Watercolour 3
Alexandria, a Deltaic City next to Sunken Cities

Chapter 3
Resourceful and Resilient Cities and Marine Ecosystem Services

Abstract The great wealth of coastal areas, whether in terms of access to the sea, maritime trade, tourism, fishing, or natural resources, increasingly attracts urban populations. However if this precious coastal capital is unsustainably managed, the potential of its benefits can be easily undermined. Coastal urbanisation affects land use and cover of the shore, biodiversity, soil, water and air quality and global climate. Responsible coastal cities try to reduce their ecological debts on land and the sea. Urban coastal organs and functions have to boost the resilience of places and assist in transition to a civilisation of sustainability. Sustainable cities and oceans, among the priority areas of the Rio+20 conference and the dialogue for the post-2015 sustainable development goals, need ecological and environmentally friendly cells and neurons to thrive in harmony with the planet and the seas. Together with their citizens and stakeholders, they can play a cardinal role for exploration and protection of our precious marine resources.

This chapter focuses on coastal cities as vital and interdependent ecosystems able to manage crucial amounts of scarce resources and materials, ensure food security, offer sustainable goods and services and reduce greenhouse gas emissions and waste, especially preventing marine debris. Many coastal cities provide outstanding models of emission-neutral, waste-free eco-neighbourhoods and intelligently designed waterfronts to celebrate the sea which links them to the conscience of the world. Furthermore, they can send an impulse for maritime routes to become vectors of responsibility for sustainable development.

3.1 Coastal Biodiverse Cities and the Well-Being of the Ecosystems

Coastal cities are required to offer citizens the possibility of leading a happy and fulfilling life in balance with nature and the sea. They have to provide fresh air and water, healthy food, shelter, energy and transport, materials, services and opportunities for education, employment and leisure. For this, cities interact with the surrounding land and sea and impact a broader terrestrial and marine environment. Their

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ecological footprints, which depend on the nature and nurture of cities, reflect their resource consumption over multiple terrestrial and sea value chains. Cities can collectively influence over 70 % of the global ecological footprint.

Marine ecosystems offer ample possibilities for food, recreation, health and wellbeing. The global ocean produces almost half of the oxygen supporting life on Earth and absorbs more than a quarter of the carbon dioxide emitted into the atmosphere. It has been described as the kidney of the planet or as a huge biological pump at the heart of global atmospheric and thermal regulation and water and nutrient cycles. But the ability of the ocean to continue providing these essential ecosystem services is being compromised due to marine pollution, environmental degradation, overfishing, and rising temperatures and absorbed emissions (GOC 2014).

Greenhouse gas emissions are changing the chemistry of the planet, raising ocean temperatures and acidity levels, which in turn are endangering coral reefs and marine life. In the future, climate change is expected to have the greatest impact on the ocean capacity to provide its ecosystem services. Humanity is rapidly approaching unprecedented tipping points that, if unheeded, may inexorably lead to systemic collapse. Since 2008, the World Ocean Day, celebrated each year on 8th June, emphasises various aspects of individual and collective responsibilities in sustainably managing ocean resources.

Food from the ocean first drew humans to urban settlements by the sea. Coastal cities are the places where human, atmospheric, terrestrial and water ecosystems interact and influence each other. Their natural capital is very diverse and most promising in an era in which depletion of the global natural capital becomes less and less reversible. The sustainable use of resources, respecting the carrying capacity of the biosphere and supporting the provision of ecosystem services, is a major challenge for the world's cities and citizens.

Humanity consumes far more than the ecological resources and services that the planet can sustainably regenerate every year, and, if current trends continue uncurbed, the biocapacity of two planets will be needed for its survival before 2050. Earlier and earlier each year, the Global Footprint Network informs us about the overshot day, a recently coined term, when global demand for natural resources and ecological services starts surpassing annual supply. In 2014, the Earth Overshoot Day was on August 19th. In less than 8 months, humankind had already exhausted the equivalent amount of natural resources that the planet generates during the entire year. The ecological deficit, signalling the gap between supply and demand of natural resources, is seriously eroding the planet's ecological capital assets (Ecological Footprint Network et al. 2012).

Humanity is jeopardising its very future, on land and sea. A critical threshold was already crossed in the 1970s when global demand began outstripping our planet's biocapacity. Since then, ecological overspending has entered a vicious cycle. As resource deficits become larger and resource prices remain high, pressures become unbearable and accumulation of the debt weakens the ability of communities to initiate virtual global cycles. Years of unbridled consumption have led to the depletion of many finite resources, on land and sea, and the consumption of renewable

resources at paces have become more rapid than their regeneration rates (WWF 2014).

To curb these trends, responsible cities started introducing ecosystem-based management involving local approaches to conscious resource management, recognising that humans are an integral part of their ecosystems, which are vital in supporting human life. The process emphasises the necessity of sound scientific understanding and strong citizen participation in addressing complex and often contentious issues. The future role of ecosystems for human well-being depends increasingly on their health and self-regenerating capacity (UNEP 2011).

Marine resources are often perceived as "less finite" than terrestrial ones. Deterioration of marine ecosystems has long been hidden by the apparent immensity and relative, until recently, inaccessibility of large parts of the global ocean. The need to reduce greenhouse gas emissions has driven both the deployment of offshore renewable energy, but has also provided a further impetus to seaborne transport over land transport. Improvement of the energy efficiency of ships and the use of cleaner fuels hold a significant potential to further reduce greenhouse gas emissions, and increase the sustainability advantage of maritime transport.

Coastal cities are among the ecosystems of highest concern. This has, with participative foresight, been highlighted by international organisations such as the 2010 UNEP. The UNEP foresight panel, convened to identify crucial emerging environmental issues, has succeeded in shedding light on many cities and land-sea interactions. Cities and the seas were recognised as critical emerging issues for the global environment, of almost universal spatial scale, and subjected to new developments, scientific knowledge, scales and impact. A number of other issues were declared by the scientific community to be "emerging", but which had not yet received strategic attention from the research and policy community. The process also suggested that the linkage between the policy and science communities is inadequate or even deteriorating, and this broken bridge is detrimental to positive global environmental change (UNEP 2012a).

The UN Conference on Environment and Development (Rio de Janeiro 1992) and Agenda 21 had already underlined the role of cities and local governments for sustainable development. Irresponsible land use planning, rigid zoning and urban sprawl, and low-density urban development into green areas, resulted in increased consumption of land, energy and resources, air, soil, water and noise pollution and greenhouse gas emissions. The impacts of climate change on oceans and the cities, the role of seas and green areas as carbon sinks and the effects of compact cities versus urban sprawl are subjects of ongoing research. The growth rate of urban land cover has been double that of the growth rate of the urban population between 1990 and 2000 (Angel et al. 2011).

In 2012, cities and the oceans were two among the seven critical issues of the Rio+20 conference that intended to give a new impetus and turn sustainable development from aspiration and irregular implementation into a genuine systematic

path to responsible prosperity for the present and the next generations. Crucial links among cities and the oceans were also reflected on other critical issues, including food, water, jobs, disasters and energy. Governments and businesses underlined issues of concern, including threats from climate change and ocean acidification, overfishing, illegal fishing, and subsidies that drive unsustainable consumption. They also debated the need to conserve and protect marine ecosystems to both restock the ocean and build its resilience to change.

The 2012 Rio+20 declaration "The Future We Want" encouraged nations to introduce green growth policies and strengthen efforts to eliminate poverty and inequality. By the end of the conference, hundreds of voluntary commitments for sustainable development had been registered by governments, businesses, civil society organisations and universities. More than 80 companies and 50 countries also committed to boost natural capital accounting, after a proposal by the World Bank to take into account the value of assets, such as clean water and marine ecosystems, into national accounting systems and government and business decisions.

However, in spite of hundreds of internationally agreed goals and voluntary commitments, the world continues on an unsustainable path. Inaction is considered to be a major bottleneck. UNEP's 5th Global Environmental Outlook (GEO 5) stressed that drastic large-scale actions are needed to reverse the trends of resource overconsumption. Action has to follow commitment. Some goals that were crowned with success include elimination of substances that deplete the ozone layer, removal of lead from fuel, access to improved water supplies and research to reduce pollution of the marine environment. The assessment emphasised that sustainability targets can still be met if current policies are radically changed and best practices are scaled up to optimise their overall effect (UNEP 2012b).

"Business as usual" approaches can have an unbearable weight on the future, especially in times of a worrying deficit in global governance (Gore 2013). The OECD Environmental Outlook to 2050 suggests that the potential cost of inaction on climate change could be as high as 14 % of average world consumption per capita in 2050. Continued degradation and erosion of the natural environmental capital, together with irreversible effects, could endanger two centuries of continuous upgrading of living conditions. Multiple-benefit best cases confirm that green growth is not prohibitively expensive and can help humanity to strike a renewed green deal (OECD 2012).

Dynamic world cities emerge as both the main drivers and beneficiaries of a paradigm shift towards green growth, proposed as a shortcut to sustainable development. Inclusive green growth brings opportunities for new environment-friendly businesses and jobs, while managing the necessary structural changes for transition to a greener society. Greening growth is necessary and can be efficient and affordable (World Bank 2012). A concert of international reports on green growth suggests that the way forward requires integrated innovative solutions to tackle political economy constraints, change deeply entrenched behaviours and develop the methodological instruments to monitor progress (UNEP/ILO 2012).

Sustainable management of natural resources, including marine resources and ecosystem services in an increasingly urbanised world, is a major challenge for

cities, long typified as concrete jungles inhospitable to flora and fauna, ecosystems and habitats. Depending on their values, performance and governance, cities can be an opportunity or a threat for biodiversity. Seizing the opportunity asks for a mix of high quality green and blue public spaces in dialectic symbiosis with dense and compact built-up areas (EEA 2010).

The sustainable development of terrestrial and marine resources is cardinal for coastal cities in search of new models to impregnate and transform local production and consumption patterns, social values and lifestyles, socio-economic and environmental policies and citizen awareness and participation towards sustainable development. Many cities have conducted assessments of their ecological footprints on land and the sea and identified ways to influence and reduce them.

Furthermore, many cities together with their main stakeholders have declared their will and readiness to act and correct their enormous ecological footprints on the indebted planet. Urban design and infrastructures have crucial links to footprint trends. Population density and public transport significantly reduce the per capita ecological footprint, while the affluence of citizens often leads to higher final consumption. This was the case of San Francisco, the city by the Bay, which tried to evaluate the ecological footprint of the metropolitan area. The assessment concluded that the overall impact of average San Franciscans had absolutely to be reduced and provided options for more environmental-friendly lifestyles (Ecological Footprint Network 2011).

Vancouver is reputed to have the lowest carbon footprint among major North American cities through high density built environment, limited urban sprawl, sustainable public transport, and the provision of many green and open spaces. The Greenest City Initiative, involving all levels of city government, citizens and business in a range of projects, aims at Vancouver becoming the greenest city in the world by 2020. Long-term planning, a 15-year long investment in multimodal transport, and an open attitude towards migrants, made the city environmentally friendly and culturally diverse (Government Office for Science 2014a, b).

The Cities and Biodiversity Outlook, the world's first global analysis of the links and opportunities between urbanisation and biodiversity, highlights a wide range of worthy initiatives by cities, local authorities and sub-national governments in both developed and emerging countries. The assessment underlined the potential benefits from taking into full account terrestrial, freshwater and marine ecosystem dynamics in urban planning and policy. This should be seen as a major opportunity to make giant leaps for the reduction of biodiversity loss and the improvement of quality of life. The 10-year global initiative "Cities in Biodiversity Hotspots", involving more than 250 cities located in and around the 35 biodiversity hotspots of the world, provides a platform for action and mutual learning (UN Convention on Biological Diversity et al. 2012).

Urban regions must take increased responsibility for conceiving, designing and implementing actions that take into account their profound connections with and impacts on the rest of the planet. Urban areas are expected to continue to expand faster than urban populations. The total urban area is likely to triple between 2000 and 2030, while urban populations are likely to nearly double. Urbanisation draws

heavily on natural resources on a global scale, with serious effects on biodiversity and ecosystem services. Food, materials and energy are drawn in great quantities from all parts of the world, despite the sustainability calls for giving priority to the local and seasonal food resources.

However, there are untapped opportunities for cities to sustainably manage ecosystem services. For example, a portfolio of measures can be used to decrease waste and reduce consumption, while at the same time invest in protecting biodiversity, water quality, local food production and carbon-sequestering ecosystems. A global system of cities wishing to lead the world towards sustainable futures has to closely cooperate with other actors such as national, regional, and local governments, multinational corporations, and civil society. Each of these actors has important roles to play in sharing and managing planetary resources.

Many cities have begun to take an increasing responsibility in the management of terrestrial and marine resources and impacts at regional or even global scale. Actions by a consortium of municipalities or state governments operating at larger scales are likely to accomplish even more in addressing challenges of ocean sustainability. Partnerships across urban and rural communities are also expanding to address multiple global sustainability issues, and the inter-connections and impacts on broader variable geometry territorial scales.

In 2002, the signatory countries of the Convention on Biological Diversity (CBD) committed to achieve, by 2010, a significant reduction in the rate of biodiversity loss. This year of high and noble intent was defined as the International Year of Biodiversity and expanded later to the Decade of Biodiversity to frame efforts with a longer perspective (2011–2020).

Effective stewardship of ecosystem services must consider the interconnectedness of resources that link cities to ecosystems outside of their boundaries, and the multitude of actors and factors that shape and sustain the resource flows. This responsibility includes implementing the ecosystem approach of the Convention on Biological Diversity and supporting local governments in addressing the Aichi Biodiversity Targets, the 20 ambitious goals of the CBD's Strategic Plan for Biodiversity 2011–2020. The targets provide a framework of action for all stakeholders striving to preserve biodiversity and enhance its benefits for citizens. The first target suggests that by 2020, at the latest, people will be aware of the values of biodiversity and the steps they can take to conserve and manage it sustainably.

Some of the Aichi Biodiversity Targets concern directly the marine environment and are crucial for coastal cities. Target 6 asks for all fish and invertebrate stocks and aquatic plants to be managed and harvested sustainably by 2020 and the impacts of fisheries on stocks, species and ecosystems to be within safe ecological limits. Cities are also concerned by the development of marine protected areas and should deploy efforts to achieve the Aichi Target 11 asking for at least 10 % of coastal and marine areas and 17 % of land, especially areas of particular importance for biodiversity and ecosystem services, to be preserved by 2020, through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other area-based conservation measures (CBD 2010).

Coastal cities, bridging human, land and sea biodiversity, are pioneers in bringing forward new initiatives. Connecting fragmented ecosystems on land and the

sea is particularly useful to increase ecological function. This can be achieved through planting trees by the waterfront to expand the tree canopy, establishing corridors of multilayer plantings along the seaside, as well as creating ocean gardens or water parks. Cities can also focus on improving and restoring their blue and green spaces to draw increased attention to local wetlands and hybrid spaces. Sustainable planning, design and management of urban areas are crucial factors for the preservation of biodiversity and healthy ecosystem services.

Monitoring and performance evaluation are fundamental to understanding the impacts of biodiversity management. The Cities and Biodiversity Index (CBI) is proposed as a self-assessment inventory that enables cities to track their progress in conserving and enhancing biodiversity. Other initiatives to benchmark environmental stewardship include notably the Environmental Sustainability Index. After a preliminary assessment of data availability and feedback by several world cities, indicators and scoring systems were developed, tested, revised and improved upon and a user's manual was prepared. Efforts continued towards a single index aggregating the contributing indicators.

Every coastal city and region should have a marine biodiversity strategy with shared objectives and a policy portfolio for achieving them. Lisbon established a Cooperation Protocol with the pioneering goal of enhancing its biodiversity capital by 20 % until 2020. In this Protocol, the cooperating parties also committed to prepare an Urban Biodiversity Matrix of Indicators.

The "Fibre City: Tokyo 2050" is a vision for the future of the first world metropolis aiming at a radically new balance between nature and the built environment. The vision responds to four urban challenges, including a shrinking population, an ageing society, environmental crisis and the risk of earthquakes. While unprecedented population declines are expected in Japan due to falling birth rates and continued resistance to immigration, the metropolis could benefit from preserving the freed up land as a precious resource. The concept of the Fibre City 2050 focuses on the ways in which urban fibres can be used to construct an alternative image of a metropolis. As a visionary view of Tokyo, from macro to micro, Fibre City intends to inspire global cities retrofitting for greater harmony with nature, better access to public transport, and improved liveability with rediscovery of historic features like Edo canals and bridges that have been covered by elevated expressways.

New York took a comprehensive and integrated approach to its ocean and coastal resources, leading to better management decisions and healthier communities and ecosystems. The New York Ocean Action Plan (OAP) is a coordinated and inclusive effort for improving the health of ocean ecosystems and their capacity to provide sustainable benefits to citizens. Through concerted action, the goal of the OAP is to achieve sound ocean ecosystems for the benefit of citizens, communities and the world. Grounded in stakeholder participation and short-term actions to reach long-term goals, the Plan guides State government funding, research, management, outreach, and education.

The necessity of the Ocean Action Plan was highlighted already in 2009 by the New York Ocean and Great Lakes Ecosystem Conservation Council, which aimed at promoting healthier ecosystems in New York through the use of ecosystem-based management and greater coordination of stakeholder activities. The geographic action area encompasses the State's ocean waters stretching from New York City to

the end of Long Island, including ecological connections to offshore waters out to the edge of the continental shelf. The New York Department of State, working with all concerned stakeholders, drew a map of offshore uses and compiled resource data to identify offshore habitat areas and locations that may be best suited for offshore wind energy development. Additionally, it explored the ecological relationship with several estuaries and their habitats, given the interconnectedness of ocean waters with waters near shore.

As a contribution to the UN Decade on Biodiversity, the City of Brest hosted, in 2012, an international meeting on Marine and Coastal Biodiversity. It provided a multi-disciplinary platform for scientists, international organisations, and cities to discuss interactions between the development of marine territories and biodiversity management. UNESCO's Intergovernmental Oceanographic Commission presented projects for managing and protecting marine and coastal biodiversity, including the Ocean Biogeographic Information System.

Many cities strive to provide citizens with easy access to high-quality wetlands and local nature reserves. Singapore and Perth have built elaborate urban forest canopy walks. More cities designed imaginative parks in aquatic and marine settings. Central Park in New York City, Park Guell in Barcelona, Pharo gardens in Marseille, Griffith Park in Los Angeles and Stanley Park in Vancouver are prime examples of accessible green urban oases. Stanley Park is a magnificent green oasis in the heart of the built urban landscape of Vancouver, which has already celebrated its 125 years. It includes 400-ha natural West Coast rainforest and enjoys scenic views of water, mountains, sky, and trees along the famous Seawall. Since its opening, in 1888, the City and the Park Board have worked together to preserve and protect the ecology of the park and ensure its sustainability, while enhancing Vancouver's liveability through the enjoyment of Stanley Park.

Sydney intends that each and every citizen will live less than 250 m distance from a green area. According to the concept of plaNYC, the city's ambitious plan for 2030, all New Yorkers should live within a 10-min walk of a park, usually with a water pond. A Greener, Greater New York has been the consensual vision of many organisations and public agencies, which committed to prepare the city for one million more residents, strengthen the economy, combat climate change, and enhance the quality of life for all New Yorkers. Public spaces and parks are among the plaNYC areas of highest interest (New York City Mayor's Office of Long-Term Planning and Sustainability 2011).

In Porto, the waterfront, both along the river and the ocean, is teeming with happy pedestrians and visitors, enjoying all the way from the city centre to the ocean. The Passeio Alegre echoes well its name. The City Park is a most spectacular landscape expanding 83 ha near the sea. Opened in 1990 after a long gestation, the park is a meandering labyrinth of winding paths that extends over 10 km, covered by trees, shrubs, and aquatic plant species. From physical exercise to kite flying, the park supports a very diverse array of activities bridging the city with the Atlantic coast. The city also has several themed gardens including the garden of feelings, the garden of aromatic plants, the garden of roses and the apple tree estate for citizens to rediscover their environment.

Many international initiatives try to identify and celebrate the brightest best cases. The Local Action for Biodiversity Initiative introduced by the International Council for Local Environmental Initiatives (ICLEI) highlighted the achievements of pioneering coastal cities. The City of Amsterdam is a biodiversity world leader, home to a vast network of rivers and lakes, as well as urban beaches and marine ecosystems with hundreds of species. From a small fishing village in the twelfth century to a world class city in the twenty-first century, Amsterdam had made sustainable development its utmost goal. Although highly urbanised, the city has a wide diversity of flora and fauna and a unique network of urban parks which provide recreational ecosystem services. The city's environmental policy plan, reviewed every 4 years, ensures that the environment is given dynamic priority and is well integrated with its economic and social development.

Just 6 km away from Amsterdam's central station, the Ilperveld fen is part of the Natura 2000 protected sites in Europe, the larger world coordinated network of protected areas, established according to the Birds and the Habitats Directives that collectively form the "nature legislation" of the European Union. The area offers uninterrupted views of large flat fens, criss-crossed by a myriad of ditches and canals. Originally used for hay-growing and pasture, the area was degraded as a municipal dump in the 1980s and was abandoned by thousands of meadow birds. The site has since been protected within the framework of Natura 2000, and a large restoration has been undertaken. Farming and cattle grazing has also been re-introduced to maintain the wet meadows in good condition for the benefit of the birds which have since returned. The area is also very popular with bird watchers, nature lovers and school children (EC 2012).

Water parks are amongst the most vital urban commons and they can beautifully integrate with green parks. Biodiversity and ecosystem services are global public goods, but local and regional authorities have the legal power to designate conservation areas and the ethical obligation to protect them through incorporation of biodiversity concerns into their spatial planning processes. Public commitment is essential for sustainable communities which identify biodiversity as a precondition for resilient cities. The designation of marine protected areas and the development of green infrastructures offer cities an opportunity to integrate biodiversity and resilience into local and regional plans taking into account the land and the sea dimensions (EEA 2010).

Protected marine parks can be of special interest for cities and the recreation and well-being of citizens. The Arcachon Park, opened in 2014, is the sixth French marine park. Governed by local actors, the park enables different activities such as tourism, oyster farming, fishing or scientific observation to sustainably coexist in a natural environment. Marine protected areas are part of the French strategy for the sea that was launched following the Grenelle of the Sea in 2009 with the ambitious goal of protecting 20 % of the waters under French jurisdiction by 2020. All French protected areas accounted in 2014 for about 4 % of these waters. Their geographical distribution is quite uneven, with most of them located overseas. The Basin of Arcachon is a place of exchange for many species and has the particularity of being empty of two thirds of its capacity at low tide, revealing sandy islets and tidal

marshes. As the second global maritime domain, France tries to lead by example by establishing effective means to protect and enhance its marine areas.

Attractive green areas and blue waterfronts are essential for urban populations and wildlife to thrive. Copenhagen provides a prime example. An ancient Viking fishing village, strategically located at the entrance to the Baltic Sea, the Danish capital/European Green Capital in 2014 made the Blue and Green City one of its priorities. Swimming races and cliff-diving contests with athletes jumping into the harbour from the roof of the opera pay tribute to the city's long symbiosis with the sea. Copenhagen's ambitious goal of being carbon neutral by 2025 and the eco-metropolis pathway are among the world best practices.

Many more cities work hard to transform urban grey by the sea to urban blue green spaces. All roofs could become candidates for micro-farms and all walls could support vertical gardens and micro-farms. Inventors already proposed self-regulated urban farms to the size of a parking place. Some cities are equally interested in ecosystem services delivered by biodiversity in green areas in the hinterland and in faraway lands and oceans. They can cooperate with the farming sector, responsible for 80–86 % of all food-related global GHG emissions and 14–24 % of total global emissions, to improve its performance. It has been estimated that as much as 30 % of all food grown worldwide is wasted before reaching the consumer. In industrialised countries, more than 40 % of food losses occur at retail and consumer stages.

Urban agriculture has the potential to become pervasive within cities and could even provide citizens with a considerable part of the needed food. Vertical farming in tall buildings could replace less productive single-story greenhouses as the source of all city-grown produce. Some forms of vertical farming already exist and Chicago claims the largest multi-storey greenhouse of special interest to densely constructed cities. Urban aquaponics, combining plants and vegetable farming with fish farming in a clean water environment, promises to further expand the limits of the possible (van Veenhuizen 2006).

Cities and agriculture are responsible for nutrients and waste entering the marine environment. Furthermore, many hundreds of fishing nets are lost or abandoned every year, often due to conflicts between trawlers. The problem of lost or abandoned fishing nets is severe due to the non-degradable netting materials which can maintain 10 % of their catching capacity once lost. Much waste comes from food packaging, which does not always meet the performance standards required at equivalent cost, and the industry remains reliant on fossil-based coatings and films. Various research and innovation projects try to develop sustainable, eco-friendly food packaging coating products made from seaweed extracts and starch and applied to paper and cardboard in the form of a spray. This is a prime field for cities and businesses to join efforts.

Coastal litter, a prime symbol of resource inefficiency and inaction on land and the sea, is a huge problem, as it can be ingested by and entangling wildlife. Marine debris comes mainly from land activities and only one fifth is due to shipping. Only 15 % of the debris remains on the surface, while 70 % goes to the seafloor. It pollutes beaches, causes harm to ecosystems, undermines the recreational value of the

places and prevents the optimal enhancing of marine resources and the development of the blue economy (GOC 2014). If no urgent action is taken, marine litter is projected to increase by 44 % by 2030.

Plastics are by far the most prevalent debris contributing an estimated 60–80 % of the total marine debris. It seems that eight million tonnes of plastic waste are entering the world's oceans every year. The worst offenders are in Asia, with China responsible for 28 % of all plastic entering the ocean, followed by Indonesia with 10 % of it. The global plastics sector, of which bio-plastics make up only 1 % of the market, is a large sector leading to large amounts of non-biodegradable plastic waste. Plastic marine debris contains highly toxic substances in concentrations that are more than 100 times higher than those normally found in ocean waters, affecting marine life and ecosystems.

Synthetic polymers in the ocean should be regarded as hazardous waste (Eriksen et al. 2014). Marine debris affects all marine habitats, from densely to remote populated regions. It has been estimated that the average density of marine debris varies between 13,000 and 18,000 pieces per square kilometre, with far higher concentrations, more than 200,000 pieces per square kilometre, in the convergence zones between two or more ocean currents. Computer model simulations, based on data from about 12,000 satellite-tracked floats deployed since the early 1990s as part of the Global Ocean Drifter Program, confirm that debris is transported by ocean currents and tends to accumulate in a limited number of sub-tropical convergence zones or gyres.

The accumulation of floating garbage in the oceans led to potentially five garbage patches scattered globally, located in the North and South Pacific Ocean, North and South Atlantic Ocean and Indian Ocean. The total amount of plastic garbage, estimated around 36,000 tonnes, is unequally dispersed, and twice as much in the North Pacific as in the North Atlantic. The ecological impacts range from over a million of seabirds and one hundred of thousand marine mammals killed by ingestions of plastics or entanglement. Economic impacts, estimated after beach clean-up costs, tourism losses and damages to fishing and aquaculture industries, are also very important (Sesini 2011).

In the North Pacific, the immense cauldron known as the Great Pacific Garbage Patch contains an estimated 100 million tonnes of plastic waste and chemical sludge, much of which is produced by cities. Cities from all sides of the Pacific and beyond can make innovative alliances and engage in research and innovation to jointly address this major challenge. Technologies for recovering ocean garbage and converting it into fuel for energy production would only have multi-beneficial impact.

Demonstration programmes were developed to support large scale removal and exploitation. A NOAA's programme collects derelict fishing equipment and nets and supports the recycling scheme "nets to energy" which generates power from the collected debris. In Hawaii, the nets, once removed by fishermen, communities, and trained divers, are transported to a scrap metal recycler facility and are chopped into pieces suitable for combustion. The nets are then burned, producing steam which drives a turbine that creates electricity, enough to power nearly 350 homes for a year.

In the EU, the 7th EU Environmental Action Programme calls for a quantitative waste reduction headline target, supported by source-based measures. Research projects have been trying to better shed light on not just reducing waste from marine activities but using it for new products, e.g. bio-based polymers from shell waste from the fishing industry. The EU-funded Ocean Sampling Day is another inspiring initiative which took place on mid-summer day (21 June 2014), the longest day of the year. Science teams around the world with the help and involvement of citizen scientists gave oceans a health check. Schools are often associated with such initiatives and coastal cities can organise their regular sea health checks while promoting science for the youth (EC 2013d).

Advanced cities have to show the way forward. San Francisco has set the ambitious goal of zero waste by 2020 and deployed an ambitious solid waste management programme. The city's zero waste goal implies that products are conceived, designed and used according to the principle of highest and best possible use. Zero Waste also means that discarded materials cascade through reduce, reuse, and then recycle or compost. To meet its zero waste goals, San Francisco developed a long-term strategy and a threefold approach to address the legal, administrative, and social dimensions of waste management. The City enacted strong waste reduction policies and partnered with Recology, a materials management company, to innovate and promote a culture of recycling and composting. Policies embraced a wide-range of fields, from production and packaging to consumption, public and private management and government procurement.

A culture of Zero Waste has been created through strong citizen engagement and the participation of many organisations. The municipality provides policy guidance and oversight, sets framework conditions and financial incentives for product and service providers, conducts outreach and enforcement, while partner Recology tests and operates infrastructure to collect and process recyclable, compostable and landfilled waste. The achieved results are significant. From 1990 to 2010, landfill diversion increased from 35 to 80 %. A construction and demolition debris ordinance has recovered tens of thousands of tonnes of material. Mandatory recycling and composting increased organics collection by 50 % to more than 600 tonnes per day.

Pollution from shipping is estimated to about 20 % of the total pollution. Dumping of garbage from ships is a serious element of the problem of marine debris. In 2013 new, more stringent controls under International Convention for the Prevention of Pollution from Ships (MARPOL) came into force. Port waste reception facilities have to play an important role. The European Union Member States have introduced requirements for delivery of waste ashore before a ship leaves port. Sewage pollution from ships is mainly a problem with cruise ships: with up to 7000 passengers and crew, they are the equivalent of a small town, and can contribute to local eutrophication problems. The local conditions around the ship are significant for the impact of any sewage discharges. The increased requirements under MARPOL on discharges near the shore are likely to reduce the problems.

Clean seawater can also be precious as a drinking resource. Coastal aquifers may contain seawater and salty groundwater from ancient times. State-of-the-art

desalination technologies can remove salt from both seawater and brackish water, thus providing a new source of freshwater. Techniques used to desalt water are also useful for removing other impurities common to contaminated source waters. The process tends to be very costly and energy intensive. Desalination can impose an environmental toll and has to be managed according to strict sustainability principles. Research suggests that combining alternative energy sources with desalination technology can lead to more economical and environmentally friendly systems. Desalination is high in the agendas of water-poor countries such as Kuwait, Saudi Arabia, and Israel. In Tunisia, four desalination plants produce nearly 4 % of the national water resource. The plants use reverse osmosis, a process that orients water through a membrane with tiny pores that retain most of the dissolved salts as well as most organic compounds and microbiological contaminants.

3.2 Sustainable Aquatic Resources and Urban Food Security

During the industrial revolutions, increases in agricultural productivity have served as a driving force for urbanisation. As farms became more profitable, excess labour from agriculture moved to industrial jobs in cities. However, while past urbanisation promoted growth and prosperity, the current urban explosion in the emerging world is occurring faster than the pace that allows cities to integrate newcomers without major shocks and risks and to provide them opportunities for a better life. Poverty, food insecurity, and malnutrition are shifting rapidly from rural areas to urban centres. Furthermore, political instability in many emerging countries make cities inadequately equipped in infrastructures, and vulnerable to natural disasters, urban poverty, food insecurity, high malnutrition, and the least able to sustainably address these challenges.

Food from the ocean could be decisive for the food security of coastal cities, which often are highly dependent on imported foods. In many cities in Africa, 30–50 % of food staples and vegetable oil found in the markets are imported. Imported staples most often cost more than urban garden produce or street vendor foods. Urban dwellers, and especially the urban poor, are more affected by international food prices than small farmers. Food security in urban areas tends to be tied to consumption patterns and affordability, while food security in rural areas is related to the availability of food.

In many African cities, the urban poor spend up to 90 % of their household income on food. Up to 70 % of the caloric intake of a poor urban household is from street food. Street vendors are largely unregulated, lack access to clean water and refrigeration, and do not respect standards of hygienic food preparation and packaging. Cutting back on the amount and diversity of food is the most common solution for poor households. If such solutions last long, food insecurity increases and malnutrition rates climb quickly, especially among children.

The link between proper nutrition and normal physical and cognitive growth is a hardwired system. Access to sufficient, nutritious and affordable food is not only

a basic human right but it provides the foundation for citizens' ability to grow, learn, prosper, and reach their full potential. Emerging cities have to ensure food for all slum populations, especially the youths less than 18 years old facing high malnutrition risk and expected to form 60 % of the urban slum population in 2030. This has huge implications not only for national wealth creation but also for political stability at often regional scale.

Fisheries and aquaculture are a vital source of nutritious food, economic opportunities and jobs (World Bank et al. 2014). They already account for 16.6 % of all animal protein consumed globally and 6.5 % of all protein for human consumption. They are a precious food for the full spectrum of populations, rich and poor, urban and rural. The contribution of fish to food is likely to increase as consumers become more conscious about the nutritional value of seafood. Stronger sustainability performance of the value chains could also have an important impact in terms of jobs and growth, in particular in coastal areas (FAO 2013, 2014).

One out of two citizens of the emerging world takes its animal protein from the sea. Ninety-seven percent of the world's fishermen are from the emerging world. Urban fish and wet coastal markets concentrating on the catch of the day are progressively replaced by supermarket chains with aquaculture products. The global development of aquaculture has been spectacular. Since 2014, aquaculture contributes more than capture fisheries to seafood at the world level. Food security programmes specifically tailored to meet the local conditions, and designed and implemented by the producers and consumers associations, are more likely to have a positive impact (OECD–FAO 2014).

For hundreds of years, fisheries had provided humankind with good quality food; then overfishing became a major global problem. It is estimated that 53 % of the world fisheries are fully exploited and 32 % overexploited, i.e. 85 % of the world's ocean fisheries are fully exploited, over-exploited or depleted. The world's fleet was evaluated to be 2.5 times larger than is necessary to sustainably catch global fish stocks. The combined engine power of the global fleet has grown tenfold since the 1950s and continues to rise. Illegal, Unreported and Unregulated Fishing (IUUF) and the negative financial incentives that maintain a global fishing fleet, with too many boats for an ever- diminishing supply of fish, represent a world plague. The global economy has lost $2.2 trillion in the last 30 years from fisheries mismanagement, reflecting technological advances and increased fishing subsidies (GOI 2013). Enshrined in the Rio+20 Declaration of 2012, the need to eliminate subsidies that contribute to unethical fishing and to overcapacity has to be thoroughly addressed. On the high seas, it is largely only States, mainly from the developed world and China, which can afford to subsidise their fleets with public funds (GOC 2014).

Other major problems for fisheries include eutrophication, as algal blooms can produce toxins which infect seafood. Climate change is also having an impact, since changing ocean temperatures affect the health and distribution of valuable fish stocks, and make efforts to sustainable management of fisheries more difficult. Cities could cooperate with States in eliminating harmful subsidies and close their harbours to illegally harvested fishes. The acceptable balance is a crucial challenge and cities should not undermine the health of global fisheries by ensuring food

security through products of subsidised industrial fisheries distorting the seafood markets.

The concept of "maximum sustainable yield", embedded in the United Nations Convention on the Law of the Sea, can be instrumental for the restoration of fisheries stocks. Managing capture fisheries according to maximum sustainable yield has been successfully implemented in many single-species fisheries. However, sustainable management taking account of fishery interactions, the way different fishing gears catch different mixtures of fish at certain place and times, and ecological interactions among different fish stocks predating on each other or competing for food, is still just beginning.

Sustainable fisheries can contribute much to the food security of cities. Food security issues have been among the most forgotten urban issues. Hardly raised during Rio+20, they are of paramount importance for eradicating extreme hunger and poverty, instability and uncertainty. A new framework for addressing food and nutritional security in both rural and urban areas is critical. The Chicago Council on Global Affairs proposed an Urban Food Model designed for policy makers and city leaders as an analytical tool to evaluate a city's current food security situation and to examine policy options (Chicago Council on Global Affairs 2013).

The importance of addressing urban food security is increasingly highlighted by studies indicating policy recommendations for the nutritional security of cities. Rapid demographic growth and urbanisation, dietary consumption changes, and more frequent and extreme weather phenomena linked to climate change bring enormous challenges to cities, many of which already face the overwhelming burden of providing basic services to poor citizens. Urban food security should advance hand in hand with sustainable trade practices. The global community has witnessed a revival of efforts since the 2007–2008 food price spikes. Discontent over poverty and food insecurity can be politically explosive in cities (FAO 2009).

The international community should acknowledge that poverty and food insecurity and malnutrition issues are serious urban problems. The need to address urban poverty, food security, and nutrition is equally critical in fragile states. The private sector should build linkages between a country's domestic food production and its urban markets, while public policy should pay special attention to the employment, health, and nutritional needs of the poor. More research is needed on the food security and nutrition needs of the urban citizens in the emerging world (CSIS 2013).

Fish production could well change due to global climate change. Warming oceans could result in distributional changes, with fish moving polewards or into deeper and warmer waters. Substantial changes in the dominant species are possible in the world's most productive marine ecosystems. In addition, ocean acidification is likely to change the composition of the plankton, with unpredictable effects on the fish populations.

Given the limited potential for further growth in world capture fisheries production, future demand will mainly rely on a substantial increase in aquaculture production. Global aquaculture has grown at an impressive rate over the past decades and could provide two-thirds of world fish production by 2030. Further substantial expansion of this production is possible, and even essential if world supplies of

fish products are to keep pace with human population growth. China and other countries are increasing their investments in aquaculture to help meet this mounting demand. European aquaculture is subject to strict environmental and animal health rules and follows very high standards of safety and sustainability (FAO 2013, 2014; OECD–FAO 2014).

Global freshwater aquaculture production is currently around 37 million tonnes annually and is growing at a rate of around 7 % per year. This production is important for local food security, but has probably little scope for expansion as the productivity of these areas is close to fully exploited. Marine aquaculture production is around 18 million tonnes, of which around 14 million tonnes shellfish and 4 million tonnes finfish. Marine finfish farming has a high potential for expansion but presently needs substantial marine protein inputs.

Aquaculture and capture fisheries are co-dependent, as feed for many high-value cultured fish is provided in large part from capture fisheries. They are also competitors for space in coastal areas, markets, and potentially for labour, and governmental support. Marked progress has been made in replacing feed sources from capture fisheries with agricultural production. Feed conversion and substitution of fish-based feed with products and especially waste from land-based agriculture and forestry could be instrumental.

Sustainable aquaculture promotes consumption and production patterns that preserve the natural resources basis. Main challenges include adequate space, feed, and the development of breeding technology. More space for marine aquaculture can be freed up by the development of extensive, offshore production systems that can use remote locations. Progress in feed technology could help marine fish to be produced more efficiently and with a higher than present proportion of feed of plant origin. Improvement of the breeding technology could make new species available for sustainable aquaculture. Marine shellfish farming requires limited inputs and provides important environmental services by removing nutrients from the water. This type of farming is particularly sensitive to water quality and research is focusing on selective breeding of the most resistant shellfish families.

Further development of aquaculture should consider many synergies. The development of offshore wind farms and/or tidal energy harvesting systems could create areas suitable for siting aquaculture installations, so allowing increase productivity. Integrated multi-trophic aquaculture, e.g. the integrated farming of algae or shellfish and finfish, could be further developed to ensure the optimal use of available space. Biofuels from cultivated algae could be developed in integrated multi-trophic aquaculture. The integration of activities such as angling and tourism in extensive aquaculture ponds could add environmental and landscape management services.

Both finfish and shellfish farming need appropriate sites and can be in competition for space with other coastal economic activities. Strategic planning for sustainable urban development tries to develop synergies among activities which are often seen as antagonistic, such as shipping, tourism, recreational fishing and aquaculture. Possible adverse environment impacts of aquaculture have also to be prevented and addressed. They include localised eutrophication events, changes in benthic communities, contamination from antibiotics and introduction of non-indigenous

species. The development of genetically-modified marine organisms tailored for high aquaculture productivity may offer benefits but also raise ethical issues for marine environmental protection and for social acceptance.

The development of offshore wind farms could create new areas suitable for aquaculture installations. Integrated multi-trophic aquaculture, i.e. the integrated farming of algae or shellfish and finfish, can ensure the optimal use of available space. Second-generation biofuels from residues of fish and algae could be developed and provide energy for shipping or coastal activities. The integration of activities such as angling and tourism in extensive aquaculture ponds could add environmental and landscape management services.

Coastal cities can also support the development of alternative fish production systems, investing for example in demonstration project of urban aquaponics, combining aquaculture with hydroponics, growing plants and vegetables in mineral nutrient solutions in a symbiotic environment. In an aquaponic system, water from an aquaculture system is fed to a hydroponic system and the by-products are used by the plants as nutrients. The water is then recirculated back to the aquaculture system. Coastal cities can offer the testing grounds for simulated wetlands with fish waste fertilising plants and the plants filtering the water. Aquaponics has been suggested by the STOA service of the European Parliament in 2015 as one among the ten technologies which could change human lives (STOA 2015).

3.3 Exploration and Preservation of Precious Marine Resources

Oceans cover most of the planet's surface at an average depth of 4000 m, forming earth's largest ecosystem and serving as the primary regulator of planetary chemistry. Every second breath that humanity takes comes from the oceans, which also provides invaluable marine resources and ecosystem services. Environmental health, food and energy security, transport, temperature and climate regulation, and carbon sequestration are dependent upon the global ocean.

Urban biodiversity maps of coastal cities traditionally include only what is above the land and omit the rich and diverse world under the waves and the marine wealth of the nearby seas and of the oceans. The 2010 the decade-long Census of Marine Life, a major international effort, brought impressive results and produced a comprehensive inventory of known marine life. The census investigated life in the global ocean from microbes to whales, from top to bottom, and from pole to pole and helped discovering more than 1200 new species, with another 5000 or more awaiting formal description (Snelgrove 2010).

Many of the discoveries necessary for the future of humanity are still immersed in the deep ocean. As little explored as the space that surrounds the Earth, the global ocean is a huge biogeographic puzzle. Some million species have been estimated, of which science has only described some 10 %. The first census established a baseline of marine life abundance, diversity and distribution, to help

understand, assess and foresee changes in the global marine environment, as well as to inform the conservation and exploitation of marine resources. New vision-expanding techniques included genetic barcoding for the identification of species, tracking methodologies and acoustic innovations. While advancing technology, scientists also set to work on standardising sampling protocols comparing species across the global ocean, and offering a clearer picture of marine populations (McIntyre 2010).

The census has created major legacies such as the data base OBIS (Ocean Biogeographic Information System), the world's largest open access, online repository of geo-referenced marine life data under the auspices of the UNESCO International Oceanographic Commission's programme and the International Oceanographic Data and Information Exchange. It has also supported frameworks to aggregate information about marine life, making it possible to estimate the number of species newly described by the entire marine taxonomic community.

Coastal cities can direct resources toward ocean exploration and health, leveraging assets at every level, from the municipality board to the chamber of commerce, citizen associations and the public transport and energy enterprises. Schools can be very creative in promoting ocean literacy that depicts the close relationship between cities and oceans. The spectacular global map from the Census of Marine Life that flips the perceptual field to emphasise oceans is a good example. Terrestrial areas are black or empty, while oceans are presented in blue, with underwater topography, habitats and migration patterns. Other maps are being made possible by new technologies that enable researchers to track previously invisible marine animal movements.

Cities across the globe interact with a significant diversity of species, habitats and ecosystems. Urban biodiversity surveys are essential and they have to equally consider the underwater and the terrestrial environment. The Comprehensive Marine Biodiversity Survey of Singapore launched in 2010 was the first concerted effort to comprehensively catalogue its marine biodiversity. Carried out in phases over 5 years, the survey brought together the broader community of experts, citizen organisations, government agencies and volunteers to collect biodiversity information on mudflats, intertidal areas, coral reefs and the seabed of Singapore. A diverse group of citizens, experts and organisations contributed to this large-scale, multi-disciplinary purposeful project.

Singapore hosts more than ten ecosystems within its bounds and the recent surveys have recorded more than 500 species of plants and animals new to the island, of which more than 100 are new to science. Cape Town is host to almost 50 % of South Africa's critically endangered vegetation types and 3000 indigenous plant species. Such urban development trajectories are critical for rich biological resources and their potential ecosystem services.

Ocean literacy can be a noble cause for coastal cities and link them to the conscience of the planet. Conscious coastal cities can raise awareness about the most crucial marine biodiversity threats. Each blue city can adopt a marine habitat or waterfront space or an exceptional underwater heritage site. School children can learn about the protected resource, neighbourhood associations can support cultural

exchanges, and corporate donors can fund research and intervention actions (UNESCO World Heritage Centre 2013).

Public institutions can promote a blue ethic that encourages informed personal engagement and enables shifts in public perceptions, policies and incentives. In Lisbon, the Oceanario, 1 of some 140 public aquaria in Europe, offers a promising model. The Oceanario attracts about one million visitors annually with its message of "One Ocean". Exhibits include information about lifestyle changes to reduce impact on the seas. The aquarium works with schools throughout Portugal to help teachers educate children about themes such as overfishing, or ocean acidification. Vasco, an ocean mascot recognised by children across the country, serves as a model of sustainable living.

With advancing climate change, the evolving role of the ocean merits particular attention. Blue carbon sequestrated by the vast sinks of the oceans and coastal ecosystems amounts at 20–35 % of anthropogenic CO_2 emissions, and plays an important role in mitigating the effects of climate change. Blue carbon sinks, including mangrove forests, sea grass beds, and other ocean habitats, can sequester up to five times as much carbon as tropical forest. Mangroves are reputed to be outstanding carbon sinks, able to accumulate, store and sequester carbon, but 20 % of these have been lost between the years 1980–2005. Tidal marshes and sea grasses are also being destroyed at a rapid pace. These ecosystems have stored carbon for centuries and also provide other ecosystem services, including supporting fisheries, contributing to clean coastal waters, and protecting coasts from floods, storms and erosion. Coastal cities can play an important role to enhance coastal blue carbons through the prevention of threats to these ecosystems, including pollution and unsustainable coastal developments and the restoration and sustainable use of coastal and marine ecosystems (Rockefeller Foundation 2014).

Ocean acidity, "the other CO_2 problem", has increased by 26 % globally since the industrial revolution and is projected to further increase unless global carbon emissions are significantly curtailed. It could cause irreversible damage to marine species. Informing society about the growing threats of ocean acidification through education and outreach is essential (IPCC 2014).

Global marine ecosystem services are likely to be impacted by the acidification of the seas. The effect of ocean acidification on marine crustaceans can be very harmful, as decreases in survival, growth rate, and egg production have been reported for some species. Effects on non-calcifying organisms have also been demonstrated, including on the development of larval stages of some fish and on the ability to detect predators. Reduced survival and growth of sea urchins, sea stars, sea cucumbers, and brittle stars may also occur.

Ocean acidification is projected to differ among regions. Tropical waters hosting coral reefs are expected to experience the greatest overall change and polar waters may become corrosive by 2100. Socio-economic modelling suggests that the impacts on marine habitats and marine resource availability can be serious and cause substantial revenue declines, job losses, and economic costs. Effects to human communities would include changes in shellfish harvest, coral and oyster reef ecosystem services and indirect impacts across marine food webs. Coral reefs provide

a habitat for an estimated one million species and offer food, income generation for tourism, and coastal protection against storms for about 500 million people globally (Gore 2013; NOAA 2013). The alterations could be irreversible and unbearable.

Some started already grieving for exceptional reefs. The Economist previsions for 2015 alerted that the Great Barrier Reef, the world's most complex expanse of coral reefs extending about 2300 km along Australia's eastern state of Queensland, is in danger. The Great Barrier Reef is a natural monument, hosting 400 types of coral, 1500 fish species, whales, dolphins, seabirds and turtles. But the reef has never been more threatened. Over the last decades, the reef's coral has been disappearing. Marine scientists largely blame rising sea temperatures and acidification, linked to climate change, and nutrients and pesticides entering into the Coral Sea and the Pacific Ocean. Thirty-four years after having listed the reef as a World Heritage Site, UNESCO will decide in June 2015 whether to add it to the World Heritage in Danger list (UNESCO World Heritage Centre 2014).

The federal and Queensland governments produced a draft plan in late 2014 for protecting and managing the reef up to 2050. Its tourism industry, worth about $4.6 billion a year to Queensland alone, is founded on the health and the natural beauty of the Great Barrier Reef. Visitors to the Great Barrier Reef can enjoy many experiences including snorkelling, scuba diving, aircraft or helicopter tours, glass-bottomed boat viewing, semi-submersibles and educational trips, cruise ship tours, whale watching and swimming with dolphins. All these activities are undermined from the risks to the sustainability of the Reef (Economist 2015).

3.4 Building Strong Urban Resilience to Climate Change

Planet Earth is already 0.8 °C warmer in average than in pre-industrial times. As all average values, this conceals an array of unequal realities and impacts. Communities around the world could experience the harsher impacts of a 2 °C warmer world within 20–30 years, and 4 °C is likely to happen by the end of the century in the absence of decisive concerted global action. International scientific cooperation has been intense and global governance was organised around the Kyoto Protocol, which became law for the 141 countries that had ratified it by 16 February 2005. The Lima Accord, reached at the conclusion of COP 20, marks the first time that all nations have agreed to cut carbon emissions. Although non-binding, it is an encouraging development that sets the stage for more action ahead towards the next steps which will define the post-2015 horizon.

Many analyses describe the COP 21 (Paris, December 2015) as the last chance milestone and suggest that the sooner countries prepare for the inevitable march of time towards a low-carbon future, the better and the less costly. The longer countries wait, the more their carbon-intensive assets will lose value in a low-carbon future. Economies that are not planning their transition to a low-carbon future are vulnerable to unpredictable events such as consumers and investors turning against carbon-intensive assets.

Political decisions involve value judgments, but scientific knowledge can play a key role in, for example, analysing the potential effects of climate change, and their likelihood, identifying and evaluating the potential consequences of various policy responses, expanding the portfolio of possible options, and improving the effectiveness of policies. Robust and long-term climate observations are crucial for reliable foresights and evaluations to illuminate and orient political action. A call for a new era of climate change science and policy highlighted the importance of "citizen-inspired" research, which not only improves understanding of the causes and consequences of climate change, but assists decision makers at the local, regional, national, and international levels in mitigation and adaptation actions (NRC 2010).

Cities are both drivers of climate change and privileged places of concentrated climate responses. The decade 2001–2010 was the warmest period ever recorded. The past few decades have been warmer than any other comparable period for at least the last 400 years. Limiting the global average warming to 2 °C above pre-industrial levels and ensuring the survival of humanity on Earth is likely to require emission reductions larger than 80 % below peak levels (IPCC 2013; Footprint Network et al. 2012).

Cities represent a leading force for global action on climate change. Economic growth mainly taking place in cities has been the main cause of the continuous increase of CO_2 emissions since 1990. Climate change is partially resulting from millions of decisions made by the world's citizens within their immediate environments. In 2007, urbanising China overtook the US as the biggest emitter of the world. It is not urbanisation per se, but rather higher levels of income and the related consumption patterns that drive the higher GHG emissions. Urgent action is needed in both the developed and the emerging world, in anticipation of a new investment cycle of capital renewal and expansion, mainly for urban infrastructures.

Cities have a responsibility to create solutions to climate change. Acting both locally and in network, they can have a meaningful global impact. Each city is unique in its morphology, culture, infrastructure, municipal services, and potential impacts to and from climate change. However, the underlying drivers of emissions in cities largely reflect the same inefficiencies and include energy losses, traffic congestion, unsustainable resource and waste management, water leaks and biodiversity losses.

The impacts of climate change pose significant social, environmental and economic threats and risks to the urban, national and global communities. Coastal cities are particularly vulnerable. More frequent and extreme weather events, especially rains and floods, heat waves and droughts, increasing temperatures and rising sea levels seriously affect livelihoods, food and energy supply, infrastructure, ecosystems and society and the economy as a whole. Concerted responsible action guided by unshakable commitments and assisted by performance monitoring and reporting, can help build a strong case for local climate action. Most climate-conscious cities involve citizens and local stakeholders in climate commitments to mobilise action and provide guidelines for implementing policies to reduce greenhouse gas emissions.

High urban densities and short distances yield many opportunities for low-carbon lifestyles, such as the use of cycling paths or public transport. In most countries, energy use per capita of urban residents is lower than the national average. In cities

in the emerging world, climate impacts may aggravate poverty conditions and social inequalities. Climate change could also exacerbate other existing knotty environmental problems such as low air quality and poor water supply. More and more climate reports warn that poor cities and communities are the most vulnerable to climate change. As the coastal cities of Africa and Asia expand, many of their poorest residents are being pushed to the edges of liveable land and into informal settlements often clustering in low-lying areas with poor public infrastructures and services and inadequate protection from storm surges, and flooding (World Bank 2013).

In the industrialised world, many cities engineer advanced protection measures. Venice plans ingenious gates, the Experimental Electromechanical Module, a flood barrier system, to seal the lagoon and tame the destructive tides. The city is notoriously vulnerable to flooding and "aqua alta", the Adriatic's high tide water, which partly caused its sinking by 23 cm during the twentieth century and became more frequent over the last years. The rise in sea level could be very impactful, since it is estimated that, in the absence of drastic measures, a 30 cm rise in sea level would flood St Mark's Square 360 times a year. The completed project is expected to include 78 mobile barriers blocking the three inlets to the Venice lagoon. The barriers will be housed in enormous tanks anchored to the seafloor and will rise whenever high water threatens to flood the city. Once the threat is over, the released air will allow the barriers to sink down again. The system would only be mobilised to address the most extreme risks.

Climate change happens everywhere but it impacts very differently the cities of the various world regions. Water scarcity in some areas and overabundance of water in others are the hallmarks of climate change in many parts of the globe. Inconsistences in the monsoon season and unusual heat extremes may have extremely serious consequences. Dhaka, Kolkata and Mumbai may be confronted with increased flooding, intense cyclones, sea-level rise and warming temperatures. In South East Asia, coastal cities may have to face intense stress. A sea-level rise of 30 cm, possible by 2040 if inaction continues, would cause massive flooding in cities and inundate low-lying cropland with saltwater corrosive to crops. The Mekong Delta, in Vietnam, a global rice producer that is particularly vulnerable to sea-level rise, could lose much of its crop production (World Bank 2013).

The most affluent global cities have to show the way forward. In Tokyo, the top coastal world city, most major corporations, such as Sony and Shimizu, are proud of green low-emission headquarters. The government suggests that the era of eco-buildings is rising on the megacity. In 2010, Tokyo introduced the first urban cap and trade programme in order to reduce its GHG emissions and reach its target of 25 % less emissions by 2020 comparing to its 2000 emissions. The scheme covers 1400 installations, including 1100 business facilities and 300 factories which are large CO_2 emitters. Although these account for only around 0.2 % of some 700,000 industrial and commercial facilities, their carbon dioxide emissions in 2007 stood at about 20 % of total metropolitan emissions. Carbon revenues have to be truly and transparently invested in sustainability projects. Most successful campaigns insist on the good communication of tax reforms so that the carbon taxes are not perceived as part of an intelligent structural tax reform (Tokyo Metropolitan Government 2010).

The cap for the first compliance period (2010–2014) has been set at a level of 6–8 % below 2000 emissions and for the second compliance period (2015–2019) at a level of 15 %. Monitoring is permanent and compliance assessment follows the completion of each phase. Mandatory reporting of emissions is an important prerequisite and asks for the cooperation of all, in order that consensual action is implemented. Annual reports insist on the importance of a well-designed consultation process and the capacity of the programme to bring together developers, owners and tenants to curb CO_2 emissions in buildings. The second year report presents remarkable results, far beyond obligations. In total, a 23 % reduction was achieved versus the obligation for 6–8 and 93 % of the participating facilities overpassed their obligations (Tokyo Metropolitan Government 2012).

Coastal cities, like Amsterdam and London, acted early and formulated climate objectives and targets, conceived mitigation and adaptation policies and created dedicated agencies to monitor progress in achieving the objectives. Many cities see adaptation as an opportunity for better urban planning and policy to develop the adequate infrastructures, improve quality of life and create new innovation trajectories and employment possibilities.

In order to confront the challenge of climate change as an opportunity rather than a threat, the City of Rotterdam launched the Rotterdam climate-proof programme in 2008 with the aim of making the port-city resilient to climate change by 2025. Permanent protection and accessibility of the Rotterdam region are key elements. Rotterdam has started to adapt in order to strengthen its position on the global chessboard. The central focus of the adaptation programme is to create and grasp further opportunities to make Rotterdam a more attractive city for citizens, visitors and investors. The Rotterdam Climate Initiative aims at improving the climate for the benefit of people, the environment, and the economy. The initiative adopted an integrated approach and ten sustainability tasks (City of Rotterdam 2010). Since the end of 2013, Rotterdam has its Climate Change Adaptation Strategy to prepare for Climate Change. Furthermore, the city, which lies 6 m below sea level, making it the lowest city in Europe, is helping Jakarta in developing a dredging plan. Amongst other things this includes Dutch floating bulldozers being used to deepen rivers, decreasing the impact of flooding during extreme rainstorms.

In 2007, Boston developed a city-wide Climate Action Plan. The plan aims at reducing greenhouse gas emissions 25 % by 2020 and 80 % by 2050, through taking into account climate in all formal planning and project processes, engaging all communities and developing innovative businesses and skills to take advantage of climate action opportunities. The city was the first in the region to adopt Green Building Zoning, and to include climate resilience to the large new construction review process. Additionally, a Green Ribbon Commission brings together businesses, non-profits, and community leaders from a variety of sectors to develop shared strategies for fighting climate change in coordination with the city's Climate Action Plan, which is being updated every 3 years.

Boston has been designated among the cities of the first cohort of the US Climate Action Champions (White House 2014). A Climate of Progress, launched on Earth Day 2011 encompasses the recommendations from the Climate Action Leadership

Committee and the Community Advisory Committee. Boston's update climate action plan, launched in 2013, focused on climate preparedness and community engagement. The city is interested in developing indicators to assess progress in achieving its climate objectives. The City of Boston, the Boston Harbour Association, EcoAdapt, and SeaPlan are working together to develop and vet a climate change preparedness indicators framework to track and evaluate progress (Boston Foundation 2011).

The climate of the New York metropolitan region is changing, with annual temperatures getting hotter, heavy downpours increasingly frequently, and sea levels rising. In New York City, the creation of the Office of Environmental Remediation and the release of the Sustainable Stormwater Management Plan marked more steps forward. The second phase of "Schoolyards to Playgrounds" was launched for municipal buildings as part of the commitment to reduce City government greenhouse gas emissions. The New York City Panel on Climate Change (NPCC), an independent body that advises the City on climate risks and resilience, works in partnership with the City, to assist achieving the most ambitious target of reducing GHG emissions by 80 % by 2050.

The NPCC latest report includes climate projections through 2100, new coastal flood risk maps to the end of the century for the current 100- and 500-year coastal flood events, enhanced dynamic flood inundation modelling of future coastal flooding that includes the effects of sea level rise, a review of key issues related to climate change health risks for citizens and a process for enhancing a New York City climate resiliency indicators and monitoring system. Mean annual precipitation has increased at a rate of approximately 0.8 in. per decade over 1900–2013 in Central Park. Sea level rise in New York City has averaged 1.2 in. per decade since 1900, nearly twice the observed global rate of 0.5–0.7 in. per decade over the same period. These trends are projected to even worsen in the coming decades. The mean annual temperatures are projected to increase by 4.1–5.7 F by the 2050s, and the mean annual precipitation to grow from 4 to 11 % by the 2050s. The frequency of heat waves is projected to increase from two per year to roughly six per year by the 2080s. Projections for sea level rise in New York City, in relation to the 2000–2004 base period, suggest an increase between 11 and 21 in. by the 2050s and between 22 and 50 in. by 2100, with a worse case projection of up to 6 ft by 2100 (NPCC 2015).

Copenhagen's 2009 Climate Plan was a conscious milestone and the first in Scandinavia. Copenhagen pledged to become CO_2 neutral by 2025 and provide the world an international gold standard for sustainable cities. In order to achieve its ambitious goal, the city has established precise targets including for energy efficiency and renewable energy sources, and green building standards. All new buildings have to be carbon neutral by 2020. Cycling rates exceed 40 % of all commutes. The city also developed a smart bike equipped with sensors to provide real-time information not only to riders but also to administrators for open data aggregation on issues of air quality and traffic congestion.

As most coastal cities, Copenhagen has a symbiotic relationship with the sea, strengthened and demonstrated in times of heavy thunderstorms and exceptional rain levels. A network of temporary reservoirs was built, already in the 1990s, to store excess rainfall and wastewater, preventing the overflow of sewage systems and the

risk of flooding in the city. The works also improved the surrounding environment. Since then, the water in the harbour is clean enough for swimming. More frequent intense rain could require infrastructure expansion in the future to maintain the achieved high standards, along with other measures to increase the city's resilience to climate change. A torrential rain in 2010, a once in 100 year's event, stressed the vulnerability of the city and put enormous pressure on its drainage infrastructure.

The Climate Plan asked for green roofs to be integrated in city policy instruments. One of the district plans focuses on North Harbour, one of the largest urban developments in Northern Europe. The long-term vision for the area is to turn it into a true and diverse city district, hosting up to 40,000 citizens. The creation of North Harbour made strides towards the combined model of an eco-friendly city, a vibrant city, a city for all and everyone, a city by the water, a dynamic city and a city with sustainable energy and mobility (EC 2013a).

The Copenhagen Green Roofs offered an inspiration for Recife, in Brazil. The Green Roof Law approved by the Municipal Council of Recife in 2014 requires buildings with more than four floors to have their roofs covered with native vegetation. The Torre Charles Darwin, a 35-storey building in the city centre, serves as the first example of a green roof building. The building will have a cover crop of 2.8 million square feet, along with a rain harvesting tank to power the air conditioning system. The city has more to showcase as member of a world league of excellence. As much as 46 % of the city's total area is green, 60 % of which is protected under conservation laws. A plan for enhancing bike lanes and the creation of bus corridors to facilitate commuters and reduce private cars are among the initiatives undertaken by the city government to reduce its impact on the environment and greenhouse gas emissions. The Apibaribe River Navigability Project is focused on ensuring that the 6 rivers and 66 canals of the city are used as alternative sustainable routes.

The national-local dialogue is crucial to reduce GHG emissions. The Local Government Climate Change Leadership Summit, in June 2009, was a prime milestone in the process leading up to the climate change COP 15 in Copenhagen, in December 2009. It advocated for a national-local dialogue and a partnership with cities to reduce GHG emissions. The City Climate Catalogue, an interactive instrument highlighting accomplishments versus objectives, was launched 5 months earlier to provide a substantial contribution to national governments in the international climate negotiations. All cities are invited to contribute their greenhouse gas reduction targets and engage in concerted actions to achieve and overcome them.

The Durban Adaptation Charter, adopted in 2011, recognises that the majority of climate change impacts and the appropriate proactive and reactive responses will occur at the local level. It marks a clear milestone in inviting local governments to adopt a holistic ecosystems-based approach for developing secure city-region food systems, work for urban poverty eradication, protect and enhance local biodiversity and strengthen urban resilience. The charter stressed that the costs of adaptation and loss and damage resulting from climate change should be covered from local, subnational, national and global sources. It called for new modalities of interaction for local and subnational governments in order to fulfil their role as critical stakeholders and decisively contribute to national and global effort for a better future for all.

Alliances among cities working together to decrease emissions are extremely important for mutual awareness and noble emulation. The World Mayors Council on Climate Change is an alliance of committed local leaders concerned about the contribution of their cities to climate change. The Council was founded in December 2005 by Y. Masumoto, Mayor of Kyoto, soon after the Kyoto Protocol entered into force in February 2005. The members of the Council advocate for enhanced engagement of local governments as stakeholders in multilateral efforts addressing climate change and related issues of global sustainability.

The C40 coalition, also created in 2005, forged a partnership in 2006 with the Cities Programme of Clinton's Climate Initiative (CCI) to reduce carbon emissions and increase energy efficiency in large cities across the world. In less than a decade, the coalition positioned itself as a major global actor for implementing meaningful and sustainable local actions to help address climate change. In 2011, the C40 created new partnerships with the World Bank and ICLEI to accelerate climate action in cities through streamlined financing, greenhouse gas accounting and uniform reporting. The release of two reports developed in collaboration with the Carbon Disclosure Project and Arup respectively, emphasised the critical role of measurement and transparency in tackling climate change in megacities.

Both for cities and companies, measuring and disclosing the amount of emissions are the first steps for preventing and mitigating global warming and also creating a new culture for adaptation. The Carbon Disclosure Project (CDP), a non-governmental international endeavour, launched a transformative global system for cities and businesses to measure, disclose, manage and share climate change and water information. The CDP brought together over thousands of organisations across the world's largest economies to report their greenhouse gas emissions and share their assessed climate change risks and opportunities, in order to set reduction targets and improve performance. Some leading companies have moved to become carbon neutral, while other organisations managed to reduce greenhouse gas emissions by adopting ambitious initiatives.

In 2014, 207 cities disclosed their climate mitigation, adaptation and water management data. Cities also reported 757 adaptation activities and 102 urban climate adaptation plans. Cities are reducing the climate risks faced by citizens and businesses through investment in well-performing infrastructure and services and by developing impactful policies and incentives. The benefits that business brings to cities, including jobs, tax revenue and services, are among key drivers for cities to improve their climate resilience. Similarly, businesses are reliant on public infrastructure and policies to support and guide their operations. Both public and private sectors can benefit from a greater understanding of each other's climate change risks, and companies can help reduce city-wide risks by embedding local adaptation needs within their operations (CDP 2014a).

Transparent disclosures, including to investors and citizens, enables local and regional authorities to underline commitment, reduce risks and associated insurance costs, and demonstrate their visions and values in a competitive globalised world. There is significant opportunity for cooperation between governments and business to improve climate resilience. Companies worldwide seem already ahead of their

governments in planning for climate change risks, costs and opportunities. They are calling for clear pricing and regulatory certainty in order to better plan their activities and their climate-related investments, and more secure, interconnected carbon markets (CDP 2014b).

Peer pressure and network emulation are crucial for mitigation and adaptation. The CDP Public Procurement Programme channels information through five distinct programmes, one of which focuses on cities. The project is designed to enable local and national governments to create new climate-friendly markets. This is an effective way for local and national governments to ask their suppliers about energy consumption patterns and climate implications. This information allows governments to better understand climate change risks, which in turn can help work towards building a low carbon government supply chain.

Climate change risk assessment is increasingly being adopted by coastal cities. In search of an advanced methodology, the EC-supported RAMSES project presented urban climate impacts and estimates of adaptation costs and benefits using a common currency. The aim is to empower policy makers, businesses and the civil society to make direct comparisons across cities and activities. The project offers a generalised approach on key infrastructures and characteristics and their relation to climate mitigation and adaptation. This is complemented with selected case studies and simulations of the effects of climate change. The analysis of the institutional and political context can help establishing the transition strategies for specific cities including Antwerp, London, New York and Rio de Janeiro. The project is expected to improve understanding of urban systems and provide quantitative evidence of the costs and benefits of mitigation and adaptation in cities.

Awareness about the effects of climate change before extreme events occur is necessary for drastic changes in city and regional management. Innovations bringing multi-dividend responses are the most powerful. Strong ecosystem-based spatial planning especially for risk-prone areas can be an effective and sustainable way to deal with risks. Keeping public space and buildings cool by using for example green roofs, rather than air conditioning, could help saving energy and resources.

Extreme weather events resulting in hazards such as heat waves, floods and droughts are expected to happen more frequently and affect quality of life for citizens and attraction of visitors. Urbanisation, population ageing and other socio-economic trends interact with climate change and can compromise public health, reduce productivity and constrain the functionality of infrastructures. An ageing population in OECD cities increases the share of citizens vulnerable to heat waves and asks for additional urban services.

Urbanisation can increase the vulnerability of places and ecosystems. The replacement of natural vegetation with artificial surfaces and buildings impacts temperature, moisture, wind and rainfall patterns. Excessive amounts of rain water cannot drain into the ground, especially in sealed urban areas, and this can generate or worsen floods. Artificial surfaces store heat and cause higher temperatures in cities compared to the surrounding agricultural or forest land.

Most cities initiated their adaptation journey and adopted plans to reinforce their capacity to withstand threats. Copenhagen's Climate Plan includes an adaptation

plan with a range of interlinked environmental initiatives. To reduce the risk of flooding, vegetation throughout the city expanded through green walls and roofs, as well as through the creation of a network of "pocket" or "climate parks", i.e. small green spaces artfully integrated in the urban fabric. Well-designed small green areas dotted throughout the city can slow rainfall run-off and reduce the risk of flooding.

Green and blue areas help the city to cool down during summer months and cope with the expected higher temperatures. Sea and vegetation areas have an immediate refreshing effect as they hold moisture and release it into the air. Conversely, artificial surfaces tend to absorb and retain heat. Furthermore, beaches and parks also increase recreation spaces for residents and visitors and improve conditions for biodiversity and human well-being. Clean urban beaches, often after "dirty waters", as in Boston, provide clean bathing waters.

Melbourne's adaptation action began in 2008 with the publication of "Future Melbourne—City of Melbourne" which acknowledged that climate change presents key strategic risks for the community and must be collectively addressed. By 2030, Melbourne is likely to be significantly affected by warmer temperatures, drought and heat waves, lower rainfall, intense storm events, sea level rise and flash flooding. The plan for the future direction of the city was developed through open collaborative public engagement with key stakeholder groups including professional networks, other city councils, the Victorian and Australian Governments, universities and non-government organisations. Future Melbourne provided the impetus to undertake a comprehensive climate change risk assessment, culminating in an integrated City of Melbourne Climate Change Adaptation Strategy and supporting Action Plan and the ongoing implementation of action plans enhancing the resilience and diversity of urban forests, and design strategies for cool roofs to reduce the Urban Heat Island effect (C40 Cities and Siemens 2014).

In the European Union, the Adaptation Strategy focuses on promoting action by Member States, devising climate-proofing action at EU level ensuring that Europe becomes more resilient and decision-making better informed. The "EU Cities Adapt" project was launched in 2012 together with the European Climate Adaptation Platform (http://climate-adapt.eea.europa.eu), the "one-stop shop" for information and policy advice, to help cities adapt. The Initiative "Mayors adapt—the Covenant of Mayors Initiative on Climate Change Adaptation" was promoted to engage cities in taking decisive action to adapt to climate change. Cities signing up to the initiative commit to contributing to the EU Adaptation Strategy, through a comprehensive local adaptation strategy or the integration of adaptation measures into relevant existing policies. Mayors Adapt aims to increase support for local adaptation activities, provide a platform for greater awareness and networking, and a heightened attention and public dialogue (EC 2013c, EEA 2012).

Resilience fortifies the immunity of cities against irreversible losses. Resilient cities and communities are the ones that have citizens, businesses, institutions, organisations, assets and flows which can withstand economic, social, environmental and political threats without serious interruptions or irreversible damage. Cities reaching turning points in many regions of the world should invest as early as possible to prevent disasters. European cities have started providing models for the

design and organisation of urban transformation processes and the mainstreaming of adaptation measures into spatial planning. The success of the annual global forums on Resilient Cities which attracts experts and decision makers to Bonn, every year since 2010, signals the interest of local governments in adaptation and urban resilience. Handbooks for making cities more resilient contributed to the global campaign 2010–2015 (UNISDR 2012).

The Mayors Adaptation Forum, the leadership segment of the annual global forums on Resilient Cities, fosters close dialogue between local and global leaders, engages in a comprehensive debate of all major strategic issues linked to urban resilience and helps advancing towards concrete political commitments. The 2013 Bonn declaration of Mayors, during the adaptation forum, expressed concern that the historical threshold of 400 ppm CO_2 was crossed in May 2013, underlined the inter-linkage between climate change action and the overall development agenda, and confirmed commitment to globally coordinated local climate action. The declaration welcomed the Durban Adaptation Charter as a powerful mechanism to enhance urban adaptation action by building networks of communication and cooperative action among local governments world-wide, creating a global platform for the dissemination of best practice.

The 2013 Open European Day coincided with the final conference of "EU Cities Adapt", a key event for urban adaptation in Europe. In this framework, European cities, in different stages of adaptation, have worked together towards well-informed and enhanced actions on climate change adaptation. This Open European Day, jointly organised by ICLEI, the European Commission and the European Environment Agency, became a regular annual platform for European cities to exchange experiences on practical challenges and solutions towards local climate resilience. The 2014 event focused on vulnerability and risk assessments, the economics of adaptation and multilevel-governance cooperation and approaches (ICLEI 2014).

In the US, the White House announced measures to help cities adapt in autumn 2014. A task force of US governors, mayors and other leaders focused on recommendations for policies to incorporate climate change and provide tools to help local communities better design their adaptation measures. A Web-based climate resilience toolkit has been designed to help local leaders adopt measures to prepare cities for facing extreme events of rising sea levels, droughts, diseases and other climate impacts. Building a culture of resilience is a shared responsibility among citizens, the private sector, and governments. Sixteen local and tribal communities were selected as Climate Action Champions for their decisive action to cut carbon pollution and build resilience. The selected communities benefit from facilitated peer-to-peer learning and mentorship (White House 2014).

In the emerging world, poverty and informal housing neighbourhoods undermine resilience and social cohesion. Although the poorest metropolitan area in South Africa, Durban strives to be a global leader in climate change adaptation. Rich in its racial, linguistic and cultural mix, including English (49.8 %), Zulu (33.1 %), Xhosa (5.9 %) and Afrikaans (3.6 %), Durban is actively exploring ways to adapt institutions, systems, and processes in order to facilitate integrated, innovative, and flexible planning for a more secure future. This approach can help build the foundation for a more resilient society, economy, and governance.

Present and future buildings and urban infrastructure need huge investments, alongside those for climate proofing, in order to continue supporting urban services even under extreme phenomena. Urban planning and architecture should incorporate lessons from humanitarian emergencies and the creation of temporary shelters for refugees. Social innovations can also unlock multiple opportunities. Climate change adaptation concerns have to be incorporated into building design and standards and eco-retrofitting activities, to ensure that systems can respond under heavier conditions. Adaptation is strongly reinforced through green and blue infrastructure such as parks, wetlands, green walls and roofs, and ocean gardens, wherever feasible and sustainable.

Community resilience is as important as the resilience of the built environment. The US National Academies of Science Koshland Museum celebrated its tenth anniversary in 2014 with the opening of the Idea Lab, a space for visitors to experiment with new approaches to building community resilience, citizen's ability to come together to prepare for, absorb, recover from, and adapt to adverse events. Immersions in interactive games helped in addressing the fundamental questions and creating a model of a resilient coastal city with a jumbo jigsaw puzzle. From disaster simulation and the mapping of risks to alerts and connection to resilience networks, citizens had the opportunity to experiment and engage with uncertainty.

3.5 Blue and Green Urban Eco-Cells, Eco-Organs, Eco-Functions

To lead to sustainable development, cities have to continuously regenerate their bodies, their blood, their vital organs and nerves, but also their minds, with their individual ideas and concepts, and their souls, with their emotions and capacity to wonder. Coastal cities have also to regenerate their marine cells. Recent concepts of innovative cities include the flexible and even instantaneous cities that can adapt instantly, and the frugal or lean city, which enhances innovations to optimise resource use and minimise the generation of waste. Better use of resources in coastal cities is essential for preventing pollutants entering the marine environment. This also links to the concepts of circular or sufficiency economy.

Frugal ideas may inspire innovations for cutting urban costs to the bone, overcoming fragmentation among land and the sea, and leading to flexible modular amphibious products and processes. Frugal urban innovations exploit new possibilities focusing on the epitome of minimalism with all the functions stripped down to their bare essentials. From the initial invention to the final transformation, a chain of interactive processes can bring a thorough change that can further open up an array of opportunities (Haëntjens 2012).

Land, air and water are fundamental resources for all urban settlements. Urbanisation increases pressure on all ecosystems and results in soil, water and air pollution. Forests are being transformed into agricultural land or urban areas. Soil is a living medium which supports human life. It is a vital, natural, multifunctional,

largely non-renewable resource that has to be sustainably managed. Soil sealing, the covering of the ground converted into urban land by an impermeable material, is one of the main causes of soil degradation. The expansion of grey infrastructure and urban engineering projects has disastrous consequences for biodiversity. Soil sealing often affects fertile agricultural land and fragile shores and results in the loss of important ecosystem services, such as food production, flood protection and biological diversity. It also increases the risk of flooding and water scarcity and contributes to climate change.

Everywhere in the world, land consumption has grown at more than twice the rate of population growth. In the European Union, an area five times that of Greater London has been consigned to urban sprawl during the last decade of the twentieth century. Comprehensive survey results for the years 1990–2000–2006 suggest that discontinuous peri-urban areas grew far more rapidly than continuous urban areas Although artificial cover accounts for just 4 % of the EU's surface, its intense use and multiple fragmentation and dispersion makes its impacts directly affect more than a quarter of the EU territory (EEA 2006).

The USA experienced large waves of urban sprawl and a surge of suburban satellite developments which sometimes expanded two long fingers on coasts from both sides of a city and some fingers radiating towards the hinterland and across major transport axes. Despite the fact that residential development along the coast affects only 17 % of the total US land, it creates a disproportionately higher impact (Beach 2002).

The extension of urban areas into previously green coastal areas allows some citizens to enjoy more living space in single-family houses, surrounded by gardens and with access to the nature and/or the sea. But it can create serious negative environmental, social and economic problems for society, in particular in the case of low density and scattered urban sprawl. These include increasing travel flows and energy consumption which affect air quality and coastal erosion.

Dispersed low-density residential developments far away from essential places such as work, home, school, and services, and highly-dependent on a car for travel, has increased the fragmentation and degradation of critical ecosystem services in the coastal environment. Important ecosystem services, such as the removal of pollutants from air and water, the mitigation of floods and drought, the protection of coastal shores from erosion and open space and wildlife habitat for recreation, are threatened with disruption and impairment.

Air pollution critically affects humans in both natural and built environments. Poor air quality, both ambient and indoor, can cause respiratory and other serious diseases. The primary source of air pollution is the combustion of fossil fuel in energy generation, industrial processes and transport. Exposure to air pollution is largely a multi-pollutant process, and, in coastal cities, shipping is a major contributor. Nitrogen oxides (NOx), particularly nitrogen dioxide (NO_2), are known to cause specific damage to lung tissues and to contribute to acidification, eutrophication and photochemical smog. The great majority of NOx emissions are produced by energy production and consumption. Despite cuts in nitrogen oxides and non-methane volatile organic compounds, air pollution due to ozone persists. Heat waves can further boost ozone exposure. Particular matter from transport and construction is another

major polluter. In USA, more than half of citizens live in areas that do not meet the health-based air quality standards established by the Environment Protection Agency (NOAA 2012). In emerging countries, air quality problems could seriously undermine development and need particular attention from the scientific and policy community (Friends of Europe 2013).

Some emerging cities are notoriously polluted. According to a report by the Ministry of Environmental Protection, only 3 out of 74 Chinese major cities were able to meet national air quality standards in 2013 and 11 of China's most polluted cities were among the 13 cities in the Beijing-Tianjin-Hebei area. Even in the EU, the air pollution problem is still far from being solved, despite falling emission levels and reductions of some air pollutant concentrations in recent decades, and the European cities being among the cleaner in the world. Particulate matter and ground-level ozone continue to be a cause of breathing problems and cardiovascular diseases. Large parts of the population do not live in a healthy environment. Between 2009 and 2011, up to 96 % of city dwellers were exposed to fine particulate matter concentrations above WHO guidelines and up to 98 % were exposed to ozone levels above WHO guidelines. Lower proportions of EU citizens were exposed to levels of these pollutants exceeding the limits or targets set out in EU legislation, which, in some cases, are less strict than WHO guidelines (EEA 2013).

An innovative approach for making citizens highly aware about air quality is by making information available on a platform such as "Dublinked" in the Irish capital. Measurements from five air monitoring sites around Dublin city provide hourly results for Sulphur Dioxide (SO_2), Nitrogen Dioxide, Carbon Monoxide (CO), and particular matter. Black smoke monitoring is also carried out although this has been scaled down since the introduction of the coal ban in heating in the early 1990s (EC 2013b).

In coastal cities, the shipping industry has to become cleaner. Making shipping greener and preventing pollution was one of the original aims of the International Maritime Organisation (IMO), set up in 1948. Environmental rule-making has intensified in recent years as pollution became more serious. The International Maritime Organization asked to limit the sulphur content of maritime fuel, especially in emission-control areas along heavily populated coasts in North America and Europe.

Major port cities cooperate with the maritime industry to reduce air pollution. They have committed themselves to reduce greenhouse gas emissions through the World Port Climate Initiative (WPCI), impacting the sustainability of supply chains, taking into account local circumstances and port management structures. Shipping firms are also under pressure to cut their emissions of carbon dioxide and other greenhouse gases. The IMO reckons that ships cause about 2.7 % of total man-made emissions, a little more than planes but much less than cars and trucks. Ships will have to introduce fuel-economy measures with the aim of reducing their emissions by 20 % by 2020 and 50 % by 2050. The IMO is also pressing on with planned new rules on cleaning up ships' ballast water. An estimated 60,000 ships worldwide would need refitting with one or more cleansing units.

Making shipping greener is subject to technical, organisational, economic and social innovation. The shipping industry is showing increased interest in the use of

Liquefied Natural Gas (LNG) as a cleaner transition fuel towards renewable sources and a decarbonised future. Sulphur and particle emissions would be reduced to almost zero, nitrogen oxide emissions by 85–90 % and net greenhouse gas emissions by 15–20 %. Industrial partners and stakeholders, including port authorities, fuel suppliers and shipping companies, ask port cities to prepare to offer safe storage and bunkering of LNG. Singapore, the world's largest bunkering hub strives to lead on LNG bunkering by 2020.

Voluntary measures are usually preferred by industries that can use them in the most flexible way. The Environmental Ship Index (ESI) is a voluntary instrument designed to improve the environmental performance of vessels. It only includes ships that perform better than obliged by the international legislation defined by the IMO. It assesses the environmental performance of ships regarding air pollutants and CO_2 and scores NO_X and SO_X emissions directly and proportionally. The Environmental Ship Index is intended to be used by ports to reward ships participating in the scheme and can also be used by business associations wishing to share their environmental performance results. The programme is flexible and dynamic and can raise awareness among the global port community and improve the maritime and port environment.

Fresh water, the blue gold, is a vital and scarce natural resource that, unlike oil, cannot be replaced. Access to clean water is regarded as a fundamental human right. Intelligent infrastructure and surveillance systems in order to limit leakage, which often reaches 30 %, are being implemented or planned in many cities. Leakage and risk detection are increasingly parts of integrated management and early warning systems. The Tokyo system for identifying leaks is considered to be exemplary, while Stockholm and Singapore are well known for their proactive water management policies.

Major world cities literally suck water from their surrounding areas to satisfy the needs of their populations. A global survey suggests that large cities occupy only 1 % of the Earth's surface but the watershed providing their water covers 41 % of the land surface. Cities with at least 750,000 inhabitants move 504 billion litres of water each day in an accumulative distance of 27,000 km. Los Angeles, Boston, Mumbai, Karachi, Hong Kong, Tokyo, New York, Tel Aviv, Sydney, and Athens, all coastal cities, top the list of the cities that most suck water from their surrounding regions (McDonald 2014).

Stockholm, the first European Green Capital, is a pioneer city in water protection and management. The Swedish capital stands out for its high quality of environment and life, and demonstrates strong public health performance, high educational attainment and social protection levels. The municipality has done much to improve wastewater treatment and reduce the impact from storm water. The Radically cutting down the discharge of phosphorous and nitrogen has been instrumental for improving water quality. The sensitive Stockholm archipelago has a high water and environmental quality and great recreational value.

Singapore's water and sanitation utility received the Stockholm Industry Water Award for its holistic approach to water resources management. The city-State ranks high in water supply and sanitation in the challenging environment of a

densely populated island. Access to water is universal, affordable and efficient. Innovative integrated water management approaches such as the reuse of reclaimed water, the establishment of protected areas in urban rainwater catchments and the use of estuaries as freshwater reservoirs have been introduced along with seawater desalination to reduce dependency on imported water. Singapore's approach does not only rely on physical infrastructure, but also emphasises proper legislation and enforcement, water pricing, public education and heightened awareness, as well as research and development.

Australia is the driest populated continent. Sydney faces particular challenges as an additional 1.3 million people are predicted to move into the city over the next decade. Urban renewal projects are planned around corridors and hubs that have access to public transport, and major job and housing growth in Western Sydney. As a result, Sydney Water is exploring options for future supply models that complement the existing centralised system to provide intelligent and affordable options. A study, led by Arup and Sydney Water, tried to map future water supply in Sydney and other major cities in the face of population growth, increasing scarcity of water and continued budget pressures. The study suggests that water authorities should migrate towards a more hybrid model which incorporates greater decentralisation and autonomous management of water supply, greater participation of additional service providers and smarter management of the water grid (Arup and Sydney Water 2014).

Water is visible and valued in many initiatives. The Canadian Water Sustainable City of the Near Future is built on the expectations of key stakeholders sharing their views on a water-sustainable city. Canada faces a water and wastewater infrastructure deficit which is expected to grow. The Blue Economy Initiative, a national project, seeks to inspire dialogue among Canadian decision-makers and influential actors on the opportunities and benefits of preserving water, and the severe risks of inaction. Responsibility is respected and shared. Four broad areas were identified to make tangible progress towards sustainability, including financial responsibility, progressive regulation and governance, customer-oriented information, and cutting-edge technology. Coastal sustainable cities can incorporate social innovations for the adoption of coastlines and water wise projects.

The water/energy nexus merits special attention. The energy sector already accounts for 15 % of the world's total water use. Its needs are set to grow, making water an increasingly important criterion for assessing the sustainability of energy projects. Expanding power generation could lead to an 85 % increase in the volume of water that is not returned to its source after use, through to 2035 (IEA 2013).

Sustainability asks for water to be respected throughout the life cycle. A US overview of water recycling applications, including drinking water, non-drinking urban and industrial uses, irrigation, groundwater recharge, and ecological enhancement, shed light on various municipal water reuse projects, such as irrigating parks or providing industrial cooling water. Drinkable water projects account for only a small fraction of the water being recycled. However, many drinking water treatment plants draw water from a source that contains wastewater discharged by a community located upstream (NRC 2012).

Wastewater treatment technologies processes are easily adapted to reclamation plants to meet the quality requirements of intended future applications in the water cycle. The concentrations of chemicals and microbial contaminants in reuse projects designed to provide drinking water supplies can be comparable to or lower than those commonly present in many drinking water supplies.

Water reuse projects tend to be more expensive than most water conservation options and less expensive than seawater desalination. Although the costs of reclaimed water are often higher than current water sources, external costs and benefits, for example seasonal peak demands on the drinking water system, can strike a difference. Depending on the specific requirements, recycling and reuse projects could also have a larger or smaller carbon footprint than existing alternatives (NRC 2012).

Effective wastewater management is one of the most widespread challenges to water quality and is linked to climate adaptation policies and urban resilience. Green infrastructure captures and filters pollutants. The green alternative is often less expensive than structural engineering options, and can help reduce costs of flooding. Green roofs, permeable materials, alternative designs for streets and buildings, trees, gardens and parks and rain harvesting systems are increasingly supplementing aquatic or substituting hard infrastructure investments (NRC 2008).

Noise is a local disturbance that seems sometimes strongly linked to port activities and can seriously affect the well-being of residents. Anthropogenic noise in the ocean has also been increasing steadily over the past decades. Shipping is the main source, and the produced noise is often in frequency bands used by many marine mammals for communication. Other significant sources of noise include seismic exploration for the offshore hydrocarbon industry and seabed mining. The impact of noise can be both to disrupt communication between animals and to displace them from their breeding, nursery or feeding grounds, with consequent potential effects on their survival. Cities which care about their marine biodiversity should be very sensitive to this kind of effects.

Apart from their fundamental land, water and air resources, cities impact an amazing array of resources originating from their hinterland, their territorial waters, and, increasingly, the rest of the world. Ecosystem services from surrounding regions provide fresh air, store or drain flood water, as well as drinking water. Differences in urban design and management can greatly impact urban resource efficiency. Eco-efficiency could help decrease the heavy dependency of cities to satisfy their needs in food, water and energy. Urban Eco-Efficiency Labs organised in China and India by the World Resources Forum, searched ecological and smarter solutions for sustainable cities and more efficient and better urban life. Optimising the use of the pedestrian infrastructure, public transport, bicycles, and electric cars can reduce ecological footprint and the loss of biodiversity. Advanced enabling technologies have the potential to cut global carbon emissions by as much as 15 % (WRF 2012).

The Global Partnership on Waste Management, introduced by the UNEP in 2010, suggests that the waste crisis is a very serious one and needs urgent action. Globally, waste production is dangerously mounting. The World Bank highlighted that the annual total amount of 1.3 billion tonnes of generated municipal waste could

increase to 2.2 billion tonnes by 2025. Waste management is one of the most complex and cost-intensive public services, absorbing large parts of municipal budgets. Packaging, although only 2 % of the weight of total waste, represents 30 % of the volume, and only 54 % of it is recycled. The threat posed by poor waste management is particularly prominent in low-income countries where waste-collection rates are often below 50 % and garbage concentrates along river and sea banks. Urban population explosion, rapid industrialisation and economic development are generating increasing quantities of waste that are overburdening systems. The vicious circle is aggravated by the advent of a more affluent global middle-class longing for more sophisticated consumption goods and services (UNEP 2010).

Sound waste management is inextricably linked to resource efficiency and the performance of the urban economies. Integrated resource policies take care of the full life-cycle of materials from the extraction of natural resources, through their design, manufacture, assembly, marketing, distribution, sale and use to reuse, repair, recycling and recovery, including energy recovery. It is most important for cities to have a comprehensive picture of the resources required and the waste generated by all urban activities. Business actions and on-line exchange facilities encourage the sharing of resources in order to reduce costs and the environmental footprint. Urban concentrations can enhance multiple-win schemes based on the concept that "the waste from some activity can be a valuable resource for some other activity", orchestrated by cities, business or citizen associations.

Generation of waste mirrors economic growth. Preventing the loss of precious resources is essential. Precious metals discarded as waste also have a global and an ethical dimension. Waste often hides goldmines and the European Environment Agency provided some interesting assessments. Electric household appliances and electronic equipment contain hazardous substances, but also include valuable metals, estimated to contain 450,000 tonnes of copper and 7 tonnes of gold in 2005. At the London Metal Exchange, these metals would be worth €2.8 billion and €328 million respectively, in 2011. However, only a small part of such electronic equipment is collected and reused or recycled. The business case for "urban waste mining" is evident (EEA 2012).

In an era during which the price of raw material is high, coastal cities might be tempted by seabed mining. Conscious cities should insist that such activities not have severe and irreversible effects on marine ecosystems. Transparency, trust and societal acceptance are fundamental issues, as the world has entered uncharted waters and moved towards deep-ocean mining and extracting precious metals from a depth of 1500 m.

Conscious resource management is particularly reflected on eco-buildings which, for residential, commercial or industrial use, are the main cells of all cities. The concept of Eco-habitat, which is a luminous and healthier environment with sustainable use of materials and water and low zero energy requirements, has already endowed many cities with attractive eco-cells. Good integration into a landscape, orientation and adaptation to climatic conditions, recourse to ecological materials and renewable energies, and sustainable management of water and resources, including waste, are critical requirements for eco-performance of an entire built environment.

Bioclimatic architecture and design has made great strides over recent years. Architects, designers, eco-builders and eco-citizens are promoting green constructions and more ecologically sound techniques on coastal environments. Source, design and performance information about the latest low-impact materials and technologies, the best options for the use of renewable energy, water and resources and best practices can help make a difference (Roaf 2007).

Buildings hold the largest potential for cost-effective energy savings. Given the long lifetime of buildings in cities, the largest potential for improving energy performance is in existing buildings. Public buildings and privately owned buildings open to the public can act as pioneers and serve as models for intelligent resource-saving and performance-enhancing buildings. The display of building plans and energy performance certificates and recommended optimal climatic conditions, such as the most favourable indoor temperatures, in all public buildings, can promote awareness about the benefits of eco-performance.

Melbourne offers a prime example with the Council House 2 municipal eco-office, a multi-award winning building which managed to reduce CO_2 emissions by 8 %, electricity consumption by 82 %, gas by 87 % and water by 72 %. It is a ten-storey office building for about 540 staff members of the City of Melbourne. Opened in 2006, the state-of-the-art building also features ground-floor retail spaces and underground parking. The Council House 2 has embraced the best environmental options and local solutions. An in-situ multi-water treatment plant filters out the water and creates clean water suitable for non-drinking uses. Some of the recovered water is used for water cooling and irrigation, and the rest is used in other municipal buildings and public fountains.

The Council House 2 building has been designed to respect ecological principles and enhance the natural 24-h cycle of solar energy, natural light, air and rainwater, to power, heat, cool, and water the building, which purges stale air at night and pulls in pure fresh air during the day. Like a sunflower, the building follows the movement of the sun to collect heat. The north façade of the building has ten dark-coloured air ducts that absorb heat from the sun, then the hot air rises taking the stale air up and out of the building. The south façade has light-coloured ducts that draw in pure fresh air from the roof and distribute it down through the building. The west façade has louvers made from recycled timber and powered by photovoltaic roof panels that move according to the position of the sun.

Schools can be the most instrumental eco-organs of a city and great places for promoting marine environmental awareness and sowing the seeds of a smart and inclusive society. The international award programme “Eco-Schools” has created a movement of schools embedding sustainability principles into school life and action. School children lead the project in all its aspects and help carry out audits to assess and improve the environmental performance of their school. They also learn principles and practices to apply in other spaces including homes and public spaces. Many “cleaning the beach” local action programmes in coastal cities have been initiated by local schools influencing public values.

From the transformation of buildings to the transformation of districts, the scale is of importance. Hamburg embarked on a thorough transformation in an exemplary

regeneration project. HafenCity (Harbour City) enhanced the possibilities of abandoned harbour space. At the beginning of the last century, Hamburg's bustling harbour, at the edge of the city centre, hosted the infrastructures and warehouses of the shipping industry. But the advent of bigger ships led to the creation of a new harbour, leaving a vast empty space near the city centre which provided the fundamental resource. By the time HafenCity is finished in 2025, it will stretch 1.5 km between the city centre and the Elbe River (HafenCity Hambourg 2013).

The proximity of the sea is essential for the new district featuring high-quality, high-tech residential and office space, a waterfront promenade, a five-star hotel, a university, and sustainable public transport. HafenCity aims to become a living, breathing part of the city, a place where people want to both work and enjoy their leisure time. Achievements already include a ground-breaking Ecumenical Forum inaugurated in 2010, sponsored by 19 Christian churches in Hamburg and designed according to the strict sustainability standards of the HafenCity Eco-label. In 2011, the district welcomed "Osaka 9", the HafenCity sustainability pavilion with an exhibition space on ecological, sustainable urban development. The jewel in the crown will be a new opera house.

In Malmö, Västra Hamnen, the Western Harbour, provides a fine example of radical transformation of a previously industrial site into an ecological urban area. In 2001, its reconstruction began with 500 residential units, mostly part of an exhibition to develop energy self-sufficient housing units. Among the new buildings is the emblematic Turning Torso, the city's 190 m tall landmark, a residential skyscraper with a twisting design.

Despite Malmö's chilly climate, the beach Ribersborg, stretching along the coastline, hosts open-air baths, opened in the 1890s. The long boardwalk to the Western Harbour has become a new favourite summer hang-out for both citizens and tourists. The harbour is particularly popular with Malmö's vibrant student community.

In Stockholm, Hammarby Sjöstad is an innovative district on the former waterfront industrial land set aside for its ultimately unsuccessful 2004 Olympic bid. The concept includes bioclimatic design, sound surroundings and ecological organisation of local life. The eco-cycle model of Hammarby aims to make the district autonomous throughout its life cycle. In Hanover, the design and construction of the Kronsberg district, built for Expo 2000, incorporated state-of-the-art ecological material and techniques. Construction waste was reduced by 80 % through sorting and recycling measures, but also social and educational models like the waste-free breakfasts for children (Mega 2010).

Stockholm plans to consolidate the urban fabric and brand Stockholm as a leader in green urban planning. The Royal Seaport is the city's latest flagship sustainability project. In 2011, Stockholm Royal Seaport was 1 of 27 projects that received financial support from the Swedish government, through the Delegation for Sustainable Cities. The area has been partly industrial land and royal hunting grounds, and has a particular identity. It is located right by the water and the Royal Urban National Park, making it a very attractive area for citizens and visitors. The Royal Seaport project aims at creating an organic part of the city with 10,000 new apartments and 30,000 new work places. In addition to housing and offices, the area will also host

urban parks, cultural spaces and a harbour for cruise ships. The City of Stockholm, owner of the land, is placing high expectations on the project to be at the forefront of urban sustainability. The project aims at being fossil fuel free, through initiatives such as energy efficient transport and generation of biogas from food waste.

Environmental and cultural sustainability are given high attention and much effort is invested in the quality of the natural and built environment, through the planting of oaks for biodiversity and the construction of eco-innovative green buildings. There is also a far-reaching analysis on the effects of the city form on travel patterns and an emphasis on the district´s effect on the marine environment. Social sustainability is also given attention. The Royal Seaport will have a mixed housing composition, with rented flats coexisting with owner-occupied housing and an array of diverse urban functions (City of Stockholm 2014).

SymbioCity, the Swedish trademark for sustainable urban development, launched in 2008, aims at exporting the national know-how on exemplary cities. The essence of the concept is the generation of environmental and economic benefits through unlocking synergies between urban systems. A network of Swedish environmental technology companies and organisations promotes the SymbioCity model in their international exchanges. SymbioCity is scalable, and adaptable to any context. For example, the excessive heat from an industry can warm up a household or the waste from an industry can be useful material for a service. The seven building blocks of the SymbioCity concept include urban functions, industry and buildings, energy, transport, resource management, water supply and sanitation, architecture and landscape design.

Coastal cities can offer a fertile environment for eco-innovation to thrive on the articulated land and space domains and functions and can serve as a magnet for talent, financial capital and entrepreneurship. They can provide a competitive environment to maritime companies and ancillary services and serve as blue green platforms that give partners an unmatched opportunity to develop, test and validate their technologies at a large scale and real-world conditions. Green urban procurement and voluntary practices such as eco-labels are useful instruments.

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