EMISSIONS AND SEQUESTRATION – THE BINDING OF CARBON

Anthropogenic climate change is caused by the rising content of greenhouse gases and particles in the atmosphere. Firstly by the burning of fossil fuels, releasing greenhouse gases such as CO_2, ("brown carbon") and dust particles (part of "black carbon"); secondly by emissions from clearing natural vegetation, forest fires and agricultural emissions, including those from livestock; and thirdly – by the reduced ability of natural ecosystems to bind carbon through photosynthesis and store it – so called green carbon (Trumper *et al.*, 2009). The uptake of CO_2 into a reservoir over long (several decades or centuries) time scales, whether natural or artificial is called carbon sequestration (Trumper *et al.*, 2009).

Fact box 1. The colours of carbon: Brown, Black, Blue and Green

Climate Change has driven widespread appreciation of atmospheric CO_2 as the main greenhouse gas and of the role of anthropogenic CO_2 emissions from energy use and industry in affecting temperatures and the climate – we refer to these emissions as "brown carbon" for greenhouse gases and "black carbon" for particles resulting from impure combustion, such as soot and dust. The Emissions Trading System of the European Union (EU-ETS) is a "black-brown carbon" system as it does not incorporate forestry credits. The Kyoto Protocol's Clean Development Mechanism (CDM) does in principle include forestry credits, but demand (in the absence of a linking directive and demand from the EU-ETS) and prices have always been too low to encourage success, so CDM has also become, for all practical purposes, another "black carbon" mechanism.

Terrestrial carbon stored in plant biomass and soils in forest land, plantations, agricultural land and pasture land is often called "green carbon". The importance of "green carbon" is being recognized through anticipated agreement at the United Nations Framework Convention on Climate Change Conference of the Parties (COP) in Copenhagen, December 2009, which includes forest carbon – through various mechanisms, be they REDD and afforestation, REDD-Plus, and/or others (e.g. 'Forest Carbon for Mitigation'). The world's oceans bind an estimated 55% of all carbon in living organisms. The ocean's blue carbon sinks – particularly mangroves, marshes and seagrasses capture and store most of the carbon buried in marine sediments. This is called "blue carbon". These ecosystems, however, are being degraded and disappear at rates 5–10 times faster than rainforests. Together, by halting degradation of "green" and "blue" carbon binding ecosystems, they represent an emission reduction equivalent to 1–2 times that of the entire global transport sector – or at least 25% of the total global carbon emission reductions needed, with additional benefits for biodiversity, food security and livelihoods. It is becoming increasingly clear that an effective regime to control emissions must control the entire "spectrum" of carbon, not just one "colour".

In the absence of "Green Carbon", biofuel cropping can become incentivized, and can lead to carbon emissions if it is not done correctly. The conversion of forests, peatlands, savannas and grasslands to produce food-crop based biofuels in Brazil, Southeast Asia and the United States creates a biofuel carbon debt by emitting 14 to 420 times more CO_2 than the annual reductions in greenhouse gases these biofuels provide by replacing fossil fuels. In contrast, biofuels produced from waste biomass and crops grown on degraded agricultural land do not accrue any such carbon debt.

BROWN, BLACK, GREEN AND BLUE CARBON

Brown and black carbon emissions from fossil fuels, biofuels and wood burning are major contributors to global warming. Black carbon emissions have a large effect on radiation transmission in the troposphere, both directly and indirectly via clouds, and also reduce the snow and ice albedo.

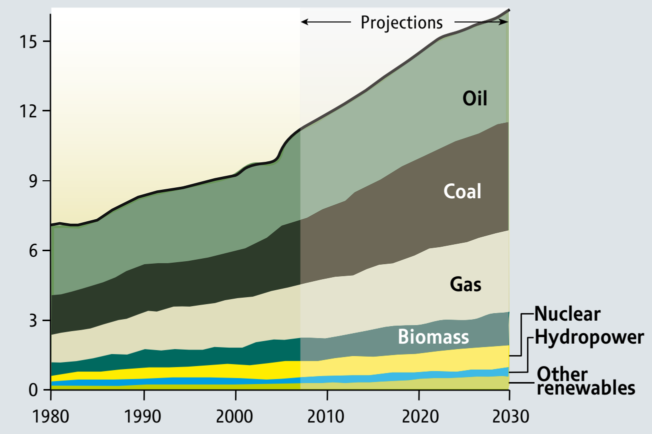
Black carbon is thought to be the second largest contributor to global warming, next to brown carbon (the gases). Thus, reducing black carbon emission represents one of the most efficient ways for mitigating global warming that we know today.

Black carbon enters the ocean through aerosol and river deposition. Black carbon can comprise up to 30% of the sedimentary organic carbon (SOC) in some areas of the deep sea (Masiello and Druffel, 1998) and may be responsible for 25% of observed global warming over the past century. Black carbon tends to remain in the atmosphere for days-weeks (Hansen and Nazarento, 2004) whereas CO_2 remains in the atmosphere for approx 100 years (IGSD, 2009).

The total CO_2 emissions of are estimated to be between 7,200 Tg C yr^{-1}, and 10,000 Tg C yr^{-1} (Trumper *et al.*, 2009), and the amount of carbon in the atmosphere is increasing by approximately 2,000 Tg C yr^{-1} (Houghton, 2007).

Actual and projected energy demand

Gigatonnes of oil equivalent



Note: All statistics refer to energy in its original form (such as coal) before being transformed into more convenient energy (such as electrical energy).

Source: International Energy Agency (IEA), World Energy Outlook 2008.

Figure 2: Projected growth in energy demand in coming decades.

GREEN CARBON

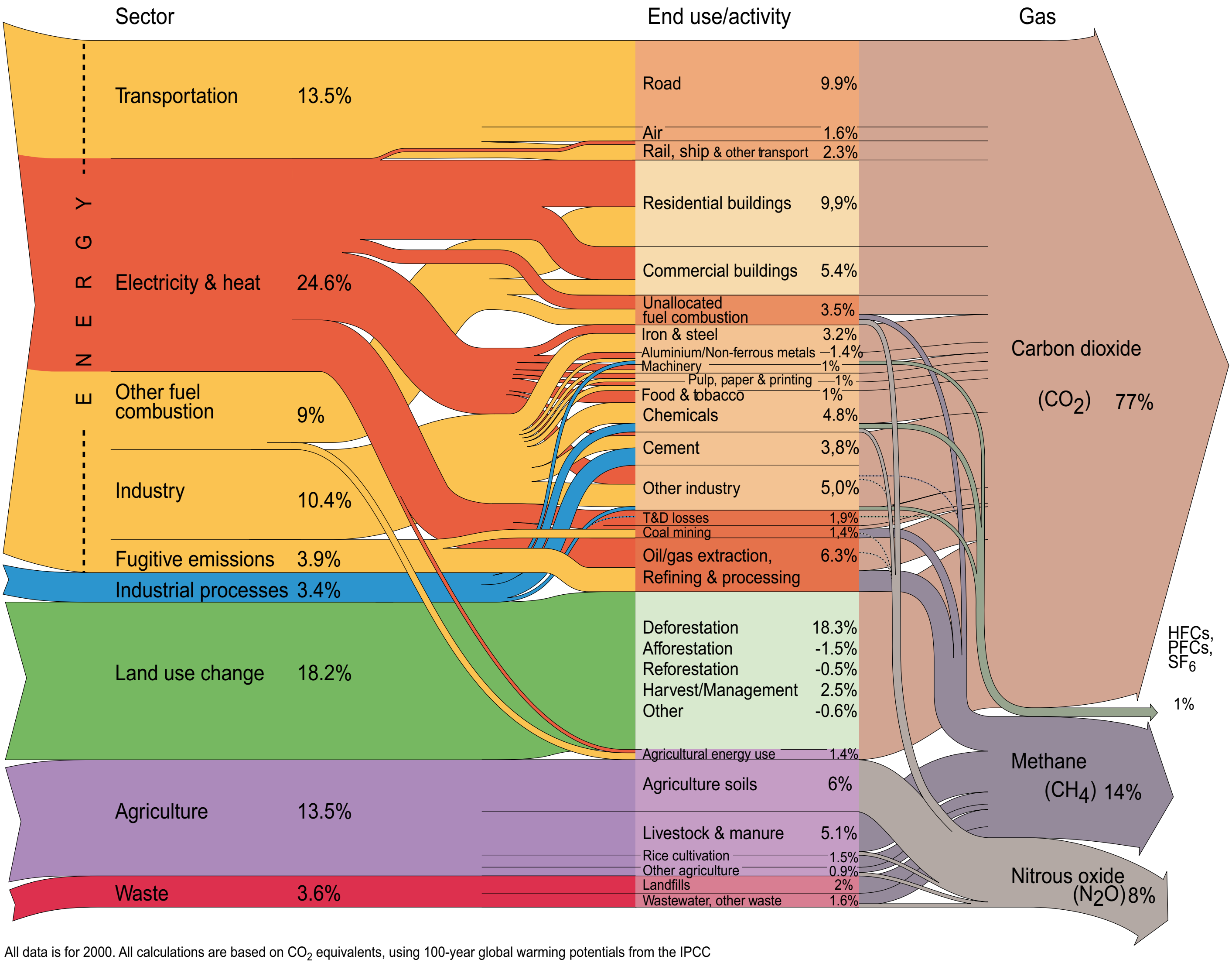
Green carbon is carbon removed by photosynthesis and stored in the plants and soil of natural ecosystems and is a vital part of the global carbon cycle. Sofar, however, it has mainly been considered in the climate debate in terrestrial ecosystems, though the issue of marine carbon sequestration has been known for at least 30 years.

A sink is any process, activity or mechanism that removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas or aerosol from the atmosphere. Natural sinks for CO_2 are for example forests, soils and oceans.

Unlike many plants and most crops, which have short lives or release much of their carbon at the end of each season, forest biomass accumulates carbon over decades and centuries. Furthermore, forests can accumulate large amounts of CO_2 in relatively short periods, typically several decades. Afforestation and reforestation are measures that can be taken to enhance biological carbon sequestration. The IPCC calculated that a global programme involving reduced deforestation, enhanced natural regeneration of tropical forests and worldwide re-afforestation could seques-

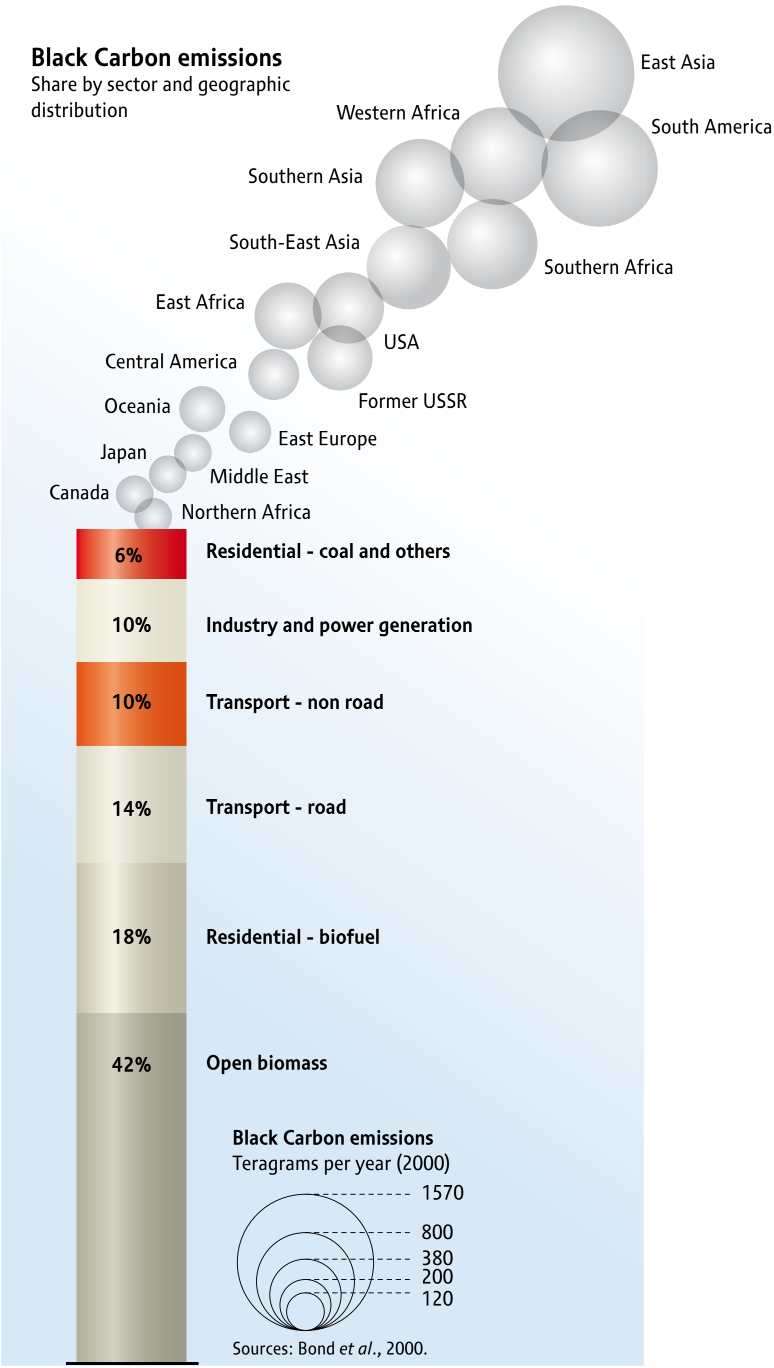
➔ **Figure 3: World greenhouse emission by sector.** All transport accounts for approximately 13.5% of the total emissions, while deforestation accounts for approximately 18%. However, estimates of the loss of marine carbon-binding ecosystems have previously not been included.

World greenhouse gas emissions by sector



All data is for 2000. All calculations are based on CO_2 equivalents, using 100-year global warming potentials from the IPCC (1996), based on a total global estimate of 41 755 $MtCO_2$ equivalent. Land use change includes both emissions and absorptions. Dotted lines represent flows of less than 0.1% percent of total GHG emissions.

Source: World Resources Institute, Climate Analysis Indicator Tool (CAIT), Navigating the Numbers: Greenhouse Gas Data and International Climate Policy, December 2005; Intergovernmental Panel on Climate Change, 1996 (data for 2000).



ter 60–87 Gt of atmospheric carbon by 2050, equivalent to some 12–15% of projected CO_2 emissions from fossil fuel burning for that period (Trumper *et al.*, 2009).

It is becoming better understood that there are critical thresholds of anthropogenic climate change, beyond which dangerous thresholds will be passed (IPCC, 2007a). For example, to keep average temperature rises to less than 2°C, global emissions have to be reduced by up to 85% from 2000 levels by 2050 and to peak no later than 2015, according to the IPCC (Trumper *et al.*, 2009).

But while the loss of green carbon ecosystems have attracted much interest, for example by combating the

← **Figure 4: Combustion sources of black carbon.** (Source: Dennis Clare, State of the World 2009, www.worldwatch.org).

loss of tropical rainforests, the fact that near 55% of all green carbon is captured by living organisms not on land, but in oceans, has been widely ignored, possibly our greatest deficit in mitigating climate change. The carbon captured by marine organisms is herein called "blue carbon".

BLUE CARBON

Blue carbon is the carbon captured by the world's oceans and represents more than 55% of the green carbon. The carbon captured by living organisms in oceans is stored in the form of sediments from mangroves, salt marshes and seagrasses. It does not remain stored for decades or centuries (like for example rainforests), but rather for millennia. In this report, the prospects and opportunities of binding carbon in oceans is explored.

➔ Figure 5: 45% of green carbon stored in natural terrestrial ecosystems and the remaining 55% is captured by living organisms in oceans by plankton and ocean's blue carbon sinks.