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Climate Change Impacts and Adaptation: A Challenge for Global Ports

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I. Introduction and Background

Ports are critical infrastructure assets that serve as catalysts of economic growth and development. In addition to playing a key role in international trade, they create jobs, generate wealth and value, contribute to national gross domestic product (GDP) and promote the expansion of related and near-by industries and cities. World port activity is estimated to have contributed US$31,115 million globally or 4.8 per cent of the total value of marine operations in 2004.[1]

More recent data available at the regional and national levels illustrate the growing strategic economic importance of ports and their hinterlands. For example, in the European Union (EU), around one-third of the population lives within 50 kilometers of the coast with the value of the economic assets within 500 meters of the coastline being estimated at € 500-1000 billion and 35 per cent of the total GDP of the 22 European coastal member states being generated within 50 km of the coast.[2] At the national level, for example, the port of London is reported to be associated with over 46,000 full-time jobs (e.g. manufacturing workers, cargo handlers, drivers, warehouse staff and ships' agents);[3] for the port of Rotterdam, the total direct and indirect seaport-related value added and employment has been assessed as around € 22.2 billion and 145.000 employees, respectively.[4]

As a sea-land interface and a point of convergence between various modes of transport, ports act as gateways to trade, providing access to global markets for all countries, including those that are landlocked. With over 80 per cent of global merchandise trade by volume and more than 70 per cent by value being seaborne, ports constitute key nodes in global supply chains and are core to global production processes that rely heavily on manufacturing, outsourcing and low cost shipping.

While ports are at the heart of international trade and globalization, they are also exposed to the risk of climate change impacts, particularly in view of their location in coastal zones, low-lying areas and deltas. They can be particularly affected by rising sea levels, floods, storm surges and strong winds. Given the concentration of populations, assets and services associated with ports - as well as the size and value of built infrastructure - and the crucial role of ports as part of international supply-chains, climate change impacts on ports and their land-based access points, linking the maritime interface with the hinterland, may have serious broader implications.

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[1] See IMO, 2009. *Second IMO GHG Study 2009*. Table 2.1 "Contribution of marine and shipping activities to the economy". Relevant marine operations referred to include merchant shipping, naval shipping, cruise industry and ports.

[2] European Commission, 2009. *The economics of climate change adaptation in EU coastal areas (Full Report).* Study done on behalf of the European Commission Directorate-General for Maritime Affairs and Fisheries. MARE.C.1 Maritime Policy: Atlantic, Outermost Regions and Arctic.

[3] Port of London Authority. *Port of London Handbook 2010*, Compass Publications Limited: United Kingdom.

[4] Frans A.J. Van Den Bosch, F.A.J., R. Hollen, H.W. Volberda, M.G. Baaij, 2011. *The strategic value of the Port of Rotterdam for the international competitiveness of the Netherlands: A first Exploration*. Research Report for the Port of Rotterdam Authority, Rotterdam. With further references. Data relate to 2008. http://www.rsm.nl/portal/page/portal/home/about/Havenrapport%20Engelse%20versie_0.pdf.

While the type, range and the magnitude of climate change impacts will vary depending on local conditions, ports are expected to be directly and indirectly affected by climatic changes. Direct impacts are those likely to affect infrastructure, operations and services while indirect impacts include changes in demand for port services resulting from climate change effects on trade, investment decisions, demographics, agriculture production, forestry, energy exploration and consumption as well as fishing activity. Associated risks, vulnerabilities and costs may be considerable, in particular for ports in developing regions with low adaptive capacity, and those in Small Island Developing States (SIDS). With SIDS being sea-locked, climatic factors that may severely impact coastal transport infrastructure and services pose particularly serious threats to national economic development prospects.

When considering the potential impacts of climatic factors on ports, it is important to take into account the fact that global transport and trading systems are interconnected. Although not associated with climate change, the earthquake, tsunami and resulting nuclear threat that affected Japan in March 2011 and their disruptive effect on some businesses, ports and shipping operations illustrate the interdependency of production, trade and transport systems in a globalized world. The ripple effects of these events were cross-border with impacts being felt by manufacturing operations in Europe and North America. There have been reports about a shortage in the supply of parts needed in the production of computers, automobiles, and mobile phones, including in Germany and the United States.[5]

Given the strategic role of ports as part of the globalized trading system, adapting ports in different parts of the world to the impacts of climate change and building their resilience is an urgent imperative. A good understanding of the relevant risks and vulnerabilities based on accurate information, including climate and socio-economic data at the local level, is a pre-requisite for informed decision making and well-designed and effective adaptation response measures that enhance the robustness of systems, structures and processes and minimize the adverse effects of climatic factors. In this context, cooperation among a wide range of public and private sector stakeholders at the local, national, regional and international level is required.

To help advance the important debate on how best to move forward UNCTAD has convened the Ad Hoc Expert Meeting on *Climate Change Impacts and Adaptation: A Challenge for Global Ports*, providing a platform for considered discussion of relevant issues. The meeting aims to bring together a wide range of interested parties from the public and private sectors - including policy makers and planning authorities, port industry representatives and operators, port users, relevant international organizations, as well as scientists and engineers - to share their insights and discuss relevant issues with a view to identifying, in particular:

- Vulnerabilities and risks
- Associated adaptation requirements
- Existing best practices, information and data sources
- Issues requiring further study, including data requirements
- Partners and mechanisms for effective collaboration

[5] United Nations Department of Economic and Social Affairs, 2011. *World Economic Situation and Prospects 2011*. New York: United Nations.

Earlier related activities by the UNCTAD Secretariat

The present meeting follows two previous meetings at which the importance of further consideration of climate change impacts and adaptation requirements for ports was highlighted.[6] These were the first session of the UNCTAD Multi-year Expert Meeting on Transport and Trade Facilitation: *Maritime Transport and the Climate Change Challenge*, held in February 2009, and the joint UNECE-UNCTAD workshop on *Climate Change Impacts on International Transport Networks*, held in September 2010.

Experts at the 2009 UNCTAD Expert Meeting considered both climate change mitigation and adaptation in maritime transport, together with cross-cutting issues, such as energy, technology and financing. They highlighted the urgent need to reach agreement in the ongoing negotiations towards a regulatory regime for greenhouse gas (GHG) emissions from international shipping. At the same time, they noted with great concern that so far, insufficient attention had been paid to the potential impacts and implications of climate change for transportation systems, and in particular for ports - key nodes in the supply-chain, and vital for global trade. They emphasized that increased focus on responding to the challenge was important for the long-term prospects of the maritime transport sector and, more generally, global trade.

In this context, experts also noted that planning for the already predicted impacts should be pursued without delay; they called, among other things, for increased scientific research and well targeted vulnerability studies, especially for ports and transport infrastructure in coastal zones in developing countries, to help assess potential climate change impacts and develop appropriate adaptation responses. Greater cooperation among scientists, engineers, industry, international organizations and policy makers was considered crucial to ensure that up to date relevant information on climate change impacts and adaptation measures was available, widely disseminated and taken into account by policy makers, transportation planners and development strategists.[7]

Against a background of growing concerns over the potentially important impacts of climate change on international transportation infrastructure and services across modes, experts at the joint UNECE-UNCTAD workshop emphasized that further information sharing was required and that appropriate adaptation policy action, involving policy makers, as well as stakeholders throughout global supply-chains needed to be further considered. To this end, an international Group of Experts on Climate Change Impacts and Adaptation for International Transport Networks has since been established under the auspices of the UNECE to help advance the

[6] UNCTAD's relevant mandate arises from paras. 168 and 100 of the Accra Accord. A link to the relevant meetings websites, providing access to all relevant documentation and presentations is available through www.unctad.org/ttl/legal under "Meetings and events".

[7] See also UNCTAD Multi-year Expert Meeting on Transport and Trade Facilitation: *Maritime Transport and the Climate Change Challenge*, 16-18 February 2009. Summary of Proceedings UNCTAD/DTL/TLB/2009/1, available at www.unctad.org/ttl/legal.The meeting brought together some 180 expert delegates from a variety of public and private sector backgrounds. Key points emerging during the deliberations of relevance to climate change impacts and adaptation are set out in full in the report of the meeting and in document UNCTAD/DTL/TLB/2009/1.

understanding of climate change impacts on international transport networks and related adaptation requirements.[8]

To facilitate the deliberations, the remainder of this note briefly sets out some of the relevant issues for consideration. It draws in part from documentation prepared by the secretariat in relation to the 2009 UNCTAD Expert Meeting and the 2010 joint UNECE-UNCTAD workshop, which may also be consulted by way of background.[9]

II Climate change impacts on ports and the need for effective adaptation action

Against a background of compelling scientific evidence about climate change[10] and concerns about its potential economic impacts,[11] the issue has moved to the forefront of the international agenda as one of the "greatest challenges of our time".[12] Despite existing uncertainties, it is clear that climate change can pose a serious threat to human development and prosperity,[13] with potentially wide-ranging implications.[14] More recent scientific findings indicate that matters may be worse than previously thought, with forecasts about global warming, sea-level rise and the intensity and frequency of extreme climatic events exceeding earlier predictions[15] and adding

[8] The first meeting of the international Expert Group, held on 5 September 2011, approved the work plan of the Expert Group and its key deliverables, which will include a substantive report on relevant issues as well as an international conference to disseminate the results of its findings. See the UNECE website at http://live.unece.org/trans/main/wp5/wp5_ge3_01.html for further details and related documentation.

[9] See UNCTAD. Multi-year Expert Meeting on Transport and Trade Facilitation: *Maritime Transport and the Climate Change Challenge*, 16-18 February 2009. Summary of Proceedings. UNCTAD/DTL/TLB/2009/1 and Joint UNECE-UNCTAD Workshop on *Climate Change Impacts on International Transport Networks*. Note by the United Nations Economic Commission for Europe and United Nations Conference on Trade and Development secretariats. ECE/TRANS/WP.5/2010/3. Both documents are available at www.unctad.org/ttl/legal.

[10] See the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), 2007.

[11] See Stern N, *Stern Review: The Economics of Climate Change*. 2006; Lenton T, A. Footitt and A. Dlugolecki. 2009. *Major Tipping Points in the Earth's Climate System and Consequences for the Insurance Sector*. 89 pp. (http://knowledge.allianz.com).

[12] See Copenhagen Accord, (Decision 2/CP.15, FCCC/CP/2009/11/Add.1, 30 March 2010), at para.1.

[13] Given their high vulnerability and low adaptive capacity, developing countries, particularly Least Developed Countries (LDCs) are likely to be hardest hit. See, for instance Dasgupta, S., B. Laplante, S. Murray and D. Wheeler, 2009. *Sea-Level Rise and Storm Surges: A Comparative Analysis of Impacts in Developing Countries*. Policy Research Working Paper 4901, the World Bank Development Research Group, Environment and Energy Team. 41pp. A key-finding of the study is that very heavy potential losses are much more concentrated in highly vulnerable large cities at the low end of the international income distribution.

[14] Including for water and food security, energy supply and consumption, human health, biodiversity, coastal infrastructure, economic development, migration, global trade and security.

[15] See, for instance, Richardson, K., W. Steffen, H.J. Schellnhuber, J. Alcamo, T. Barker, D. M. Kammen, R. Leemans, D. Liverman, M. Munasinghe, B. Osman-Elasha, N. Stern and O. Wæver., 2009. *Synthesis Report. Climate Change: Global Risks, Challenges and Decisions.* University of Copenhagen, 39 pp. www.climatecongress.ku.dk.

weight to the worst-case scenarios outlined in 2007 by the Intergovernmental Panel on Climate Change (IPCC) in its Fourth Assessment Report.[16]

Climate change is expected to have a range of diverse environmental, social and economic impacts. While the severity of these will vary widely by geographical location and depend on a number of factors,[17] it is clear that a changing environment gives rise to a need to adapt.[18] Seaports, as well as their hinterland connections, are vulnerable to the effects of certain climatic events. In particular, ports located in estuaries and deltas, or low-lying island settings, especially in developing regions, which are often characterized by high-exposure potential and low adaptation capability.[19]

Rising mean sea levels,[20] increased frequency and intensity of extreme storm surges and waves,[21] droughts and/or river floods and increased mean temperatures as well as extreme temperature variability[22] constitute some of the climatic changes that pose serious threats to both coastal (e.g. ports) and related transport infrastructure and services (see Table 1). Direct threats include accelerated coastal erosion, port and coastal road inundation/submersion, increased runoff and siltation requiring increased dredging, water supply problems, access restrictions to docks and marinas, deterioration of the condition and problems with the structural integrity of road pavements, bridges and railway tracks. In addition, port and other transport operations (e.g. shipping volumes and costs, cargo loading/capacity, sailing and/or loading schedules, storage and warehousing) may also be severely impacted.

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[16] See, for instance, Allison, I, N. L. Bindoff, R.A. Bindschadler, P.M. Cox, N. de Noblet, M.H. England, J.E. Francis, N. Gruber, A.M. Haywood, D.J. Karoly, G. Kaser, C. Le Quéré, T.M. Lenton, M.E. Mann, B.I. McNeil, A.J. Pitman, S. Rahmstorf, E. Rignot, H.J. Schellnhuber, S.H. Schneider, S.C. Sherwood, R.C.J. Somerville, K. Steffen, E.J. Steig, M. Visbeck, A.J. Weaver. 2009. *The Copenhagen Diagnosis: Updating the world on the latest climate science*. University of New South Wales Climate Change Research Centre (CCRC), Sydney, Australia, 60pp.

[17] Note, for instance, that low elevation coastal zones, while covering only 2 per cent of the world's land area, contain 10 per cent of the world's population and 13 per cent of the world's urban population (e.g. small island countries and countries with heavily populated deltas). See McGranaham G., Balk D., Anderson, B., 2007. *The Rising Tide: Assessing the Risks of Climate Change and Human Settlements in Low Elevation Coastal Zones*. International Institute for Environment and Development (IIED).

[18] More generally, this will require integrating climate change considerations into a broader development agenda and long term planning regarding resource management and infrastructure development.

[19] See, for example, Niang, I., M. Dansokho, S. Faye, K. Gueye and P. Ndiayeet, 2010. "Impacts of climate change on the Senegalese coastal zones: Examples of the Cap Vert peninsula and Saloum estuary". *Global and Planetary Change*, doi:10.1016/j.gloplacha.2010.01.005.

[20] See Rahmstorf, S., 2007. "A semi-empirical approach to projecting future sea-level rise". *Science*, 315, 368 – 370.

[21] For an update of the recent findings on the increase in the frequency and intensity of coastal extreme phenomena, see Ruggiero, P., P.D. Komar and J.C. Allan, 2010. "Increasing wave heights and extreme value projections: The wave climate of the U.S. Pacific Northwest". *Coastal Engineering*, 57, 539–552, Fiore, M.M.E., E.E. D'Onofrio, J.L. Pousa, E.J. Schnack and G.R. Bertola, 2009. "Storm surges and coastal impacts at Mar del Plata, Argentina". *Continental Shelf Research*, 29, 1643–1649. Brominski , P.D. and Kossin, J.P., 2008. "Increasing hurricane wave power along the US Atlantic and Gulf coast". *Journal of Geophysical Research*, 113, CO7012 doi: 10.1029/2007/JC004706. See also references in fn. 11, 13, 15, 19 above and fn. 42, below.

[22] Cambridge Systematics Inc., 2009. *Transportation Adaptation to Global Climate Change*. White Paper. Bipartisan Policy Center. Washington DC. See also fn. 15 and 16, above.

While at present difficult to assess with any certainty, the costs associated with any potential climate change impacts on ports are considered to be very substantial and highly variable.[23] One recent study has estimated that assuming a sea level rise of 0.5 meter by 2050, the value of exposed assets in 136 port megacities may be as high as US$ 28 trillion.[24]

Indirect impacts on ports and, more generally, international transportation, which are even harder to assess, arise through, for example, changes in the population concentration/distribution, as well as through changes in production, trade and consumption patterns, which are likely to lead to considerable changes in demand for transportation. The potential climate-change related opening of the Northern Sea Route[25] may also affect the demand for port services, both in the region and elsewhere. Greater economic and shipping activity in the northern region may bring new business to existing northern ports as well as lead to the emergence of new ports. This would entail implications for investment and port development decisions as well as port equipment manufacturing. Fully navigable Arctic sea lanes may also compete with existing routes, offering savings in terms of distance, time and costs. Although existing trade lanes are likely to continue serving the bulk of international trade, new trade may emerge with some existing trade being diverted towards northern routes.[26]

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[23] Ward, R. E. and N. Ranger, 2010. "Trends in Economic and Insured Losses from Weather-Related Events: a new analysis". The Munich Re Programme of the Centre for Climate Change Economics and Policy (CCCEP), *Insurance Industry Brief*, November 2010. Note, for instance, that the Mississippi Department of Transportation (DOT) spent an estimated US$1 billion on debris removal, highway and bridge repair, and rebuilding the Biloxi and Bay St. Louis bridges in the four years following Hurricane Katrina. See Cambridge Systematics Inc., 2009. *Transportation Adaptation to Global Climate Change*. White Paper. Bipartisan Policy Center. Washington, DC.

[24] Lenton T, A. Footitt and A. Dlugolecki. 2009. *Major Tipping Points in the Earth's Climate System and Consequences for the Insurance Sector*. 89 pp. http://www.worldwildlife.org/climate/Publications/WWFBinaryitem14354.pdf. The data suggest that nearly 70 per cent of the global increase in cities' exposed assets occurs in just three countries (in rank order: China, USA, and India) and 90 per cent in eight countries (China, USA, India, Japan, Netherlands, Thailand, Vietnam,and Bangladesh). The study follows an earlier study by the Organization for Economic Cooperation and Development (OECD), assessing the exposure of 136 port megacities to coastal flooding; see Nicholls, R.J., S. Hanson, C. Herweijer, N. Patmore, S. Hallegatte, J. Corfee-Morlot, J. Château, R. Muir-Wood, 2007. *Ranking Port Cities With High Exposure And Vulnerability to Climate Extremes: Exposure Estimates*. OECD ENV/WKP 2007-1. 62 pp.

[25] By 2080, the ice-free season of the Northern Sea Route (NSR) could increase by up to 80 days per year. Pinnegar, J.K., D. Viner, D. Hadley, S. Dye, M. Harris, F. Berkout, and M. Simpson, 2006. *Alternative Future Scenarios for Marine Ecosystems*: *Technical Report*. Centre for Environment, Fisheries and Aquaculture Sciences, Lowestoft, April 2006; Hansen K (2008). *NASA Data Show Arctic Saw Fastest August Sea Ice Retreat on Record*. The National Aeronautics and Space Administration (NASA). 26 September.

[26] A navigable North West Passage offers a route between Tokyo and New York that is 7,000 km shorter than the route through the Panama Canal, thus saving on time, fuel and transit fees. Taking into account canal fees, fuel costs and other relevant factors that determine freight rates, the new trade lanes could cut the cost of a single voyage by a large container ship by as much as 20 per cent, from approximately US$17.5 million to US$14 million. A fully operating Northern Sea Route would reduce the sailing distance between Rotterdam and Yokohama via the Suez Canal by more than 40 per cent. See Borgerson, S.G. 2008. "Arctic Meltdown, The Economic and Security Implications of Global Warming". *Foreign Affairs*. March/April http://www.foreignaffairs.com/articles/63222/scott-g-borgerson/arctic-meltdown.

Table 1 Overview of Select Potential Climate Change Impacts on Ports

Climate change factor	Potential implications
Rising sea levels – Flooding and inundation – Erosion of coastal areas	– Damage to infrastructure, equipment and cargo (coastal infrastructure, port-related structures, hinterland connections) – Increased erosion and sedimentation – Variation in demand for and supply of shipping and port services (e.g. relocating) – Modal shift – Change in the structure and direction of trade (indirectly through impact on agriculture, fishing, energy) – Relocation of business and migration of people, with further economic repercussions (e.g. labour market, closures) – Challenge to service reliability – Increased dredging – Reduced safety (e.g. sailing conditions) – Increased construction, maintenance and replacement costs
Extreme weather conditions – Hurricanes – Storms – Floods – Increased precipitation – Wind	– Damage to infrastructure, equipment and cargo (coastal infrastructure, port-related structures, hinterland connections) – Erosion and sedimentation, subsidence and landslide – Reduced safety (e.g. sailing conditions) – Modal shift – Change in the structure and direction of trade (indirectly through impact on agriculture, fishing, energy) – Relocation of business and migration of people, with further economic repercussions (e.g. labour markets, closures) – Increases in weather-related delays and traffic disruptions – Drainage systems being overloaded causing flooding – Increases in soil moisture can undermine structural integrity of infrastructure – More frequents and extensive emergency evacuations – Reduced clearance under bridges – Increased construction, maintenance and replacement costs – Challenge to service reliability
Rising temperatures – Increases in very hot days and heat waves – Melting ice – Large variations (spatial and temporal) – Frequent freeze and thaw cycles	– Longer shipping season (NSR), new sea routes (e.g. NWP) – Shorter distance for Asia–Europe trade and less fuel consumption – Additional support services and navigation aids such as ice-breaking search and rescue – Competition, lower passage tolls and reduced transport costs – New trade, diversion of existing trade, changes in structure and direction of trade (indirectly through impact on agriculture, fishing and energy) – Damage to port infrastructure, equipment and cargo – Increased construction, maintenance and replacement costs – New ship design and strengthened hulls – Environmental, social, ecosystem related and political implications – Higher energy consumption in ports, including for cargo storage and air conditioning – Variation in demand for and supply of shipping and port services – Challenge to service reliability – Increased maintenance and replacement costs

Source: UNCTAD based on literature review.

Ports' vulnerability (see Box 1) varies across regions, and depends on many factors, including the type of risks faced, the degree of exposure and the level of adaptive capacity. SIDS are among the most vulnerable, as they are both prone to being affected by climate change-related (and other) natural disasters, and have low adaptive capacity.[27]

Box 1 Climate Change Impacts: some relevant concepts

- **Vulnerability** describes how susceptible a system is to the adverse effects of climate change
- **Vulnerability Factors** include the age of the infrastructure element, condition/integrity of the infrastructure element, proximity to other infrastructure elements/concentrations, and the level of service
- **Exposure** is the degree to which a system comes into contact with climate conditions or specific climate impacts, and the probability, or likelihood, that this stress will affect transportation infrastructure
- **Risk** characterizes both the probability of the event occurring and the consequence of the event

Source: Federal Highway Administration (FHWA), U.S. Department of Transportation. *Regional Climate Change Effects: Useful Information for Transportation Agencies.* Last modified 22 April 2011.

While the potential risk exposure for ports is significant and may necessitate extensive adaptation expenditure, [28] there are at present important knowledge gaps about vulnerabilities, as well as the specific nature and extent of exposure that individual ports may be facing. This is illustrated by the results of a survey carried out by the International Association of Ports and Harbours (IAPH), American Association of Port Authorities (AAPA) and Stanford University which, among other things, revealed that while 81 per cent of respondent ports consider that climatic changes may have serious implications for the port community, only 31 per cent feel that they are sufficiently informed on the potential risks and costs concerning port operations. [29]

Despite the potentially important broad implications of adverse climate change impacts on ports, to date there is relatively little relevant detailed research available in

[27] For example, in April 2007 an earthquake and a tsunami in the western Solomon Islands cost the country an estimated equivalent of 90 per cent of the year's operating budget. In 2009, losses from flooding in Fiji were equivalent to 7 per cent of GDP whereas, an earthquake and a tsunami in American Samoa and Tonga led to losses of more than 5 per cent of GDP. Global Climate Change Alliance (GCCA) Support Facility, 2011. *Background note for policy dialogue on climate change adaptation and disaster risk reduction in the Pacific (Group 2)*. 4 March. Port Vila Vanuatu.

[28] See, for instance, Lenton T, A. Footitt and A. Dlugolecki, 2009. *Major Tipping Points in the Earth's Climate System and Consequences for the Insurance Sector*. 89 pp. http://www.worldwildlife.org/climate/Publications/WWFBinaryitem14354.pdf. Climate change impacts on ports may also affect levels of insurance coverage and premiums.

[29] Becker, A., S. Inoue, M .Fischer and B. Schwegler, 2011. "Climate change impacts on international seaports: knowledge, perceptions, and planning efforts among port administrators". *Climatic Change*. DOI 10.1007/s10584-011-0043-7.

the public domain. Several studies have addressed climate impacts on transportation infrastructure generally and possible adaptation measures (e.g. in the United States, Canada, Australia and the United Kingdom),[30] but most are not mode-specific and very few specifically focus on ports.[31] A compelling study is the US Gulf Coast Study on Impacts of Climate Change and Variability on Transportation Systems and Infrastructure[32] which includes two phases. Phase 1 (completed in 2008) examined the impacts of climate change on transportation infrastructure at a regional scale. Phase 2 (expected completion in 2013) is focusing on a smaller region and aims to enhance regional decision makers' ability to understand potential impacts on specific critical components of infrastructure and to evaluate adaptation options. Two further particularly relevant studies in relation to seaports have been completed recently. One of these, commissioned by the International Finance Corporation (IFC) to help develop knowledge, tools and methods for analyzing climate-related risks and opportunities, and for evaluating adaptation responses,[33] focuses on the case of the Terminal Maritimo Muelles El Bosque (MEB), in Cartagena, Colombia. The other, commissioned by the IAPH focuses on adaptation measures for seaports.[34]

Stakeholders and policy makers involved in port planning, development and operations will need to take into account the effects of climate change in their decision making processes. Various mechanisms in support of adaptation action have already been developed or are under consideration at the international, regional or national levels (see Box 2). While not sector-specific, these may provide useful support and, importantly, help mobilize resources for adaptation action, a matter of crucial importance, in particular for developing countries most vulnerable to climate change impacts.

[30] A review of literature reveals that the majority of potential adaptation actions address in particular road transport. Means proposed for adaptation are also often non-specific with reference being made to technological/physical solutions, planning frameworks, monitoring, information provision, education, research, and some specific investment proposals for new or changed infrastructure. There are few proposals for policy instruments with the exception of spatial planning. Eisenack, K, R. Stecker, D. Reckien, E. Hoffmann, 2011. *Adaptation to Climate Change in the Transport Sector: a Review.* PIK Report No.22. Potsdam Institute for Climate Impact Research (PIK). Potsdam, May 2011.

[31] U.S. Environmental Protection Agency, 2008. *Planning for Climate Change Impacts at U.S. Ports*. White Paper, July 2008.

[32] U.S. Climate Change Science Program (CCSP) 2008. *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I.* Synthesis and Assessment Product 4.7/ March 2008.

[33] See for instance Stenek, V., et al., 2011. *Climate Risk and Business: Ports – Terminal Marítimo Muselles el Bosque Cartagena, Colombia*. International Finance Corporation (IFC). Word Bank Group, April 2011.

[34] *Seaports and Climate Change - An Analysis of Adaptation Measures*, 2010. Study commissioned by the International Association of Ports and Harbors (IAPH) - Port Planning and Development Committee. Unpublished Draft, November 2010, 56 pp.

Box 2 Some mechanisms in support of effective climate adaptation policy action

Although adaptation to climate change impacts is less at the centre of public attention than climate change mitigation, the international community has been developing mechanisms to support effective adaptation action [35] Relevant international instruments include the Nairobi Work Programme on impacts, vulnerability and adaptation to climate change (NWP). [36] The NWP was adopted by the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) to assist countries, in particular developing countries, including the least developed countries and small island developing States, to (a) improve their understanding and assessment of impacts, vulnerability and adaptation; and (b) make informed decisions on practical adaptation actions and measures to respond to climate change on a sound, scientific, technical and socio-economic basis, taking into account current and future climate change and variability.

Parties to the UNFCCC have agreed to undertake national adaptation measures and cooperate in preparing for the impacts of climate change. Least developed countries (LDCs) may identify their immediate priorities for adaptation options via the National Adaptation Programmes of Action (NAPAs). Many LDCs have received funding under the Convention to prepare their NAPAs, and many have already submitted their NAPAs to the UNFCCC secretariat.

Adaptation action is also growing in importance and rising high on the political agenda of many advanced economies. For instance, in 2010, the European Commission created a dedicated Directorate-General to focus on climate change to make adaptation to climate change a priority of all EU-level policies and coordinates EU adaptation policies. In 2009, the EU issued a *White Paper on Climate Change Adaptation* which - following completion of the consultation process - is expected to lead to a European strategy by 2013. [37] At the country level, many EU countries are developing specific adaptation strategies to help them cope with the expected impacts of climate change. [38]

Yet, while the development of an effective adaptation strategy is important, implementation of any such strategy on the ground will be crucial. Whereas a number of countries have well-developed adaptation plans or are in the process of finalizing them, significant additional resources will be needed for the purposes of implementation, especially in developing countries. So far, resources generally allocated to adaptation remain inadequate, especially when compared with significant adaptation costs estimated in various reports and studies which provide a wide range of estimates. [39] It is against this background that the High-level Advisory Group on Climate Change Financing (AGF) - established by the Secretary-General of the United Nations in February 2010, to consider, among other things, the potential sources of revenue that will enable achievement of the level of climate change financing that was promised during the UNFCCC in Copenhagen in December 2009. [40]

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[35] For an overview, see also Sven Harmeling, S, S Kreft, S. Chamling Rai, 2011. *Institutions for Adaptation - Towards an Effective Multi-Level Interplay*. Published by Germanwatch E.V. and WWF International, June 2011, available at http://www.germanwatch.org/klima/ad-inst.htm.

[36] See http://unfccc.int/adaptation/nairobi_work_programme/items/3633.php. Special information on the Private Sector Initiative under the Nairobi Work Programme can also be found on the same website.

[37] *White Paper: Adapting to climate change: Towards a European framework for action*, COM (2009) 147 final. Note also Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks, which entered into force on 27 November 2007 and aims to provide a regulatory basis to reduce and manage the risks that floods pose to human health, the environment, cultural heritage and economic activity. See also http://ec.europa.eu/environment/water/flood_risk/index.htm

[38] For a summary of adaptation strategies in select European countries, see Biesbroek, G.R., R. J. Swart, T. R. Carter, C. Cowan, T. Henrichs, H. Mela, M. D. Morecroft, D. Rey, 2010. *Europe Adapts to Climate Change: Comparing National Adaptation Strategies. Global Environmental Change*, 2010, 20(3): 440-450. For information about a recently initiated adaptation strategy for transport in the United Kingdom, see *Preparing for climate change: adapting local transport*, April 2011. UK Climate Impacts Programme, Oxford. http://www.ukcip.org.uk/wordpress/wp-content/PDFs/UKCIP-Adapting-Transport.pdf.

[39] See, for instance, *The Economics of Adaptation to Climate Change (EACC) Synthesis Report*, published in 2010 by the World Bank, which estimates that for developing countries the cost between 2010 and 2050 of adapting to an increase in temperature by approximately 2 degrees C by 2050 would be in the range of US$75-100 annually. See also UNCTAD/DTL/TLB/2009/1 at p. 21, for further references.

[40] United Nations, 2010. *Report of the Secretary-General's High-Level Advisory Group on Climate Change Financing*. 5 November. New York: United Nations. Available at www.un.org/climatechange/agf.

In relation to ports and related coastal infrastructure, coastal protection measures may play an important role as part of a broader adaptation strategy.[41] At the same time, however, effective adaptation for global ports will require a range of well-targeted interventions to enhance the resilience of ports and their hinterland connections through changes in infrastructure design and maintenance, operations, planning and management (see Table 2). Planning for known impacts and timely risk-assessment will play an important part of any strategy to enhance resilience with a view to reducing the long-term impacts and costs associated with climate change. This is important for all, but particularly for those most vulnerable to climate change and with low adaptive capacity.

Given the long service life of port infrastructure, effective adaptation requires re-thinking established approaches and practices early[42] despite some of the uncertainties surrounding climate change and its broader long-term implications for transport and trade. Existing infrastructure has been designed and maintained to standards that do not necessarily reflect the climate change risks known today and currently projected for the years to come.[43] Thus in respect of infrastructure development particularly, it is evident that today's decisions may determine future vulnerability to climate change.

However, effective adaptation action at the local level requires a good understanding of relevant climatic impacts and likely vulnerabilities. This information, important and urgently needed for the purposes of both risk-assessment and planning, is at present not readily and widely available. Thus for the purposes of developing effective adaptation measures, as an important first step, appropriate approaches and mechanisms need to be identified/developed to ensure improved availability and dissemination of data and other information on climate change impacts, exposure and vulnerability. In this context, extensive cooperation among policy makers, stakeholders, scientists and engineers is required both at local and national levels, but also at the regional and international levels.

It is envisaged that the Ad Hoc Expert Meeting will serve to raise awareness and better dissemination of available information, foster cooperation and synergies among relevant interested parties, and help develop useful suggestions and recommendations on the best way forward.

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[41] Nicholls, R.J., 2011. *Sea Level Impacts of Climate Change*. Improving the Assessment and Valuation of Climate Change Impacts for Policy and Regulatory Analysis: Research on Climate Change Impacts and Associated Economic Damages. January 27-28 2011. Washington, DC. See also the results of the EU funded PESETA (Projection of Economic impacts of climate change in Sectors of the European Union based on bottom-up Analysis) project, comparing the cost of adaptation with the cost of inaction at the EU level and suggesting that the benefits of adaptation outweigh the costs, http://peseta.jrc.ec.europa.eu/index.html.

[42] See e.g. Von Storch, H., G. Gonnert and M. Meine, 2008. "Storm surges—An option for Hamburg, Germany, to mitigate expected future aggravation of risk". *Environmental Science and Policy*, 11, 735-742.

[43] On the importance of using regularly updated climatic design values for infrastructure construction, see Neumann, J., 2009. "Adaptation to Climate Change: Revisiting Infrastructure Norms", *Resources for the Future*, December 2009. Issue Brief 09-15.

Table 2 Select Potential Adaptation Measures for Ports

Climate change factor	Adaptation measures
Rising sea levels – Flooding and inundation – Erosion of coastal areas	– Relocation, redesign and construction of coastal protection schemes (e.g. levees, seawalls, dikes, infrastructure elevation) – Insurance – Strengthening and elevation of infrastructure e.g. ports and harbour facilities – Reduction or avoidance of development/settlement in coastal flood prone areas though economic incentives and regulation – Provision for evacuation routes and operational plans – Preparation for service delays or cancellations – Adjustments to speed and frequency of service
Extreme weather conditions – Hurricanes – Storms – Floods – Increased precipitation – Wind	– Integration of emergency evacuation procedures into operations – Setting up of barriers and protection structures – Relocation of infrastructure – Ensuring functioning of alternatives routes – Greater monitoring of infrastructure conditions – Restriction of development and settlement in low-lying areas – Construction of slope-retention structures – Preparation for service delays or cancellations – Adjustments to speed and frequency of service – Strengthening of foundations, raising dock and wharf levels – Smart technologies for abnormal events detection – New design for sturdier ships – Development of new design standards for hydraulic structures such as drainage channels – Better land use planning in flood prone areas – Construction of storm retention basins for flush flooding
Rising temperatures – Increases in very hot days and heat waves – Melting ice – Large variations (spatial and temporal) – Frequent freeze and thaw cycles	– Greater use of heat-resistant construction and materials – Continuous inspection, repair and maintenance – Monitoring of infrastructure temperatures – Adjustments to cargo loads – Adjustments to speed and frequency of service – Preparation for service delays or cancellations – Refrigeration, cooling and ventilation systems – Insulation and refrigeration – Modal shift – Transit management scheme and regulation of navigation in northern regions – Ship design, skilled labour and training requirements – Development of new designs for building transportation systems on less stable soils.

Source: UNCTAD based on literature review.