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Carbon Footprint - Application in Graphic Art Technology

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Abstract

The need for more sustainable products and processes has triggered the development of a large number of environmental assessment tools. These tools measure environmental performance and identify improvement potentials from the environmental point of view. The life cycle assessment (lca) methods take into account all effects on the environment, direct and indirect resource inputs and/or emissions during the whole life cycle of products. The carbon footprint is a sub-set of data covered by life cycle assessment.

The aim of this paper is to describe the potential environmental impacts (greenhouse gases, carbon footprint) of printed paper and new media.

Abstract

Carbon Footprint, lca, Printed Substrate, New Media

1. Introduction

The society is becoming increasingly aware of the aim of sustainable development. It is interested in contributing to it by decreasing negative environmental and social impacts.

The procedure of learning about environmental impacts has been made easier by developing and employing tools for environmental assessment. The field of graphic arts and media is experiencing rapid development which provides new solutions contributing to sustainable development.

The objectives of this paper include: the comparison of printed and electronic versions of newspapers and novels respectively, the assessment of potential impacts on energy consumption and greenhouse gas emissions taking place during the transfer from printed paper to new media.

2. Global warming and greenhouse effect

Human activities contribute to the climate change by causing changes in the amounts of greenhouse gases, aerosols, and cloudiness in Earth's atmosphere. Greenhouse gases and aerosols affect the climate by altering incoming solar radiation and outgoing infrared radiation that are part of Earth's energy balance. Changing the atmospheric abundance or properties of these gases and particles can lead to warming or cooling of the climate system.

Figure 1 shows on the left hand side what happens with the incoming solar radiation, and on the right hand side how the atmosphere emits the outgoing infrared radiation. Any physical object radiates energy of an amount and at wavelengths typical for the temperature of the object: at higher temperatures more energy is radiated at shorter wavelengths.

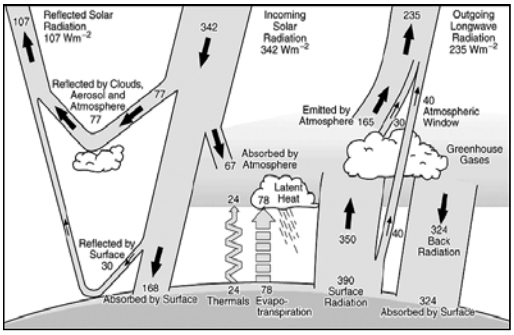

Figure 1. The Earth's surface energy balance (IPPC, 2001)

Of the incoming solar radiation, 49% (168 Wm^{-2}) is absorbed by the Earth's surface. That heat is returned to the atmosphere as sensible heat, as evapotranspiration (latent heat) and as thermal infrared radiation. Most of this radiation is absorbed by the atmosphere, which in turn emits radiation both up and down. The radiation lost to space comes from cloud tops and atmospheric regions much colder than the surface. This causes a greenhouse effect *(Kiehl & Trenberth, 1997).*

3. Greenhouse gases and particles

The atmosphere contains several trace gases, the so-called greenhouse gases, which absorb and emit infrared radiation. These gases absorb infrared radiation, emitted by the Earth's surface, the atmosphere and clouds, except in the transparent part of the spectrum (the atmospheric window – *Figure 1*). They emit in turn infrared radiation in all directions including downward to the Earth's surface. Thus greenhouse gases trap heat within the atmosphere. This mechanism is called the natural greenhouse effect. The net result is an upward transfer of infrared radiation from warmer levels near the Earth's surface to colder levels at higher altitudes. The infrared radiation is effectively radiated back into space from an altitude with a temperature of, on average, -19°C, in balance with the incoming radiation, whereas the Earth's surface is kept at a much higher temperature of on average 14°C. The natural greenhouse effect is part of the energy balance of the Earth, as can be seen schematically *(Figure 1).*

Since the beginning of the industrial era, anthropogenic (man-made) activities cause emissions of greenhouse gases (carbon dioxide, methane, nitrous oxide, the halocarbons, ozone) and aerosols, which are accumulated in the atmosphere, thus substantially contributing to the effect of global warming. Carbon dioxide is produced by fossil fuel used in transportation, heating and cooling and the manufacture of pulp and paper, graphic products and the manufacture of other goods. Deforestation releases CO_2 and reduces its uptake by plants. Carbon dioxide is also released in natural processes such as the decay of plant matter.

The rise of carbon dioxide gas in atmosphere has been measured continuously since 1958 and follows an oscillating line known as the "Keeling Curve," named (Dr Charles David Keeling, professor at Scripps Institution of Oceanography in California was the first to measure carbon dioxide in the atmosphere on a continuous basis). Measurements are conducted at the station on top of Mauna Loa in Hawaii. When the Keeling curve for Mauna Loa is extended back in time from measurements of CO_2 in gas bubbles trapped in Antarctic and Greenland ice cores, it is visible that the emission of this gas increased from 270 ppb in the year 1600 to 370 ppb in 2005 *(*** 2010a)*. Carbon dioxide varied the way it did during the year (i.e. the little squiggles, *figure 2*). Every spring, when trees bloom, the concentration of carbon dioxide in the air decreases, reflecting the uptake from photosynthesis. In autumn, when leaves fall down and decompose, the concentration rises again.

At present moment the anthropogenic activities add about 7-9 gt/y of carbon to the atmosphere in the form of CO_2 (80% is from the burning of fossil fuels).

The concentration of methane, the most important greenhouse gas, has increased as a result of human activities related to agriculture, the distribution of natural gas and landfill but also due to natural processes that occur, for example, in wetlands. Concentrations in the atmosphere have more than doubled since the Industrial Revolution, as core samples taken from glacial ice revealed. *(IPPC, 2007)*.

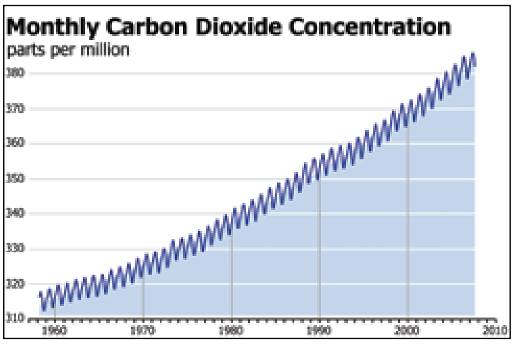

*Figure 2. Dr Keeling's curve of increasing carbon dioxide concentration (*** 2010a)*

Nitrous oxide is a product of human activities such as fossil fuel burning and biomass burning, as well as the use of fertilizers. It is also produced in agricultural processes via anaerobic denitrification processes. This gas is harmful not only for the troposphere (it causes the greenhouse effect), but it also affects the stratosphere, where it contributes to the destruction of ozone.

The concentrations of halocarbons gas have increased primarily due to human activities but the gas is also generated in natural processes. CFCs like nitrous oxide are long-lasting and contribute both to global warming in the troposphere and the ozone destruction in the stratosphere. The concentrations of chlorofluorocarbon gases are decreasing as a result of international regulations designed to protect the ozone layer.

Ozone is a greenhouse gas that is continually produced and destroyed in the atmosphere by chemical reactions. In the troposphere, human activities have increased the concentrations of ozone through the release of gases such as carbon monoxide, hydrocarbons and nitrogen oxide, which take part in chemical reactions to produce ozone (through the action of sunlight on pollutants, such as the photochemical smog). Major sources are automotive traffic, agrocultural wastes and burning forests.

Water vapour absorbs infrared energy and is the most abundant and important greenhouse gas in the atmosphere. Human activities have only a small direct influence on the amount of atmospheric water vapour. However, people have a substantial indirect potential to affect water vapour by changing the climate. Water vapor temperature raises the positive feedback mechanism. Positive feedback mechanism is a mechanism that causes temperatures to change further in the same direction as that of the initial temperature pertubation. This is a highly disturbing feature of future warming, because it increases the sensitivity of the climate to the increased concentrations of anthropogenic greenhouse gases.

Aerosols are small particles in the atmosphere that vary in size, concentration and chemical composition. Some aerosols are given off directly into the atmosphere while others are formed from emitted compounds. Aerosols contain both naturally occurring compounds and those emitted as a result of human activities. Fossil fuel and biomass burning have increased the concentration of aerosols containing sulphur compounds, organic compounds and black carbon *(Jacobson,* *2002)*. Some aerosol particle components warm and others cool the air. Particle components that warm near-surface air, primarily by absorbing solar radiation, although they also absorb thermal IR radiation, include black carbon, iron, nitrated aromatic compounds and polycyclic aromatic compounds. Some particle components (sulfate, nitrate, water, most organic compounds) cool the near-surface air by backscattering incident solar radiation to space more than they absorb thermal IR radiation.

The most significant impact on the environment produced during the printing process is caused by air emissions *(Shapiro, 2002)*. The evaporation of liquid during prepress, printing and post printing processes produces vapour that contains a variety of pollutants which are then released into the workplace and/or out of the facility. The major problem arises from the use of volatile organic compounds. They are common solvents used in printing. Some solvents are found in inks, fountain solutions and claning agents. A tipical list of solvents used in a printing plant would include propanol, 2-propanol, hexane, heptane, toluenen, propyl acetate, ethyl acetate, xylene and number of petroleum destillates. The solvents used in printing and related industries are activated by heat and light to create the ozone.

Non-methane hydrocarbons are greenhouse gases and are hence involved in global warming *(Jackson & Jackson, 1996)*. These compounds are oxidized in a simiular way to methane within the troposphere, yielding a huge number of secundary pollutants.

Some of the materials used by printers contain powders or powders suspended in a solution, such as in inks or coatings and some process may create dust or small particles i.e. paper dust or Oxydry powder.

Printing technology is constantly changing. Computers contributed to the removal of a vast number of chemicals that were used (digital and direct to press technology). As ink and solvent suppliers examined materials used to produce inks, they developed products that are less hazardous (cleaner chemicals contain renewable raw materials).

Projections of the future effects of greenhouse gases on the climate are made using computer models of the atmosfere and oceans called Atmosfere Ocean Generall Circulation Models *(Pepper et al., 2006)*. Recognizing the problem of global climate change, the World Meteorological Organization and the UN Environment Program established the Intergovernmental Panel on Climate Change IPPC. It provides relevant information that would lead to a better understanding of anthropogenically induced climate changes (assessments of scientific issues; evaluations of impact on the climate and the prospects of adapting to it; studies of methods to mitigate the effects) *(*** 2010b)*.

4. Carbon footprint

Climate change creates a growing demand for carbon footprint. Carbon footprint is the overall level of greenhouse gas emissions associated with a product along its life cycle. The carbon footprint is quantified using indicators such as the global warming potential. The Intergovernmental Panel on Climate Change defines the global warming potential as an indicator that reflects the potential relative climate change effect per kg of greenhouse gas over a fixed time period such as 100 years.

Table 1. Global warming potential GWP_{100}

Species	*Lifetime (years)*	*Global-Warming Potential*
Carbon dioxide	*variable*	*1*
Methane	*12±3*	*21*
Nitrous oxide	*120*	*310*
HFC-23	*264*	*11700*
Sulphur hexafluoride	*3200*	*23900*
Perfluoromethane	*50000*	*6500*

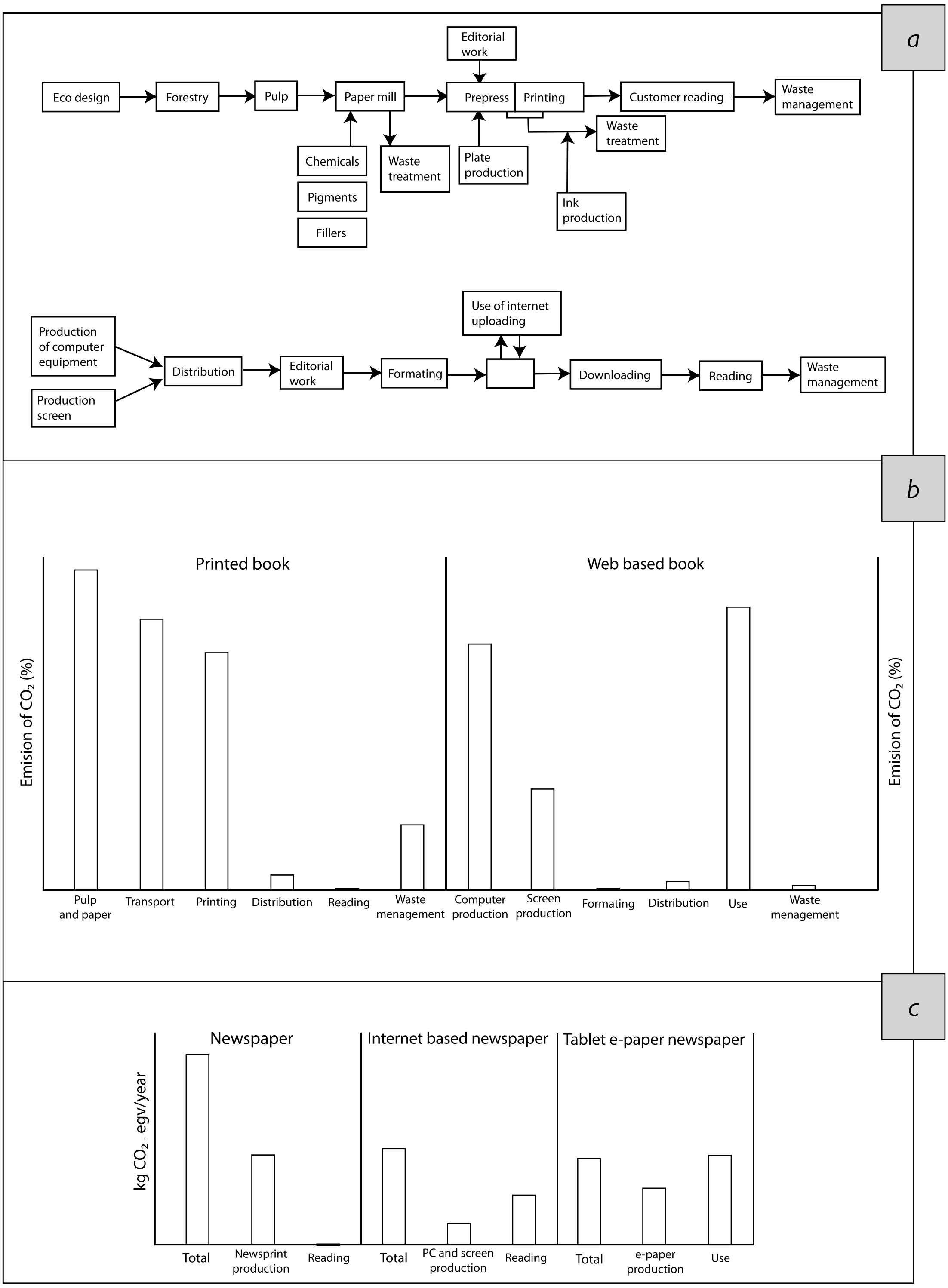

Figure 3. Life cycle inventory of the printed book (offset) and electronic product (a); Carbon dioxide of life cycle of a printed book and web based book (b); Global warming potential (c)

For instance, nitrous oxide is a significant factor of the greenhouse effect and has a GWP of 310. This means that nitrous oxide is approximately 310 times more heat-absorbend than carbon dioxide per unit of weight.

Carbon footprint uses data covered by life cycle assessment *(Finnveden, 2000)*. Life cycle assessment is an internationally standardized method for the evaluation of environmental impacts exercised along the life cycle of products *(ISO 14040, ISO 14044)*.

Figure 3 presents a life cycle inventory flow for a printed book, a web based book and the global warming potential.

As shown on the inventory example, the amounts of fossil carbon dioxide emissions can be calculated for functional units, inputs and outputs *(*** 2010c)*. Carbon flows in the graphic reproduction are easily studied using life cycle inventory, and the carbon footprint can be reported for processes, production units and products.

The main impacts of printed media on the environment are usually a result from the production of pulp and paper *(Trudel, 2007)*. The amount and type of paper used for a specific product lied in direct connection with environmental impacts. Distribution of printed media also plays a significant role. Printing process was proved to be less hazardous to the environment than paper (it is hard to generalise as many parameters are very specific for each case e.g. type of paper, number of pages, and printing technique). The greenhouse gas respective printed product accounted for as kg printed product ranged from 0.5 kg CO_2 to 9.5 kg CO_2 eq. per kg printed media *(Moberg, 2009)*.

In the case of electronic media using e-reading devices in the use phase, the production and, for some impact categories waste management of the device, had the strongest influence on the environment *(Gard & Keoleian, 2003)*.

The energy consumption of electronic devices related to electronic media depends on the time of use and on the power draw of the device. If electronically distributed products are printed, the environmental impacts as a result of paper production and the printing process are added to those of the electronic device used. This increases environmental impacts related to electronic media. The magnitude will depend e.g. on the amount of pages printed, the printer used and the potential effect on the use of the electronic device.

5. Conclusion

Human activities contribute to climate change by causing changes in the concentrations of greenhouse gases, aerosols, and cloudiness in Earth's atmosphere. Greenhouse gases (carbon dioxide, methane, nitrous oxide, the halocarbons, ozone) and aerosols affect the climate by altering the incoming solar radiation and the outgoing infrared radiation that are part of Earth's energy balance. Climate change creates a growing demand for carbon footprint. The carbon footprint is quantified using indicators such as global warming potential.

The carbon flows in the graphic reproduction are easily studied using life cycle inventory, and a carbon footprint can be reported for processes, production units and products. The most significant phase of the life cycle for printed and for tablet e-paper product is the production of substrate (paper) or platform (tablet e-paper) device respectively. The main characteristic of the tablet e-paper is the low energy requirement during use. Compared to an internet-based newspaper, the tablet e-paper has the advantage of very low energy consumption during reading. Printed newspaper has the lowest environmental impact in the use phase. On ther hand, paper production, printing process and the distribution have a major environmental impact. The sources and amounts of energy used for the pulp- and papermaking processes are an important environmental performance of the printed newspaper.

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