) scenario seems unrealistic now there is a need to develop alternative pathways:
  - **New Policies Scenario:** based on existing policies with incorporation of present trends in emission reduction: Emissions 37 Gto by 2035, warming 3°C by 2100.
  - **4-for-2 °C Scenario:** allows for a small increase in the GHG emissions till 2020; thus delays reduction efforts, but still aims at reaching the 2°C target by 2100 through enhanced efforts later on: Emissions 31 Gto by 2035.
  - Reduction of emissions: efficiency measures (transport, industry, households, heating and cooling), reduction of carbon emissions in power generation, improved oil and gas management, reduction of fossil fuel subsidies

Part 7 - Socioeconomic challenges:

Population growth and aging:

- Evolution of Global Population: 0,7 billion in 1750, 7 billion in 2012, 10 billion in 2050
- Current growth rate: 1,1 % (75 million) per year
- World population by region: Asia (ca 60 %), Europe total (ca 12 %), [EU 7%], North America (ca 6 %), Sub-Saharan Africa (ca 12 %), Latin America (ca 10 %)
- Evolution of population till 2050: Africa + 100 %, Latin America + 50 %, Asia + 30 %, North America + 30 %, Europe minus5 - 10 %.
- Urban population 80% in industrialised countries, ca 50 % in developing countries. Tendency: rising. In the South the majority of the urban populations lives in slums.
- Population ageing means that the median age of a country or region rises. Globally nearly all countries experience this process.
- The sources of population ageing lie in two (possibly related) demographic phenomena:
  - rising life expectancy, and
  - declining fertility (dominant factor).
- Population ageing is most advanced in the most highly developed countries.
- Effect particularly pronounced in Europe:
  - „Greying of Europe" has the effect that the productivity of Europe is decreasing and the population of Europe as a percentage of the world population is reduced, which are likely to reduce the competitive position of Europe in the world.
  - In any case the already existing problems in financing an elaborate social security systems will be dramatically enhanced.
  - Experts generally agree that the present system of pensions and social welfare provided by the state cannot be maintained in the future.
- Educational Level of Populations: very different in different parts of the world, e.g. in Singapore 85% of the age group 15/20 have a secondary education, in Kenya only 15%

Economic aspects:

- **Competitive Strengths of EU:**
- Europe has enjoyed a period of peace since 69 years now.
- Generally it has stable political systems based on the principles of democracy.
- Involvement of the citizen in elections and other public affairs rather high.
- The EU has the best education system in the world.
- High integration of females in work force.
- High level social system (pensions, health insurance, unemployment services…)
- European Union has become the largest economic region of the world. GDP of all member states with the „current currency exchange rate" is ca 12.000 billion EUR = ca 20 % of the global GDP).
- The citizen of the EU experience an unprecedented wealth.
- European Union expansion to CEE led to a dynamic large region due to substantial growth in new Member States of the European Union.
- The Euro has become a major currency (25% of global currency volume).
- The political „Leitmotiv" of the EU - Sustainable Development" – can serve as a model for the whole world.
- Very positive development with neighboring regions (Russia, Mid-Asia, Near East) and excellent political relations with practically all countries in the world.

- **WTO treaty of 1995** created essentially a borderless world for goods and money – covering 95% of the global production and financial services.
- EU deficit in trade with China. 2000: 32 billion EUR, 2012:136 billion EUR
- Exports of China into EU: machinery and equipment, footwear and clothing, furniture and lamps, and toys.
- Exports of EU into China: machinery and equipment, motor vehicles, aircraft, and chemicals.
- Growth of GDP: China (and other SE-Asian states) 5-10%, EU 1-3%

- **Competitive Weaknesses of the EU:**
- Ongoing de-industrialisation, but growth of service industries.
- EU much slower in innovation than USA, Japan, not enough R&D investments in future technologies and technology leadership in key areas not with Europe.
- Still low mobility of work force.
- Not very attractive for highly skilled immigrants.
- Extremely high dependence on energy and raw materials delivered from outside.
- Military expenses very high, but low efficiency of defense systems due to ,lack of cooperation (EP 2013: annual loss 26 billion EUR).
- High taxes,high labor costs and high costs of state owned social security and health insurance systems. EU social expenses are 50% of all global social expenses!. The European social model is not sustainable.
- Fairly large sovereign debts and budget deficits of most EU member states.
- European Union has a complex structure with an often tedious decision making process and national interests of the member states often dominate over common interests: *„EU politics is the science of muddling through"*.
- Consequently up to now no common economic, social or foreign policy.
- Lack of dynamism compared to some other regions („Wellness Society"): Share of EU-27 in global GDP will drop from 24% to14 % by 2050.

Development cooperation:

- Life expectancy: 50 years in Africa, 75 years in Europe
- Global income distribution:
  - The „upper“ 20% of the global population posess 82,7% of the means of this world.
  - The „bottom“ 20% own only 2% of the global wealth.
  - The income of the wealthiest 20% is in average 80 times higher than the income of the poorest 20%.
- **Indicators for global poverty:**
- 1 billion people live on less than 1 Euro per day.
- 2,6 billion people without proper sanitation services.
- 1,1 billion people are without access to safe drinking water. This number will increase to 2 billion by 2030.
- 400 million people undernourished
- 2,5 billion people without energy services, like access to electricity.
- **Basis of EU policies for shaping a global partnership for sustainable development:**
  - Johannesburg Declaration of 2002 and its Implementation Plan.
  - Doha Development Agenda (Trade) of 2001.
  - Monterrey consensus (Financing for Development) of 2002.
  - Cotonou Partnership Agreement for Africa's Development, the Caribbean and Pacific (ACP) of 2000 involving 77 developing contries.
  - 2002 Communication of European Commission “Towards a Global Partnership for Sustainable Development” and Council Decision of 2002: Commitment of the EU to promoting sustainable development on a global level.
- **Relation of EU with Africa:**

- Europe must provide development aid, particularly for the improvement of infrastructure,
- open the European markets for agricultural products of Africa,
- invest in exploration and mining of valuable raw materials and development of local/regional industries,
- generate/develop markets for European products based on a rising purchasing power, and
- realise that this huge continent offers much potential for a mutually fruitful cooperation.
- Presently 3 billion Euro annually development aid for Africa from European Union.

Part 8 - Third Industrial Revolution:

Concept of Third Industrial Revolution:

- The global economic growth is accompagnied by a dramatically increased demand for energy and natural resources.
- In addition, global warming – which largely caused by the consumption of fossil fuel - has been recognised as a global threat.
- Air pollution is strongly increasing in emerging economies and developing countries.
- This evolution requires the development of clean energy and resource efficient technologies.

- **Key development areas in the Third Industrial Revolution:**
  - Resource efficient technologies in materials processing:
    - recycling of materials
    - lighter and smaller products
  - Energy efficient technologies:
    - new efficient transport systems
    - energy efficient houses and offices
    - energy efficient consumer devices
  - Low carbon electricity generation:
    - renewable energies
    - carbon sequestration and storage
    - new energy storage and distribution systems
  - New information and communication technology systems: new global monitoring techniques to achieve a more efficient and effective governance
- Estimated costs of energy shift:
  - perhaps 1% of global GDP = ca 500 billion EUR annually (Stern Report).
  - Global subsidies for fossil fuel production 500 billion EUR
  - Total global annual military spending: > 1.000 billion EUR
- **EU-27 primary energy consumption by fuel, 1990–2011 shows substantial changes on the production side:**
- coal declined from 27% to 17%
- gas increased from18% to 24%
- oil unchanged
- nuclear increased from 12% to 14%
- RE increased from 4% to 10%
- dependence on fossil fuels decreased slightly from 83% to 76 %
- **EU imports 85% of the oil and 62% of the gas consumed (EUROSTAT 2013):** total costs 350 billion EUR annually

EU Energy Targets:

- **Enhancement of energy efficiency:** consumption minus 20 % by 2020 compared to projections
- **Industrial production:**
  - responsible for 20 % of GHG emissions, partially old and energy inefficient technologies used;
  - *Approaches:* emission limits for industrial production sectors, promotion of Best Available Technologies (BAT).
- **Electricity generation:**
  - responsible for 25 % of GHG emissions, thermal power plant: typically 40 % efficiency for electricity generation;
  - *Approaches:* enhancement of efficiency for primary energy consumption by use of heat generated (cogeneration technology)
- **Transport:**
  - responsible for 25 % of EU GHG emissions; *Approach:* low weight electrical cars based on fuel cells or high power batteries for urban transport (80 % of Europeans live in urban regions)
  - *Policy measure:* limitation of CO_2 emissions to 130 g/km by 2012 resp. 95 g/km by 2021 (fuel consumption <6 l/100km resp. <4,5 l/100km) for passenger cars and 147 g/km for light duty vehicles by 2020

- *Approaches:* enhancement of efficiency for diesel and gasoline driven cars, CO_2 tax, hybrid technology saving up to 50% of fuel in urban traffic, new technologies: low weight electrical cars based on high power batteries or fuel cells for urban transport, advanced public transport systems

- **Hydrogen as an energy carrier:**
  - As an energy carrier, hydrogen can store and deliver energy in a widely useable form and is one of the most promising alternative fuels for future energy applications ("hydrogen economy").
  - Production of hydrogen from water:
    - high efficiency electrolysis at high temperatures (800°C)
    - catalytic thermochemical production, e.g. using concentrated solar power, high temperature nuclear reactors („generation4" nuclear power plants)
  - Underground storage in salt stocks, caverns: large quantities of hydrogen as grid energy storage
  - Storage in vehicles: tanks for compressed hydrogen (350 – 700 bar) in vehicles, highly insulated tanks for liquid hydrogen in vehicles (cryogenic temperature – 253°C), development of solid state hydrogen storage (such as MgH_2, $NaAlH_4$, LiH...)

- **Biofuels:** 10 % share of fuel consumed for transport by 2020 **(***from "sustainable production")*
  - First generation of biofuels: methanol from sugars and cereals, diesel from plant oils.
  - Second generation biofuels:syngas (carbon monoxide and hydrogen) production by thermochemical gasification from biomass or production of fermentable sugars from cellulosic, fibre or wood based waste biomass by hydrolysis based on enzymatic degradation.
  - Third generation biofuels: algae fuel
  - Fourth generation "biofuels": direct synthesis of alkanes from CO_2 and water
- **Heating and personal electricity use:**
  - responsible for 12 % of EU GHG emissions
  - *Policy measures:* requirement of "energy consumption pass for housing", forbidding sales of incandescent lamps, regulation on stand-by loads
  - *Approaches:* enhancement of efficiency of energy use by improving insulation of houses and installation of energy-efficient illumination devices; new technologies: fluorescence lamps, LEDs, intelligent electronic devices, energy efficient motors, tv sets and refrigerators; passive and surplus houses, new architectural concepts like energy autonomous villages.
  - conventional light bulbs have a yield of 4 % and are phased out in the EU.

Low carbon electricity production:

- Shares in global electricity production: coal 40 %, gas 20 %, hydropower 16 %, nuclear 15 %, oil 7 %, wind, solar, biomass 2 %.
- Electricity consumption is expected to at least double till 2050.
- Nearly 70 % of electricity produced is from burning of fossil fuel or biomass.
- Principal approaches for low carbon electricity production:
  - Capture of emitted CO_2 in power plants burning fossil fuel and safe storage underground or under sea (CCS).

  - Use of low carbon emission production technologies, nuclear power generation, renewable energies (hydropower, wind energy, solar energy production, biomass utilisation, geothermal energy, tidal energy).
- CCS: Theoretically reduction of CO_2 80-90% possible, but increased fuel needs of a coal-fired plant with CCS by 25%-40%. Recycling of captured CO_2 for production of methanol by reaction with H_2 („methanol economy“).
- Renewable Energies: EU goal is 20 % of consumed energy from renewable sources by 2020
- Wind energy: Share in electricity production 2012: 6 % in EU-27 (EUROSTAT), ca 50.000 wind turbines installed in EU; OECD/IEA Blue Scenario: globally >500.000 wind turbines by 2050
- Solar energy: Share in electricity production 2012: <1% in EU-27 (IEA), share 10% in 2020. OECD/IEA Blue Scenario: globally >2.000 km^2 solar PV panels by 2050
- By 2020 wind and solar could provide 30 – 40 % of the electricity consumed in the EU.
- **Concentrated solar power (CSP) systems:**
  - use mirrors or lenses with tracking systems to concentrate a large area of sunlight, or solar thermal energy, onto a small area.
  - electrical power is produced when the concentrated light is converted to heat, which drives a steam turbine connected to an electrical power generator.
- **Back-up facilites:**
  - large gas power plants
  - network of household gas plants – ca 100.000 connected („Schwarmstrom“)
- **Storage possibilities for wind and solar electricity:**
  - Water reservoirs (Kaprun, underground mines): insufficient capacity
  - Hydrogen production by electrolysis for use in fuel cells: addtl. costs ca 10 cts/kWh
  - Hydrogen production by electrolysis for synthesis of methane (reaction with CO_2): direct feed-in gas pipelines
  - Millions of batteries in intelligent grid established in households, cars.....

Global monitoring:

- **GMES-Copernikus operational dimension**: Land Monitoring; Marine Services; Atmospheric services; Crisis Management
- **GEOSS**: Building a Comprehensive Global Earth Observation System (USA, EU, Japan……).
- **SEIS** is based in *in-situ* monitoring and earth observation data to produce policy relevant information