PV & ENVIRONMENT

Contents

Photovoltaic energy is one of the most promising ways to contribute towards a greener planet, lowering carbon footprints and ensuring the earths balance remains intact. The generating component produces electricity silently and does not emit any harmful gases during operation. Environmental issues do exist ranging from CO²-emission in the production process of, scarcity of materials to the use of toxic materials in the fabrication of modules.

General: Cell / Module / System

Recycling & Disposal of Si- and Thin Film Modules: Example BP-Solar

"BP Solar has been developing procedures for processing waste materials and recycling silicon the primary feedstock in solar cell manufacture for many years. Modules that can be recovered and repaired will be. Modules that cannot be repaired will undergo a de-manufacturing process to recover aluminum, and all other recoverable materials. Specialized recyclers will then recycle materials appropriately. The remaining non-recoverable parts of the modules will be crushed and disposed of, according to all legislative requirements, in controlled landfill sites.

Thin film Millenia™ modules are currently suitable for disposal in municipal landfill sites in the US, because they contain no regulated hazardous materials. However BP Solar as part of their product stewardship process, will accept back any failed, end of life or unwanted Millenia™ thin film modules and will undertake to ensure their disposal in the most environmentally appropriate manner. In the short term all such modules will be disposed of in appropriate landfill sites according to local legislation. In the longer term, BP Solar is actively working on a regime to recycle the materials in returned Millenia™ modules. This process will constitute part of a recycling strategy review to be finalized and introduced in the near future.

For recycling options, please contact the distributor you purchased your BP SOLAR product from or your closest BP Solar Sales & Marketing office.

Please note: The responsibility for the costs of any on-site labor and any costs associated with the removal or transportation of your BP SOLAR product for recycling, resides with the customer."

www.bp.com/sectiongenericarticle.do?categoryId=9012884&contentId=7025016

System
- Almost no maintenance
- Allows in a lot of applications mobility

A man can take his pv cells and go in the wild. They and maybe his radio as well, will survive him.

Effective Utilization of Solar Energy
It is said that the amount of solar energy that strikes the Earth's surface is the equivalent of about 1 kW per square meter. This works out to 1 kWh worth of sunlight per hour. A PV-system with an overall conversion efficiency of 10% would produce 0.1 kWh of electricity per hour.
CIGS requires a layer 100 times thinner than conventional silicon solar systems, a few dollars' worth of CIGS raw ingredients can deliver the same power as a hundred dollars' worth of silicon wafers.

Durability
Most of the PV-modules are guaranteed to function at least 20 to 30 years. And although we will have to wait and see if this prediction will hold, the fact that the pv-panels have no moving components is one of it's key qualities and some even say that they should last longer than 30 years. The weak point lies in the risk of water infiltration, corrosion of the metal parts and deterioration of the EVA-coating. Also, modules with a frame should be cleaned once in a while because of dirt concentration in the edges and corners which might influence the efficiency.

Energy payback time & Energy Return on Investment
The technologies also need to have acceptable energy payback times – this is the time taken for a device to generate as much energy as was needed to fabricate the device. One criticism of early PV modules was that they consumed more energy during their production than they generated during their lifetime. With modern production methods and improved operational efficiencies this allegation is no longer true. The exact energy payback is obviously dependent on the available solar resource and on the degree to which the system is operational. High levels of solar irradiation and a high utilization factor will offer more rapid energy paybacks than if there is less sun and less usage, but typically for Crystalline and multicrystalline devices have energy payback times of 3–4 years and the thin-film technologies, 12–18 months.

Energy Return on Investment is the ratio of electricity generated, divided by the energy required to build and maintain the equipment.

Renewable, clean and distributed energies
In contrast to fossil fuel based technologies and nuclear energy photovoltaics can be classified as *renewable, clean* and *distributed* energies:

> *Renewable* describes any energy source whose availability or supply will not be permanently depleted as a result of exploitation over a period of time that is meaningful to people. Fossil fuels (coal, oil and natural gas), which formed over millions of years of geological conditioning, are considered *nonrenewable* because their global supply will not be regenerated at a rate

that is proportional to current and future uses. By contrast, solar power is in constant supply every day and will be for another several billion years (until the end of the Sun).

Clean describes any energy source the exploitation of which does not generate significant amounts of pollution, and therefore negatively impact the health of human populations and the biosphere as a whole. Conventional electricity generation typically entails the combustion of fossil fuels and the production of harmful emissions or other waste byproducts, as in the case of nuclear energy. These sources can therefore be considered 'dirty'. Photovoltaics, on the other hand, produce no waste or pollution while in use, and only 'negligible' amounts are produced in their production.

Distributed describes any energy source that can be deployed – often rapidly - on small, medium or large scales close to the point of consumption. *Distributed* g*eneration ('DG')* contrasts with *centralized generation*, a term that characterizes conventional large-scale fossil fuel or nuclear power plant generation. While photovoltaics can be installed in large, centralized systems equivalent in output to small or medium power plants, they are more commonly deployed in distributed systems that are integrated directly into the homes and buildings that they power.

Emission – Greenhouse gases

Solar cells do not generate carbon dioxide (CO2) which contributes to global warming, or sulfur oxide (SOx) or nitrogen oxide (NOx) which cause acid rain. A 3 kW solar power generation system of the type designed for general home use can produce in general approximately 3,000 kWh of electricity over the course of a year. The effect of this is equivalent to a 540 kg-C lowering of carbon dioxide emissions (carbon equivalent) annually.

Life cycle greenhouse gas emissions are now in the range of 25-32g/kWh. For comparison, a combined cycle gas-fired power plant emits some 400g/kWh and a coal fired plant with carbon capture and storage some 200g/kWh. Nuclear power emits 25g/kWh on average. Only wind power does better with a mere 11g/kWh.

CO2 emissions of the average US electricity supply are higher than those of the average European supply, resulting in higher CO2 emissions for US produced modules.

USE OF MATERIAL DURING PRODUCTION - Life Cycle Analysis

Thin Film

There are some potential hazards allied to the production of some of the more exotic thin film technologies. The two most promising options, cadmium telluride and copper indium diselenide, both incorporate small quantities of cadmium sulphide, which poses potential cadmium risks during module manufacture. There are established procedures governing the handling of such compounds, which are adhered to throughout the production process.

Coating of conductive wires of flexible thin film --> with **tin**.
See e.g. www.fvgenergy.com/photovoltaic_eng/powerfilm_eng.html

Example 'green bashing'

"The new plant from Oerlikon Solar is based on an LPCVD process (Low Pressure Chemical Vapour Deposition), using low-cost, environmentally friendly zinc oxide instead of the commonly used fluoride doped tin oxide...." - www.oerlikon.com/ecomaXL/index.php?site=SOLAR_EN_top_issue_detail&udtx_id=4292

-> Exposure to zinc oxide in the air (also while welding) can result in a nervous malady called metal fume fever.[7] - http://en.wikipedia.org/wiki/Zinc_oxide

-> Zinc is the 23rd most abundant element in the Earth's crust . The earth has been estimated to have 46 years supply of zinc.[12] - http://en.wikipedia.org/wiki/Zinc#Abundance

CIS / CIGS

"the only thin film that can produce both conversion efficiencies (10 to 14%) and lifetimes (20 years or more) comparable to polycrystalline silicon-based products. CIGS requires a layer 100 times thinner than conventional silicon solar systems, a few dollars' worth of CIGS raw ingredients can deliver the same power as a hundred dollars' worth of silicon wafers.

- Advantages of CIS modules
  - Better Energy Payback Time compared to silicon type modules
  - Free from world's solar grade silicon supply shortages that affects the stable supply of silicon solar modules
  - Free from toxic materials including cadmium, lead
  http://www.solarfrontier.co.jp/product/index.html

Cadmium Telluride (CdTe)

An issue that has often raised concerns is the use of cadmium in the Cadmium telluride (CdTe) modules. Cadmium is in its metallic form a toxic substance that has the tendency to accumulate in ecological food chains. The amount used in PV is relatively small (5-10g/m²) and with proper emission control techniques it can almost be zero. Most of these emissions actually arise through the use of coal power for the manufacturing of the modules, and coal and lignite combustion leads to much higher emissions of cadmium. Lifecycle cadmium emissions from coal is 3,1 microgram/kWh, lignite 6.2 and natural gas 0,2 microgram/kWh.

The energy payback time of a CdTe PV module varies from 6-8 years, and the total life cycle GHG emissions from 12g to 19g CO2-eq./kWh, based on the current module efficiency of 9%, a Performance Ratio of 80%, Southern Europe insolation conditions (1700 kWh/m2/yr), and a system lifetime of 30 years.

CO2 emissions of the average US electricity supply are higher than those of the average European supply, resulting in higher CO2 emissions for US produced modules.

In combination with the Balance of System of a ground-mount installation (Springerville, TEP), the energy payback time and GHG emissions for the CdTe PV fuel cycle would be 1 to 125 years and 19 to 25 g CO2-eq./kWh, respectively, for average European (1700 kWh/m2/yr), conditions.

The low estimate corresponds to the data from the production line in Germany and the high corresponds to the US production data. The external costs of the whole system are about 013 sc/kWh, based on ExternE-Pol8 base case damage factors (Table 1). For South Germany (1300 kWh/m2-yr insolation)9 the calculated CO2 emissions during the life cycle of the whole system are 23 to 32 g/kWh, for the German and the US production data correspondingly.

Bioplastic Technology
Today, petroleum-based plastics are used in the production of virtually all solar cells and modules. However, the cost of these plastics has been steadily increasing due to rising oil prices, which runs counter to the industry's effort to further cost reductions to make solar energy competitive with conventional fossil fuel. Furthermore, petroleum-based plastics are not environmentally neutral. Bio-based plastics can be produced inexpensively, and because they are derived from renewable plant sources their costs are not tied to high oil prices. In the past, conventional bio-based plastics have not been successfully used in solar cell applications, due to their low melting temperature and fragile molecular structure. Conventional bioplastics available today will not withstand most existing solar cell manufacturing processes. New bioplastic is a result of enhancements to some widely available bio-based polymers.
BioSolar is developing a comprehensive line of bioplastic films and resins for solar cell manufacturers, based on its breakthrough bioplastic technology.
www.biosolar.com/overview_technology.html

Crystalline Silicon modules
With the cooperation of 11 European and US photovoltaic companies, an extensive effort was made to collect Life Cycle Inventory data that represent the current status of production technology for crystalline silicon modules; this was part of the European Commission's CrystalClear project. The new data cover all processes from the producing of silicon feedstock to manufacturing cells and modules. For each step in the production process,
going from silica mining up to PV system installation, all significant inputs of materials and energy were accounted for in the Life Cycle Inventory. Moreover, all commercial Si-wafer technologies are covered i.e., multi- and mono-crystalline wafers and ribbon technology.

These data can be considered representative of the status of technology in 2004, at least for Europe and the US. With this information, we analyzed the environmental impacts of PV electricity generation,4 and demonstrated that the life-cycle greenhouse gas emission of complete rooftop PV systems based on multicrystalline silicon and under average Southern-Europe insolation (1700 kWh/m2/yr) is only 37 g CO2-eq/kWh (Figure 2). For silicon ribbon and monocrystaline silicon technologies the respective numbers are 30 and 45 g/kWh (not
shown in figure).

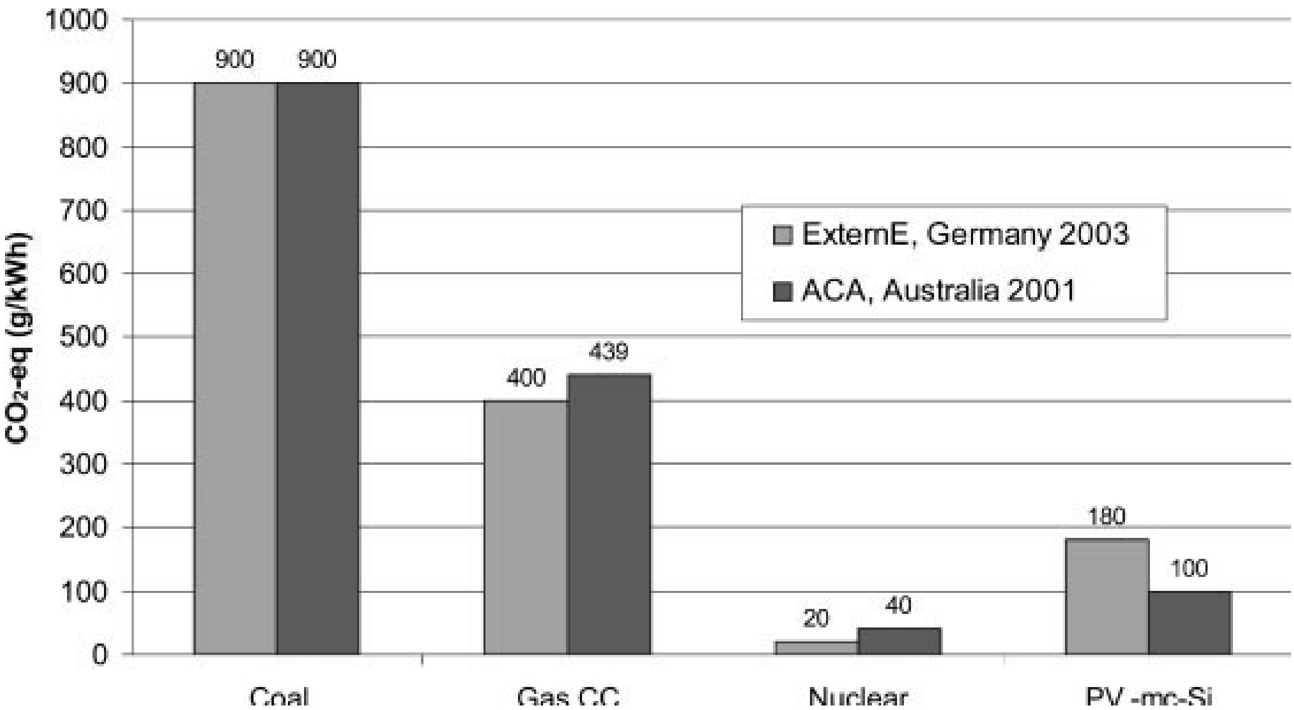
The Energy Pay-Back Times (EPBT) of such systems are, respectively, 17, 22, and 27 years for ribbon, multi-, and mono-Si technology. Figure 3 shows the EPBT estimates for multi-Si PV modules and systems, in comparison with those for CdTe thin film PV modules and systems). Note that a Performance Ratio of 75% (accounting for the effects of shading, snow cover, heat loss and DC–AC conversion loss)11 was assumed for the roof-top systems, a value which might be somewhat conservative.

External costs
Furthermore, we estimated external costs using the baseline damage factor method developed within the ExternE-Pol project (see Table 1). For Southern Europe average conditions (i.e., 1700 kWh/m2/yr insolation), the health and environmental external cost would be 018 sc/kWh. For a system in South Germany with optimal latitude insolation (i.e., 1300 kWh/m2/yr)9 the external cost will be 023 sc/kWh.

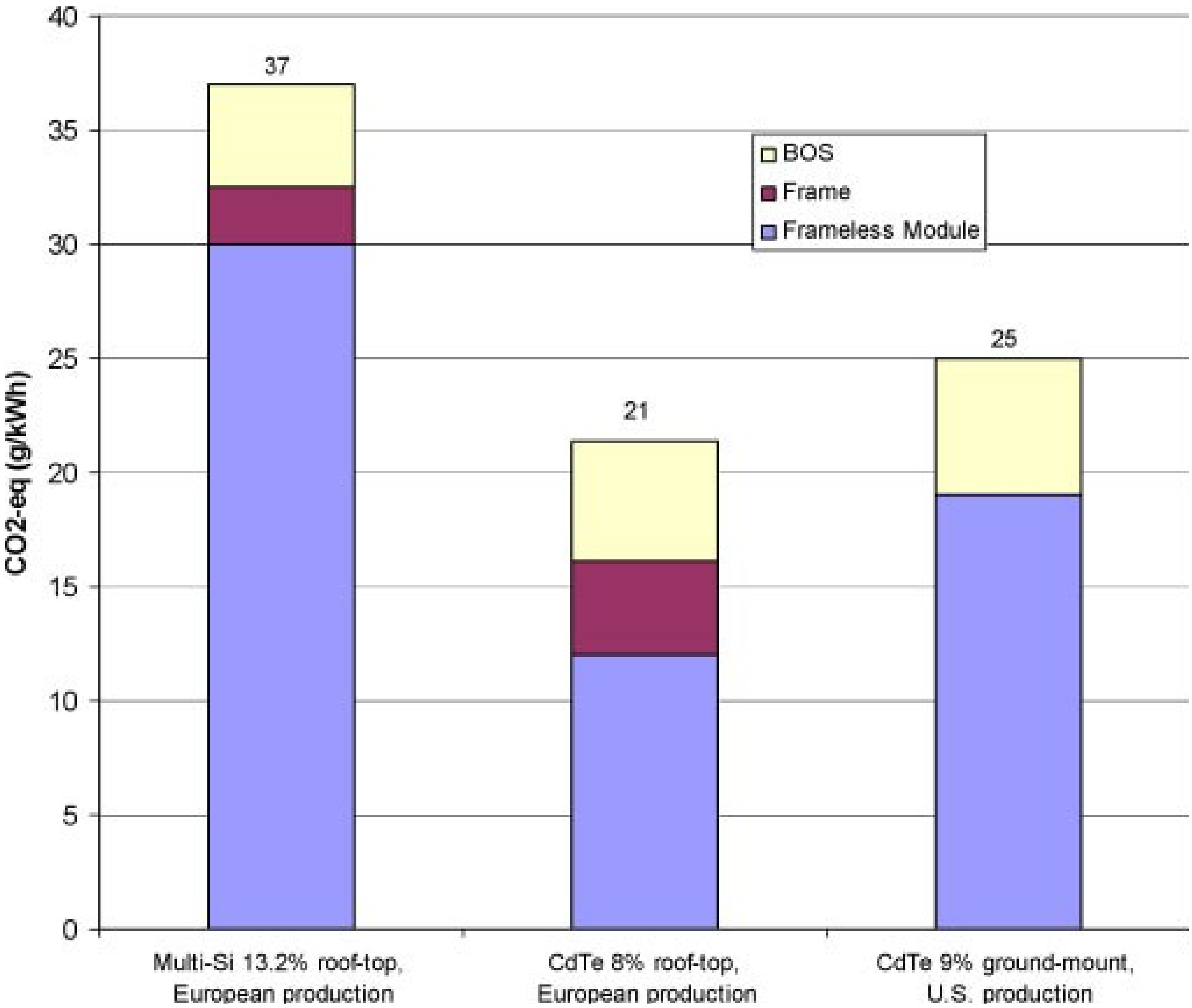
External Costs

An external cost, also known as an externality, arises when the social or economic activities of one group of persons have an impact on another group and when that impact is not fully accounted, or compensated for, by the first group. Thus, a power station that generates emissions of SO2, causing damage to building materials or human health, imposes an external cost. This is because the impact on the owners of the buildings or on those who suffer damage to their health is not taken into account by the generator of the electricity when deciding on the activities causing the damage. In this example, the environmental costs are "external" because, although they are real costs to these members of society, the owner of the power station is not taking them into account when making decisions. Note that external costs are unintended and result from there being no property rights or markets for these environmental effects. The potential value of the 'ExternE project' therefore lies in valuing external costs in order for those values to be included in the design of policy to correct for the present lack of such property rights and markets. - www.externe.info/

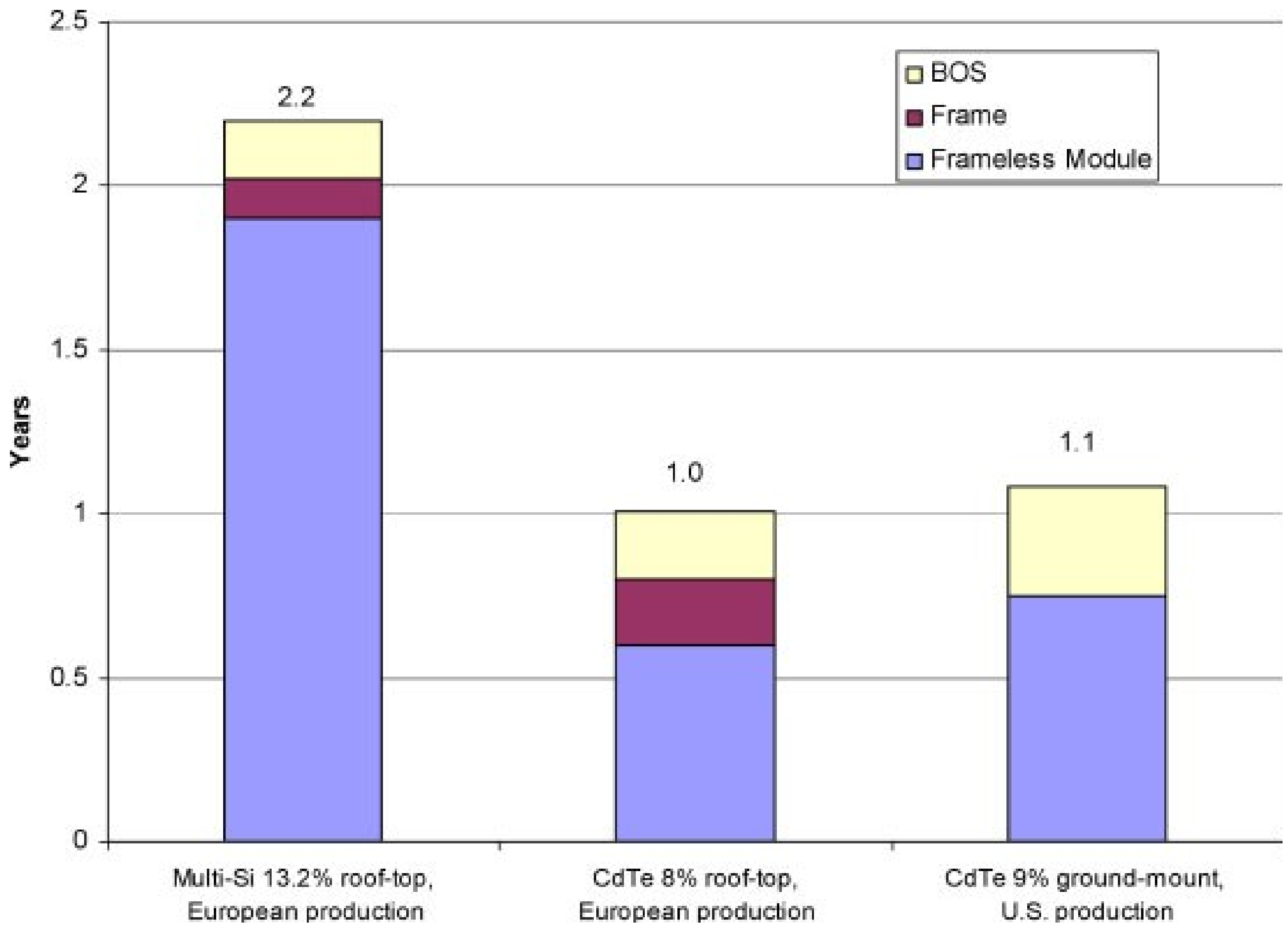
An update is given on energy pay-back times, greenhouse gas emissions and external costs of PV technology, based on up-to-date data from real production processes. For average South European solar irradiation (1700 kWh/m2-yr) the energy pay-back time for complete installed PV systems range from 1 years to 27 years depending on the module technology. The corresponding GHG emissions range from 21 g CO2-eq./kWh to 45 g CO2-eq./kWh for South Europe and 27–59 g CO2-eq./kWh for Southern Germany conditions (1300 kWh/m2-yr). These emissions are 60 to 85% lower than the GHG emission estimates shown in the latest ExternE report to the European Commission.1 Based on the ExternE damage factors, the external costs of PV associated with health and environmental impacts during their life-cycle are about 015 sc/kWh.



GHG emissions from life cycle energy of electricity production; -ExternE & Australian Coal Association research programs



Updated GHG emissions from the life cycle photovoltaic electricity production for average southern European insolation (1700 kWh/m2/yr), 30 years lifetime, 75% performance ratio for roof-top installations, 80% performance ratio for utility ground-mount installations.4–7 The place of production is indicated because CO2 emissions of the average US electricity supply are higher than those of the average European supply, resulting in relatively higher CO2 emissions for US produced modules.



PV energy payback times of 2004 PV technologies for average southern Europe insolation (1700 kWh/m2/yr), 75% performance ratio for roof-top installations, 80% performance ratio for utility ground-mount installations4–

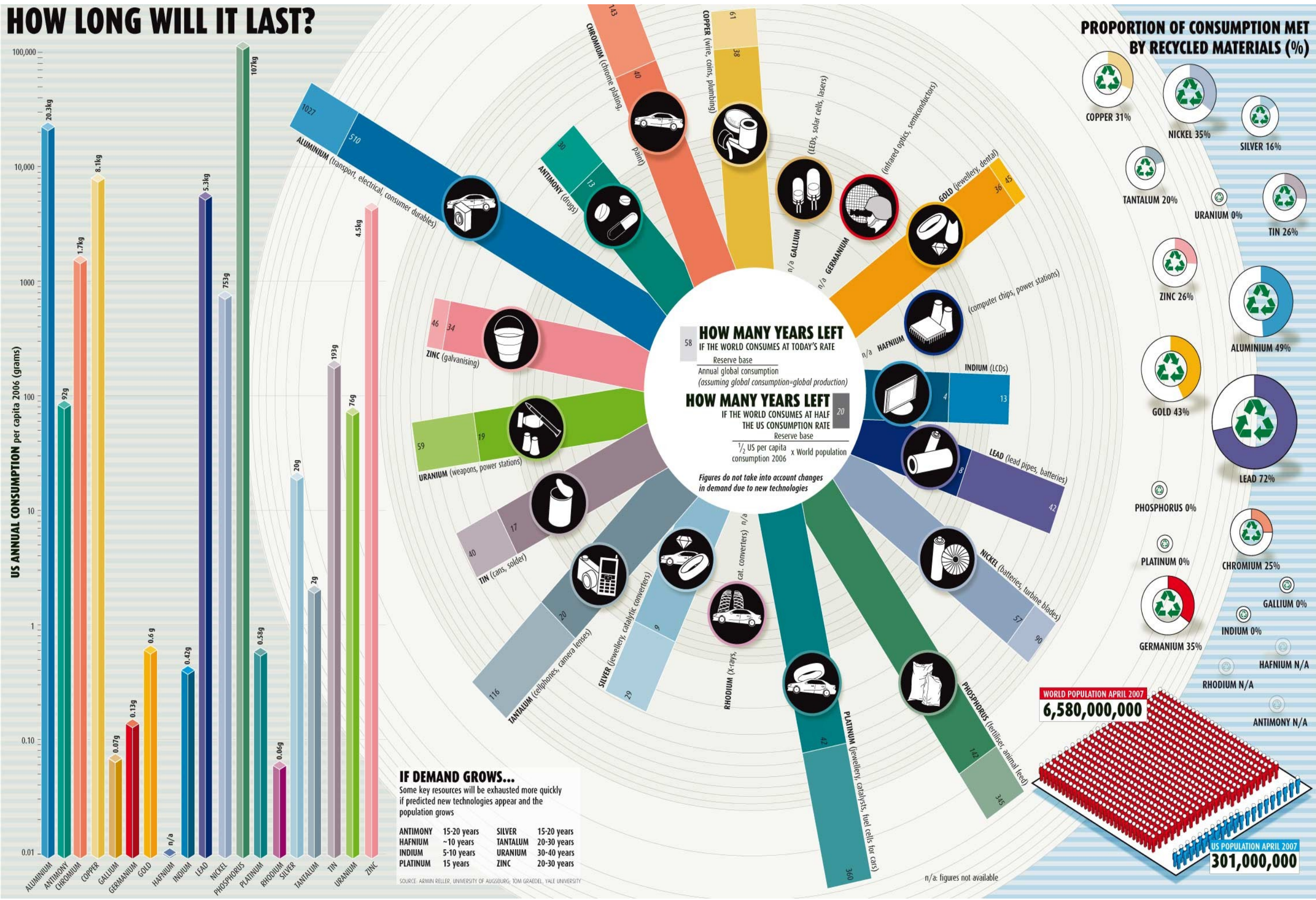
Lead Solder Coating Modules

In the production process of PV modules lead solder coating has been required to ensure that PV modules remain moisture resistant and weatherproof for years on end. **Mitsubishi says to be "**the first in Japan to produce lead-free solder module by developing environmentally friendly composite materials and manufacturing processes for silver electrodes used on the surface of crystalline silicon photovoltaic cells. We also now use lead-free solder for the solder and solder plating members used in the cell modularization process."
http://global.mitsubishielectric.com/bu/solar/index.html

The Minerals Reserves
The basic photovoltaic material for most common Silicon modules made out of silicon is entirely benign, and is available in abundance. Si-based, second-generation, thin-film technologies and Third-generation approaches to photovoltaics -aiming to achieve high efficiency devices but still using thin-film, second-generation deposition methods - use materials that are both nontoxic and not limited in abundance. This opposed to thin-film solar cells based on compound semiconductors like CdTe (toxic Cadmium) and chalcopyrite compounds CIS, CIGS (Cupper, Indium, Gallium and Selenium; not limited in abundance).

"Take the metal gallium, which along with indium is used to make indium gallium arsenide. This is the semiconducting material at the heart of a new generation of solar cells that promise to be up to twice as efficient as conventional designs. Reserves of both metals are disputed, but in a recent report R. Kleijn, a chemist at Leiden University in the Netherlands, concludes that current reserves "would not allow a substantial contribution of these cells" to the future supply of solar electricity. He estimates gallium and indium will probably contribute to less than 1 per cent of all future solar cells - a limitation imposed purely by a lack of raw material."

- **Cohen, D.** Earth's natural wealth: an audit. In: NewScientist.com news service. 23 May 2007. Pp.: 34-41 - http://environment.newscientist.com/article/mg19626271.700



Hopes for Preserving Supplies of Fossil Fuels
Using a solar power generation system to cover some of the household's power

consumption can indirectly reduce the amount of fossil fuels used by thermal power stations. It can therefore be anticipated that the popularization of solar power generation will help to preserve existing supplies of fossil fuels.*

- Extract from PV Building Design Guide, published by the New Energy and Industrial Technology Development Organization: A solar power generation system with a capacity of 10 kW generates 10,016 kWh of electricity annually (assuming the average amount of sunlight in the Tokyo area), and by taking the place of electricity generated by a thermal power station this has the effect of lowering consumption of petroleum by the equivalent of 135 drums (2,436 liters) of kerosene.

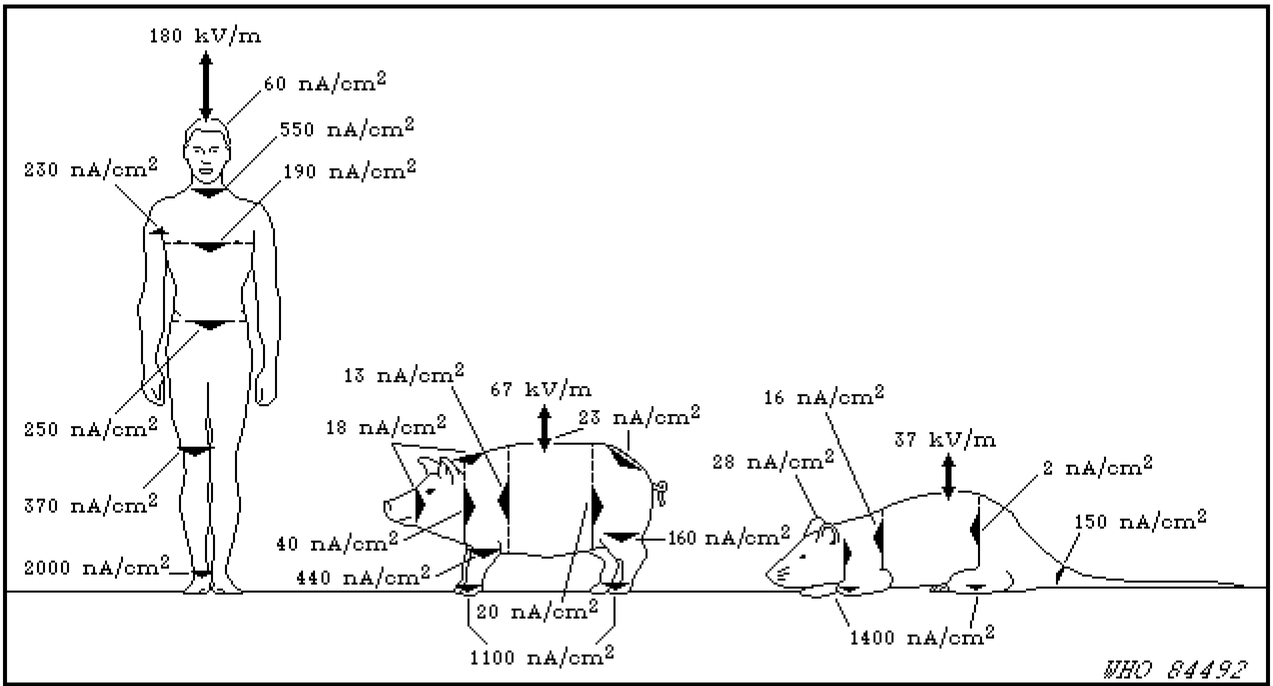
Compliance with European waste legislation
One guideline for the purchase of 'green' pv-products would be to check whether they are compliant to the **EU-legislation on WEEE** (Waste Electrical and Electronic Equipment) **and RoHS** (Restriction of use of certain Hazardous Substances in electrical and electronic equipment), designed to tackle the fast increasing waste stream of electrical and electronic equipment and complements European Union measures on landfill and incineration of waste.

“In order to prevent the generation of hazardous waste, Directive 2002/95/EC requires the substitution of various heavy metals (lead, mercury, cadmium, and hexavalent chromium) and brominated flame retardants or polybrominated diphenyl ethers (PBDE)) in new electrical and electronic equipment put on the market from 1 July 2006.”

An example is the adoption of lead-free solder for substrates, power modules and other products by certain PV-companies.

PV-Farms: Use of Land
Placement of photovoltaics affects the environment. If they are located where photosynthesizing plants would 'normally' grow, they simply substitute one potentially renewable resource for another. However, the biomass cycle converts solar radiation energy to electrical energy with significantly less efficiencies than solar energy. If they are placed on building, façades, fences, rooftops (as long as plants would normally not be planted there) or in the desert they are purely additive to the renewable power base.

Electricity and health
As we are dealing with the exposure of the body to electromagnetic fields & electricity here are some links to websites dealing with these issues from the angle of the possible impact on health.



Grounded man, pig, and rat exposed to vertical, 60-Hz, 10-kV/m electric field. Relative body sizes are not to scale. Surface electric field measurements for man and pig and surface field estimates for rats are shown. Estimated axial current densities averaged over selected sections through bodies are shown. Calculated current densities perpendicular to the surface of body are shown for man and pig (From: Kaune & Phillips, 1980).

“Below 100 KHz the main effect of electromagnetic interferences is the production of electric currents within the body. Power transmission and domestic electricity work in this range (50 to 60 Hz)” - www.biotele.com/EMI.htm

www.electrosensitivity.org/
www.powerwatch.org.uk
http://en.wikipedia.org/wiki/Wireless_electronic_devices_and_health

References

- Bioplastics: www.biosolar.com/overview_technology.html
- BP Solar Waste Program: www.bp.com/sectiongenericarticle.do?categoryId=9012884&contentId=7025016
- **Cohen, D.** Earth's natural wealth: an audit. In: NewScientist.com news service. 23 May 2007. Pp.: 34-41 - http://environment.newscientist.com/article/mg19626271.700

– EU Waste Legislation: http://ec.europa.eu/environment/waste/weee/index_en.htm
– External cost: www.externe.info
– **Fthenakis, V.** (1) and **Alsema, E.** (2) (2006). *Photovoltaics Energy Payback Times, Greenhouse Gas Emissions and External Costs: 2004–early 2005 Status.* (1) PV Environmental Research Center, Brookhaven National Laboratory, USA; (2) Copernicus Institute of Sustainable Development and Innovation, Utrecht University, The Netherlands www.chem.uu.nl/nws/www/publica/publicaties2006/E2006-27.pdf
– S.N.
– www.iea-pvps.org/pv/index.htm
– http://solar1.org/resources/photovoltaics/
– S.N. Progress in Photovoltaics: Research and Applications. Prog. Photovolt: Res. Appl. 2006; 14:275–280. Published online in Wiley InterScience (www.interscience.wiley.com).
– Zinc reserves - http://en.wikipedia.org/wiki/Zinc#Abundance

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To INTEGRATE

More PV for more electricity using more land (also in 'the bizz')

Entropy and growth model?...

Poly-Si Process: Distillation columns, distil Si to gas (tri-chlorocylene) like gasoline, siphon of the pure stuff and convert back to Si.

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www.parc.com/cms/get_article.php?id=543

Environmental

"At present you would need tens of tonnes of very rare and expensive materials for large scale production of solar cells to produce sizeable amounts of power.

"Some of the materials currently used may not be sustainable in 20 years time which is why we have to conduct research into alternative materials that are cheaper to buy and more sustainable.

Professor Durose, Ken, Department of Physics, Durham University. Quoted in: Kitson, L. Durham University leads UK research project into cheaper solar energy. Jan. 15, 2008

www.alphagallileo.org - http://www.innovations-report.com/html/reports/energy_engineering/report-101243.html

By using 30 kilo-watts of photovoltaic capacity, you reduce carbon dioxide emissions equal to the emissions from driving approximately 96,291 miles in an average passenger car!

By using 30 kilo-watts of photovoltaic capacity, you reduce carbon dioxide emissions equal to the carbon dioxide absorbed by approximately 11 acres of trees in one year! (www.photovoltech.be/html/UK/set_main.asp)

About high purity poly-Si production shortage

2005: 31.000 tons
Solar: 12.650 tons
Electronics industry: 16.800 tons

***Ex. Hemlock Poly-Si plant* (US); Wacker/Berghausen (Germany)**

Since 10 years they cannot follow production and do not take PV seriously.
It takes 3 years to build a new Poly-Si plant. Three are being built in China since 2006. - Dr. Richard Swanson, President and CTO of SunPower

www.parc.com/cms/get_article.php?id=543

BIPV is receiving much attention, as using photovoltaic cells in this way **minimizes land use** and offsets the high cost of manufacture by the cells (or panels of cells) acting as building materials hereby **reducing the amount of used of materials.**

The technologies also need to have acceptable **energy payback times** – this is the time taken for a device to generate as much energy as was needed for it's fabrication. Crystalline and multicrystalline devices typically have energy payback times of 3–4 years and the thin-film technologies, 12–18 months. Of course in practice this depends heavily on the site-specific context where the system will be used.

[RENEWABLE] ENERGIES & ENVIRONMENT

TO INTEGRATE

Solar power is doubling worldwide every two years and could provide energy for more than 1 billion people, creating over 2 million jobs by 2020, and 26% of global energy needs by 2040, according to a report released by the European Photovoltaic Industry Association and Greenpeace.

Excerpts from "World in Transition" Study
A Summary for Policy Makers
www.wbgu.de
A study that was carried out by the German Advisory Council on Global Change in 2003. The Authors are a group of internationally known, high ranking scientists.
“The reports of the German Advisory Council on Global Change (WBGU) are an indispensable reference and resource on global environmental change policies. Every scientist, decision maker and institution concerned with the pressing issue of environment and development should have them."

Prof. Dr. Klaus Töpfer - Executive Director of the United Nations Environment Programme.

Conclusions of the Study:
It is essential to turn energy systems towards sustainability world-wide, in order to
1) protect the natural life support systems on which humanity depends, and
2) eradicate energy poverty in developing countries
Another benefit of this global reconfiguration of energy systems will be to promote peace by reducing dependency upon regionally concentrated oil reserves - and it is not only economically feasible but also cheaper!

UPDATE – latest study ;
"With World in Transition – Climate Change as a Security Risk, WBGU has compiled a flagship report on an issue that quite rightly is rising rapidly up the international political agenda. The authors pull no punches on the likelihood of increasing tensions and conflicts in a climatically constrained world and spotlight places where possible conflicts may flare up in the 21st century unless climate change is checked. The report makes it clear that climate policy is preventative security policy."

Achim Steiner
UN Under-Secretary General and Executive Director, United Nations Environment Programme (UNEP

StatoilHydro’s Sleipner field is the largest and longest running carbon dioxide capture and storage project in the world. Excess carbon dioxide from the natural natural gas taken from the field is extracted and pumped into a sandstone formation 1,000 metres below the sea floor.

The success of the Sleipner effort subsequently led Statoil to apply this approach to the In Salah field in Algeria beginning in April 2004, where 17 million metric tonnes of CO_2 will be stored in the underground reservoir over the life of the project. More recently, as natural gas from the giant Snøhvit natural gas field in northern Norway has begun to flow, StatoilHydro is storing 700,000 tonnes of CO2 annually in a formation 2,600 metres under the seabed.

...by the year 2100, coal- and natural gas-fired power plants built to meet the world's demand for energy will require an estimated 7,500 CO2 emissions control systems.
Aker Kvaerner ASA

A European Test Centre
One of the most intriguing carbon capture efforts under development on Norwegian soil is a power project at StatoilHydro's Mongstad refinery. Due to be operational in 2014, the combined heat and power plant project will be the world's largest with full-scale CO2 capture and storage. "With this project we are writing industrial and environmental history," says Prime Minister Jens Stoltenberg.

The Mongstad facility will also be home to a European Test Centre for CO2 capture and storage. DONG Energy, Shell, StatoilHydro and Vattenfall are all partnering with the Norwegian Ministry of Petroleum and Energy on the project; the companies involved all have different CO2 capture technologies that can be tested at the facility.

www.nortrade.com/index?cmd=show_article&id=257

"One statistic makes clear the demand placed upon our economic system: every day the world wide economy burns an amount of energy the planet required 10,000 days to create." - Paul Hawken, The Ecology of Commerce
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The era of fossil fuels is coming to an end
"...a new energy system is awaiting us – a big change compared to the present situation. A change that in its being and character will be as big the as past change from a charcoal based system to a system based on fossil fuels." (Rifkin p. 17)

After the transition from wood -since medieval times the universal energy source- to coal in the United Kingdom in the 18th Century, the first signs of a major disturbance of photon flux can unsurprisingly be found in London:
"Pollution is not a modern phenomenon and in 1789 William Curtis had to move his botanical garden from Lambeth to Brompton to escape the smoke that was invading Lambeth Marsh: 'the smoke of London, which except when the wind blows from the South constantly envelopes my plants'."
Heath, T. The Botanic Blake. In: *The Blake Journal* www.writing.com/main/view_item/item_id/273813

The switch from wood to coal and it's use with the steam engine was the first step towards the industrialized way of living that would change the world in the two following ages for ever.

'The word access is a all encompassing concept for a generation that is mutually communicating via an electronically connected 'central nerves system' spreading out over the entire world'. In the information society networks give access to services and knowledge. End users pay for the time they have access to certain goods and services.'

This era in which we are now living has been made possible by coal, oil and natural gas and every form of progress -commercial, political or social- is in one way or another related to the enormous increase of the amount of available energy that could be generated through the burning of fossil fuels.
Western society has -over the last 200 years- consumed more energy than all other societies together in the history of men.

The prices went up in 2007 reaching 100USD / barrel on Dec. 21st.
The worldwide peak in oil and natural gas-production will have two consequences:

1. a shift in global power as most of the remaining oil reserves will be located in the Middle-East.
2. Countries and energy companies look out for alternatives, esp. the dirty fossil fuels like coal, heavy oil and tar sand.

This will cause further and faster damage to the planet's surface and atmosphere with consequences for the biosphere that will be even more severe than predicted.

"An incandescent light bulb uses 3 percent of the coal burned for the electricity needed for visible light; 97 percent is emitted as heat (Infra Red radiation).

GLOBALIZATION / DEPENDENCE / ACCESS

LIMITS
The rules of thermodynamics learn how far we can go in the attempt to dominate the environment. The energy system imposes restrictions on a society, and when these are not acknowledged than this society is risking it's downfall.

Beijing, 1000 cars a day - Documentary panorama VRT, Jan. 18

'Renewable energy can be defined as 'energy obtained from the continuous or repetetive currents of energy recurring in the natural environment' (Twideel and Weir, 1986), or as 'energy flows which are replenished at the same rate as they are "used"' (Sorensen 2000). The various forms of renewable energy depend primarily on incoming solar radiation, which totals some 5,4 billion exajoules (EJ) per year. Approximately 30% is reflected back into space. The remaining 70% is in principle available for use on Earth, and amounts to approximately 3.8 million EJ, more than 10 000 times the consumption of fossil and nuclear fuels (370EJ in 2002). Two non-solar renewable energy sources are the motion of the ocean tides, caused principally by the Moon's gravitational pull (with a smaller contribution from the Sun's gravity); and geothermal heat from the Earth's interior, which manifests itself in convection in volcanoes and hot springs, and in conduction in rocks.' (Boyle 2003 pp. 11,12)

"The quest to find a suitable renewable energy source is becoming increasingly urgent. Yet wind power is unreliable, hydroelectric systems spoil natural landscapes and nuclear power has associated heath risks."

By the end of the 21th century, if current trends continue, the world's population is likely to have almost doubled and its wealth increased by a factor of between 8 and 16 times. World energy demand will probably have doubled and possibly quadruppled, despite major improvements in energy efficiency. How can this enormous demand be supplied, cleanly, safely and sustainably? ...

The renewable energy sources are essentially carbon-free and appear to be generally lore sustainable than fossil or nuclear fuels, though many technologies are still under development and the costs of some are currently high. ... ...But remarkable progress has been made in the field and recognition increased that renewable energy could provide a major proportion of the world's needs by the middle of the 21st century.

G. Boyle, p.vi

Phos – Light (Greek)
Volt: Unit of electric potential

Environmental impacts of energy production / consumption (EU)
The energy sector is the main contributor to total greenhouse natural gas emissions and generates significant environmental impacts, such as emissions of other air pollutants (acidifying substances, ozone other precursors and particulates), oil spills, and nuclear waste. Since 1992, emissions of air pollutants and, to a lesser extent, greenhouse natural gases from energy production and consumption have been reduced. This is due mainly to reduced use of coal (due both to fuel switching and to overall reductions in energy use in some countries) and, for air pollutants, the introduction of abatement measures in the electricity production and transport sectors. As a result, emissions of greenhouse natural gases and air pollutants per unit of total energy consumed
and unit of electricity generated both decreased substantially throughout the pan-European region.
However, the benefits of this were to a large extent offset by rising energy and electricity consumption.

World wide coal is the most important source for electricity generation (almost 40 percent). We burn three times more coal now than in the '70ies.

A coal central produces per kWh twice as much CO2 as a natural gas central, and almost 50 percent more than a diesel central or a combustion engine on natural gasoline.

Oil and natural gas reserves will be exhausted halfway the 21st century, uranium by the end and the coal reserves in 155 years.

In the pan-European region total energy consumption is growing and remains dominated by fossil fuels, resulting in increasing greenhouse natural gas (GHG) emissions, despite energy efficiency improvements and an increased use of renewable energy in certain areas. The energy supply sector remains a major contributor to air pollution and greenhouse natural gas emissions. Current policies are unlikely to be sufficient to meet long-term climate change and air quality objectives. p. 322

Top 5 coal consumers are USA, China, India, Germany and Japan.

Coal is worldwide well distributed, has a stable price and is cheapest. In 2007 in China their was a new coal central started up almost every week. The US plan 150 new coal plants in the next ten years. Also the European countries are planning new coal plants leading to an estimate increase of world production of 60 percent by 2030. This would eradicate all the benefits for the climate using renewable energies.

Burning the coal reserves would generate 2000billion ton of CO_2, adding up to the current amount of 750billion ton of CO_2 in the atmosphere. Energy manufacturing companies are opting for more efficient technologies and storage of the CO_2 deep under the earth's surface (in former oil/natural gas containing layers; est. capacity 2000 billion tons). But they will always remain a source of emission as there is a max. of 80 to 90 percent. Also, the exploitation of the coals contaminates the sub-soil and water supplies, mutulates the earth's surface, produces tons of waste and causes the loss of thousands of human lifes. Coal centrals with CO_2 storage cause extra environmental damage because they need more coal for the same amount of electricity, not to mention the risk on leaks of the underground reservoirs for hundreds of years (CO_2 is a reactive natural gas).

Coal combustion also releases substantial amounts of greenhouse natural gases. One of the most promising technologies to reduce these emissions is carbon capture and storage (CCS), where CO_2 is captured direct from the plant and stored deep underground, either in depleted oil and natural gas wells, or in aquifers. However, the technology has yet to be deployed on a commercial scale, and the environmental risks need to be further investigated. The technology is most likely to be used first in the EU-25 due to its initially high costs, but these are expected to fall if the technology is widely used. Its use in EECCA countries may be an important option for limiting greenhouse natural gas emissions, but will probably require foreign investment. p.326

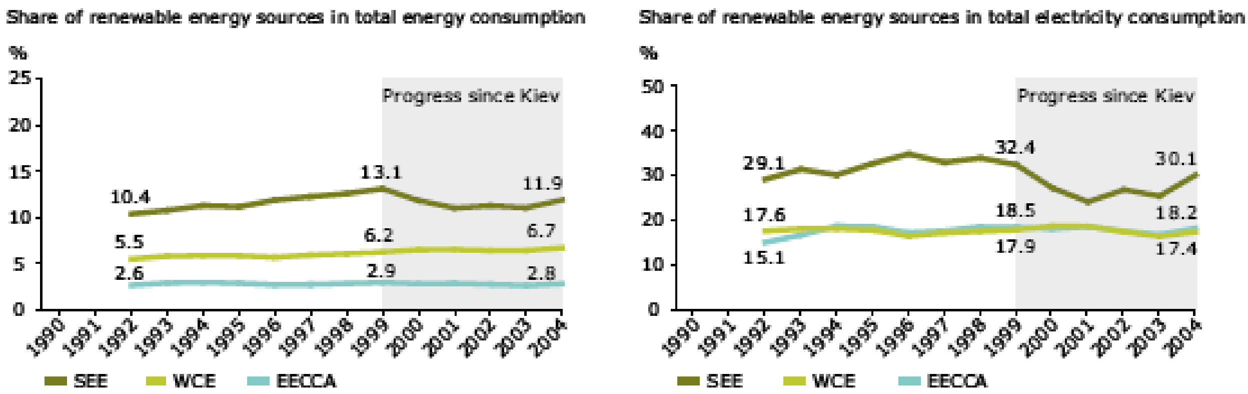
Consumption of **nuclear power** increased by 22 % overall between 1992 and 2004. A downward trend is expected in the EU over the coming years since several EU Member States have decided to phase out nuclear power and many existing plants will be decommissioned. This will not be offset by the fact that some other Member States have begun or plan to start the construction of new plants. The Russian Federation has published plans to build at least 20 new reactors.

Renewable energy showed some growth in absolute terms, increasing by 11 % across the region between 1999 and 2004. Its relative overall share in total energy consumption has been stable since 1999 (Figure 7.3.5). The overall growth in renewable energy masked significant regional differences. In EECCA, 2004 consumption of renewable energy. P.326

Total energy consumption throughout the pan-European region is growing and remains dominated by fossil fuels. Despite large reductions in some air emissions in parts of Europe, the energy supply sector remains a major contributor to air pollution and greenhouse natural gas emissions. Current policies are unlikely to be sufficient to meet long-term climate change and air quality objectives. P.322

Improvements in **energy efficiency** signify the use of less input energy to provide the same level of energy service (e.g. less electricity via the use of a compact fluorescent light bulb or less primary energy used to produce one unit of electricity). The goal is to achieve **energy savings**, thus reducing energy consumption in absolute terms. P.328

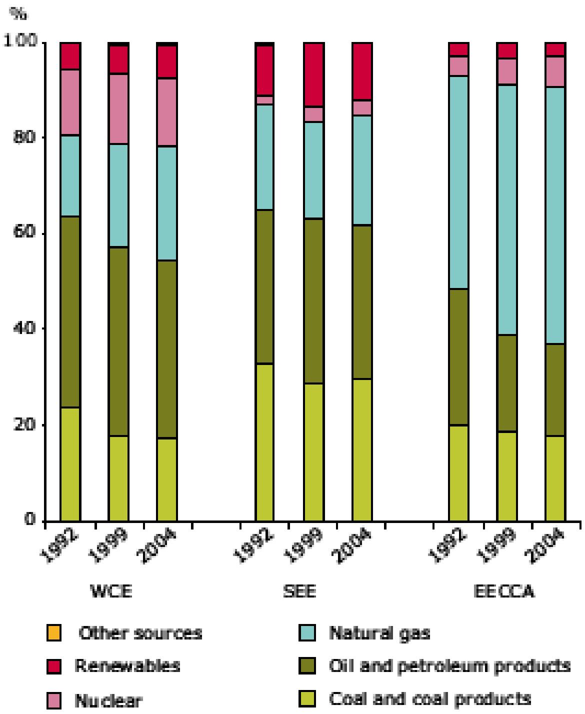
Figure 7.3.5 Shares of renewable energy sources in total energy consumption and in total electricity consumption, 1992–2004



Note: No data available for several countries in all three regions for years 1990 and 1991.

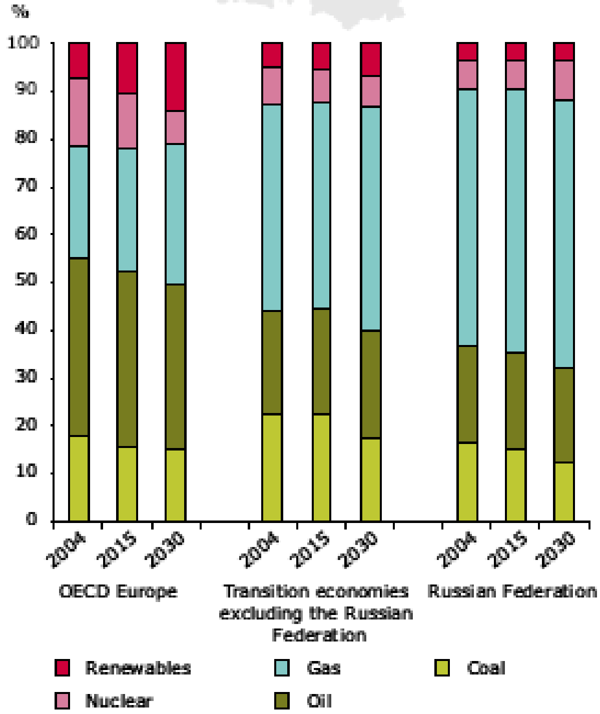
Source: OECD/IEA, 2006a.

Figure 7.3.3 Total energy consumption by fuel, 1992–2004



Source: OECD/IEA, 2006a.

Figure 7.3.4 Total energy consumption by fuel source, projections 2004–2030

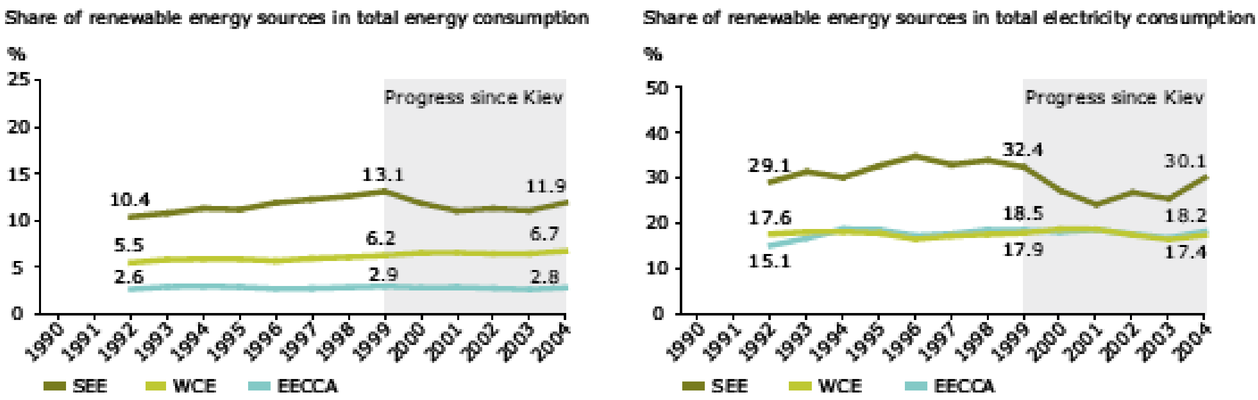


Source: OECD/IEA, 2006b.

was only at 84 % of 1992 levels, due to a decrease in production from combustible renewable sources, primarily due to poor maintenance of existing plants. In SEE, renewable energy had increased by 31 % between 1992 and 2004, primarily from an increase in hydropower and combustible biomass, but energy production from biomass has been decreasing since 1999. The increase was greatest in WCE (39 %), mainly driven by a strong increase in biomass use for energy production and, to a lesser extent, to increased wind capacity. Installed wind capacity in WCE grew by approximately 600 % between 1997 and 2003 and 23 % in 2003 alone. This was largely due to the implementation of a number of fiscal and regulatory support measures, such as feed-in tariffs and obligations regarding share of renewable energy. The EU has set targets for both renewable energy and electricity of 12 % of total energy consumption and 21 % of electricity consumption, respectively, by 2010, but meeting these targets will require significant ongoing efforts.

Improvements in **energy efficiency** signify the use of less input energy to provide the same level of energy service (e.g. less electricity via the use of a compact fluorescent light bulb or less primary energy used to produce one unit of electricity). Improvements in energy efficiency can be offset by increased demand. The goal is not just to improve energy efficiency or reduce energy intensity but to achieve **energy savings**, thus reducing energy consumption in absolute terms.

Figure 7.3.5 Shares of renewable energy sources in total energy consumption and in total electricity consumption, 1992–2004



Note: No data available for several countries in all three regions for years 1990 and 1991.

Source: OECD/IEA, 2006a.

Land use and other environmental impacts p.333

Although power plants occupy relatively small geographical areas, the associated mining, transportation and waste can have significant impacts on land. These differ in nature and intensity according to the activity and the fuel used. The extraction of oil and natural natural gas can destroy natural habitats for animals and plants. Waste products,
such as wastewater sludge and residues, can cause land contamination if not properly disposed of.

Land use and other environmental impacts of energy production are much more prominent in EECCA than in EU. Examples include the rupturing of an oil pipeline in the Komi Republic and the network of leaking pipes and wellheads in the Caspian Sea. Raising environmental standards can impose costs on companies developing or upgrading existing fields. Future oil and natural gas projects, particularly in EECCA, are expected to be undertaken in increasingly remote areas (east Siberia and Kamchatka), where large industrial projects could have major environmental impacts. Transport of oil and natural gas can result in pipeline accidents and oil tanker spills.

The important and increasing energy trade will affect energy transportation, and the associated environmental impacts could become an issue in the context of pipeline construction between EECCA and EU.

The storage and transport of radioactive waste from nuclear power production (e.g. spent fuel) and uranium mining may also exert environmental pressures. Tailings from historic mining operations represent a significant amount of low-level radioactive waste in Europe. While uranium mining in WCE has decreased significantly since 1990, production continues in the Russian Federation, Ukraine and Kazakhstan.

Table 7.3.3 EU energy import dependence

	EU import dependence %	Imports from Russia, % of EU consumption, 2003	Imports from Russia, % of EU consumption, 2030
Oil	80	27	> 90
Natural gas	46	25	85

Source: European Commission, 2006.

p. 336

The influence of future environmental impacts on energy supply — especially those of unavoidable climate change — must also be considered. An example of this is the siting of pipelines in areas of melting permafrost, where warming may lead to ground sinkage, disruption of transport of energy supplies, and pollution.

Chapter 7 Sectors that drive environment change. Europe's environment - The fourth assessment - The European Energy Association, 2004.

Chapter 3 Climate Change. Europe's environment - The fourth assessment -
The European Energy Association, 2004.

New scientific insight and new research have confirmed that global climate change is taking place and is projected to continue. Impacts of climate change on society and natural resources are already occurring worldwide and are projected to become even more pronounced. Much of the recent global warming can be attributed to greenhouse natural gas (GHG) emissions from human activities. The EU has proposed a target of limiting temperature increase to a maximum of 2 °C above pre-industrial levels. To achieve this, a global emission reduction of up to 50 % by 2050 is necessary.

The earth's climate is changing. The average temperature — globally and in Europe — continues to increase. Globally it has increased 0.74 °C between 1906–2005. In Europe the temperature is about 1.4 °C higher than pre-industrial levels with the last decade the warmest for 150 years, and 1998 and 2005 warmer than any year on record (CRU, 2006; GISS/NASA, 2006; IPCC, 2007). Global mean temperatures are projected to increase by 1.8–4.0 °C, during this century, with some studies suggesting a wider possible range of 1.1–6.4 °C (IPCC, 2007).
Europe is likely to become warmest in the eastern and southern parts of the continent.

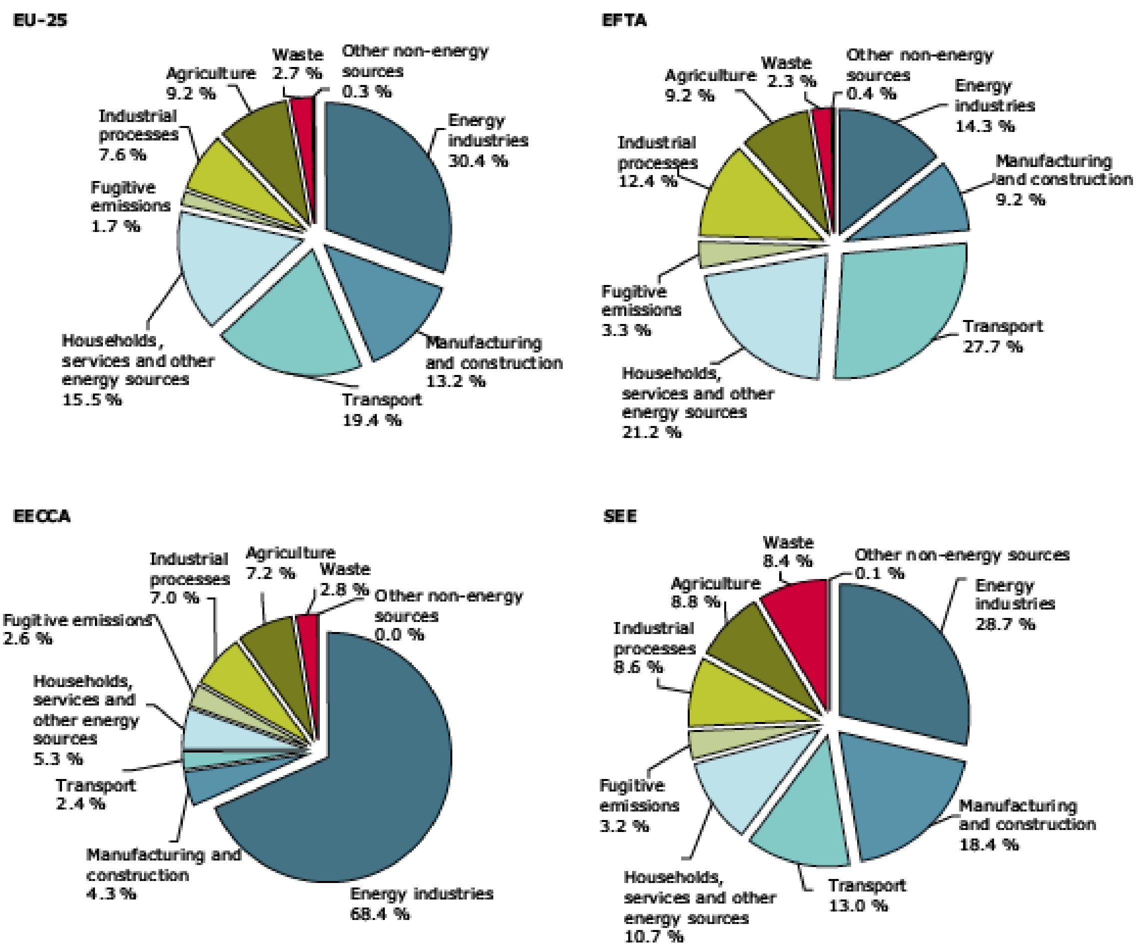
Sea levels are rising and the melting of glaciers is accelerating. The global mean sea-level rose by more than 1.7 mm/year during the 20th century and is projected to rise by 0.18 m to 0.59 m during the 21st century (IPCC, 2007).

The impacts of climate change, including those on natural ecosystems, biodiversity, human health and water resources such as floods and droughts, are already being observed and are projected to become more pronounced. The least developed countries, such as some of those in EECCA, are among the most vulnerable, having the least financial and technical capacity to adapt, for example, to droughts or increased flooding.

Even if global warming is to some extent the result of natural factors, the latest scientific insight shows that over recent decades much of it can be attributed to greenhouse natural gas (GHG) emissions from human activities (IPCC, 2007): carbon dioxide (CO2) is the largest contributor at about 80 % of total GHG emissions. Substantial reductions in GHG emissions are needed if the impacts of climate change are to be kept at manageable levels.
p. 146

Climate change is one of the factors that threaten biodiversity. Its influence has increased over recent decades and it is expected to be the main driver of biodiversity loss in the future (Thomas *et al.,* 2004). The most vulnerable European regions appear to be mountain areas, the Arctic and the Mediterranean (Brooker and Young, 2005; Schröter *et al.,* 2005). p. 159

Figure 3.5 Share of total greenhouse gas emissions by sector in 2004



Note: The sectoral shares have been calculated using available sectoral data at the time of writing this chapter. For the EECCA countries the sectoral shares presented in the chart above fail to capture the current situation. This is mainly due to incomplete sectoral reporting by the Russian Federation. Emissions from transport and fugitive emissions were not reported separately in their NC4, and seemed to have been included under energy industries. The Russian Federation submitted their greenhouse gas national inventory report and CRF tables to the UNFCCC in January 2007. According to the CRF for 2004, fugitive emissions account for about 10 % of total greenhouse gas emissions. Transport was not reported separately. Since the Russian Federation represents more than 2/3 of the total emissions in the EECCA countries, the share of fugitive emissions in EECCA countries would be closer to 9–9.5 %.
The volume of emissions in million tonnes of CO_2-equivalents in 2004 was: EU-25 = 4 980; EECCA = 2 996; SEE = 599; EFTA = 111.

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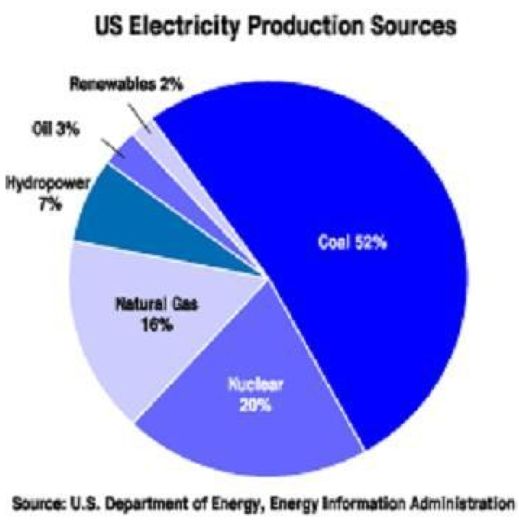
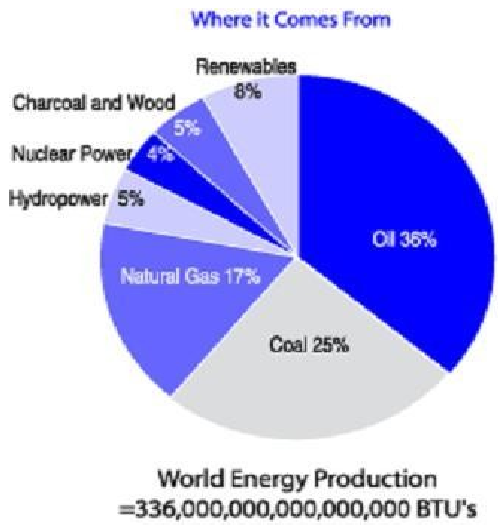
Total greenhouse natural gas emissions per capita in 2004 See page 163





In terms of human history, the fossil fuel event will be brief. After using fossil fuels for about 600 years we are probably on a permanent downward course in worldwide production of natural natural gas, at or just past the peak in the production of oil and within a few hundred years of reaching our peak in coal. If world energy consumption continues to grow at 2.8% the consumption of energy doubles from 336,000,000,000,000,000 BTU’s to 672,000,000,000,000,000 BTU’s in just 25 years

www.forestinfo.org/Discover/energy.htm