EuropeAid

ENVIRONMENT & CLIMATE CHANGE

EC Cooperation:

Responding to climate change

Sector Script for Infrastructure

Information Note

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This document was developed by EuropeAid in cooperation with DG RELEX, DG DEV and DG ENV with the support of the "environmental integration advisory services" project. It was designed to provide practical guidance on the links between climate change and a specific sector, together with possible responses to climate-related challenges. The purpose of this "script" is to support political dialogue on climate change implications between the European Commission, partner governments and other national partners involved in EC development and external cooperation activities, as well as to facilitate strengthened climate change integration in ongoing and future cooperation programmes and projects, with a focus on developmental benefits for the partner countries.

This sector script is one of a series prepared in a standard format. Scripts are available for the following topics:

- Introduction and Key Concepts
- Agriculture & Rural Development *(incl. forestry, fisheries and food security)*
- Ecosystems & Biodiversity Management
- Education
- Energy Supply
- Governance
- Health
- Infrastructure *(incl. transport)*
- Solid Waste Management
- Trade & Investment *(incl. technological development, employment and private sector development)*
- Water Supply & Sanitation

Note that the script is not country or region-specific, and has been prepared to cover a wide range of possible effects and responses. Users are invited to appreciate which elements, among those proposed, are relevant to their specific needs and circumstances.

Note: This sector script was written with a focus on infrastructure in general and some specific aspects of infrastructure, including transport. The text makes references to other related and complementary scripts.

Users of this script are advised to read it in conjunction with the Introduction and Key Concepts information note, which introduces the series and puts things in context.

Comments are welcome and can be addressed to the following e-mail:
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RESPONDING TO CLIMATE CHANGE: SECTOR SCRIPT

SECTOR: INFRASTRUCTURE

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0. EXECUTIVE SUMMARY

Climate change impacts on infrastructure

Generally speaking, climate change makes the planning process and physical location of infrastructure an even more critical issue than it used to be. The increased frequency and severity of extreme weather events has the potential to damage, destroy or severely impair the operation of practically all types of infrastructure, including transport infrastructure, residential and commercial buildings, cities and urban infrastructure, as well as communication, industrial and tertiary sector infrastructure (including tourism infrastructure). Infrastructure is notably at risk from sea surges, storms, rising sea levels, floods, increased river bank erosion, sand storms, soil erosion, increasing water scarcity, and the melting of the permafrost. Infrastructure, industry and settlements are usually more vulnerable to extreme weather events but gradual climate change may also have implications, such as faster degradation of buildings under increased humidity conditions, poor thermal performance under conditions of increasing temperatures, etc.

Some socio-economic consequences of climate change are likely to have damaging effects on infrastructure in more indirect ways. Economic disruption resulting from the effects of climate change could lead to a reduction in the budgets dedicated to the maintenance of both public and private infrastructure. The migrations potentially generated by the loss of livelihoods, deteriorating living conditions and a surge in conflicts may cause some infrastructure to be damaged, abandoned or used over capacity.

Attention should also be paid to the question of whether infrastructure development may by itself increase the exposure and vulnerability of populations to the effects of climate change. For instance, the building of new roads and other infrastructure in coastal areas to support economic development may attract migrants and swell coastal populations, ultimately resulting in more people living in areas recognised as particularly vulnerable. Infrastructure building, if not carefully thought out, may also compound existing pressures on the environment to exacerbate the consequences of climate change.

Adapting to climate change

Infrastructure investment is by definition made for the long term, with time horizons of several decades. Generally speaking, it is recommended to include long-term strategic considerations of the possible consequences of climate change in the overall spatial and location planning considerations for new infrastructure, and to the extent possible for the upgrading and/or rehabilitation of existing infrastructure. The list of possible (generic) adaptation measures notably includes:

- taking account of the potential effects of climate change, and notably of exposure to extreme weather events, in the choice of location for all new infrastructure; this will require, in addition to the identification of areas vulnerable to climate risks, the adoption of more stringent land planning practices/zoning codes;
- selectively relocating key infrastructure, where it is identified as particularly vulnerable;
- adopting appropriate engineering standards and building norms, so as to make new infrastructure more resilient to adverse weather conditions and natural disasters;
- retrofitting existing infrastructure, and re-designing operating systems and processes, to make them more resilient to adverse weather conditions and natural disasters;
- creating backup capacity and "workaround" solutions, so that a problem in one specific location in an infrastructural system does not paralyse the whole system;
- building defensive infrastructure to protect existing key assets;
- raising the awareness of infrastructure managers, both public and private, about climate-related risks and adaptation options – and building the capacities of planning and engineering departments;

- strengthening infrastructure maintenance and repair capacities, in terms of planning, organisation (including logistics and spare part supply chains), financial and human resources;
- taking account of new or increased vulnerabilities (e.g. of ecosystems, of populations, of livelihoods) potentially induced by climate change in the characterisation and evaluation of impacts in infrastructure-related Environmental Impact Assessment (EIA) studies;
- developing emergency preparedness plans and disaster risk reduction strategies in relation to key infrastructure assets; closely monitoring trends in migrations and population resettlements, so as to anticipate future needs at the time of planning investments in infrastructure.

The script also lists a number of possible adaptation measures in relation to specific domains of infrastructure.

In the field of infrastructure as in other areas, attention should be paid to the possible unintended consequences of adaptation measures, and in particular to trade-offs between adaptation and mitigation. For instance, the increased use of air conditioning and/or heating systems to adapt buildings to new temperature conditions will result in increased CO_2 emissions, if the energy is produced from fossil fuels.

Contributing to climate change mitigation

Possible (generic) mitigation measures include:

- opting for energy-efficient, low-carbon infrastructure and building materials, and ensuring that these considerations are included at the start of the planning and design process;
- minimising the transport of materials over long distances, minimising the energy requirements of construction techniques;
- wherever possible, switching to low-carbon, renewable sources of energy to power infrastructure;
- at the policy level, raising awareness of the advantages of, and creating incentives for investment in, low-carbon infrastructure and building materials.

The script also lists a number of possible mitigation measures in relation to specific domains of infrastructure. Among these, the modification of building standards and the retrofitting of existing buildings to improve the energy efficiency of housing and buildings feature prominently; improved urban design and investment in more energy-efficient communication and IT infrastructure and equipment can also make a valuable contribution to the mitigation effort. Although this is not exclusively related to infrastructure, the contribution transport policies can make to the mitigation effort is also highlighted.

1. HOW CLIMATE CHANGE MIGHT AFFECT INFRASTRUCTURE

Climate change may affect infrastructure and in particular transport through a range of biophysical and socio-economic impacts. The table below shows the main links between such impacts and the sectors considered in this script.

	Infrastructure	Transport
Biophysical effects		
Changes in temperature and rainfall patterns	√	√
Shifts in seasons		√
Increase in extreme weather events / natural disasters	√	√
Raised sea level and increased coastal erosion	√	√
Increased river bank erosion	√	√
Desertification, soil erosion	√	√
Reduction in the availability of freshwater	√	
Changes in hydrological flows, in permafrost	√	√
Changes in atmospheric pollution patterns	√	
Socio-economic impacts		
Damage to infrastructure	√	√
Reduced availability of energy (hydropower)	√	√
Economic and social disruption, loss of livelihoods	√	
Increased probability and intensity of conflicts	√	√
Population displacement and human migrations	√	√

Infrastructure is not a "sector" in the way the term is normally used; rather it is the "hardware" foundation on which the functioning of many other sectors, as well as the livelihoods of many people, depend. For the purpose of this note however, we will handle it as a "sector" in the sense that the implications of climate change for various types of infrastructure are often quite similar. First we review some aspects that are shared by all types of infrastructure, then we examine in more detail the implications of climate change for specific types of infrastructure.

1.1. INFRASTRUCTURE IN GENERAL

Generally speaking, climate change makes the *planning process* and *physical location of infrastructure* an even more critical issue than it used to be. The increased frequency and severity of extreme weather events has the potential to damage, destroy or severely impair the operation of practically all types of infrastructure. Coastal infrastructure is particularly at risk from sea surges, tropical storms and inexorably rising sea levels. Infrastructure located on river banks and more generally in flood plains may be at risk from more frequent floods and increased river bank erosion. Infrastructure located in semi-arid areas may be threatened by sand storms and soil erosion. Infrastructure the operation of which depends on the availability of water (e.g. hydropower stations, irrigation systems, human settlements, some industries) may also be at risk from increasing water scarcity. At high latitudes, infrastructure may be at risk of collapsing due to permafrost melting and the resulting ground subsidence.

Infrastructure, industry and settlements are usually more vulnerable to extreme weather events than to the *effects of gradual climate change*. Nevertheless, gradual climate change may also have implications (e.g. faster degradation of buildings under increased humidity conditions, poor thermal performance under conditions of increasing temperatures), so gradual changes may also warrant some adaptation measures.

Some *socio-economic consequences of climate change* are also likely to have damaging effects on infrastructure, in more indirect ways. Economic disruption resulting from the effects of climate change could lead to a reduction in the budgets dedicated to the maintenance of both public and private infrastructure. The migrations potentially generated by the loss of livelihoods, deteriorating living conditions and a surge in conflicts may cause some infrastructure to be damaged, abandoned, used over capacity.

Attention should also be paid to the question of *whether infrastructure development may by itself increase the exposure and vulnerability of populations* to the effects of climate change. For instance, the building of new roads and other infrastructure in coastal areas to support economic development may attract migrants and swell coastal populations, ultimately resulting in more people living in areas recognised as particularly vulnerable. Infrastructure building, if not carefully thought out, may also compound existing pressures on the environment to exacerbate the consequences of climate change. For example, in Bangladesh, it has been shown that the development of roads in the delta area impairs the already limited natural drainage capacity; roads are not the only culprits, but their development adds up to the pressures resulting from higher sea levels, swelling rivers and siltation to aggravate flooding at times of higher water.

1.2. Transport

Roads and railways and the associated works (e.g. bridges, tunnels, culverts) may be permanently damaged or made temporarily unusable by floods, storms, wild fires, moving sand dunes, etc. The alteration of soil mechanical behaviour due to moisture content changes, and the melting of permafrost, also have implications particularly for the stability of linear transport infrastructure.

Inland waterways may be made more difficult to navigate by increasing irregularity in stream flows. In some regions, average flows have already decreased and may keep decreasing; in other regions, more frequent episodes of heavy rainfall cause floods or rapid increases in flow rates, making rivers equally unsuitable for navigation; in some places, drought periods alternate with devastating floods at a rate not observed in the past. In regions where the current trend is increased stream flows (e.g. because of accelerated melting of upstream glaciers), accelerated river bank erosion may also be an obstacle to navigation.

Harbours are primarily threatened by sea surges, coastal storms and rising sea levels. Their operation may also be impaired by events such as power cuts, and by disruption of the land-based transport infrastructure to which they are connected.

Airports and runways, depending on local circumstances, may be threatened by floods, rising sea levels, sand dunes, wind and rain storms, deteriorating visibility linked to surges in air pollution, etc. The functioning of airports can also be disturbed by disruptions in other infrastructure to which they are connected.

1.3. Residential and commercial buildings

Buildings may be damaged or even destroyed by the effects of extreme weather events and natural disasters. Buildings may become less comfortable as spells of extreme temperatures become more frequent or severe. They could also suffer accelerated degradation if changes in rainfall patterns cause the climate to become more humid, or if changes in air pollution patterns increase their exposure to acid deposits. Their use may become more problematic as the other infrastructure to which they are connected (in particular energy, water supply and sanitation, but also transport and communication) is damaged or made temporarily unusable by the effects of climate change.

1.4. CITIES AND URBAN INFRASTRUCTURE

Urban infrastructure, both public and private, may be damaged by the effects of *extreme weather events and natural disasters*. The increasing severity or frequency of *episodes of very high temperatures* may make some cities "unliveable" during some periods of the year, amplifying the "heat island" effect[1]. *Changes in atmospheric circulation patterns* may also considerably affect living conditions in urban areas, as locally-produced pollutants remain trapped above some cities for longer periods of time or react with other pollutants; higher ground-level ozone concentrations are a particular concern in cities.

Extreme weather events may cause *disruptions in the functioning of energy supply, water supply, sanitation, transport and communication infrastructure* (either within or outside cities). The failure of key protective infrastructure such as dikes, levees and sea walls, as well as wide-scale damage to housing from natural or "semi-natural" disasters, all have the potential to cause very chaotic conditions and even civil unrest. Food supplies, for instance, could be disrupted by the interruption of traffic on some key transport axes.

Besides the effects of more or less sudden disasters, the functioning of cities could also be deeply affected by the *acceleration of migratory flows* and the rural exodus. Swelling slums are already a problem in most cities in developing countries, and the situation could become worse. All types of infrastructure, including social services infrastructure (health, education, …), could be unable to cope with rapidly growing urban populations; this phenomenon already exists in many cities, but it could be amplified by the effects of climate change.

1.5. COMMUNICATION INFRASTRUCTURE

Telecoms infrastructure, both above ground (e.g. cell phone masts, aerial telephone cables, transformers, buildings hosting telecoms and internet hubs) and underground (e.g. buried copper and optic fibre cable networks), may be damaged by the effects of extreme weather events and natural disasters. Telecoms and internet services may also suffer interruptions if the supply of energy is disrupted. Data and computer centres, which produce huge quantities of heat (through energy dissipation in electronic circuits) and cannot operate above a given temperature, will suffer from increases in outside temperatures and heatwaves; the cost of operating them will increase if air conditioning systems have to be strengthened or consume more energy to maintain the required operating temperature.

1.6. INDUSTRIAL AND TERTIARY SECTOR INFRASTRUCTURE (INCL. TOURISM INFRASTRUCTURE)

Industrial, commercial and services infrastructure (e.g. including tourism and recreation infrastructure) could be damaged directly by the effects of extreme weather events and natural disasters. This may in turn lead to further adverse consequences: not only the disruption caused by direct damage to infrastructure, but also the indirect damage that may result, in particular environmental damage (e.g. water pollution caused by the flooding of an area where toxic products are stored, air pollution caused by the burning of a storehouse for chemicals). The capacity of industries and other businesses to operate could also be affected by damage to the public infrastructure on which they depend (in particular transport, energy, water and telecoms), and the resulting disruption in services. And of course, conflicts of all kinds may be a threat to both infrastructure and operations.

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[1] An urban "heat island" is an urban area (usually rather large) in which temperatures are significantly higher than in surrounding rural areas. This phenomenon is caused by the combined effects of: (i) the modification of the land surface (absorption of the sun's heat during the day by concrete and asphalt, which then radiate it during the night, lack of vegetation and thus reduced capacity to cool down by means of evapotranspiration, blocking of cooling winds by buildings, …); (ii) the heat generated by energy usage within the city (traffic, heating, air conditioning, industry, electric appliances and equipment, etc.), and (iii) changes in the radiative properties of the atmosphere as a result of pollution.

2. ADAPTING TO CLIMATE CHANGE IN INFRASTRUCTURE DEVELOPMENT

In the field of infrastructure as in other areas, attention should be paid to the possible unintended consequences of adaptation measures, e.g. undesirable environmental effects, negative externalities in other locations or a net increase in greenhouse gas (GHG) emissions. For instance, the increased use of air conditioning and/or heating systems to adapt buildings to new temperature conditions will result in increased CO_2 emissions, if the energy is produced from fossil fuels.

2.1. INFRASTRUCTURE IN GENERAL

Infrastructure investment is by definition made for the long term, with time horizons of several decades. Generally speaking, it is recommended to include long-term strategic considerations of the possible consequences of climate change in the overall spatial and location planning considerations for new infrastructure, and to the extent possible for the upgrading and/or rehabilitation of existing infrastructure. This approach is made difficult, however, by the fact that significant uncertainties still prevail as to the long-term consequences of climate change.

More specifically, possible adaptation measures include:

- taking account of the potential effects of climate change, and notably of exposure to extreme weather events, in the choice of location for all new infrastructure (e.g. it may be advisable to build "coastal roads" a few kilometres inland rather than on the coast itself; no new infrastructure should be built on river banks subject to accelerated erosion, in the low-lying areas of flood plains or in areas prone to landslides); this will require, in addition to the identification of areas vulnerable to climate risks, the adoption of more stringent land planning practices/zoning codes;
- selectively relocating key infrastructure, where it is identified as particularly vulnerable;
- adopting appropriate engineering standards and building norms, so as to make new infrastructure more resilient to adverse weather conditions and natural disasters (and possibly also less demanding in terms of maintenance);
- retrofitting existing infrastructure, and re-designing operating systems and processes, to make them more resilient to adverse weather conditions and natural disasters;
- creating backup capacity and "workaround" solutions, so that a problem in one specific location in an infrastructural system does not paralyse the whole system;
- building defensive infrastructure (e.g. flood defences, sea defences, runoff collectors, pumps) to protect existing key assets – with due regard for environmental considerations, and keeping in mind that defensive infrastructure never offers absolute protection: it only reduces risk, by offering protection against events with an intensity below a given protection level;
- raising the awareness of infrastructure managers, both public and private, about climate-related risks and adaptation options – and building the capacities of planning and engineering departments to integrate climate risk adaptation considerations into programme and project design;
- strengthening infrastructure maintenance and repair capacities, in terms of planning, organisation (including logistics and spare part supply chains), financial and human resources;
- taking account of new or increased vulnerabilities (e.g. of ecosystems, of populations, of livelihoods) potentially induced by climate change in the characterisation and evaluation of impacts in infrastructure-related Environmental Impact Assessment (EIA) studies;
- developing emergency preparedness plans and disaster risk reduction strategies in relation to key infrastructure assets; this includes setting up early warning systems, addressing governance issues (e.g. defining which body or level of government is responsible for what, and how to articulate the interventions of various agencies and institutions), and testing the plans in simulation exercises to identify weaknesses and promote awareness;

- closely monitoring trends in migrations and population resettlements, so as to anticipate future needs at the time of planning investments in infrastructure.

2.2. Transport

Possible adaptation measures include:

- modifying technical specifications for the building or rehabilitation of roads, railways and associated works to take account of increasing climate variability and the potential effects of climate change (e.g. higher-capacity drainage systems, resistance of road coatings to higher temperatures, strengthened measures to prevent erosion and accretion damage); this includes not only measures aimed at increasing the inherent resilience of infrastructure to climate risks, but also specifications aimed at avoiding that infrastructure development exacerbates some existing risks and vulnerabilities (e.g. drainage systems dimensioned so as to avoid aggravating the risk of flood; road construction works managed so as to avoid aggravating soil erosion problems; plant species used for re-vegetation of embankments and other cleared areas adapted to current but also anticipated climatic conditions);
- upgrading infrastructure on navigable inland waterways to improve flow control and navigability in the presence of more irregular stream flows (e.g. damming, dredging, strengthening of river banks) – with due regard for environmental considerations;
- strengthening and adapting harbour infrastructure to make it more resilient to storms and sea surges, including as relevant the strengthening of natural coastal defences (e.g. mangrove regeneration) and/or the building of artificial sea defences (with due regard for environmental considerations);
- adapting technical specifications for the building, rehabilitation or extension of airports to take account of increasing climate variability and the potential effects of climate change (e.g. higher-capacity drainage systems for runways, resistance of runway coatings to higher temperatures, use of sand barriers, purchase of equipment to allow safe take-offs and landings in conditions of reduced visibility).

2.3. Residential and commercial buildings

Possible adaptation measures include:

- modifying technical specifications for the construction or rehabilitation of buildings to increase resilience to extreme weather events (e.g. storm-resistant roofs, houses built on stilts or raised platforms in flood-prone areas);
- modifying technical specifications for the construction or rehabilitation of buildings to take account of other potential effects of climate change (e.g. improved thermal insulation, improved heating and air conditioning systems, increased protection against humidity, stronger and/or deeper foundations, higher-capacity drainage systems);
- retrofitting existing buildings to make them more resilient to adverse weather conditions and natural disasters;
- building or rehabilitating natural or artificial protective infrastructure (e.g. mangroves, flood defences) around houses and other key buildings;
- increasing the autonomy of buildings in terms of water and energy supply, so as to better withstand disruption in the provision of collective services (e.g. water harvesting from roofs, installation of solar heat and photovoltaic panels).

The implications of envisaged adaptation measures in terms of the energy consumption and energy efficiency of buildings should be assessed carefully, so as to avoid that adaptation results in higher emissions of GHGs. For instance, the installation or upgrade of energy-consuming air conditioning systems should be viewed as a solution of last resort – in some cases improved insulation and the choice of naturally insulating building materials (e.g. bricks and other traditional materials rather than concrete) may provide adequate protection against high temperatures. Where air conditioning is unavoidable, preference should be given to energy-efficient systems powered by low-carbon, renewable sources of energy.

2.4. Cities and urban infrastructure

Possible adaptation measures include:

- designing new urban developments, as well as urban rehabilitation plans, to take account of increasing climate variability and the anticipated effects of climate change (e.g. higher-capacity drainage systems, flood protection systems, adequate design and materials specifications for buildings and transport infrastructure); this includes not only making urban infrastructure inherently more resilient to climate risks, but also conceiving it in such a way that new developments do not exacerbate existing risks and vulnerabilities (e.g. hill cutting to make room for new infrastructure and settlements may increase the risk of landslides; in flood-prone delta areas, hillside erosion resulting from the clearing of vegetation aggravates the siltation of riverbeds and thus the risk of flood; infrastructure development to allow faster evacuation of stormwater runoff from urban areas may increase flood risk downstream);
- fighting the heat island effect by using white or reflective coatings for houses, pavements and roads, increasing the number and surface of green spaces ("cool islands"), increasing the amount of vegetation (e.g. lining streets with trees), promoting "green roofs", etc.;
- gradually withdrawing from the most vulnerable areas, and relocating population and economic activities in safer areas;
- strengthening and upgrading key urban infrastructure to make it more resilient to extreme weather events as well as anticipated gradual shifts in weather conditions;
- developing and testing city-wide emergency preparedness plans and disaster risk reduction strategies, including early warning systems and evacuation plans;
- adopting measures to reduce air pollution when some thresholds are exceeded;
- closely monitoring trends in migrations and human settlements, with a specific focus on slums, so as to keep track of the most pressing needs and to integrate them in urban infrastructure investment planning.

2.5. Communication infrastructure

Possible adaptation measures include:

- modifying technical specifications for new infrastructure development, or upgrading existing infrastructure, to take account of increasing climate variability and the potential effects of climate change (e.g. storm-resistant telecoms masts, replacement of aerial phone lines with underground lines);
- relocating essential infrastructure such as network hubs and data centres away from disaster-prone areas, and choosing less vulnerable areas for locating new infrastructure;
- ensuring that the public infrastructure on which essential communication infrastructure depends (in particular energy supply, in this case) is gradually made as "climate-resilient" as possible;
- improving the thermal insulation of the buildings that host data and computer centres, and if necessary strengthening the capacity and reliability of their air conditioning systems (opting for the most energy-efficient solutions);
- gradually switching to electronic equipment that dissipates less heat and/or can operate at higher temperatures.

2.6. Industrial and tertiary sector infrastructure (incl. tourism infrastructure)

Possible adaptation measures include:

- making such infrastructure as "climate-resilient" as possible, including in the choice of locations; this may be helped by the adoption of more stringent land planning practices/zoning codes;
- gradually relocating some infrastructure and activities away from risk-prone areas;
- ensuring that the public infrastructure on which industries and tertiary sector enterprises depend (e.g. transport, energy, telecoms, water) is gradually made as "climate-resilient" as possible;
- adapting storage and distribution systems, as well as business processes, to reduce vulnerability to temporary disruptions; where appropriate, this may involve promoting local and regional storage and distribution systems which reduce vulnerability while also delivering other benefits;
- implementing new techniques and upgrading infrastructure to reduce water and energy consumption, and diversifying energy supply sources;
- promoting access to financial services, including insurance or other forms of risk sharing;
- promoting the adoption of emergency preparedness plans and disaster risk reduction strategies by enterprises – including measures to limit the risk of causing dangerous pollution in case a natural disaster strikes their facilities.

3. Opportunities for reducing GHG emissions in relation to infrastructure

3.1. Infrastructure in general

Possible mitigation measures include:

- opting for energy-efficient, low-carbon infrastructure and building materials, and ensuring that these considerations are included at the start of the planning and design process;
- minimising the transport of materials over long distances, minimising the energy requirements of construction techniques;
- wherever possible, switching to low-carbon, renewable sources of energy to power infrastructure;
- at the policy level, raising awareness of the advantages of, and creating incentives for investment in, low-carbon infrastructure and building materials.

3.2. Transport

According to the 2007 IPCC report[2], in 2004 the transport sector produced 23% of the world's energy-related carbon dioxide (CO_2) emissions – and road transport accounted for 74% of total transport-related CO_2 emissions. The transport sector also contributes, to a lesser extent, to methane (CH_4) and nitrous oxide (N_2O) emissions as well as to emissions of fluorinated gases (related to vehicle air conditioning).

At the level of transport infrastructure, possible mitigation measures include:

- opting wherever possible for investment in energy-efficient and low-carbon transport modes in transport sector development strategies; for instance, train transport and ocean shipping are

[2] IPCC (2007) – *Climate Change 2007:Mitigation*, contribution of Working Group III to the Fourth Assessment Report, Intergovernmental Panel on Climate Change, downloadable from: http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

comparatively low-carbon and efficient means of transport, and should be preferred where they constitute a realistic alternative to road and air transport;

- developing public transport infrastructure and (especially in urban areas) non-motorised transport infrastructure (e.g. dedicated bicycle lanes, footpaths, pedestrian areas), while curbing the anarchic development of private motorised means of transport (e.g. constraints on the availability of parking places in urban centres accessible by other means than private vehicles);
- improving traffic management systems and guiding route choice, so as to reduce congestion.

However, to have a real impact on GHG emissions, transport policies must simultaneously address non-structural aspects. Policies may for instance:

- promote the use of less carbon-intensive fuels such as biofuels (to the extent that they can be produced without adverse impacts on food security, water availability and ecosystems – and in a way that really significantly reduces GHG emissions – see sector script on Energy for further details);
- promote the use of electric or hybrid vehicles, and in future possibly cars powered by fuel cells (to the extent that electricity and hydrogen can be produced using renewable sources of energy, otherwise net GHG emissions, calculated over the entire lifecycle of these technologies, may decrease very little or even increase);
- support improvements in vehicle fuel efficiency and fleet modernisation (e.g. mandatory emission thresholds and fuel economy standards, more stringent technical control for vehicles);
- provide economic incentives (i.e. taxes and subsidies) for the modernisation and improved energy efficiency of fleets of vehicles, trains, barges, ships and aircraft;
- support technological innovation (e.g. material substitution, more aerodynamic designs, improved engine designs, improved batteries);
- support non-structural measures aimed at reducing traffic and road congestion (e.g. taxation of private vehicle use in city centres, enforcement of stricter speed limits coupled with traffic light harmonisation);
- raise awareness and encourage changes in behaviour by households (e.g. promotion of non-motorised transport modes in cities and for small journeys, campaigns for and availability of training in eco-driving styles) and enterprises (e.g. provision of incentives in support of a modal shift both for employee mobility and for the transport of goods).

Synergies may be found between GHG emission mitigation and other transport policy priorities, such as reducing traffic fatalities and injuries, reducing road congestion, curbing air pollution and lessening the sector's dependence on oil products.

3.3. Residential and commercial buildings

Possible mitigation measures include:

- modifying building standards to improve (in a mandatory way) the energy efficiency of new housing and buildings; this may involve the use of modern thermal insulation techniques coupled with efficient ventilation systems, of double- or triple-glazing, of high-reflectivity building materials, of passive or very efficient active cooling and heating techniques (e.g. ground-to-air heat pumps), of energy-efficient lighting and appliances, etc.; architectural design (e.g. passive solar design, which notably involves optimising the orientation of windows and openings and the use of natural light) can also play an important role;
- retrofitting existing housing and buildings to improve their energy efficiency (which, it must be noted, is usually more costly than when energy efficiency measures are implemented from the design stage and built into the initial construction works);

- in some cases and where technically feasible, reintroducing traditional building materials and techniques (e.g. clay), since they often have much better insulating properties and may thus reduce the need for both heating and air conditioning;
- reducing the energy "embodied" in buildings, i.e. opting for building materials that require less energy and thus less carbon emissions to be produced (e.g. clay, materials produced from biomass), and reducing the energy use associated with the transport of building materials;
- switching to low-carbon, renewable sources of energy for powering buildings (e.g. solar water heaters, and photovoltaic panels but only where lifecycle analysis shows they provide a real reduction in overall GHG emissions);
- controlling emissions of non-CO_2 GHGs (e.g. fluorinated gases used in refrigeration and air conditioning systems);
- raising awareness of climate-related stakes and energy savings possibilities in order to influence behaviour, i.e. modifying the way in which occupants "use" buildings.

Implementing GHG mitigation measures in buildings is usually associated with sizeable co-benefits, including energy savings (which up to a point more than compensate investment costs), the creation of jobs and business opportunities (e.g. market for energy audits and retrofitting of existing buildings), reduced energy dependence, improved indoor and outdoor air quality, increased comfort and quality of life. However, there are also significant market barriers to implementing these options, such as the difficulties of finding reliable information on energy efficiency measures, the high costs of initial investment (especially in situations of lack of access to credit), the lack of incentives for owners to invest in buildings occupied by tenants, the disincentive created by subsidies on energy prices, the fragmentation of the building industry, etc. Coordinated policy measures are required to overcome these barriers.

3.4. Cities and urban infrastructure

Possible mitigation measures include:

- designing new urban developments, as well as urban rehabilitation plans, to rationalise the use of energy notably in relation to transport; this may involve promoting the densification of housing, moving away from the "urban sprawl" model (notably by means of more stringent and better enforced land use planning practices), developing the public transport infrastructure, developing non-motorised transport infrastructure (e.g. dedicated bicycle lanes, footpaths), or promoting the use of district heating systems as an alternative to individual systems;
- switching to energy-efficient public lighting systems.

3.5. Communication infrastructure

Possible mitigation measures include:

- further developing and opting for energy-efficient communication infrastructure and equipment (e.g. choice of energy-efficient computers, servers and data storage systems, improved efficiency of the buildings that host them);
- gradually switching to electronic equipment that dissipates less heat and/or can operate at higher temperatures, so as to reduce the need for air conditioning;
- intensifying research and development of less energy-intensive processors.

3.6. Industrial and tertiary sector infrastructure (incl. tourism infrastructure)

Possible mitigation measures include:

- investing in energy-efficient equipment, rolling stock and facilities;
- switching as much as possible to low-carbon sources of energy to power their functioning;
- adopting manufacturing and processing technologies that use less energy and produce fewer emissions of GHGs.

4. References

(1) IPCC (2007) – *Climate Change 2007 – Impacts, Adaptation and Vulnerability*, contribution of Working Group II to the Fourth Assessment Report, Intergovernmental Panel on Climate Change/Cambridge University Press. Available on: http://www.ipcc.ch/ipccreports/assessments-reports.htm (see in particular Chapter 6 on "coastal systems and low-lying areas" and Chapter 7 on "industry, settlement and society")

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