



GREEN economy

in a Blue World



United Nations Environment Programme (UNEP)

UNEP coordinates United Nations environmental activities, assisting developing countries in implementing environmentally sound policies and practices. It was founded as a result of the United Nations Conference on the Human Environment in June 1972. Its mission is to provide leadership and encourage partnership in caring for the environment by inspiring, informing and enabling nations and peoples to improve their quality of life without compromising that of future generations.

Food and Agriculture Organisation (FAO)

Achieving food security for all – to make sure people have regular access to enough high-quality food to lead active, healthy lives – is at the core of all FAO activities, including for fisheries and aquaculture. FAO's mandate is to raise levels of nutrition, improve agricultural productivity, better the lives of rural populations and contribute to the growth of the world economy. Fisheries and aquaculture have the capacity – if supported and developed responsibly – to contribute significantly to improving the well-being of poor and disadvantaged communities. The vision of FAO for these sectors is a world in which responsible and sustainable use of fisheries and aquaculture resources makes an appreciable contribution to human well-being, food security and poverty alleviation. The FAO Fisheries and Aquaculture Department, in particular, aims to strengthen global governance and the managerial and technical capacities of members and to lead consensus-building towards improved conservation and utilisation of aquatic resources.

International Maritime Organisation (IMO)

IMO is the United Nations (UN) specialised agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships. International shipping is the carrier of world trade, transporting around ninety percent of global commerce. Being an international industry shipping needs a global regulatory framework in which to operate. IMO, with its 170 Member States, provides this framework and has adopted 52 treaties regulating virtually every technical aspect of ship design and operation, the most important of which – concerning the safety of life at sea and the protection of the environment – today apply on ninety-nine percent of the world's merchant fleet. IMO adopts international shipping regulations but it is the responsibility of Governments to implement those regulations. IMO has developed an Integrated Technical Co-operation Programme (ITCP) designed to assist Governments which lack the technical knowledge and resources needed to operate a shipping industry safely and efficiently.

United Nations Development Programme (UNDP)

UNDP is the United Nations' global development network, an organisation advocating for change and connecting countries to knowledge, experience and resources to help people build a better life. UNDP is on the ground in 177 countries, working with them on their own solutions to global and national development challenges. As they develop local capacity, they draw on the people of UNDP and its wide range of partners. Through its Ocean and Coastal Governance Programme, UNDP is working in cooperation with many other UN agencies, the Global Environment Facility, international financial institutions, regional fisheries organisations and others to improve oceans management and sustain livelihoods at the local, national, regional and global scales through effective oceans governance.

IUCN Global Marine Programme

Founded in 1948, The World Conservation Union brings together States, government agencies and a diverse range of non-governmental organizations in a unique world partnership: over 1000 members in all, spread across some 140 countries. As a Union, IUCN seeks to influence, encourage and assist societies throughout the world to conserve the integrity and diversity of nature and to ensure that any use of natural resources is equitable and ecologically sustainable.

WorldFish Center

The WorldFish Center an organization dedicated to reducing poverty and hunger by improving fisheries and aquaculture. It is an international, non-profit research organization that focuses on the opportunities provided by fisheries and aquaculture to reduce poverty, hunger and vulnerability in developing countries. The WorldFish Center is one of the 15 members of the Consortium of International Agricultural Research Centers supported by the Consultative Group on International Agricultural Research (CGIAR), a global partnership that unites the organizations engaged in research for sustainable development with the funders of this work. The funders include developing and industrialized country governments, foundations, international and regional organizations.

GRID-Arendal

GRID-Arendal is a collaborating centre of the United Nations Environment Programme (UNEP). Established in 1989 by the Government of Norway as a Norwegian Foundation, its mission is to communicate environmental information to policy-makers and facilitate environmental decision-making for change. This is achieved by organizing and transforming available environmental data into credible, science-based information products, delivered through innovative communication tools and capacity-building services targeting relevant stakeholders.

UNEP, FAO, IMO, UNDP, IUCN, WorldFish Center, GRID-Arendal, 2012, Green Economy in a Blue World

www.unep.org/greeneconomy and www.unep.org/regionalseas

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FOREWORD

A worldwide transition to a low-carbon, resource-efficient Green Economy will not be possible unless the seas and oceans are a key part of these urgently needed transformations.

The marine environment provides humanity with a myriad of services ranging from food security and climate regulation to nutrient cycling and storm protection. These in turn underpin lives and livelihoods in sectors from tourism to fisheries.

Yet despite this importance, the last three to four decades have seen increasing degradation of oceans as a result of, for example, pollution from land-based sources, overfishing and increasingly, climate change.

This in turn, is threatening the livelihoods of millions of people around the world who depend on these critical ecosystems for their primary source of protein and for job security both directly and indirectly.

With a growing population, set to rise from seven billion today to over nine billion by 2050, these pressures and impacts are likely to intensify unless the world becomes more intelligent about managing these essential resources.

The Green Economy in a Blue World report analyzes how key sectors that are interlinked with the marine and coastal environment – the blue world – can make the transition towards a Green Economy.

The report covers the impacts and opportunities linked with shipping and fisheries to tourism,

marine-based renewable energies and agriculture.

The findings underline that a shift to sustainability in terms of improved human well-being and social equity can lead to healthier and more economically productive oceans that can simultaneously benefit coastal communities and ocean-linked industries.

Many countries are already acting to chart a fresh future for their seas and oceans and adopting the kinds of smart public policies needed to unlock the investments and creative strategies necessary.

The upcoming Rio+20 Summit is an opportunity to scale-up and accelerate these transitions under the twin themes of a Green Economy in the context of sustainable development and poverty eradication and an institutional framework for sustainable development.

Both the marine and the terrestrial environments are more than just an economy – they are part of humanity’s cultural and spiritual dimensions. However, through a better understanding of the enormous economic losses being sustained and the enormous opportunities from investing and re-investing in marine ecosystems, perhaps the balance can be tipped away from degradation and destruction to sustainable management for this generation and the ones to come.



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Christian Neumann (GRID-Arendal) has served as the lead editor, has handled most of the peer review process and has written the conclusions; Christina Cavaliere, also GRID-Arendal, has been the editor of the tourism chapter.

Partner organizations

This report is an inter-agency collaboration of the following organizations:

- United Nations Environment Programme
- Food and Agriculture Organization of the United Nations
- International Maritime Organization
- United Nations Development Programme
- International Union for Conservation of Nature
- WorldFish Center
- GRID-Arendal

Please refer to individual chapters for authors, contributors and reviewers.

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INTRODUCTION

Linwood Pendleton, Director of Ocean and Coastal Policy, Duke's Nicholas Institute has been the lead author of this chapter. Anne Solgaard, GRID-Arendal, has contributed the box on Life-cycle thinking. The box on Strategic Environmental Assessments was provided by Paul Siegel, of WWF.

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The early part of the 21st century has seen dramatic changes in the world's environmental and economic well-being. More fish stocks than ever before are considered overexploited, depleted or recovering (FAO, 2010), and chronic oil spills and land-based pollution continue to plague coastal seas¹. At the same time, the world's economy has experienced the deepest recession since the Great Depression; many nations struggle to repay their debts, and income inequality has increased steadily over the past 20 years (Wade, 2001). As the population continues to grow in these uncertain economic times, the role of environmental capital is likely to become increasingly important to maintain and improve social well-being around the globe. This is particularly true of poor communities that depend directly and disproportionately on ecosystems and natural resources. Despite our current understanding of the importance of environmental capital, the current economic paradigm promotes growth in economic output and consumption with only limited planning for inevitable increases in the scarcity of environmental capital.

In 1992 the need for a more sustainable economy emerged as one of the key outcomes of the United Nations Conference on Environment and Development, held in Rio de Janeiro. Twenty years later the search for a greener economy continues as the UN convenes a second global Conference on Sustainable Development (Rio + 20).

To help the world address the challenges of an economic transition, the United Nations Environment Programme launched the Green Economy series. This effort seeks to pave a new way which will align economic development with the protection or even improvement of the globe's current environmental capital. The world's oceans and coasts – the *Blue World* – are key components of the planet's environmental capital, and indeed, it's economic capital. The path towards a Green Economy must address the unique challenges that face a global economy which relies critically on coastal and ocean ecosystems.

1. For example, see UNEP. 2007. Land-based Pollution in the South China Sea. UNEP/GEF/SCS Technical Publication No. 10. And http://www.grid.unep.ch/product/publication/download/ew_oildischarge.en.pdf.

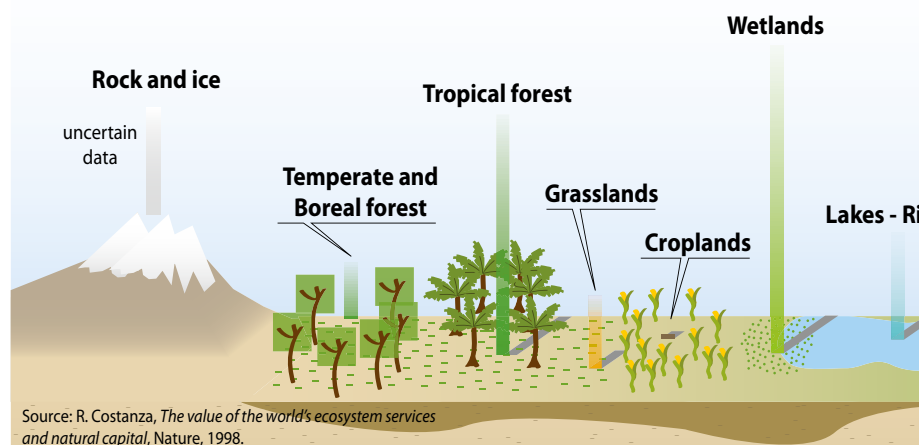
Our reliance on oceans and coasts

Throughout the course of history, humans have been drawn to coastal areas to enjoy the bounty of the sea. As much as 40 per cent of the world's population now lives within 100 kilometres of the shoreline (Martínez, et al., 2007) and this population continues to grow – increasing our reliance and impact on the ocean and coast. Two-thirds of the world's megacities are on the coast.

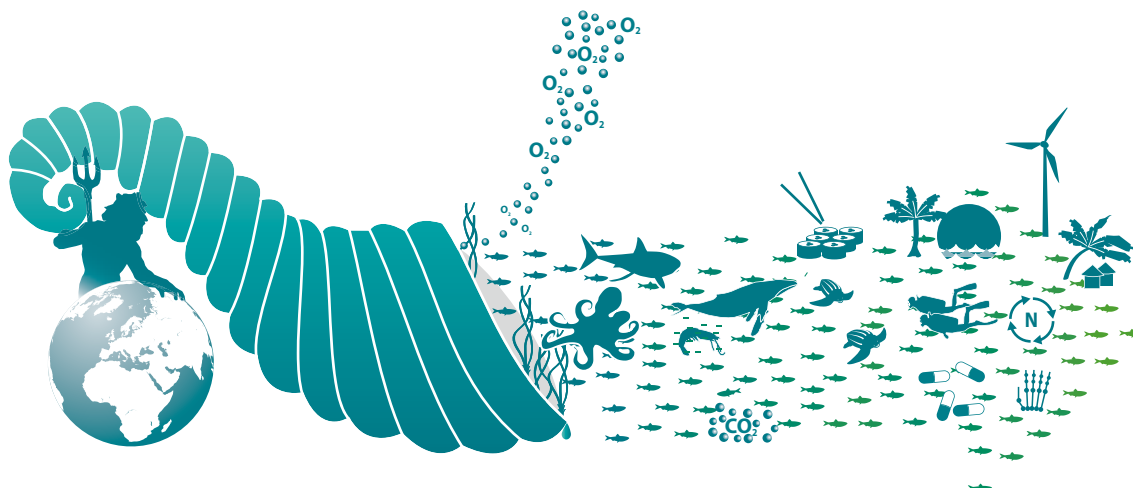
Much of the world's economy and the cultures of many peoples are founded on oceans and coasts. Modern civilization arose along the coasts and rivers because of access to trade and resources. Today 90 per cent of global economic trade travels by sea. The sea provides many of the raw materials needed to supply the world's economy, such as minerals, sand and gravel. New sources of minerals and metals are being explored in the deep sea and the areas beyond national jurisdiction. In 2011 alone, the International Seabed Authority issued four new exploration contracts for potential deep-sea mineral extraction. Plans are also underway to tap the wave, thermal, current and other energy potentials of the oceans. The International Panel on Climate Change predicts that ocean energy could one day be key to meeting the world's energy demands, but currently the development of ocean energy is still in its early stages.

Only recently, however, have we started to fully appreciate the economic importance of

Estimated ecosystem services value



World oceans, a cornucopia of goods and services



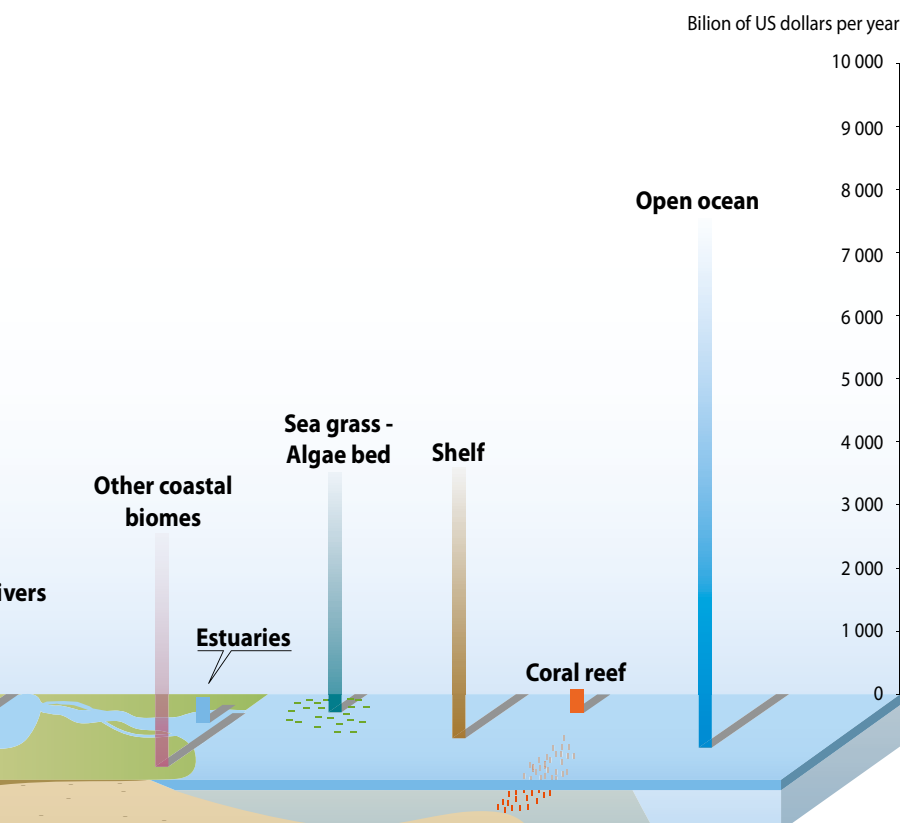
our *living* seas and coasts. Marine habitats, species, and ecosystems support natural capital and economic flows, together referred to as ecosystem services. Marine and coastal ecosystems provide many services such as food, wood, fibre and other resources. Mangroves, salt marshes and sea grasses are natural carbon sinks (Murray, et al., 2011). Coastal habitats, including coral reefs, also protect homes, communities and businesses from storms and surges.

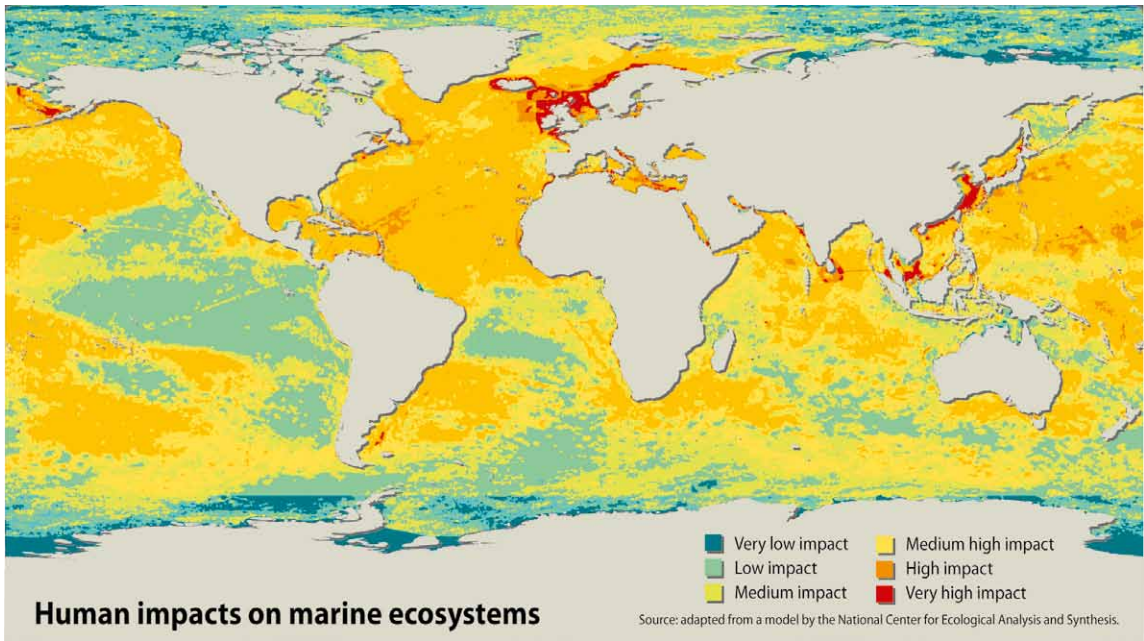
Marine ecosystem services have substantial economic value. While exact figures are still debated, attempts to estimate the value of coastal ecosystem services have found such

values to be on the order of trillions of US dollars annually (Costanza, et al., 1997). Nearly three-quarters of this value resides in coastal zones (Martínez, et al., 2007). These ecosystem services offer a renewable opportunity to meet basic human needs, support a healthy and sustainable economy, and provide jobs for a growing global population.

Seafood continues to be a major economic use of the living sea. Seafood consumption has hit an all-time high with the average person consuming more than 17 kilograms each year with more than 80 million tonnes harvested in ocean waters in 2009 with a value in excess of US\$100 billion annually. Twenty million tonnes of seafood were harvested from the rapidly increasing marine aquaculture sector alone. The seafood industry's harvest and post-harvest sectors support the livelihoods of a total of about 540 million people, or eight per cent of the world population (FAO, 2010). In developing countries, almost half of all fishing related jobs are in small-scale fisheries.

Today, we understand the ways in which many commercial activities depend directly on healthy ocean economies. Marine tourism, including traditional beach tourism, recreational fishing, scuba diving and nature tourism, continues to grow around the world. Many coastal communities depend on these types of tourism, which depend critically on clean beaches, safe water and abundant marine wildlife. Furthermore, tourism





and recreation are important reasons why so many people chose to live near the sea, either in primary residences or in second homes. Ocean recreation offers both market and non-market benefits to residents and visitors of the coasts (Pendleton, 2008). Ocean views have been shown to improve people’s well-being and are an important reason homes near the sea have higher value (Kildow, 2009).

The need for a greener economy in a blue world

Harmonizing traditional economic activity and ecosystem-dependent economic values is a challenge we must address, especially for our coasts and oceans.

Persistent environmental pressures, including pollution, overharvesting of fisheries, and habitat

Payment for Ecosystem Services

Nature provides ecosystem services to both humankind and to individuals, free of cost. However, conserving ecosystem services may come at a cost through the loss of revenue derived from another use. In particular, these costs are incurred by individuals who own ecosystems such as, for example, a forest in a river catchment area. Conserving the forest provides a range of services, whether it means the supply of clean water or the prevention of soil erosion. But these services are largely unrecognized or ‘invisible’ values. On the other hand, converting the forest to cropland would provide direct benefits to the landowner and beyond. These benefits may be smaller than the costs of losing the ecosystem services; but they are more visible and positively accounted for in prevailing economic models. Further, the individual landowner derives relatively

little benefit from conserving the services. PES can be a mechanism for overcoming this problem.

The primary objective of a PES scheme is not to generate money but to recognize the value of ecosystem services and support their sustainable use. PES schemes incentivize ‘sellers’, or ‘service providers’ to change behaviour and encourage them to continue to provide the services, usually by compensating for losses or ‘opportunity costs.’ The ‘buyer’, or ‘service beneficiary’, may be private (a company selling bottled drinking water), public (a city supplying drinking water) or other organizations, such as an environmental group involved in the conservation of forest biodiversity.

Source: GRID-Arendal, 2012: Vital Graphics on Payment for Ecosystem Services – Realising Nature’s Value

conversion are driven by growing populations and the growing economic output these populations demand. These pressures have led to dramatic declines in the ecological state of our coasts and oceans. We are in the throes of an epoch of unprecedented species-loss, the emergence of coastal waters which are no longer safe for swimming or fishing, the loss of shoreline protection by coastal habitats and coral reefs, and an unprecedented decline in the value of ecosystem goods and services. In turn the loss of ecological integrity in our oceans and coasts has impacted directly on poverty levels and development, especially in communities traditionally dependent on ecosystem-based economic activities including fishing, tourism, and harvesting. Lotze, et al., 2006 and Halpern, et al., (2008) found that human activities have impacted nearly every ocean and coast on Earth. Over time, over 90 per cent of those species formerly important to humans have been lost in coastal seas and estuaries due to human impacts. During the last decades of the 20th century, human impacts on coasts and oceans destroyed 35 per cent of mangroves; 20 per cent of all coral reefs were destroyed and another 20 per cent were seriously degraded (MEC, 2005). Current rates of annual loss for mangroves, sea grasses and

salt marshes may be as high as 2 per cent (Duke, et al., 2007), (FAO, 2007) & (Duarte, et al., 2008). Today, more than 30 per cent of the world's fish stocks are overexploited, depleted or recovering from depletion, and over 400 oxygen-poor 'dead zones' exist in the world (Diaz & Rosenberg, 2008).

While the current value of our ocean is enormous, it is clear that the ecological and economic productivity of the ocean we know today is only a fraction of what it could be. Sumaila & Suatoni, (2005) estimate that the present value of the fisheries of the United States would be \$374 million greater if only 17 seriously depleted fish stocks were at their ecologically optimal levels. A World Bank report finds that worldwide the lost economic value of overfished stocks is about \$50 billion annually (World Bank, 2009). It is likely that other sectors of the ocean economy would enjoy similar improvements in economic value if marine ecosystems were made more ecologically healthy, robust and resilient.

New opportunities for a green economy in a blue world

The decline in the ecological health and economic productivity of the world's oceans

Strategic Environmental Assessments

Strategic Environmental Assessments (SEAs) consist of high-level, participatory, decision-making tools used to promote sustainable development by ensuring that one group of development activities (and actors) does not undermine others. SEAs are implemented at the earliest stages of decision making, to analyze both the environmental impacts of a policy, programme or plan (PPP), and to help adjust them accordingly. They help decision-makers to broaden strategic planning from single-sectoral approaches (individually assessing oil and gas, mining, fisheries, tourism, etc.) to include multiple sectors for example identifying how offshore oil and gas development, coastal tourism, agriculture and fisheries together impact on each other and marine ecosystems. SEAs look particularly at combined or cumulative impacts on people and the environment. They should present alternative options for implementing PPPs. SEAs can ensure that sectoral development is aligned with

national strategies for poverty reduction and sustainable development. In a transboundary context they can be used to strengthen and support cooperation between countries in this respect.

SEAs complement and facilitate project-level Environmental and Social Impact Assessment (ESIA) by focusing primarily on the underlying framework of strategies, plans or programmes. SEA and ESIA go hand in hand: SEAs establish limits of acceptable change, and a platform for exchange among different parties, while ESIA guide the implementation of specific activities.

SEAs can help secure environmental capital by achieving more effective and efficient strategic decision-making; avoiding costly mistakes and incompatibility of plans and strengthening public participation and support of policy-making.

can be reversed by shifting to a greener, more sustainable economic paradigm in which human well-being and social equity are improved, while environmental risks and ecological scarcities are reduced. Technological advances now permit more profitable industrial output with fewer environmental impacts. Evidence presented in this volume shows that many ocean industries and businesses benefit directly from cleaner, more ecologically robust marine ecosystems.

Policies and collaborative solutions are emerging which internalize the external costs of practices which damage the environment. Similar programmes reward those who create external benefits through environmentally-sound uses of marine and coastal ecosystems. Markets, bilateral agreements and other types of payments now provide incentives for better stewardship of ecosystem services (see box on payment for ecosystem services, PES).

Novel sources of funding and public-private partnerships are emerging to promote healthier environments. In the Caribbean new financing mechanisms are being implemented by the Caribbean Regional Fund for Wastewater Management to reduce nutrient pollution in coastal areas. For instance, ocean tourism is the foundation of the local economy on the Placencia Peninsula. Recognizing the importance of clean water to sustainable tourism, local private interests and the government have joined forces to create a Wastewater Revolving Fund.

Governments can do much to promote the transition to a greener economy. Providing enhanced collaboration and coordination across agencies, at different scales of (national and local) governance and across industrial sectors will lead to more strategic decision making and efficiency in resources use. Strategic Environmental Assessment for example is a sustainable development tool which promotes coherence and coordination between related and overlapping activities. SEA is based on based on transparency, stakeholder participation and dialogue and provides a mechanism for conflict avoidance and resolution (see box). More targeted government investment in green technologies will help industries overcome financial obstacles which sometimes impede the creation of environmental technologies. Governments also can contribute directly to a greener economy by reforming harmful subsidies and policies which encourage waste and pollution. The elimination of subsidies in the energy, water, agriculture and fisheries sectors could save as much as 1-2 per cent of GDP annually (UNEP, 2011).

A framework for a green economy in a blue world

Greening the blue economy does not just make environmental sense, it is essential if society is to find a way of sustaining the three capitals upon which sustainable economies must be built: economic capital, social capital and environmental capital. Historically, civilization was built by converting environmental capital (forests, marsh lands, and non-renewable materials) into economic capital (industry). In the best cases, this new economic capital was, in turn, used to build new social capital by alleviating poverty, providing better education, and building social infrastructure and communities. In some places, environmental capital is rebuilding in both absolute terms and in economic value. Higher standards of living, increased productivity and more public capacity have allowed communities to restore forests, rebuild oyster beds, and reduce contamination of coastal waters to levels not seen in nearly one hundred years. In many other cases, however, new economic capital has not been reinvested in environmental or social capital. Poverty rates continue to rise in many parts of the world, habitat loss and pollution exist at historic levels, even while standard measures of economic well-being (gross domestic product) continue to grow. The unequal distribution of wealth continues to increase.

At a global level, our dwindling environmental capital could make it more and more difficult to find economic substitutes for lost species and ecosystem services. Technology can only go so far to create man-made replacements for the essential services provided by marine and coastal ecosystems (oxygen production, climate regulation, nutrient cycling, and the regulation of the global water cycle). If increases in economic and social capital cannot keep pace with these losses in environmental capital, global economic well-being will decline. The poor are most likely to be affected.

Even where economic and social capital continue to grow incrementally, the resilience and ultimate sustainability of these capitals is undermined by a decline in the integrity of ecosystems and environmental processes which know no boundaries and cannot be managed in isolation. New challenges from climate change, diminishing supplies of freshwater, and the demands of a growing world population only serve to make more crucial the role of ecosystems and environmental capital in sustaining economic and social well-being. The effects of climate change will be felt acutely by coastal zones, especially in areas where current levels of poverty make emigration difficult (MGEC, 2011).

Life-cycle thinking

Life-cycle thinking is an approach and a basis for strategy. It seeks to understand, account for and minimize all the environmental, economic and social impacts of producing and consuming a good or service, whether they occur locally, regionally or globally. The approach covers the entire life cycle, 'from cradle to grave', ideally 'cradle to cradle', offering a key means of improving the sustainability of industrial activities, which are about deriving economic capital from natural capital (natural resources).

The typical life-cycle stages addressed as part of a life-cycle approach include resource extraction, manufacturing, packaging and distribution, impacts of the consumption and end-of-life including re-use or redesign when possible.

Life-cycle thinking offers an integrated approach to reducing the negative impacts of production and consumption without transferring the problem from one stage of the life cycle to another. Life-cycle thinking and its supporting tools are critical to assisting policy and decision-making for sustainable development, and key to ensuring the development and design of more sustainable products and services. The toolbox for life cycle thinking includes:

- **Life-Cycle Management**, as a strategic business approach to integrate life-cycle thinking in day-to-day operations to decrease their environmental footprint and make value chains more sustainable.
- **Life-Cycle Assessment (LCA)**, as a technical tool applied to gain detailed insight into the environmental impact of aspects of a product or service (a chemical compound used in an extraction or production process, or the impacts of unloading cargo from a certain type of ship). The ISO 14040 series defines LCA criteria.

- **Social Life-Cycle Assessment (SLCA)** aims to assess the social implications or potential impacts of a good or service. SLCA complements environmental LCA, building on the quantitative LCA data and adding quantitative approaches and information to identify the overarching social impacts.

- **Life-Cycle Costing (LCC)** is the sum of all economic cost over the full life cycle (or a specified period) of a good or service. This can include the cost of purchase, installation, operation, and maintenance and estimated value at the end of its defined life cycle. After this the materials may become part of a different or new life cycle. The ISO 15600 series specifies LCC criteria.

- **Design for the Environment (DfE)** includes three main design objectives: design for environmental processing and manufacturing; design for environmental packaging; and design for disposal or reuse. LCA is a key pillar and tool to optimize DfE. There are multiple ISO standards that cover this approach, contingent on application.

- **Eco-labeling** is a communications tool to help consumers and businesses make better informed decisions. There are four main categories of labels, their criteria being defined by the ISO 14020 series.

In the context of the green economy in a blue world, life-cycle thinking and life-cycle based tools have in particular been applied to assessments of the impact of industrial activity on the environment. This includes impact studies of the fisheries sector, shipping, transport fuels, drilling and mining activities.

Source: UNEP (2011) <http://lcinitiative.unep.fr/>, UNEP (2009) Guidelines for Social Life Cycle Assessment of Products, CIRAI (2011) <http://www.ciraig.org>, and International Standards Organization (2012) www.iso.org

By better understanding the causes of environmental change, society can take steps to address and even reverse the decline of environmental capital while also maintaining economic and social capital. New approaches focus directly on changing the basic elements of the cycle of environmental degradation: a) the **drivers** of change – human needs and desires, and the activities undertaken to achieve them, b) the **pressures** these activities create including the emission of pollutants, wastes and greenhouse gases, or the extraction of resources, c) the ways in which these pressures impinge upon the environmental and ecological **state** of our coasts and oceans, and d) the **impacts** these changes in ecosystem-state have on poverty, value, and other measures of human wellbeing. Life-cycle thinking and more specifically life cycle assessment (see box) identifies steps in the processes of manufacturing, consumption, and waste disposal where environmental impacts can be reduced while improving economic efficiency and profitability.

Towards a Green Economy in a Blue World

Sustainable practices can improve the current and future economic, cultural and societal value of oceans and coasts and guarantee these values far into the future. This report highlights

ways to reduce the environmental footprint of economic activities on marine and coastal areas and improve the environmental, economic and social sustainability of traditional and emerging ocean-oriented economies – economics that can foster job creation for a growing population. The following chapters show how fisheries, tourism and maritime transport can take steps to reduce their impact on the marine environment. By reducing environmental waste, these industries themselves can become more efficient, profitable and sustainable and can contribute directly to the sustainability and productivity of other businesses and livelihoods which depend on healthy oceans and coasts. The authors explore what it will mean to green emerging ocean economic activities including energy generation, aquaculture and the mining of deep-sea minerals. Lastly, the volume highlights how greening the agriculture, wastewater and fertilizer industries could transform the nutrient economy with substantial benefits to ocean sustainability.

Throughout, the report demonstrates that creating a green economy in the blue world – one that ‘improves human well-being and social equity, while significantly reducing environmental risks and ecological scarcities’ – means creating sustainable jobs, lasting economic value and increased social equity.

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GREENING SMALL-SCALE FISHERIES AND AQUACULTURE



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1 Introduction

The fisheries sector – in particular small-scale fisheries and aquaculture – is important in the transition towards a green economy due to its interconnectivity with and reliance on aquatic ecosystems, and the potential for people employed in it to act as stewards of the wider marine environment to a larger extent than they already do.

The importance of small-scale fisheries to food and nutrition security and poverty alleviation, particularly in the developing world, is becoming increasingly understood and appreciated (FAO, 2011b). However, a failure to adequately include the sector in national and regional development policies coupled with flawed natural resource governance systems and a lack of institutional capacity continue to limit and threaten its potential contributions to sustainable economic growth, rural development, and poverty reduction and (Béné, et al., 2007; FAO, 2009b).

Aquaculture has been the fastest growing food production sector of the past 40 years and now supplies more than half of the world's food fish. Excluding aquatic plants, aquaculture production reached 52.5 million tonnes representing a value of US\$98.5 million in 2008 (FAO, 2010). The sector continues to grow and to play an important role in supplementing capture production and providing incomes. However, without proper management and responsible practices, aquaculture may have negative environmental, social and economic consequences that can jeopardize the sector's valuable contribution to global well-being in the future (Naylor, et al., 2009; FAO, 2010b; FAO, 2011b).

UNEP defines a green economy as one that results in improved human well-being and social equity, while significantly reducing

environmental risks and ecological scarcities. Its attributes include low carbon emissions, high resource use efficiency and social inclusiveness (UNEP, 2011). The greening of marine fisheries and aquaculture thus implies three main dimensions for future sector policy and investments:

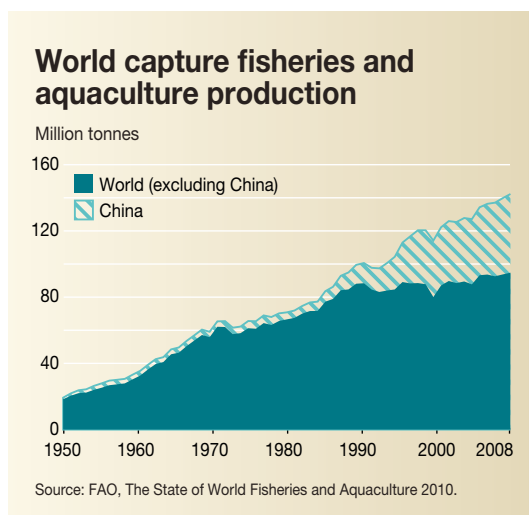
- ensuring that fish are harvested, grown and traded with efficient and sustainable use of natural resources, energy, capital and labour;
- ensuring that the economic benefits from fisheries and aquaculture are equitably distributed and socially beneficial and
- reducing the carbon footprint of the fishery and aquaculture sectors (including production, processing and trade) and pursuing opportunities to use coastal and marine ecosystems as carbon sinks..

Concern for economic efficiency and sustainability are long-standing issues in fisheries management and aquaculture development, while distributional issues are a matter of ongoing debate in both capture fisheries and aquaculture and interest in low-carbon fisheries and aquaculture is a recent and rapidly evolving area of policy. An over-arching 'green economy' approach can thus bring coherence and purpose to these different strands of fishery governance and aquaculture development, and guide the efforts to increase the sectors' contribution to sustainable development.

The purpose of this chapter is to outline how greening small-scale marine fisheries and coastal aquaculture and mariculture will enhance their contribution to food and nutrition security and poverty alleviation in developing countries. It builds upon the message by the G77 and China to the *Informal Interactive Thematic Debate of the UN General Assembly* on "Green Economy: A pathway to sustainable development" stating: "...our considerations of the Green Economy should also encompass the recognition that marine, ocean, coastal and fisheries resources are the foundation of the economies of many developing countries, including SIDS and coastal States and represents a primary pathway to future sustainable growth and poverty eradication".

2 What role do small-scale fisheries and aquaculture play?

The small-scale fisheries and aquaculture sectors contribute to food and nutrition security and poverty alleviation by providing employment and generating income – both to local communities and at a national level – and by supplying food products with high nutrition



value, locally and to markets around the world. It has been estimated that 52 million people are employed in marine small-scale capture fisheries (and another 56 million in small-scale inland fisheries) and the small-scale operators represent 90 per cent of total employment in the fisheries sector. Most live in rural areas of developing countries (World Bank, FAO & WorldFish Centre, 2010). In addition to all those formally employed in the sector, small-scale fishing is often a vital side activity forming an important part of livelihood strategies. Although data on employment in aquaculture is scarce, preliminary estimates indicate that the total number of fish farmers in the world is about 23.4 million (including in both marine and inland environments), contributing to the livelihoods of about 117 million people. The direct contribution of aquaculture to employment is hence lower than fisheries, but is expected to continue to increase in the next decades (Valderrama, et al., 2010; FAO, 2011c). Altogether, around 180 million people are directly involved in fisheries and aquaculture activities globally, including catching, growing, processing and trading aquatic products. These

fishers, fish farmers and fish workers sustain, in turn, about 0.5 billion people, equivalent to over 8 per cent of the global population (FAO, 2010)¹.

About half of all those employed in fisheries are women, working primarily in post-harvest fish marketing and processing but also found as entrepreneurs (financiers and providers of working capital for the fishing trips), fishers and in many auxiliary activities. Women are typically responsible for sustaining the fishing household, including caring for children and community members. Women hence play an important role in household nutrition and women's subsistence fishing can bring vital protein and other nutrients to poor families. Small-scale aquaculture can be especially attractive for rural women in developing countries because it often takes place close to the home and can be integrated with other food production and household activities (World Bank, FAO & WorldFish Centre, 2010 and FAO, 2010c).

1. In a recent article, Teh & Sumaila (2011) have made an alternative estimate of the number of fulltime and part-time, direct and indirect, employment in global marine fisheries of 260 million people (± 6 million).

What characterizes small-scale fisheries and aquaculture?

There is no universally applicable definition of the very diverse *small-scale fisheries* sector but there are some characteristics that generally distinguish large and small-scale operations across countries. Small-scale fisheries have many desirable features and functions on economic, social and cultural grounds. They are basically comprised of household enterprise in pursuit of a livelihood leading to a culturally conditioned way of life. Fishers use small craft and simple gear (though not necessarily simple techniques) of considerable diversity, relatively low capital investment and low energy intensity of the operations. Almost half of the world's fishing vessels are non-motorised and 90 percent of those with engines are less than 12 metres long. Fishing also takes place with handheld gear without a boat.

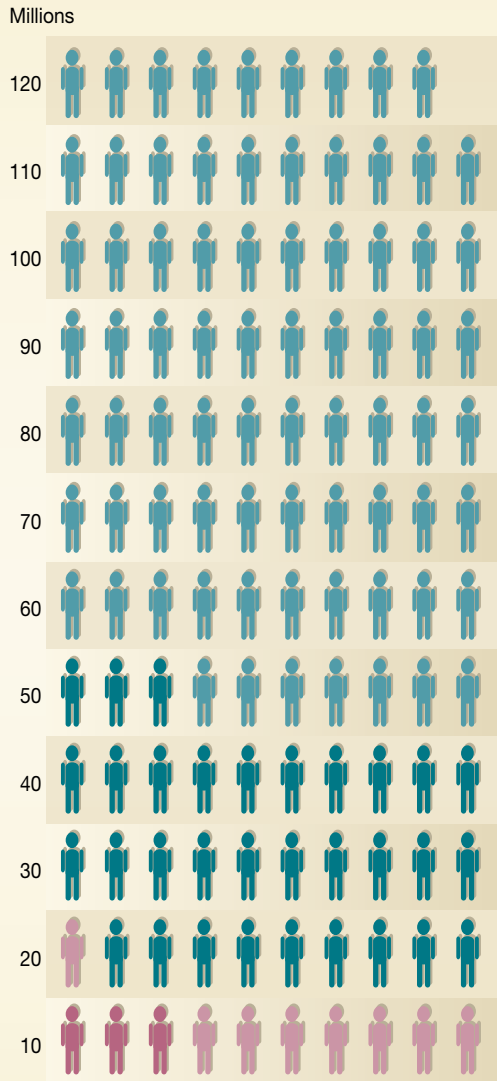
There is neither a strict definition of *small-scale aquaculture*. However, it is

often based around family labour and ponds or farms are relatively small, based on family land. It ranges from what is commonly known as rural aquaculture – i.e. systems with limited investment, informal management structures and close integration with other livelihood activities – to commercial undertakings requiring more substantial labour and capital inputs and being more specialized. However, small-scale aquafarmers often have limited access to financial and technical resources as well as poor links with markets. While no global estimates on small-scale aquaculture are currently available, it is known that nearly 89 per cent of global aquaculture production was produced in Asia in 2008 of which about 90 percent was on farms of less than 1 ha size.

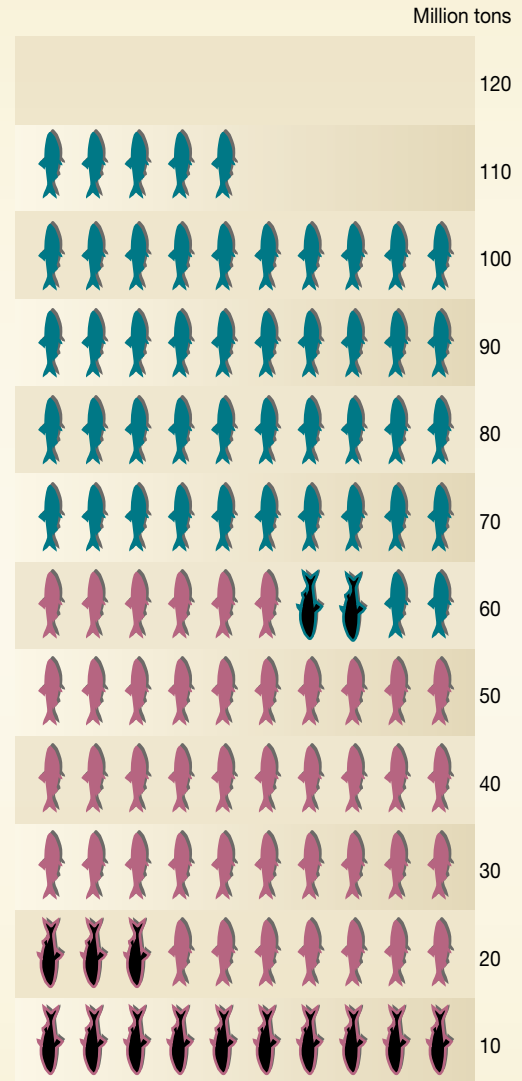
Source: FAO, 2009; FAO, 2010c; FAO, 2011c.

Small- and large-scale fishery compared

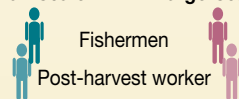
Numbers of workers employed in fishing industry



Total annual fish catches

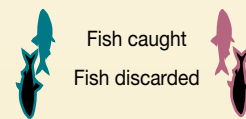


Small-scale Large-scale



= 1 million

Small-scale Large-scale



= 1 million

Source: World Bank - FAO - WorldFish Centre, The Hidden Harvests, 2010.

While large-scale fisheries land larger quantities of fish, small-scale fisheries tend to contribute more directly to food security because their catch is generally destined for direct human consumption and a greater share of their

catch is sold in local markets. For developing countries, it is estimated that over half of the catch for domestic human consumption is produced by the small-scale sector (World Bank, FAO & WorldFish Centre, 2010). The sector

also contributes to foreign exchange earnings through its role in exports. Since 1976, the trade of fish and fishery products has increased at an annual rate of 8.3 per cent in value terms whilst 39 per cent of all fisheries and aquaculture production now enters international food and feed product markets (FAO, 2010).

Small-scale fisheries and aquaculture can also act as centres of market-led growth in often remote rural areas, and as well as the employment and revenue-generation functions of the forward and backward linkages within the sector, horizontal linkages with other industries can provide the basis for local-level growth-engines. For example, the presence of fishers earning a daily or weekly wage in coastal areas can provide local markets for agricultural produce and support local non-fishery related businesses, such as shops, eating-places, lodging and service industries. However, this economic multiplier and 'growth pole' effect is largely unquantified, especially in the context of developing countries (World Bank, FAO & WorldFish Centre, 2010 and Allison, 2011).

As well as being a rich source of protein, many fish provide vital nutrition and health benefits through provision of minerals, vitamins and essential fatty acids. Recent FAO data suggests that fish accounted for 15.7 per cent of the global population's intake of animal protein and 6.1 per cent of all protein consumed in 2007. Fish is most important in low income food deficit countries (LIFDCs) where it provides at least 20 per cent of all animal-source protein – perhaps considerably more due to the underreported contribution of small scale and subsistence fisheries (FAO, 2010). In several small island developing states (SIDS), tropical Asian and sub-Saharan African countries (e.g. Maldives, Kiribati, Solomon Islands, Cambodia, Indonesia, Sierra Leone, Ghana and the Gambia), fish contribute 50 per cent or more of animal protein (FAO, 2009c; Kawarazuka & Béné, 2011) – again, probably an underestimate due to underreporting of small-scale fishery catches. The nutritional value of fish is especially important in countries where the staple crop – such as cassava or plantain – is particularly low in protein and micronutrients. In these situations, a larger proportion of foods rich in proteins and fats, such as fish, are essential, especially in the diets of young children, infants and pregnant women (Kurien, 2005; Kawarazuka, 2010). With food security defined as 'access to sufficient, safe and nutritious food' (Rome Declaration on World Food Security – World Food Summit, 1996), fish and other aquatic products are therefore a keystone of food security for the world's coastal areas.

3 Challenges and opportunities in small-scale fisheries and aquaculture

A key role of the small-scale fisheries and aquaculture sectors is also one of their main challenges: how to continue supplying products to meet the demands of a growing global population who, with increasing wealth, are demanding more animal-source foods, including fish (Delgado, 2003; FAO 2010; Hall *et al.*, 2011). How can ecosystems and the environment be safeguarded and sustainable use of aquatic resources be ensured at the same time as securing equitable social and economic development of the people whose livelihoods depend on these resources? These questions relate directly to the key issues in the green economy: environmental sustainability – including low carbon emissions – resource efficiency and social equity. The opportunities and challenges contained in this sustainability-efficiency-equity equation centre around how to promote private and public investments in technical and operational innovations and in overall governance and management reforms in order to ensure sustainable and equitable growth and development of the fisheries and aquaculture sectors. The development of new methodologies approaches and concepts – such as Life Cycle Assessment (LCA)² (see box in introduction) and indicators for measuring green economy benefits – offer new avenues for action and provide more tools for both stakeholders and policymakers.

3.1 Issues related to securing sustainable small-scale fisheries

The characteristics of small-scale fisheries lend themselves to sustainable development through green growth if the key issues in the sector – as well as in the marine capture fisheries sector as whole – are addressed through political and economic investments and reform: malfunctioning governance, lack of attention to social equity issues in economic planning; fishing fleet overcapacity, overfishing and destructive fishing practices; and inefficient use of fuel and other energy inputs.

Overcapacity in, often subsidized, fishing fleets and a decreasing resource base have reduced the profitability and economic contribution of the fisheries sector as a whole (Sumaila, *et al.*, 2008). Approximately 32 per cent of the global stocks are estimated to be overexploited,

2. LCA is a methodological framework used to quantify a wide range of environmental impacts that occur over the entire life cycle of a product or process. It allows for comparisons between different products and production systems (FAO, 2009).

depleted or recovering from depletion and a further 50 per cent to be fully exploited (FAO, 2010). It has been estimated that the world's fishing fleets are double the size they should be and the potential economic gain from reducing fishing capacity to a sustainable, economically optimal level and restoring over-exploited and depleted fish stocks is of the order of US\$50 billion per annum (World Bank & FAO, 2009). Considering solely the physical availability of fish in food supplies, Sirinivasan, *et al.*, (2010) have estimated that the undernourishment of about 20 million people could have been averted without overfishing.

Overfishing also curbs the potential of small-scale fisheries to add to income and economic growth in coastal areas of developing countries thereby worsening poverty (FAO, 2005; Béné, *et al.*, 2007). Moreover, overcapacity and over-exploitation threaten biodiversity (Pereira, *et al.*, 2010), particularly of larger, longer-lived marine organisms that are more vulnerable to depletion (Norse, *et al.*, 2012), and structurally complex habitats such as coral reefs, which are easily damaged by indiscriminate fishing methods.

While the overcapacity of the large industrial fishing fleets has been well documented (World Bank & FAO, 2009), they are not the only sources of overexploitation. If connected to large enough markets, small-scale fisheries can also deplete high value marine resources (Cinner & McClanahan, 2006). Weak governance, the high dependence of coastal communities on fishery resources and the lack of alternative livelihood options, lead small-scale fisheries to overexploit inshore resources in many parts of the world (Pomeroy, 2011).

Rights to access and use of fisheries resources are often poorly defined, ineffectively enforced, or unfairly distributed. The variability and diversity of small-scale fisheries and their close links with communities make them unsuited to traditional top-down command and control resource management approaches. Moreover, poverty in fishery dependent communities is not necessarily linked directly to resource overexploitation, but rather reflects the lack of wider institutional, political and economic advantages in rural (and in some cases urban) poverty (Béné, 2003; Béné, *et al.*, 2007). Marginalization and violation of the rights of fish workers and fishing-dependent people sometimes results in a lack of access to public services, including health and education, a lack of participation and representation in the policy making process and, in many cases, a lack of access to efficient markets or trade. There is hence a need to combine resource

management with addressing social and economic development (ICSF, 2007; FAO, 2009b; Allison, *et al.*, 2011).

Additional threats to small-scale fisheries include adverse impacts from other sectors, such as agricultural run-off, waste discharge and eutrophication which can negatively impact the ecosystems that communities rely upon. Increasingly, small-scale fisheries also suffer from the effects of climate change, the impact of which on ocean life, productivity, reproduction and food toxicity remains un-assessed (Badjeck, *et al.*, 2010; Sumaila, *et al.*, 2011). Marginalized communities are also often quite vulnerable to natural disasters, environmental stress and external socio-economic and biological shocks. Moreover, small-scale fisheries must also compete for access to land and water rights with other sectors, including tourism, construction, aquaculture and urban development, among others. Scarcity of data on the economic and social importance of small-scale fisheries exacerbates the often overall marginalized position of the sector (FAO, 2011b).

In view of this precarious situation in many small-scale fisheries, investments in policy and governance reform are needed. Recent developments present opportunities in this respect, including the recognition of the important economic and social roles of small-scale fisheries by the international community in forums such as the United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea (United Nations, 2011) and FAO's Committee on Fisheries (COFI) that recently mandated the development of international guidelines for securing sustainable small-scale fisheries (FAO, 2011). Moreover, recent developments in the governance arena in many parts of the world include decentralization of resource management responsibilities, the introduction of co-management arrangements (including recognition of traditional authorities, management processes and use rights) and the need for integrated and holistic approaches such the ecosystem system approach to fisheries (EAF). Discussions have also evolved to include a human rights perspective and the right to secure and just livelihoods, including social and economic rights, experiences of combining resource governance with social development are becoming available and the need for holistic and integrated approaches is generally accepted (FAO, 2011b).

While governance reform and distributive justice are key 'green economy' issues from a sectoral perspective, reducing energy use and 'carbon footprint' in fisheries has synergies with these other

areas of reform and could provide opportunities for fisherfolk through participation in ecosystem services markets (including carbon markets) as well as benefitting from 'green technology' efficiency gains. In fishing in general, energy use and carbon emissions are closely related because of the common use of fossil fuels. The fishing gear and its design, which is related to the biology of the target species, is the main factor determining energy consumption per kilogram of fish landed. Active demersal fishing gears (dredging and bottom trawling) are energy-intensive fishing methods, while passive fishing gears, such as hook and line, gill nets, or traps, require less energy. Mid-water pelagic fishing also tends to be less fuel consuming than fishing the sea bed (Ziegler, 2009; World Bank, FAO & WorldFish Centre, 2010). Carbon emissions are also generated from onboard and onshore cooling systems and from transportation of fish (Ziegler, 2009).

The distance travelled between fishing grounds and ports also influence the amount of fuel used and as many fish stocks have declined due to overfishing, fishing vessels often travel further and search longer for the same amount of fish (Tyedmers, 2004; World Bank, FAO & WorldFish Centre, 2010; Suuronen, et al., 2012). The fuel consumption of fishing fleets also increased due to the growing number of powerful fishing vessels, introduced from the 1950s to the millennium (Tyedmers, et al., 2005). Construction of large vessels has since slowed (Cochrane & Garcia, 2009) but overall fleet capacity remains too high (see above). Coupled with rising fuel prices, fuel hence continues to be a major cost and this has triggered research on and development of various energy saving technologies contained in the concept of Low Impact and Fuel Efficient (LIFE) Fishing. "LIFE fishing addresses the complex dynamic of energy consumption and environmental impacts with the objective of improving the economic viability and environmental sustainability of fishing operations." (Suuronen, et al., 2012)

Small-scale fisheries more often use passive gear and would hence be likely to be more fuel efficient than the large-scale sector. However, due to the great diversity of the subsector, this is not a firm rule. Non-motorized vessels continue to be an important part of the sector (see box on page 17), particularly though in inland fisheries. Still, also in small-scale fisheries of developing countries, fuel tends to constitute an important part of overall operational costs and the volatility of fuel prices is of particular concern in this respect (World Bank, FAO & WorldFish Centre, 2010). Reducing fuel consumption would hence be doubly beneficial – contributing to both environmental and socioeconomic sustainability.

3.2 Aquaculture growth and development

The production of food fish from the aquaculture sector as a whole has grown by an average of 8.3 per cent during the period 1970-2008. Aquaculture using seawater – in ponds and in the sea – accounts for close to a third of the total production quantity and value. Many high-value finfish, crustaceans and mollusc species (abalone, oysters, mussels, clams, cockles and scallops) are produced in marine aquaculture. With markets for seafood and other marine products expanding, well-managed coastal aquaculture and mariculture continue to offer significant scope for green growth and production of animal-source foods produced at lower levels of CO₂ emissions in comparison to most meat and poultry production systems (Hall, et al., 2011). Aquaculture can also contribute positively to environmental rehabilitation and mitigating negative impacts of other industries and activities at the same time as offering alternative and supplementary employment opportunities for coastal communities but careful planning and good management are required (FAO, 2010; FAO, 2011b). Innovative aquaculture production systems, including greater use of environmentally friendly feeds and reduced energy use, are also needed.

At the same time as responsible aquaculture can generate important environmental benefits, such as "recovery of depleted wild stocks, preservation of wetlands, desalinization of sodic lands, pest control, weed control, and agricultural and human waste treatment" (p. 33, FAO, 2011c), some forms of aquaculture add environmental pressures on already suffering ecosystems. These negative environmental effects include habitat destruction, effluent discharge, disease and escapes, and high use of fishmeal and oil in feeds (FAO, 2011c). Feed is key in aquaculture production and development and the growth of carnivorous-high value fish aquaculture has an explicit impact on wild fisheries. In 2006, the shares of fishmeal and fish oil that were utilized in aquaculture production were 57 per cent and 87 per cent, respectively (FAO, 2011c). If the dependency on fishmeal and fish oil were reduced, important gains could be made with regard to profitability, environmental impact as well as food and nutrition security. This will require innovations both in technologies and management. The already high costs and increasing supply limits associated with fishmeal and fish oil are likely to continue driving the trend of using crops (in particular soybean meal) as a substitute. There are also concerns that increased use of trash fish as feed in aquaculture may divert food fish from poor population groups. The situation is

however ambiguous because aquaculture may at the same time provide important livelihood opportunities (Hall, *et al.*, 2011).

For all the potential environmental impacts of aquaculture, many of its production forms continue to have advantages from a resource and ecological efficiency perspective over other animal food production systems and it has room for further efficiency gains (Hall, *et al.*, 2011; FAO, 2011c). Further technology and production system developments will however be needed to capitalize on such advantages.

As aquaculture production increases, so do the number of people employed in the sector. The sector has an important potential for economic diversification. This includes both employment directly at the farm level as well as non-farm opportunities in supply, processing and marketing activities. Small-scale aquaculture that often involves family labour can provide opportunities for women and in this way contribute to their empowerment (FAO, 2010b; FAO, 2011c). However, some types of aquaculture, e.g. coastal shrimp culture, have caused socio-economic conflicts because of adverse impacts on the livelihoods of adjacent communities due to salinization of soils, water pollution, increased frequency of flooding and the degradation or impediment of access to common natural resources such as mangroves, grazing land, fresh water aquifers, and fishing grounds. The recent trends toward automation, mergers, vertical integration and increasing labour productivity potentially exclude local communities and rural people. The impacts of increased automation and intensification on energy consumption and land tenure as well as access to water will continue to be contentious issues during aquaculture development (FAO, 2011c).

Aquaculture influences carbon emissions by the direct and indirect use of fossil fuels in production systems and the conversion of land that is high in sequestered carbon such as mangroves, sea grass or forest areas into aquaculture production. Aquaculture also generates emissions of waste nitrogen and phosphorus that impact on the environment. While more needs to be known about environmental emissions from different types of aquaculture production systems, there are strategies such as improved energy use and soil, water and waste management that can create positive results. Opportunities to increase carbon sequestration include, *inter alia*, mollusc and seaweed culture in coastal areas and integration of aquaculture and agriculture activities (Bunting & Pretty, 2007; Hall, *et al.*, 2011).

Data deficiencies in the aquaculture sector are also a key impediment to successful development. As aquaculture diversifies and the intensification of production processes continues, the need to disaggregate production data increases, since the management and governance of aquaculture may differ in different production systems. In addition, as with small-scale fisheries, data systems must improve in order to capture the full contribution of aquaculture to poverty alleviation and food and nutrition security, as well as any multiplier effects that might exist.

In order for aquaculture to fulfil its potential to contribute to food and nutrition security, active support to growth and private investment will be required. Governments will also need to support the sector's development with ensuring that enabling and adequate regulatory frameworks are in place and that innovations and technological developments – compatible with green growth – take place. An important challenge in this sector of rapid development is how to ensure that policies, incentives and institutional structures are in place that promote the desired behaviour of producers and consumers. In a world of increasing competition for resources, this includes further application of the ecosystem approach to aquaculture (EAA) and the adoption of better management practices (BMP), for example in dealing with risk to aquaculture development, such as disease management, natural disasters and stock escapement into the wild, some of which can be managed through development of risk assessment procedures and insurance markets (Secretan, *et al.*, 2007). Such approaches also help address cross-sectoral considerations and promotion of integrated marine governance and spatial management frameworks.

4 The way forward

The future vision of the small-scale fisheries and aquaculture sectors that is fully committed to the green economy is one that is more environmentally sustainable, increases productivity and distributes the rewards of that productivity more equitably throughout dependent communities, and provides goods and services that contribute to wider poverty reduction and food and nutrition security where possible. The transition from the current status quo to sustainable development through the pathway of green economy requires active participation and commitment from all stakeholders and is inextricably linked to wider development goals that consider a human

rights based approach to economic, political and social development.

There are a number of policy directions and actions that are needed to achieve this transition and to address the sustainability-efficiency-equity dimensions of the green economy pathway. Building on the challenges and opportunities discussed above, this section presents key areas to be addressed: the enabling conditions and investments required in the areas of technology, and policy and governance. This includes

- securing political commitment for support through increased understanding and recognition of the role and contribution of small-scale fisheries and aquaculture to poverty alleviation and food and nutrition security;
- governance reform including the building effective institutions that lead to the adoption of integrated and ecosystem approaches to fisheries and aquaculture with fair and responsible tenure systems to help turn resource users into resource stewards;
- support to the development of green technology and production systems; and
- promotion of market-based incentives and industry and consumer awareness-building to give preference to products from sustainable fisheries and aquaculture.

4.1 Increased recognition of small-scale fisheries and aquaculture

The first and most important step for the sustainable transition of small-scale fisheries is to recognize their current and potential contribution to poverty alleviation and food and nutrition security at all levels of management and government. For small-scale fisheries to realize this potential they need to be incorporated into national development policy with a special emphasis on the structural and institutional causes of poverty in addition to being managed for ecological sustainability and economic productivity.

In recent decades, the profile of small-scale fisheries as well as the awareness of their social and economic role has begun to increase, as demonstrated by the widespread participation in events such as the Global Conference on Small Scale Fisheries: Securing Sustainable Small-Scale Fisheries: Bringing Together Responsible Fisheries and Social Development, headed by FAO in October 2008 (FAO, 2009b), subsequent regional consultations (FAO, 2010d; FAO,

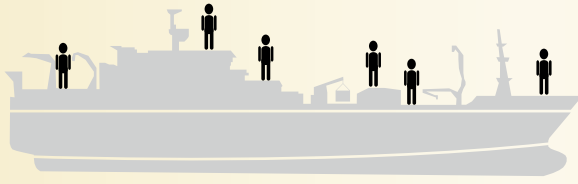
2011d; FAO, 2011e) as well as the agreement by COFI to develop a dedicated international instrument in support of small-scale fisheries within the framework of the Code of Conduct for Responsible Fisheries (FAO, 2011). The development of this instrument is underway and will further support the recognition of the sector. Still, improved information on and better integration of small-scale fisheries in economies is required. Policy coherence and enhanced linkages between small-scale fisheries, sectoral policies and strategies as well as national planning and development processes need to be promoted (FAO, 2011b).


In aquaculture, many challenges remain insufficiently assessed or inadequately addressed by current policy frameworks (OECD, 2010). An improved understanding of poverty and effective resource management are at the centre of the future challenges for sector (FAO, 2010c). Aquaculture has increasingly become “a means to increase domestic fish supply to low-income consumers, develop opportunities for employment, support local economic multipliers, and to generate revenue from trade” (Allison, 2011). The emphasis of pro-poor aquaculture development hence appears to be shifting away from directly securing food security for the poorest small-holder farmers. It may be that a wider support to the sector, i.e. to both small-scale and large-scale aquaculture, is the best strategy for realising its potential as a contributor to poverty alleviation and food and nutrition security (Allison, 2011). Policy and decision makers need to understand the rapid technological development of the sector and ensure that regulations and governance discourage environmentally, economic and socially unsustainable practices at the same time as green growth is promoted (Asche, 2011).


The challenges of transition in the small-scale fisheries and aquaculture sectors are likely to be considerable as it requires political will and commitment, organizational development and capacity building – in communities and at national and regional levels. In aquaculture, the possibilities that the development prospects of the sector offer in the context of poverty alleviation need to be better understood and explored. For this reason, enabling institutional conditions and safeguards must be put into place to protect poor and vulnerable people and enable them to safely and sustainably access and exploit the resources to which they are entitled thus lowering the short-term impact of a transition to a green economy development pathway.

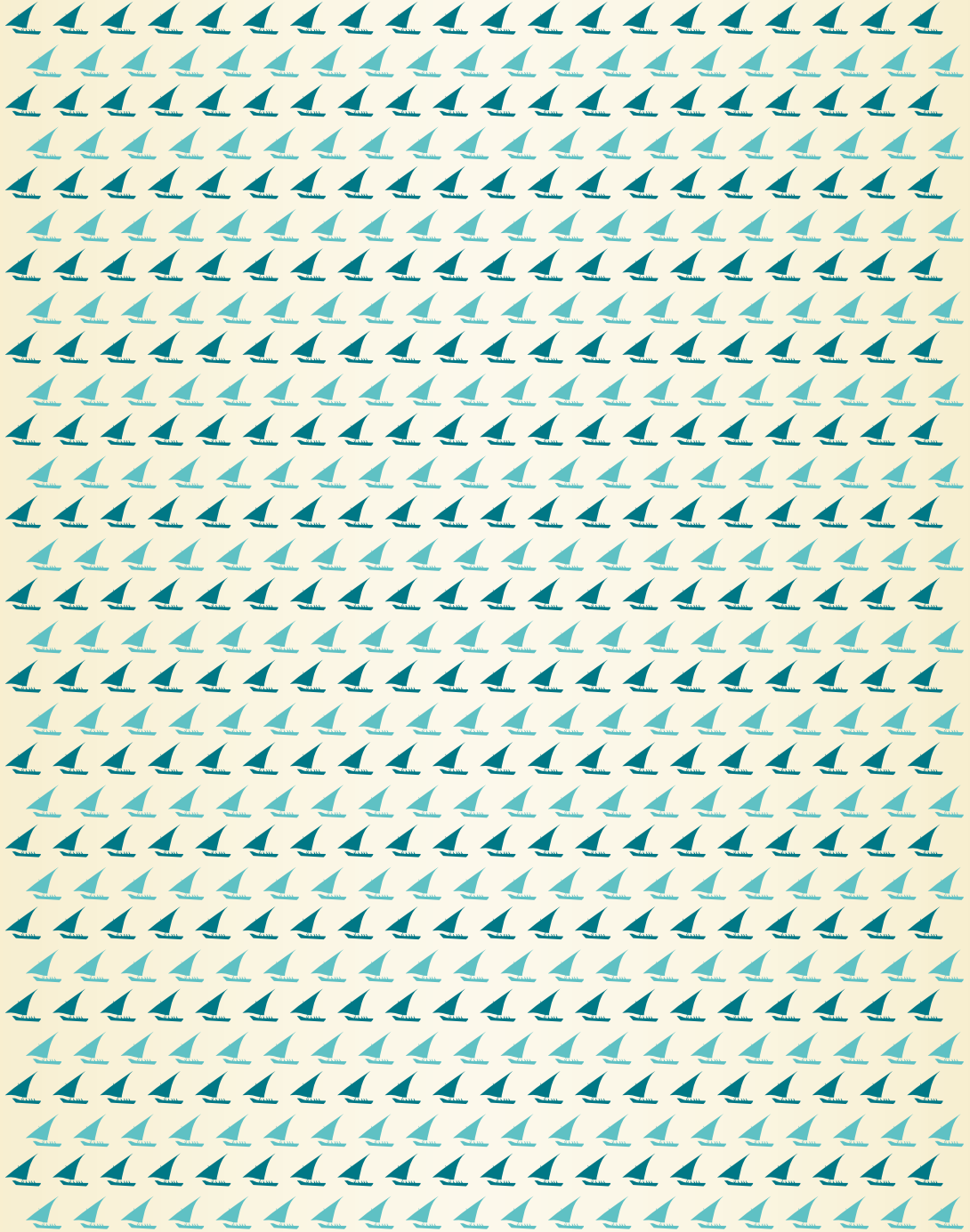
Size does matter

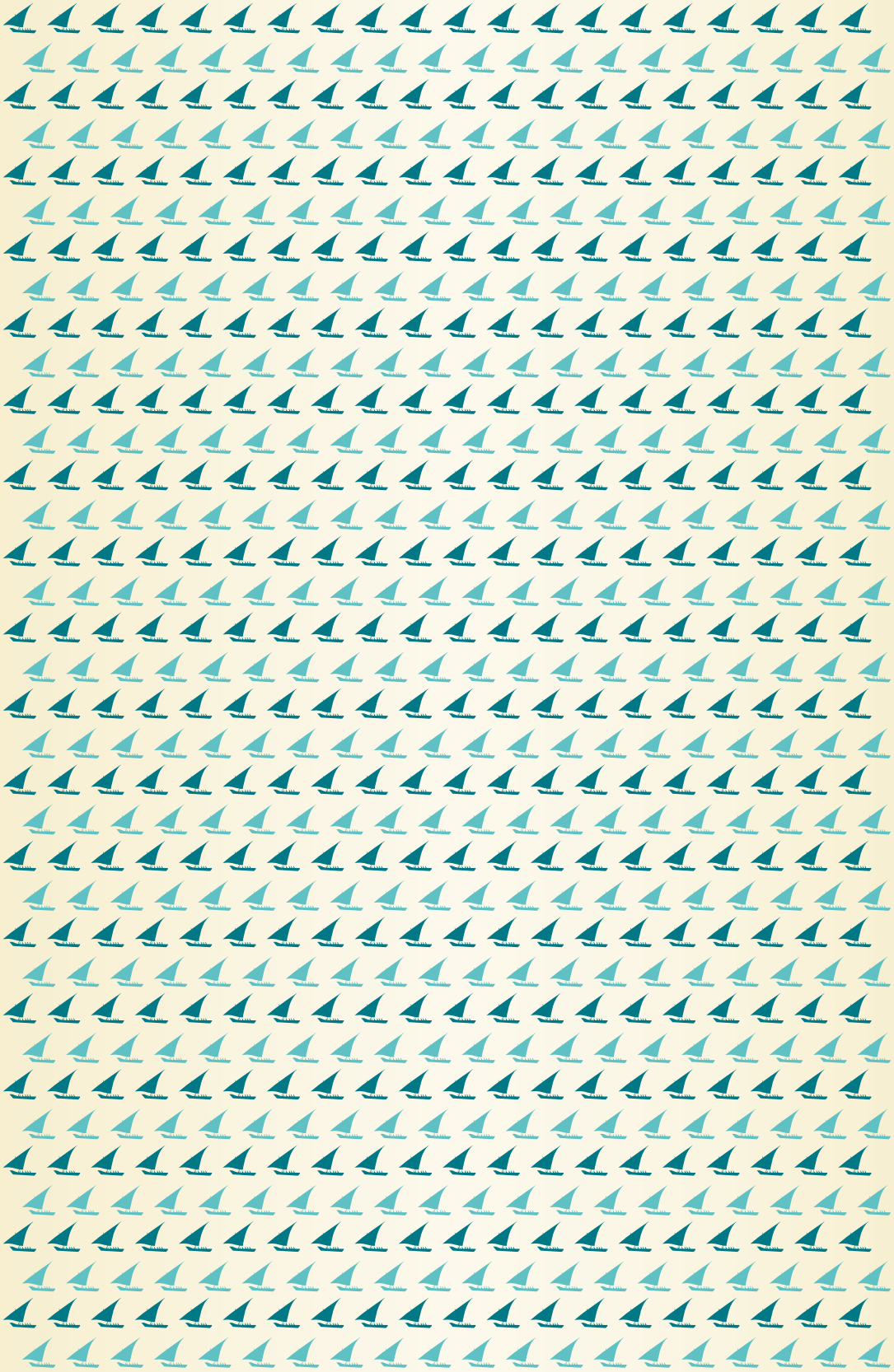
In one trip the world's largest fishing trawler produces as much as 7 000 traditional African fishing boats per year



 = 10 fishermen

 = 10 traditional fishermen





Source: www.atlantic-dawn.com; The Guardian, press review.

4.2 Governance reform, regulatory frameworks and institutional arrangements

Policy and governance reform is key to green growth transition in small-scale fisheries and aquaculture. Good governance is also fundamental for the implementation of new innovations and technologies further discussed below. Recent decades have shown rapid innovation in fisheries management, with governments, market mechanisms and fishers combining to regulate fishing activities and supply chains. This has led to increasing official recognition of the customary marine tenure and the rights of fishers, fish workers and fishery dependent communities to participate in the decision making process. There are some success stories that include fisheries managed with a range of institutional arrangements including community-based systems often centred around territorial use rights (Christy, 2000) and state-community partnership arrangements (Charles, 2005; Gutiérrez, et al., 2011). The type of use rights or tenure regime employed and its

success depend on the context and individual characteristics of different fisheries and fishery-dependent communities (Cochrane & Garcia, 2009; FAO, 2011).

In the short term, and to increase success, *primary fisheries management* could be a first course of action. Borrowing from concepts in primary human health care, primary fisheries management seeks to increase social and ecological resilience while encouraging food security and poverty alleviation in small-scale fishing communities. In general terms, rather than requiring detailed and expensive assessments, primary fisheries management that minimizes demands on managerial and scientific capacity may be adequate in the short term to move coastal fisheries towards a sustainable path (Cochrane, et al., 2011). For longer term management, in a green economy context of sustainability, growth and equitable distribution of resource wealth, policy frameworks that draw on concepts of wellbeing and on human rights principles and legislation

The impact of co-management and key indicators of success

In a study of 130 fisheries under co-management regimes, Gutiérrez, et al., (2011) found that almost 70% achieved all social, economic and ecological objectives as determined by the authors. The strongest attributes contributing to success included the quality of leadership, the presence of individual or community quotas, social cohesion and protected areas. Overall, frequency of success was also strongly correlated to the number of governance attributes stemming from both community and central governance. The results of the study suggest that fisheries co-management regimes with strong leadership and a focus on the problems of both the resources and the people that target them lead to the highest rate of success. Another study by Evans, et al., (2011) suggested that co-management regimes in developing countries resulted in benefits for users as expressed by

key process indicators (participation, influence, rule compliance, resource control and conflict) and outcome indicators (fishery yields, resource wellbeing, access, household wellbeing and income). However, when the dataset stemming from Philippine fisheries was excluded, the results were not conclusive, creating the need for more extensive and differing approaches to measure the impact of co-management on fishery dependent communities.

Even considering data deficiencies and differing measures of 'success' both studies suggest that co-management regimes, if established properly and in a wider development context, have the ability to improve resource and resource user indicators. Nevertheless, more regional and global studies are required.

Source: Gutiérrez, et al., 2011; Evans, et al., 2011.

could play an important role. (Sharma, 2009; Allison, *et al.*, 2011; Coulthard, *et al.*, 2011)

The transition towards sustainable green fisheries will also require significant investments for reducing fishing capacity and abolishing – or at least mitigating – destructive fishing practices. Up-front costs of this transition could be potentially recovered in the medium and long term by the additional resource rents generated by well-managed fisheries. The greater economic returns could also become a source for social service investments to the benefit of small-scale communities (Kurien & Willmann, 2011).

Developing a stronger framework for governing fisheries using private, community and state-based systems of access and use rights is a current priority in fisheries governance (FAO, 2011). If appropriately tailored to the variety of fisheries systems, such a transition to 'rights-based fisheries' can help sustain fisheries and aquaculture and realize and distribute their benefits equitably. Community-based management regimes or co-management arrangements that decentralize management powers to the local level and assign fishing rights such as territorial use rights (TURFs) have been shown to be effective in small-scale fisheries. Bringing decision-making closer to the people tends to allow for better accountability and transparency. However, the effectiveness of community-based management and co-management is strongly dependent on the quality of leadership and of the strong adoption and enforcement of resource conservation measures (Cochrane & Garcia, 2009 and Gutiérrez, *et al.*, 2011).

This governance reform requires investments in capacity building with small-scale fisheries organizations to strengthen their ability to participate meaningfully in fisheries policy-making and management and to draw on their unique knowledge and experience. There is also a need for regulatory frameworks that allow for and support the implementation of decentralized tenure systems. If successful, resource users may become resource stewards, participating in policy making processes and as strong implementers of the resulting management schemes. The creation of appropriate incentive systems and decentralized easily enforceable regulations engage stakeholders and facilitate their ability to comply with these regimes. In small-scale fisheries, participatory monitoring, control and surveillance measures carried out by users themselves have a greater opportunity to succeed, especially in remote and marginalized fishing communities. A regulatory framework led by the users can, in

certain circumstances, be more cost effective, thus freeing up resources for other areas³.

Regulatory frameworks and institutional arrangements must also consider the need for cross-sectoral integrated coastal area management and marine spatial planning processes. This applies to both fisheries and aquaculture. Aquaculture development affects and is affected by many other activities and there is a need for the sectoral integration of various activities. A number of sectoral integration dimensions need to be considered:

- 'Policy (institutional) integration: minimizing intersectoral conflict and coordinating policy and management measures to ensure consistency and a situation that is fair for all.
- Operational (or enterprise-level) integration: ensuring that the various activities pursued by a particular enterprise are coordinated and mutually reinforcing. This may include recycling of wastes.
- Waterbody integration: promoting a balance between different activities or sectors within an aquatic system in order to maximize the reuse of nutrients or other materials, thereby increasing efficiency and reducing pressure on the environment.
- Provision of 'green infrastructure': maximizing the delivery of ecosystem services, including waste assimilation, by ensuring that areas or corridors of a range of habitat types are conserved or re-created and managed appropriately.'

Recognizing the importance of ecosystem linkages, including both bio-ecological and human dimensions, the need for integrated approaches such as EAF and EAA are becoming widely accepted. The further application of such approaches will require a much closer coupling of science, policy and management. It will also require fundamental changes in the institutional arrangements governing fisheries management and aquaculture development, including mechanisms for effectively involving the broadened definition of stakeholders in decision-making and management, provisions for devolution of authority and the setting up of decentralised management systems (e.g. co-management) and increased coordination, cooperation and communication within and among relevant institutions and resource user groups, in fisheries and aquaculture as well as outside the sector (tourism, industrial development, etc) (FAO, 2009; FAO, 2010b).

3. Available comparative studies on the cost effectiveness of different forms of management focus primarily on OECD countries (OECD, 2003; Schrank *et al.*, 2003; Hauge & Wilson, 2009)

Accordingly, it is important to consider multi-agency multi-sectoral coordination between government and stakeholders, to create effective and accepted development initiatives. As mentioned above, the inclusion of fishery and aquaculture governance into a wider national human rights perspective can potentially lead to an improvement of standards of living in fishing and fish farming communities while increasing their ability to manage aquatic resources in the long term (Allison, *et al.*, 2011). A more specific example of coordinated national strategic planning and policy coherence is the need to include small-scale fisheries and aquaculture in climate change and natural disaster prevention and adaptation plans (FAO, 2011).

Effective institutional arrangements are needed at all levels – local, national as well as regional. Regional institutions provide the basis for coordination among countries in relation to the management and conservation of shared and transboundary resources, development of policy advice, dissemination of technology, habitat restoration and protection, and to give impetus to structured collaboration among members. Many fishery resources, including highly valuable tuna resources, are internationally shared stocks, for whose conservation and management the effectiveness of Regional Fisheries Organizations/Arrangements is critical for success. The institutional arrangements needed to establish effective and resilient management regimes for shared fish stocks have been examined by various expert groups and committees during the last decade (FAO, 2002; Munro, 2000; Munro, *et al.*, 2004; Chatham House, 2007; OECD, 2009). For SIDS and other small countries with limited capacity to govern and influence global decisions, effective regional institutions are key actors in the management and policy-making process. Overall, the key for effective regional institutions is that member states agree with them and support them wholeheartedly, through participation as well as funding.

At the international level, there is a legislative and policy framework to support national and regional structures and fisheries and aquaculture governance reform in place. The FAO Code of Conduct for Responsible Fisheries and its related international agreements and plans of action inform fisheries and aquaculture policies throughout the world (Hosch, *et al.*, 2011). The challenge is to provide incentives and adequate resources to implement this framework at the local, national and regional level.

4.3 Green technology innovations and production systems

Although both small-scale fisheries and aquaculture tend to require lower energy inputs than large-scale fisheries and other animal food production systems, new technologies will be required to make more efficient use of natural resources (e.g. fuel, and water, land, energy and feed ingredients in aquaculture). Accordingly, governments must support and invest technical and operational innovation that improves efficiency while lowering operational costs, fuel consumption and biodiversity losses. New technical options need to be supported not only in primary production but throughout the value chain.

The rise in fuel prices is already leading to investment and development of a wide variety of alternative fuels and could lead to a substitution of fossil fuels. Their potential as viable substitutes in small-scale fisheries and aquaculture though has not been clearly explored. Alternative non-fuel propulsion systems also gain popularity as energy saving complements and substitutes. Wind energy or a return to manual propulsion with oars or paddles can be a good complement – as in the wind-assisted engine-powered boats that were relatively common during the 1970's fuel price crisis. However, the resources reachable by such propulsion methods are often limited and exploited already. While a combination of technologies can lower fuel consumption in the global small-scale fishing fleet, the overall impact could be negligible if not accompanied by the restoration of depleted fish stocks in inshore areas.

The design and transfer of low impact and fuel efficient (LIFE) fishing gear and techniques (such as lighter material to reduce drag, thinner twines, improving boat shape), can improve the sustainability of SSF. Low impact passive gears should be promoted in small-scale fisheries, as a fuel efficient (although not always less destructive) alternative to active gears. These low impact passive gears include, hook and line, traps-nets and pot-fishing, among others. These are techniques that are already widely used in the small scale fishing sector (Suuronen, *et al.*, 2012).

Simple and easy-to-do operational improvements can also be pursued. For fishing, these include improved engine performance technology and maintenance (i.e. by cleaning and maintaining engines properly, by exchanging older engines etc.), reducing steaming and towing speeds, cleaning hulls regularly, etc). In the post-harvest sector, solar power (e.g. solar driers) can be effective for small-scale processing while improved storage and

transportation methods (e.g. improved insulation materials, efficiency in ice-plants, etc.) can improve energy efficiency (Suuronen, et al., 2012).

In aquaculture, possible innovations and developments include those in feed technology that reduce dependence on energy-expensive and possibly unsustainable fishmeal and fish oil from wild caught fisheries, increased use of species that do not require high inputs of feed, recycling of waste from other industries to supply nutrients for algal growth while promoting the use of algal feed for fish and increased use of more energy efficient equipment (e.g. efficient water pumps, LED lights, alternate sources of electricity, etc.).

The development of Integrated Multi-Trophic Aquaculture (IMTA) has the potential to drastically reduce or even neutralize the environmental impacts of aquaculture, especially those related to effluents discharge and eutrophication. The use of recirculating systems – Aquaculture Recirculation Systems (RAS) – is also an opportunity to minimize some of the environmental impact of aquaculture, including biosecurity and waste treatment. However, as recirculating systems tend to be intensive, consume more energy and result in higher labour productivity, both carbon emissions and social sustainability issues may arise. Opportunities also exist in closing the life-cycle in farmed species that depend on wild seeds. While an increasing share of production is based on hatcheries, an important part of is still derived from wild seed (FAO, 2010b; FAO, 2011c; Hall, et al., 2011).

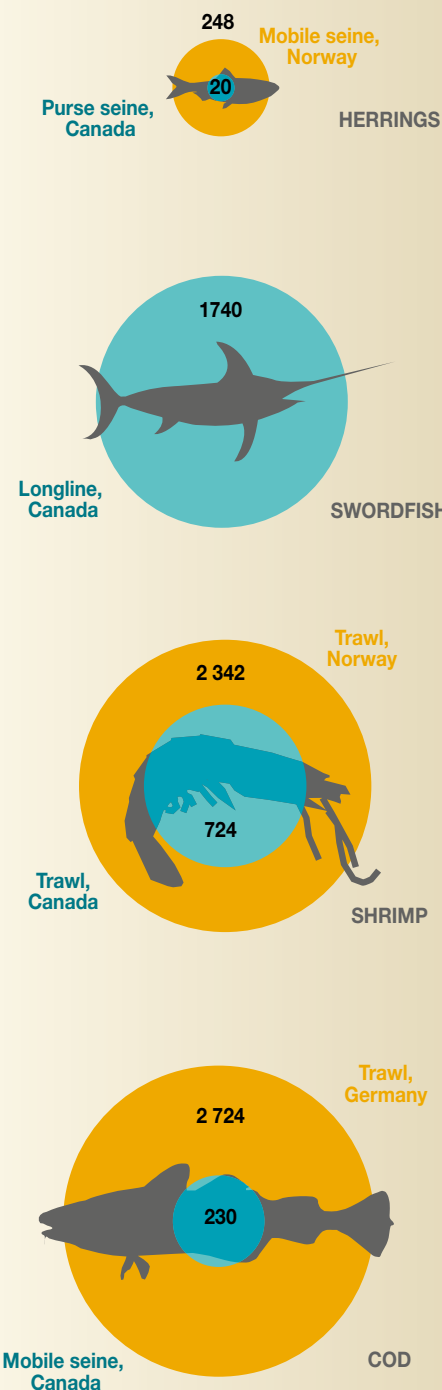
4.4 Market-based incentives and awareness raising

Economic incentives play an important role in changing behaviour. When consumers start to demand products from sustainable and fair fisheries and aquaculture production, this will constitute a strong incentive for producers and other stakeholders to pay more attention to responsible practices. This development has already started and certification and eco-labelling schemes can provide a powerful market incentive for fisheries to comply with sustainability requirements. While the evidence on the correlation of labels and good management practices is still limited to some fisheries, the impact of consumer preference is becoming a driving force for improving fisheries management in many countries. In response to the increasing use of certification and eco-labelling schemes, FAO has developed Guidelines for the Eco-labelling of Fish and Fishery Products from Marine Capture Fisheries (FAO, 2009), along with Guidelines for Eco-

Fuel for fish

Energy intensity range for selected fish species

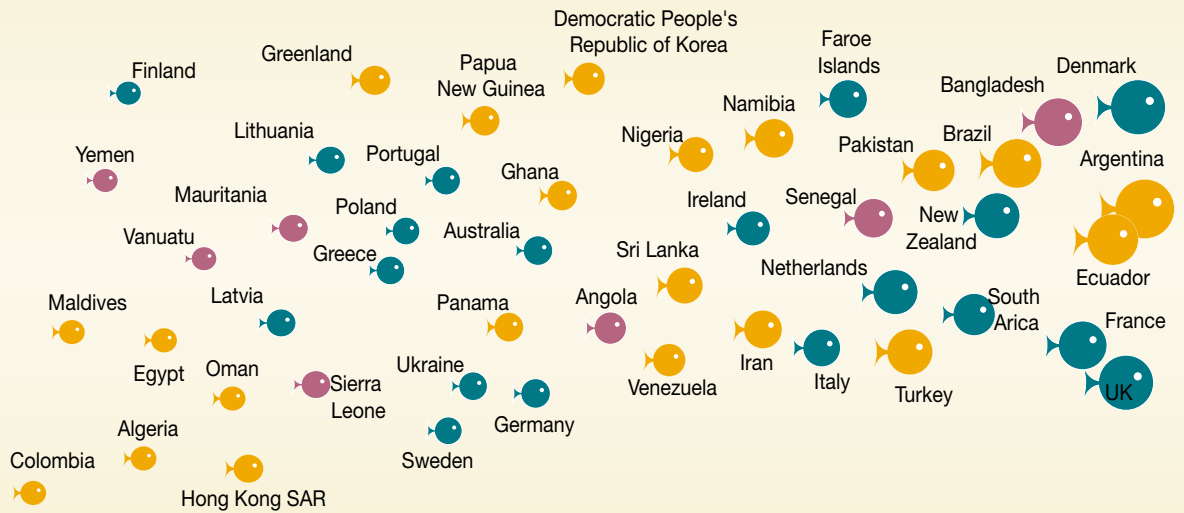
Litres per ton, type of gear used and location



Note: averages based on data collected from different vessels, between 1998 and 2000

Source: Fisheries Centre Research Reports, Fisheries Impacts on North Atlantic Ecosystems: Catch, Effort and National/Regional Data Sets, University of British Columbia, Canada, 2001.

In the fishnet



Note: Only countries with catches over 100'000 tonnes are shown.

Source: FAO aquastat, accessed in February 2012.

labelling Fish and Fishery Products from Inland Capture Fisheries and Technical Guidelines on Aquaculture Certification (FAO, 2011b).

While some internationally recognized labels, such as the Marine Stewardship Council (through its Developing World Fisheries Program), have put forth great efforts to facilitate the certification requirements of certain small scale fisheries, the relatively high cost of these schemes continues to be an impediment for many small scale fisheries of developing countries. Still, the expected positive outcomes of eco-labelling, including increased profit margins, better conservation and a shift of consumer preference towards sustainable fisheries cannot be ignored. As long as labels and certification schemes are not used as barriers to trade and their accessibility to small-scale fishers and fish farmers is improved, they should feature prominently in a green economy.

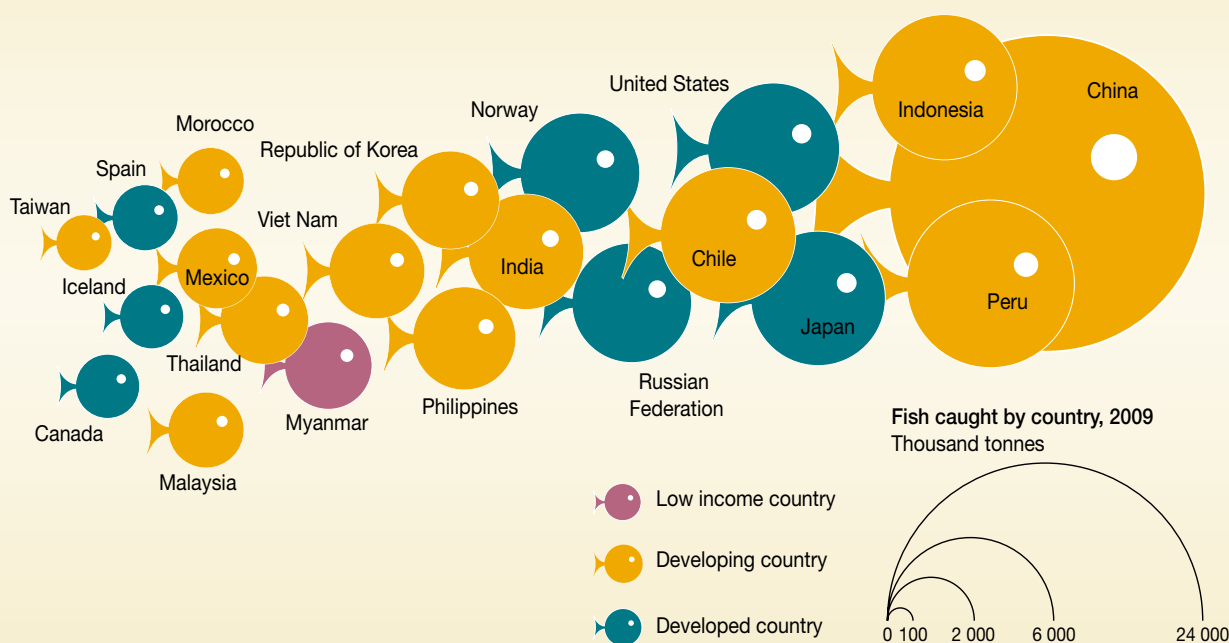
Payments for ecosystem services (PES) are another market-based measure that can promote sustainability. PES are voluntary transactions where a well-defined environmental service is purchased by a service buyer from a service provider, on condition that the provider ensures that the environmental service is maintained (Wunder, et al., 2008). The system attempts to specifically value the services that an ecosystem provides as well as the costs incurred by destruction of the ecosystem. With PES, households (or other ecosystem use decision makers) are paid to protect the resource, and

example of which are payments to coastal communities to preserve mangrove forests. The concept is being tested in other fields (e.g. oil extraction) and applications to fisheries and aquaculture could be tested. A specific example of their use is in the conservation of mangrove forests, which have recently been made eligible for carbon markets under the Reduced Emissions from Deforestation and Degradation avoided (REDD+) scheme.

For consumers to be willing to pay a premium for sustainably and fairly produced products (or to pay for or contribute to ecosystem services), they need to be informed and have access to information. Awareness raising hence becomes an important component in the context of introducing economic incentives for green growth. This is also related to the discussion above on increasing the recognition of the role and importance of small-scale fisheries and aquaculture for poverty alleviation and food and nutrition security and to ensure political commitment to the necessary reforms.

5 Conclusions

Fishers and fish-farmers should, given their dependence on ecosystem services, be stewards of the wider marine ecosystem. Greening the fisheries and aquaculture sectors requires the overall recognition of their wider societal roles – in particular that of small-scale operations for local economic growth, poverty reduction and food security – through a comprehensive



governance framework managing externalities from and on the sector; implementing an ecosystem approach to fisheries and aquaculture with fair and responsible tenure systems that foster stewardship and greater social inclusiveness; and integrating fisheries and aquaculture into watershed and coastal area management, including through spatial planning.

The reduction of fishing effort and capacity and the use of non-destructive fishing techniques will reduce the negative impacts on biodiversity, including on larger, longer-lived marine organisms that are more vulnerable to depletion, and structurally complex habitats such as coral reefs, which are easily damaged by indiscriminate fishing methods.

Strengthening regional fisheries bodies, national fisheries management agencies, fishing community and fishworkers organizations and private sector associations is critical to sustainable and equitable use of marine resources. A strong international legislative and policy framework for fisheries is already in place with the FAO Code of Conduct for Responsible Fisheries and its related international agreements and plans of action. The social, economic and cultural dimensions of this framework will be further strengthened through the development of international guidelines on securing small-scale fisheries to complement the Code as called for by FAO's Committee on Fisheries. The challenge is to provide incentives and adequate

resources to implement this framework at the local, national and regional level.

Investment to reduce fossil energy use and thus the already low carbon footprint of fisheries and aquaculture has potential gains in terms of improved economic performance and in contributing to climate change mitigation. The needed reductions in fishing capacity and effort in capture fisheries along with the adoption of green technologies can drastically lower fuel consumption and GHG emissions while greatly enhancing the fisheries sector's contribution to economic growth, food and nutrition security and poverty reduction. Well-managed coastal aquaculture and mariculture offer significant scope for green growth and employment opportunities for coastal communities at low levels of CO₂ emissions when compared to other protein production systems.

Supporting development and investment in green technology and raising industry and consumer awareness on the sustainability of fisheries and aquaculture are key approaches to behavioural change and transition to green growth in fisheries and aquaculture. Green technologies include: low impact, fuel-efficient fishing methods; innovative aquaculture production systems using environmentally friendly feeds; reduced energy use and greener refrigeration technologies; and improved waste management in fish handling, processing and transportation.

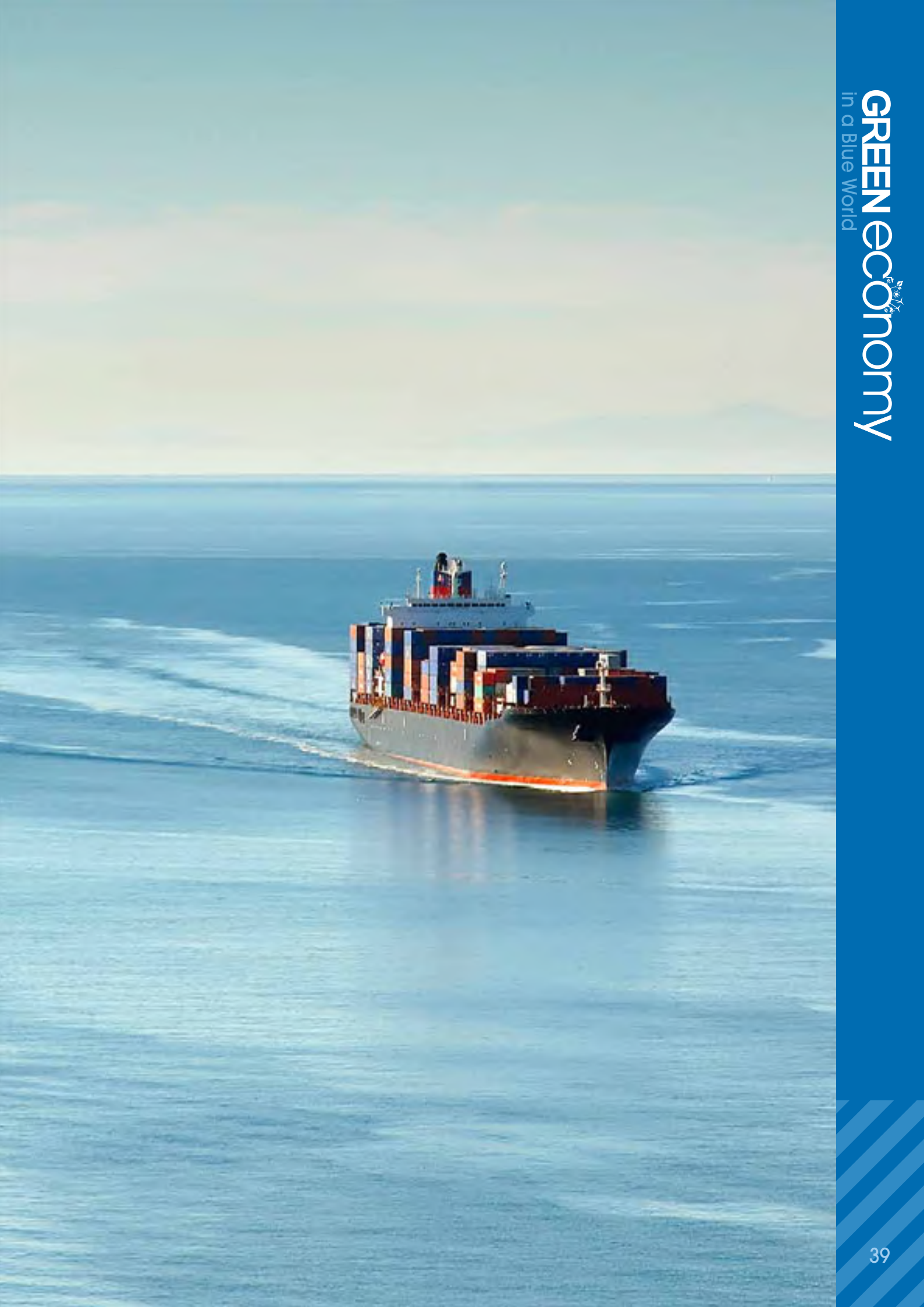
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MARITIME TRANSPORT

As the coordinator of this chapter, the International Maritime Organization wishes to acknowledge the contribution of the International Chamber of Shipping, WWF and UN-Oceans.



1 Introduction: Shipping as an important sector of a Green Economy

This chapter attempts to present the contribution of international maritime transport to the three pillars of sustainable development.

It deals essentially with international shipping which, for its effective operation as the transporter of some 90 per cent of world trade, requires global policies and regulations to ensure uniform implementation and enforcement of the technical standards which enable the safe, secure, efficient and environmentally sound operation of ships, as well as a level playing-field without market distortions.

That operational framework is the driver for shipping's contribution to, and promotion of, sustainable development and a green economy, which can be summarized in the table below:

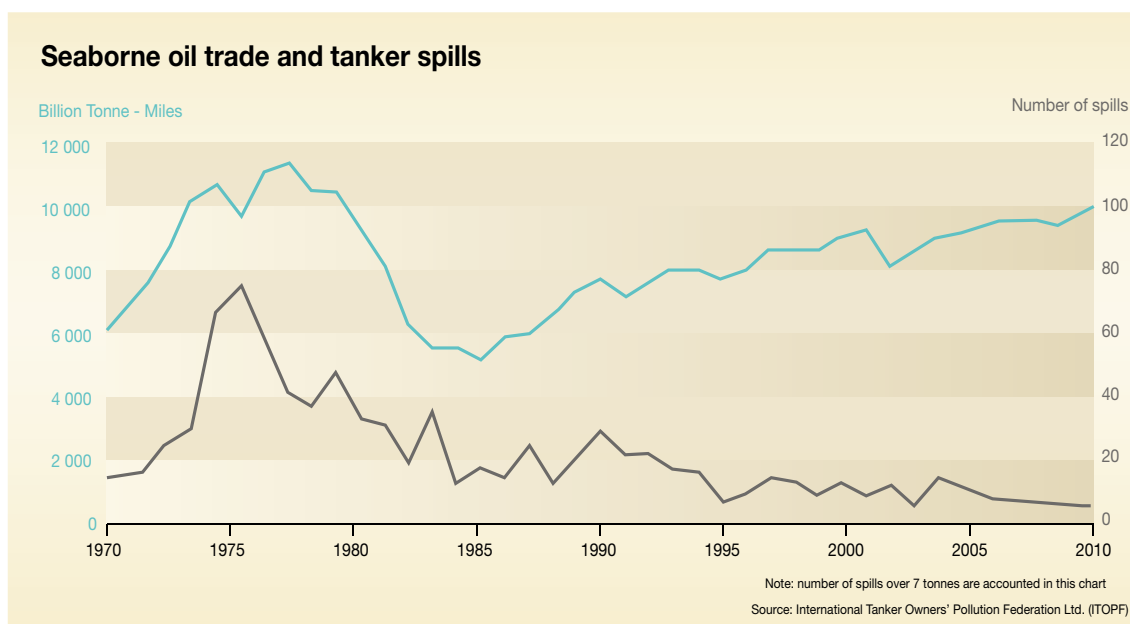
2 Challenges and opportunities

2.1 Maritime transport: driving forces, pressures, state, impact, response

The international shipping industry is essential to world trade. There is therefore a direct correlation between the growth of world trade (and global GDP and population) and the expansion of shipping activity which has the potential to impact on the environment and, by extension, the opportunities this creates for shipping to contribute to green growth and the transition to a green economy.

While there is currently a particular focus on the urgent need for maritime transport to play its part in reducing CO₂ emissions, it is important to understand that, because shipping is indeed a truly major industry, it has the *potential* to impact on the environment in many other ways (IMO, 2012b). This has required ship operators and

IMO action and it's	impact on sustainable development
Improving the safety and efficiency of maritime activities	<p>Economic</p> <ul style="list-style-type: none"> Well-run merchant and fishing fleets Improved turn-around of vessels and port throughput Increased global trade Improved balance of payments
Promoting sustainable livelihoods and poverty eradication	<p>Social</p> <ul style="list-style-type: none"> Employment for seafarers and others in the global shipping, port and fisheries industries Advancement of women in the maritime sector Increased foreign exchange earnings Consequent beneficial impact at local level, especially in coastal/fishing communities
Enhancing environmental protection	<p>Environmental</p> <ul style="list-style-type: none"> Cleaner waters and coasts Reduced incidence of invasive species Reduced air pollution and GHG emissions Increased tourism Greater access to protein through improved fisheries catches Integrated coastal zone management



their regulators to respond to various technical and political challenges, for the most part very effectively, although there is of course always more to be done. To a large extent, however, the importance of environmental protection, and the implementation of green management practices, is already a major feature of modern international shipping operations, underpinned by a comprehensive framework of international regulations, mainly developed by governments at the International Maritime Organization (IMO).

The ultimate goal of the shipping industry and its regulators is zero accidents and zero pollution. Although these goals have not yet been fully achieved, considerable progress has been made, especially in the context of pollution from ships, an achievement all the more impressive when it is considered that the total amount of seaborne trade, measured in tonne-miles, has almost doubled since the Rio Earth Summit in 1992 – from 17.54 billion tonne miles to an estimated 32.74 billion tonne miles, an increase of around 85 per cent.

By way of example, the figure above provides data showing considerable growth in seaborne oil trade since the mid-1980s, with, nevertheless, a significant reduction in the number of oil spills from ships. This is attributable to a number of leading factors, including the existence of relevant IMO standards, improving implementation and enforcement of those standards, heightened environmental awareness within the shipping industry and the application of industry best practices.

In this regard, apart from the substantial legal and commercial penalties confronting shipping companies which might be associated with

any non-compliance with widely enforced international regulations governing the protection of the marine environment, not least the International Convention for the Prevention of Pollution by Ships (MARPOL) 1973/1978, the importance of environmental protection is widely inculcated amongst shipping company personnel, both ashore and at sea. Indeed, seafarers serving on merchant ships are required by IMO's revised International Convention on the Standards of Training, Certification and Watchkeeping for Seafarers (STCW) 1978, to undertake environmental awareness training. The safety and security of life at sea, protection of the marine environment and over 90 per cent of the world's trade depends on the professionalism and competence of seafarers. In 1997, IMO adopted a resolution setting out its vision, principles and goals for the human element, which is a complex multi-dimensional issue affecting shipping operations and environmental protection and involving the entire spectrum of human activities performed by ships' crews, shore based management, regulatory bodies and others. All need to co-operate to address human element issues effectively, and environmental protection should be integral to the human element vision and actions.

Until relatively recently, the main pressure on the shipping industry, from the environmental perspective, has been to develop means of reducing its impact on the *marine* environment through the prevention of pollution of the oceans and coastlines, especially from damage which might be caused by oil spills, whether carried as cargoes or bunker fuel. The initial impetus came from the understandable outrage which followed several serious oil spills which caused dramatic (albeit temporary)

environmental damage to coastlines, as well as adversely affecting fisheries and tourist industries.

In the 1970s governments working through IMO developed the International Convention for the Prevention of Pollution by Ships (MARPOL) which contains comprehensive requirements to prevent pollution which may be caused both accidentally and in the course of routine operations. In response to more recent shipping incidents, MARPOL now contains many additional provisions such as those which require oil tankers to have double hulls.

Significantly MARPOL also includes provisions covering the prevention of other forms of potential marine pollution from bulk chemicals, dangerous goods, sewage and garbage (IMO, 2012c).

More recently, however, the focus of the industry and its regulators – encouraged by far greater awareness of the importance of environmental issues amongst all stakeholders – has also been on the wider potential impacts which shipping can have on the environment. In particular, there was awareness of the need to address the impact on local ecosystems of foreign micro-organisms imported in ships' ballast water; the danger to public health and the environment caused by atmospheric pollution from ships (in particular air pollutants such as sulphur and nitrogen oxides and particulate matter); and the need to reduce shipping's CO₂ emissions in order to contribute to worldwide efforts to stem climate change.

While further possibilities remain with respect to developing, improving and refining existing technical, operational and management measures which might help reduce even more the traditional sources of marine pollution, it is probably the need to reduce atmospheric and CO₂ emissions which presents the most obvious challenges and opportunities with regard to the transition towards a green economy. That said, recently agreed requirements to dramatically reduce sulphur emissions have also created opportunities for the development of new exhaust scrubbing technologies as a (legally permitted) alternative to the use of low sulphur fuels.

Additional potential environmental concerns continue to be identified by governments, NGOs and others, such as the potential implications of maritime transport for the welfare of marine mammals, while greater attention has also been paid to the need to dispose of and recycle redundant ships in an environmentally sustainable manner (ICS, 2012a).

While protection of the marine environment has long been a priority for industry and its regulators, this has always had to be reconciled with the overriding priority of protecting the safety of life at sea. The sea being a very hostile environment, marine transportation involves a high degree of physical risk which has to be managed effectively. In practice, however, rules and regulations governing safety also serve to prevent one of the major threats to the environment which is oil spills following an accident. More generally, the strict adherence to correct procedures required to prevent other forms of pollution reinforces the need to follow procedures in other areas and the effective practice of a safety culture.

However, because shipping is an inherently international industry, with ships trading between different countries, and ship operations involving overlapping jurisdictions, between coastal States, port States, and flag States, there has always been a need for the environmental regulation of shipping to be developed at the international level, not least though a framework of international conventions adopted by governments at IMO.

Fortunately, there is a high degree of cooperation between IMO Member States, and a well established understanding amongst governments worldwide of the need for global rules for a global industry. Most IMO conventions governing safety of life at sea and pollution prevention – including agreements on civil liability in the event that things go wrong – enjoy a high degree of international ratification and enforcement, especially when compared to international regulations governing many land-based industries (IMO, 2012d).

In particular, the MARPOL Convention has been ratified by virtually every maritime country and is applied, through a combination of flag State inspections and port State control, to virtually the entire world merchant fleet. MARPOL Annexes I and II (governing prevention of pollution by oil and chemicals) have been ratified by over 150 States covering 99 per cent of the world merchant fleet (IMO, 2012e).

Governments at IMO recognize its unique role as the specialist regulatory agency dealing almost exclusively with maritime safety and pollution prevention issues. For the most part, therefore, decisions at IMO affecting international shipping are taken on the basis of their technical merits rather than wider political or macroeconomic considerations. (Remarkably, this was the case even during the cold war years, in particular the 1970s and 1980s.) IMO has accordingly been very well equipped to respond rapidly to demands from individual governments, policymakers,

opinion formers and society at large, to develop new pollution prevention regulations, or make amendments to those already adopted.

Since the 1990s, increased environmental awareness amongst maritime transport operators and their seagoing employees has, in part, been a consequence of the adoption, implementation and enforcement of the International Management Code for the Safe Operation of Ships *and for Pollution Prevention* (the ISM Code), adopted in 1993 by IMO. In effect, this introduced a requirement for shipping companies to have a 'licence to operate' which is only obtained after they demonstrate, through rigorous internal and external audits, that they have adequate management systems in place, at sea and ashore, to prevent recognized sources of marine pollution, and to identify and rectify any deficiencies.

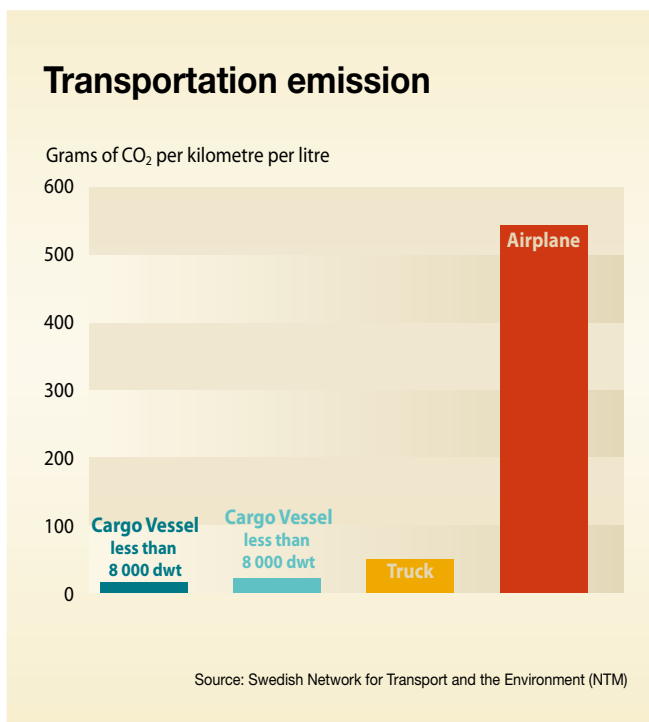
In short, the ISM Code embraces the concept of 'continuous improvement' with regard to the management of pollution prevention by ships (in addition to the management of safety) (ICS, 2010).

While safety of life at sea must always be the first priority, the recognition of the role of Safety Management Systems in preventing marine pollution cannot be over-stated as a result of increased awareness of the essential need to protect the environment, given focus by the Rio Earth Summit in 1992. In particular, the concept of 'continuous improvement' with respect to environmental importance is a significant driver toward the achievement of a fully sustainable maritime transport industry operating within the green economy.

2.2 Economic, environmental, and social issues and opportunities

As highlighted above, it is probably the challenge of reducing atmospheric pollution and CO₂ emissions which presents the most obvious opportunities with regard to the transition towards a green economy. In this respect, and as shown in the figure above, shipping is already the most environmentally-friendly form of commercial transport and, with the lowest CO₂ emissions per tonne/km also, there are significant opportunities for a modal shift towards maritime transport – especially short sea shipping and coastal shipping, away from other land-based transport modes or, even, aviation.

In this respect, because marine fuel (bunkers) is one of the largest operating costs for ship-owners, shipping companies have every



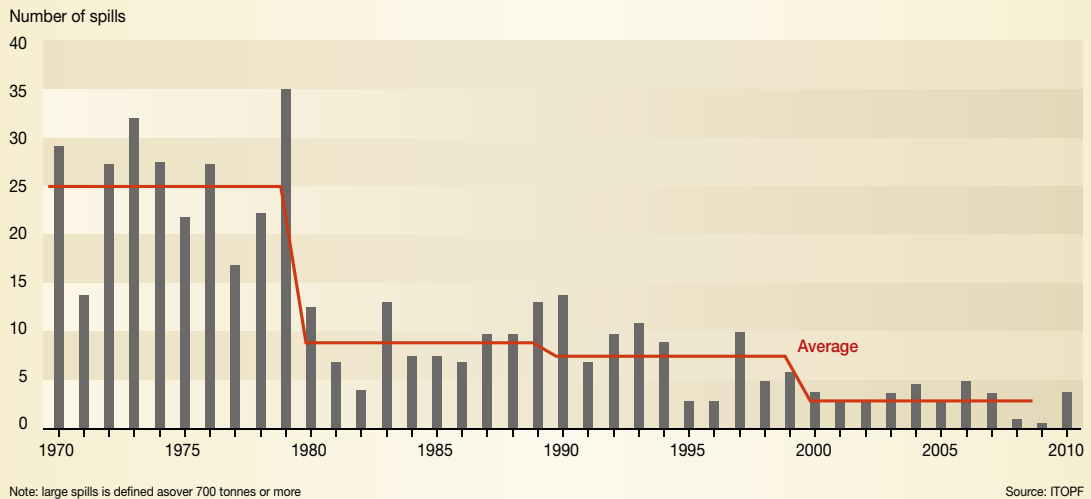
incentive to find new means of further reducing their fuel consumption and, thus, their CO₂ emissions. These issues are explored in more detail in section 2.4.3 below (ICS, 2012b).

There are, of course, other potential impacts on the environment – both marine and atmospheric – from maritime transport which, consequently, create green opportunities. In this regard, pollution can take many forms and arise from many different sources including:

- Oil, chemical and liquefied gases in bulk;
- Antifouling systems;
- Dangerous goods in bulk and packaged form;
- Sewage;
- Garbage;
- Transfer of invasive species through ballast water and biofouling;
- Engine exhaust (including sulphur, nitrous oxides and carbon dioxide);
- Cargo vapour emissions;
- Chlorofluorocarbons (CFCs);
- Halons; and
- Noise.

To prevent the more 'traditional' sources of marine pollution by ships – or mitigate their effects following the unfortunate occasion when pollution still sadly occurs – governments at IMO have adopted a comprehensive international regulatory framework, which is widely enforced. This is made up of no less than 21 global treaty instruments which are augmented by technical codes and

Large spills from 1970 to 2010



guidelines also adopted at IMO and by well-established industry guidance on best practice, developed by the industry's highly organized international trade associations (ICS, 2012c).

The immediate challenge is to build on what, for the most part, are already significant levels of ratification and implementation of international conventions on pollution prevention by IMO Member States, which the Organization helps ensure through a wide range of technical cooperation programmes directed at those States within emerging and developing economies (see section 3.1 below).

Significantly, IMO has developed a Member State Audit Scheme, whereby the performance of flag, port and coastal States with regard to the implementation and enforcement of IMO instruments – including those relevant to environmental protection – is audited, on a voluntary basis, by other IMO Member States, in order to identify possible areas for improvement. It has also been agreed in principle, by governments at IMO, that the Audit Scheme should become mandatory as of 2015 (IMO, 2012f). This, in itself, should considerably improve uniform implementation and enforcement of IMO standards, bringing further improvements to the safety and environmental records of shipping.

In this regard, the most obvious potential source of serious pollution from ships is the discharge of oil (cargoes or bunkers) as a result of ship losses. However, there has been a dramatic reduction in the number of major oil spills over the last four decades, including since the 1992 Rio Earth Summit.

A major concern for the shipping industry, and its regulators, is the maintenance of high standards

of ship construction and inspection. Significant improvements to construction, maintenance and survey standards, relevant to environmental protection, have been underwritten by frequent amendments to the International Convention on the Safety of Life at Sea (SOLAS) 1974 (IMO, 2012g). In this regard, in 2010, IMO adopted important amendments to that Convention to implement new Goal-based Standards (GBS) for the construction of bulk carriers and oil tankers (IMO, 2012h). As a consequence, it is expected that shipbuilding standards will be enhanced so that, with an appropriate level of maintenance and adequate margins for corrosion, future ships will be built to remain 'fit for purpose' throughout their typical 25-year life spans.

The shipbuilding industry, together with classification societies (international maritime survey organizations and depositories of industry's technical knowledge, which oversee the construction of ships), is constantly seeking to develop new, safer and improved ship designs (IACS, 2012). In combination with more vigorous maintenance and survey standards, and improvements to areas such as navigation systems and seafarers' training standards, this has made catastrophic structural failure – and the substantial pollution which can result – far less likely. Continuing improvements in shipbuilding standards clearly represent major opportunities with respect to the green economy.

Concerning the discharge of oily water from machinery spaces, and accidental spillage of oil cargoes and ships' bunkers, opportunities also exist for the further improvement of equipment designs (ICS, 2012d).

Similarly, opportunities are also created by the need to develop equipment which treats a ship's

ballast water in order to meet the requirements IMO's International Convention for the Control and Management of Ships' Ballast Water and Sediments 2004, which includes technical standards and requirements to prevent the import of alien marine organisms into local ecosystems (IMO, 2012i).

Furthermore, radical recent amendments to Annex VI of the MARPOL Convention (governing atmospheric pollution) require ships to reduce the sulphur content of fuel dramatically, to just 0.1 per cent in Emission Control Areas (ECAs) from 2015, and to 0.5 per cent elsewhere (from the current level of 4.5 per cent outside ECAs) (IMO, 2012a). However, these new IMO requirements to reduce emissions of air pollutants and consequent impacts on the environment and, in particular, on the health of populations living on the coastline, also create opportunities for the development of new exhaust scrubbing technologies as a (legally permitted) alternative to the use of low sulphur fuels.

2.3 Social challenges and opportunities

From the social perspective, because international maritime transport generally operates away from land, its direct social impacts are largely confined to the 1.5 million seafarers it employs, about two-thirds of whom reside in developing countries (ICS, 2010a). In this respect, the shipping industry is probably unique in that it has a mandatory framework of international employment standards, adopted by the International Labour Organization (ILO), which is enforced by governments worldwide and developed on a tripartite basis in agreement with international representatives of maritime employers and seafarers' trade unions (ILO, 2012).

Quite aside from the employment of seafarers, shipping also generates considerable opportunities ashore, be it within governmental departments (maritime administrations; port authorities; accident investigation units; maritime training academies; etc.) or the private sector (shipping companies; ship, port and terminal operators; shipbuilding and ship repair yards; offshore industries; equipment manufacturers; insurance companies; average adjusters; freight forwarders, etc.). These professions – too numerous to list – make important contributions to the world economy, while remittances from seafarers often represent notable contributions to the foreign exchange earnings of nations and to the economies of local communities. International shipping activity, therefore, has a significantly beneficial impact on the livelihoods of large numbers of people around the world.

One specific area where the environmental impact of maritime transport has such wider social implications includes the working conditions in ship recycling yards (mostly located in China and the Indian subcontinent). IMO's International Convention for the Safe and Environmentally Sound Recycling of Ships is specifically intended to help improve health and safety and environmental conditions in recycling yards (IMO, 2012j). The Convention reflects the 'cradle to grave' responsibilities of ship-owners, from the time of a ship's construction to its final demolition, and regulates the actions which will be required and which should be approved by ships' flag States and authorities in ship recycling nations (ICS, 2010b). In particular, the Convention requires the preparation and maintenance of inventories of hazardous materials and the disposal of redundant ships at approved facilities.

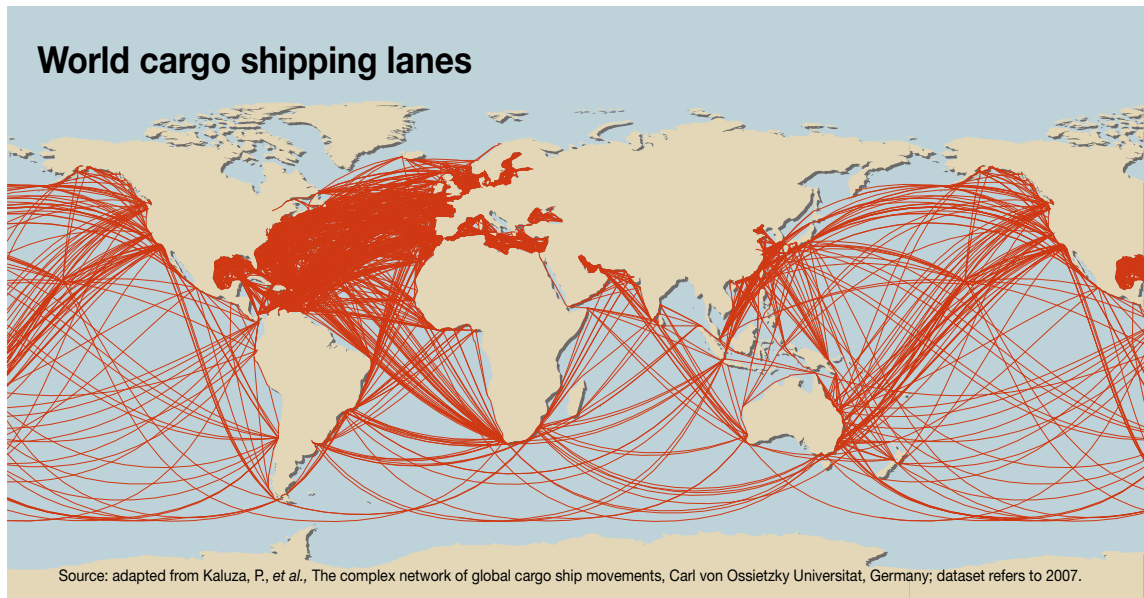
On another front, international shipping is making strides to promote the role of women within the industry, which has historically been a preserve of men. Increasing numbers of women are, however, being engaged in the various maritime industries, including for service onboard ships (as captains and senior officers) and ashore (as managers of shipping companies). While this is the outcome of enlightened policies or self-interest on the part of some stakeholders, the fact remains that there are growing numbers of professional associations around the world for women engaged in shipping (WISTA, 2012). Some of these have been established with specifically-targeted support from IMO, which has had a "Women in Development" programme for some 20 years, including a dedicated technical assistance programme designed to support the integration of women from developing countries in the maritime sector.

2.4 The economic case for greening the maritime transport sector

A distinction should perhaps be made between implementing further improvements which to help completely eliminate environmental pollution by ships (including atmospheric pollution in the vicinity of coastlines), and the contribution to the green economy which shipping can make more generally by reducing its CO₂ emissions.

2.4.1 Description of the maritime sector as a business

The international shipping industry is responsible for the carriage of about 90 per cent of world trade by volume and is vital to the functioning of the global economy. Without shipping, intercontinental trade, the



bulk transport of raw materials and the import/export of affordable food and goods would simply not be possible (ICS, 2012).

The world merchant fleet is registered in over 150 nations, and manned by over a million seafarers of virtually every nationality. The structure of the shipping industry is very international: a ship may be registered in one country, while the beneficial owner of the vessel may be located in another. The cargo carried by a ship will be of economic benefit to a variety of different nations (the value of annual maritime trade is estimated to be around US\$2 trillion) (UoS, 2012). The crews of most ships comprise more than one nationality, which are, quite commonly, different to that of the flag State and the beneficial owner.

Shipping is, almost by definition, an inherently international industry which depends on a global regulatory framework to operate efficiently. If a ship trades from Brisbane to Buenos Aires, the same rules need to apply (for example, concerning construction, navigation or atmospheric emissions) at both ends of the voyage. Otherwise, there would be chaos and serious inefficiency. As discussed elsewhere, a globally uniform regulatory framework is provided very effectively by IMO, the United Nations specialized agency charged with the regulation of international maritime transport in the pursuit of safe, secure efficient shipping on clean oceans.

Today, there are about 60 000 merchant ships trading internationally, transporting every kind of cargo. These ships are operated by about 10 000 shipping companies (ICS, 2012). However, there are variety of sectors and trades with different characteristics. In simple terms:

- Container ships carry most of the world's manufactured goods and products, usually through scheduled liner services.
- Bulk carriers are the work-horses of the fleet, transporting raw materials such as iron ore and coal.
- Tankers transport crude oil, chemicals, petroleum products and natural gas.
- Ferries usually perform short journeys for a mix of passengers, cars and commercial vehicles. Most of these ships are Ro-Ro (roll-on/roll-off) ferries, where vehicles can drive straight on and off, making it a speedy and easily accessible way to travel.
- Cruise ships expanded rapidly during the 1980s, leading to a new generation of large and luxurious 'floating hotels'.
- Specialist ships include anchor handling and supply vessels for the offshore oil industry, salvage tugs, ice-breakers and research vessels.

The worldwide operation of ships generates an estimated annual income in freight rates of over a trillion dollars or almost 2 per cent of the total GDP for the global economy.

It is the availability, low cost and efficiency of maritime transport which has made possible the major shift towards industrial production in Asia and other emerging economies which, in turn and in large part, has been responsible for dramatic improvements in global living standards.

Notwithstanding the recent contraction in trade resulting from the economic downturn in 2008, the world economy is expected to continue to grow and shipping will need to respond to the demand for its services, unless existing patterns of global trade and consumption were to be fundamentally transformed.

Due to continuous improvements in technology and efficiency, maritime transport costs are very competitive. For example (in 2011) (ICS, 2012e):

- The typical cost to the consumer in the United States of transporting crude oil from the Middle East, in terms of the purchase price of gasoline at the pump, is about US\$0.01 a litre.
- The typical cost of transporting a tonne of iron ore by sea from Australia to Europe is about US\$20.
- The typical cost of transporting a bottle of whisky from Europe to China is about US\$0.15.

Maritime transport operates in a very unrestricted trade environment. With the exception of cabotage restrictions (trade between two ports in the same country), international shipping enjoys relatively free trade without restrictions to market access. The majority of companies (especially in non-containerized trades) are small and medium-sized enterprises, and shipping is characterized by markets with very high levels of competition (CRSL, 2012).

From an environmental perspective, shipping operations have the potential for significant damage and it is IMO's role, with the collaboration of industry and civil society interests, to develop and introduce measures to minimize all such impacts.

Another very important factor in the environmental performance of shipping is the role of the shipyards which build the ships used to conduct world trade, with about 90 per cent of new shipbuilding capacity now located in Asia (China, Japan and Republic of Korea) (UNCTAD, 2011). Shipyards clearly have an important part to play in introducing new technologies which will further improve ship construction standards (for example, to help prevent oil spills caused by accidents), or which will radically improve fuel efficiency to reduce CO₂ emissions.

2.4.2 Incentives for reducing marine pollution

The shipping industry has two strong economic motivations for maintaining and improving its environmental performance. The first concerns the financial benefits of ensuring full compliance with widely enforced international environmental regulations; the second concerns the indirect economic benefits derived by companies which have a progressive and proactive approach to implementing environmental improvements. Shipping also has the potential to become greener and initiatives such as the Sustainable Shipping Initiative are

looking at a 'beyond-compliance' sustainability framework.

The financial liabilities which shipping companies, or ships' charterers, may face should they be involved with a serious pollution incident such as a major oil spill (even if entirely accidental) can potentially amount to millions if not *billions* of US dollars. Additionally, the criminal penalties which can be associated with offences which may actually result with relatively minor impacts on the environment – such as the illegal disposal of oil residues, or garbage at sea – can also be very significant and serve as a deterrent.

At a different level, any 'technical' non-compliance with MARPOL regulations which is identified during port State control inspections can result in ships being detained and not permitted to sail, with the ship operator being subjected to very significant commercial penalties, as well as damage to its commercial reputation.

It should be understood that, following the establishment and expansion, since the 1980s, of regional co-operation agreements between national port State control authorities – which share sophisticated databases on the safety and inspection records covering virtually the entire world merchant fleet – it is increasingly difficult for ships which do not meet acceptable international standards to operate to ports located in the major trading areas in Europe, the Americas and Asia (IMO, 2012k). Such ships will be targeted for inspection by port State control officers and detained so that they cannot sail. In this respect, port State control also applies to requirements such as the sulphur content of fuel and, in advance of the implementation of the stricter international standards which have recently been adopted by IMO, port States have already announced large financial penalties for non-compliance.

With the development of the internet, there has been a massive increase in transparency with regard to information which is widely available about the quality of ships, including the extent of their environmental performance, to which the customers of ships (charterers, shippers and freight forwarders), as well as insurers of ships and their cargoes, have access. In addition to insisting on full compliance with relevant international regulations concerning the protection of the marine environment (such as IMO's MARPOL Convention and ISM Code), customers and insurers of shipping companies increasingly insist that shipping companies meet additional environmental standards, such as those developed

by the International Standards Organization (ISO), or else developed independently by charterers and insurers themselves.

In short, shipping companies have a commercial imperative to operate with the philosophy that the costs of compliance with both mandatory and voluntary environmental standards are far less than the costs of non-compliance, given the potential and likelihood of being confronted with multi-million US dollar penalties and/or liabilities which can arise from being involved in an environmental incident, whether large or small, unintentional or otherwise.

2.4.3 Incentives for reducing CO₂ emissions

In the future, however, the most significant issue regarding the part maritime transport can play in greening the world economy concerns its efforts to reduce CO₂ emissions.

Because marine fuel (bunkers) is, as previously stated, among the largest operating costs for ship-owners, shipping companies have every incentive to find new means of further reducing their fuel consumption and, thus, their emissions of both air pollutants and CO₂. The international shipping industry currently consumes about 300 million tonnes of bunkers per year (IMO mid-range estimate) (IMO, 2009). The typical price of bunkers used by ships is about US\$600 per tonne (2011) so, collectively, the global shipping industry spends about US\$180 billion a year on bunker fuel.

The costs for ship operators, in particular, will almost certainly be increased even further by the introduction of new mandatory IMO requirements to use low sulphur fuels which, from 2015, in Emission Control Area (ECAs), will require many ships to burn distillate fuel. This is currently 50 per cent more expensive than the heavy fuel oil bunkers which most ships use at present. The economic case for greening the maritime sector by improving fuel efficiency, reducing consumption and thus cutting carbon emissions is therefore very clear.

The various parts of the shipping industry – ship-owners, shipbuilders and classification societies (the depositories of technical expertise in the industry) – have been actively examining a number of ways to reduce CO₂ emissions, both for new and existing ships, which are primarily linked to reducing fuel consumption. The shipping industry is therefore confident that, as a whole, it can deliver more than a 20 per cent reduction in emissions per tonne of cargo moved per kilometre by 2020, by improving ships' performance with regard to the various factors

which contribute to CO₂ emissions (ICS, 2012f). These include, *inter alia*, improved voyage planning; speed management; weather routing; optimizing engine power; hull maintenance and use of different fuel types. These may be termed 'operational' measures leading to CO₂ emission reductions.

In the longer term, however, the shipping industry is also exploring a number of other operational measures, including alternative fuel sources to help reduce CO₂ emissions. Renewable energy sources, such as wind and solar power, may have their place in helping to meet some ancillary requirements, such as lighting onboard ships. However, they are not practical for providing sufficient power to operate ships' main engines (the huge physical size of ships should not be underestimated).

Fuel cells may also be a possibility for new ships in the very long term, although they are currently too limited in range to offer a viable solution. Even nuclear propulsion for merchant ships is technically possible, although safety and security implications, and support infrastructure costs would require serious consideration.

Second generation biofuels might conceivably provide a possible alternative, although there is, of course, considerable public debate about the net environmental costs (and social effects) of the wider use of such fuels.

The current assumption, therefore, remains that ships will continue to burn fossil fuels for the foreseeable future, and that the most significant means of reducing CO₂ emissions will be achieved by further improvements in efficiency across the entire transport chain (see also section 3.3.2).

3 Enabling conditions

3.1 Learning from successful and unsuccessful international experience

The International Maritime Organization, as the regulator for the shipping industry, has an enviable track record of developing and adopting global technical standards. The three main Conventions adopted by IMO – SOLAS, MARPOL and STCW, dealing, respectively, with safety and security, environmental protection and seafarers' training standards – have all been ratified by virtually all Member States of IMO (IMO, 2012).

Since its inception, IMO has developed and adopted no less than 52 conventions dealing with all facets of ship operation and protection

of the environment from such operations (IMO, 2012d). Indeed, no less than 21 of those instruments deal exclusively with environmental protection, with two other treaties (on salvage and wreck removal having environmental benefits also). While the levels of ratification of such IMO instruments is not as high as for SOLAS, MARPOL and STCW – each of which today covers 99 per cent of the world’s merchant fleet – the entire body of IMO conventions provides for the universally applicable regulations enabling shipping to operate on a level-playing field.

From a normative perspective, therefore, there is every indication that shipping should and will continue to be regulated by IMO, taking account of technological advances, industry practice and the needs and aspirations of society at large.

A further enabling mechanism in the maritime world is IMO’s provision of technical assistance to developing countries – with the support of donors, industry and civil society interests – to help them achieve effective implementation and enforcement of global standards onboard their ships, in their ports and along their coasts.

Such support is generated through IMO’s Integrated Technical Cooperation Programme (ITCP), with the aim to assist developing countries build up their human and institutional capacities for uniform and effective implementation of IMO’s regulatory framework (IMO, 2012m). By fostering capacity-building in the maritime sector, the ITCP helps countries ensure safe, secure and efficient shipping services and protect their waters and coasts from the environmental degradation caused by ships and other maritime-related activities.

It is, therefore, both IMO’s regulatory framework and its technical cooperation programme which contribute to sustainable socio-economic development with, for the ITCP, the emphasis on meeting the special assistance maritime needs of Africa, SIDS and LDCs.

In this regard, IMO’s highest organ – the Assembly – has adopted several resolutions on technical cooperation, including A.901(21) on IMO and Technical Cooperation in the 2000s and A.986(24) on The Importance and Funding of Technical Cooperation as a Means to Support the United Nations Millennium Declaration and Development Goals. Furthermore, resolution A.1006(25) on The Linkage between the Integrated Technical Co-operation Programme and the Millennium Development Goals requested or encouraged:

- Member States and donor organizations

to recognize the importance of building maritime capacity in achieving the MDGs and to ensure that consideration is given to the inclusion of the maritime sector in Official Development Assistance (ODA) programmes;

- Member States to voluntarily use the Maritime Capacity Checklist, and the Maritime Capacity Analysis tool, to analyze and assess the levels of maritime capacity progress in developing maritime capacity over time;
- IMO’s Technical Cooperation Committee to give high priority to those activities, which not only promote the early ratification and effective implementation of IMO instruments but also contribute to the attainment of the MDGs, taking into account the special needs of the LDCs and SIDS, and the particular maritime transport needs of Africa, and ensure that these needs are reflected in the ITCP; and
- All IMO Member States and international organizations concerned to provide and, as the case may be, increase their financial and in-kind support for the delivery of the ITCP individually and through bilateral and multilateral development aid programmes.

It has been shown that IMO’s technical cooperation activities contribute, by promoting effective and uniform implementation and enforcement of maritime standards, to at least five of the MDGs, namely: eradicate extreme poverty and hunger; promote gender equality and empower women; combat HIV/AIDS, malaria and other diseases; ensure environmental sustainability; and develop a global partnership for development.

To help the foregoing objectives, IMO founded the World Maritime University in 1983 (Malmo, Sweden) and, later on, the IMO International Maritime Law Institute (Msida, Malta) and the International Maritime Safety, Security and Environment Academy (Genoa, Italy), all of which have the sole aim of providing advanced training for men and women involved in maritime administration, education and management, particularly those from developing countries.

It may be noted that IMO was recently included in the OECD DAC list of ODA organizations and this further emphasizes and recognizes IMO’s role as an important partner in technical cooperation and development assistance.

3.2 Building effective national, regional and international institutions

As discussed above, maritime transport is probably unique as a ‘blue world’ industry in that there is already widespread acceptance and recognition – among governments and industry

alike – that it requires a global regulatory framework, with rules which are enforced on a uniform and worldwide basis to all ships trading internationally, in order, among other objectives, to minimize pollution and best improve the sector’s environmental performance. In short, the IMO principle of ‘no more favourable treatment’ between the enforcement of rules which apply to national flag ships, as opposed to visiting ships of different flags, is fully accepted.

For the most part, therefore, the basic enabling conditions for the greening of shipping at the international level already exist in the form of IMO. The Organization is, of course, an intergovernmental, rather than a supra-national, entity, with a membership of 170 Member States. While it is still national laws which give effect to the implementation and enforcement of the relevant IMO Conventions, with very few and relatively minor exceptions, national regulations applicable to international shipping contain no variations to the substance of the IMO Conventions governing safety or environmental protection to which they give effect.

However, while IMO is the principal UN agency regulating international maritime transport, other international bodies and can also impact on shipping too, not least the UN itself, other agencies such as ILO and the London Convention Secretariats also. In the context of efforts to confront climate change, this is certainly the case with respect to the UN Framework Convention on Climate Change (UNFCCC). Cooperation and coordination among these entities is essential

in order to avoid duplication of effort and, in particular, opposing regulation of shipping from the technical and operational perspective.

In this respect, there may be a lack of understanding within some national government departments or agencies concerned with environmental, and/or ocean issues, about the effective role which IMO plays with respect to the environmental performance of maritime transport. The efficiency of IMO as an international regulator, and its ability to contribute to the transition of maritime transport into the green economy, would be assisted by improving awareness and appreciation of its effectiveness amongst other relevant agencies and departments which impact on shipping – especially those with broader responsibility for the environment – whether at national, regional or international level.

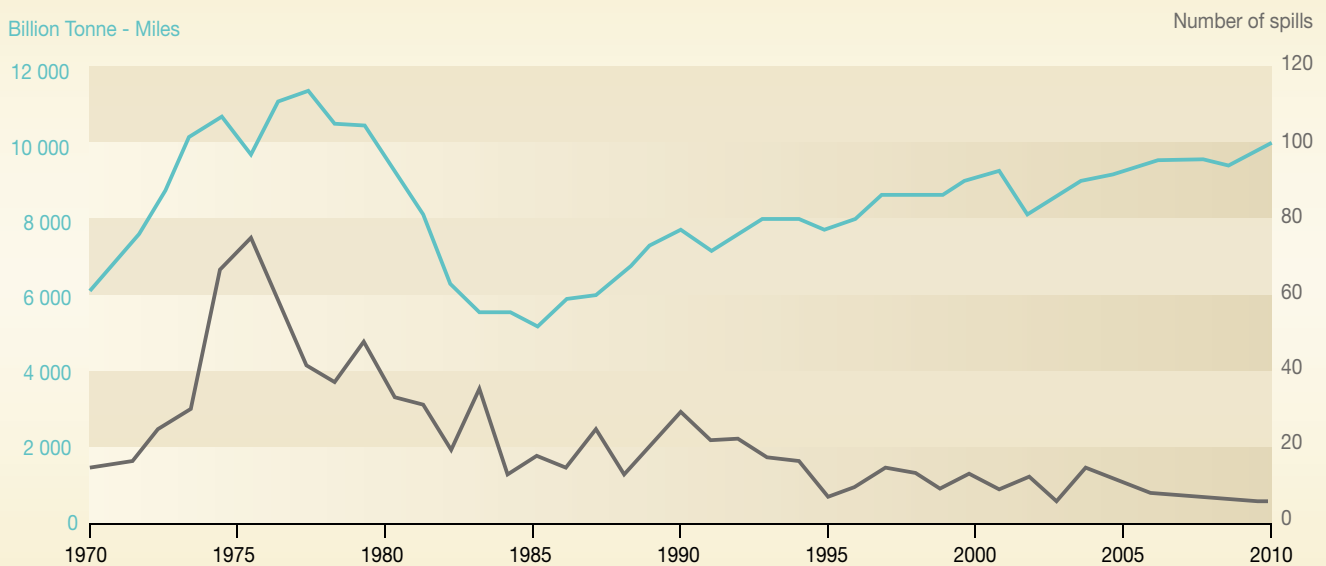
3.3 Building effective regulatory frameworks for the sector

It is again helpful perhaps to make a distinction between regulation to deliver further improvements to help eliminate marine pollution by ships (including atmospheric pollution in the vicinity of coastlines) and the contribution to the green economy which shipping can make more generally with regard to the reduction of its CO₂ emissions.

3.3.1 Regulation of marine and atmospheric pollution

As discussed above, IMO already has an impressive track record of enabling governments to agree

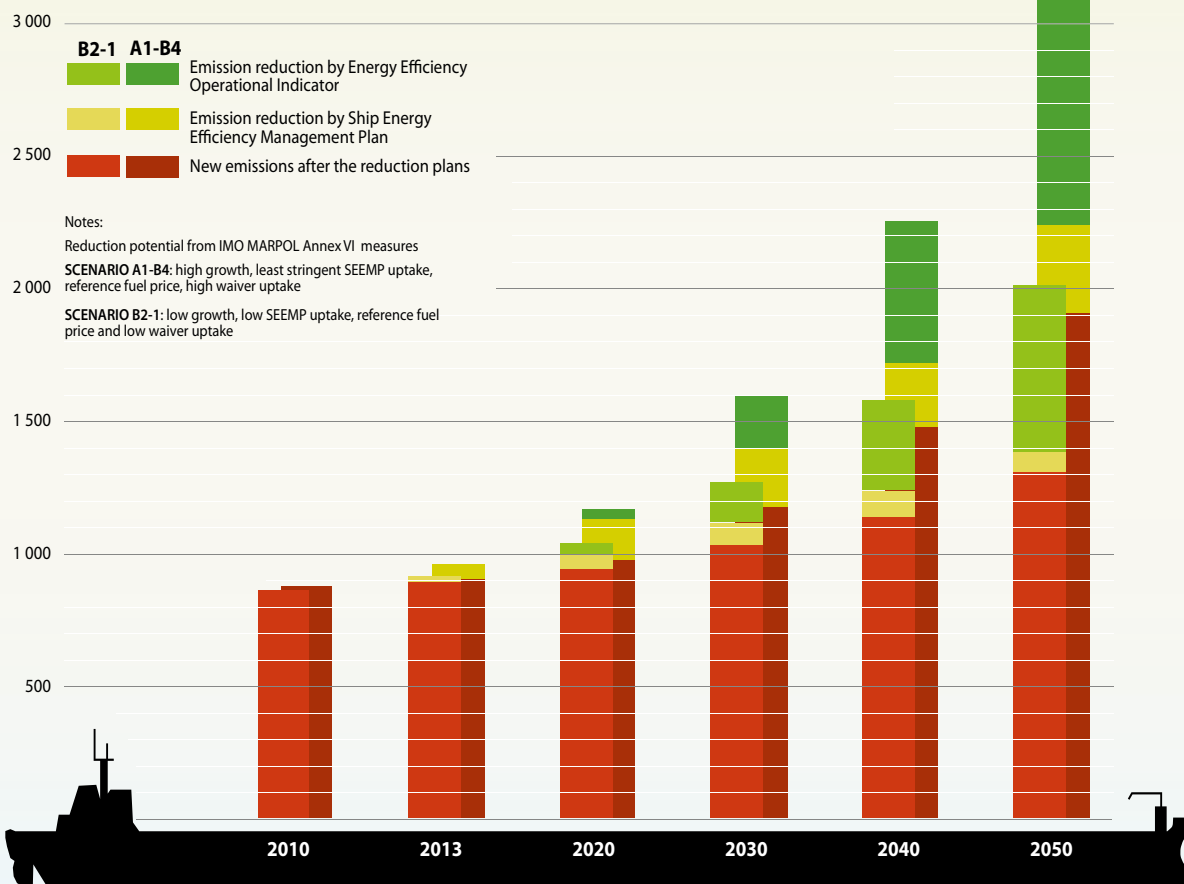
Seaborne oil trade and tanker spills



Note: number of spills over 7 tonnes are accounted in this chart
Source: International Tanker Owners' Pollution Federation Ltd. (ITOPF)

Projected annual CO₂ emissions from the shipping sector

Million tonnes



Source: Lloyd Register, NDV, Assessment of IMO Mandated Energy Efficiency Measures for International Shipping.

widely-enforced and implemented regulations governing the environmental performance of ships, not least the MARPOL Convention, plus specific international instruments to deal with issues such as ballast water management, or the use of ships' coatings which might cause harm to the environment.

Also as mentioned, amendments to MARPOL Annex VI (adopted in 2008) will dramatically reduce atmospheric emissions of air pollutants from internationally trading ships (sulphur, nitrogen oxides and particulate matter, etc.) in accordance with an agreed timetable.

These standards will be kept up to date with technological developments and concerns with respect to human health and the environment. In this respect, it should be noted that because of IMO's 'tacit amendment' procedure, changes to existing IMO Conventions can be made very quickly, with new requirements typically entering force within about 18 months of their adoption.

3.3.2 Regulation of shipping's CO₂ emissions

In July 2011, international shipping became the first industrial sector to adopt binding international rules for the adoption of technical measures to reduce CO₂ emissions. These technical measures were adopted by IMO as amendments to MARPOL Annex VI which is expected to enter into force in 2013.

The package includes a system of energy efficiency design indexing for new ships (similar in concept to the ratings applied to cars and electrical appliances), through the Energy Efficiency Design Index (EEDI). This sets technical standards for improving the energy efficiency of certain categories of new ships which will, in turn, lead to less CO₂ emissions – approximately 25-30 per cent cuts by 2030 compared to Business as Usual. On entry into force internationally, the EEDI will require a minimum energy-efficiency level for different ship types and sizes. It will be applied to the

largest segments of the world merchant fleet, first, and is expected to cover as much as 70 per cent of emissions from new ships.

There is also a requirement for a Ship Energy Efficiency Management Plan to be carried out and implemented by all ships as from 2013 – these being known as ‘operational’ measures (see also section 2.4.3).

In order to secure even greater CO₂ reductions from international shipping, IMO is also examining the development of possible Market-based Measures (MBMs) which could be applied globally to shipping. In summary, governments at IMO have agreed key principles for the development of regulations on CO₂ from ships so that they will:

- Effectively reduce CO₂ emissions;
- Be binding and include all flag states;
- Be cost effective;
- Not distort competition;
- Be based on sustainable development without restricting trade and growth;
- Be goal-based and not prescribe particular methods;
- Stimulate technical research and development in the entire maritime sector;
- Take into account new technology;
- Be practical, transparent, free of fraud and easy to administer.

The international shipping industry also subscribes to these principles.

It is recognized, however, that, with regard to reducing shipping’s CO₂ emissions, the situation is more complex than with measures to address other sources of pollution from ship’s transport. While IMO is the UN agency responsible for the protection of the environment from the impact of maritime transport, it is, of course, the UNFCCC which addresses the overall obligations of governments with regard to reducing greenhouse gas (GHG) emissions.

As already acknowledged by the Kyoto Protocol, emissions from international shipping cannot be attributed to any particular national economy. Multilateral collaborative action will be the most appropriate means to address emissions from the maritime transport sector.

This is best achieved by governments at the specialist UN agency – the IMO – which has a successful track record in the development of global regulations governing the shipping industry’s environmental performance. As previously discussed, the MARPOL Convention

– which now includes technical measures to reduce CO₂ from ships – is ratified and enforced globally through a combination of flag State and port State control by IMO Member States.

With regard to GHGs, in particular, it is generally recognized that the delivery of significant emission reductions by the maritime sector will require that any mandatory measures adopted are applied on a uniform and global basis to avoid ‘carbon leakage’.

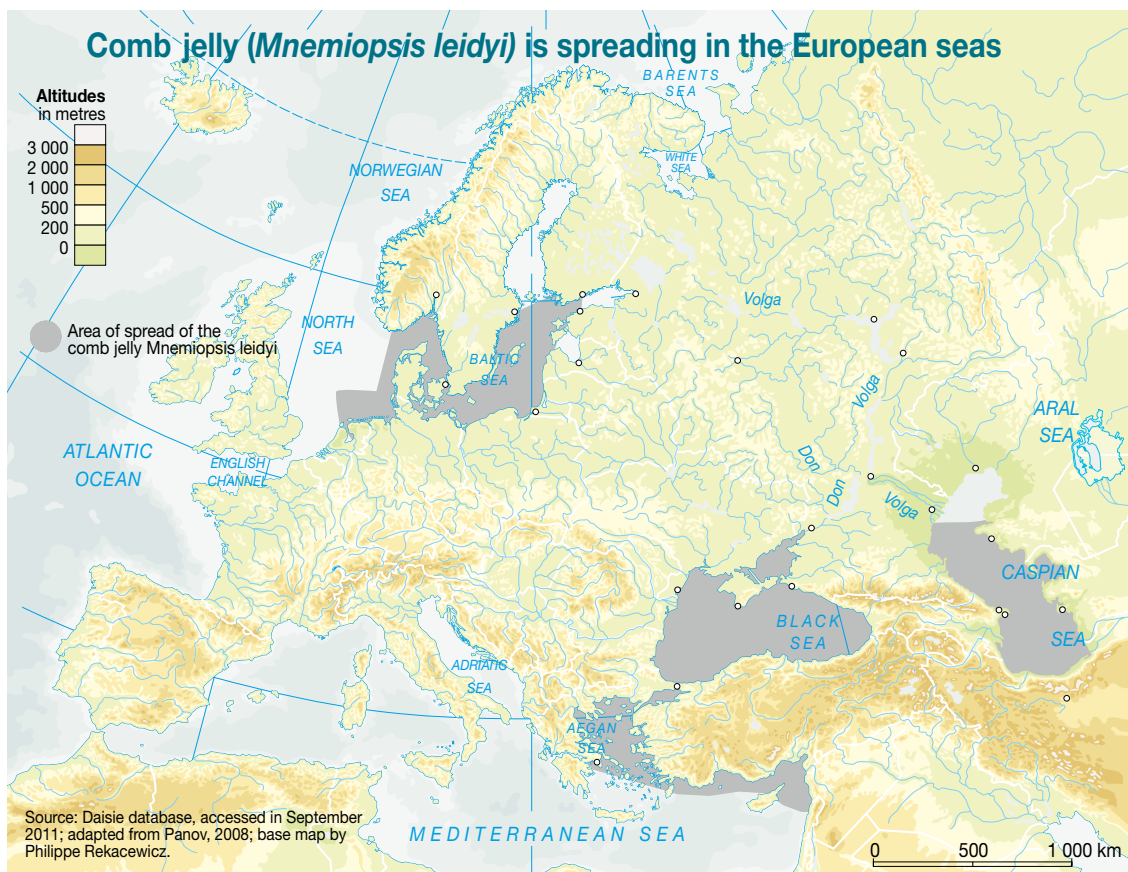
Most shipping companies have the freedom to decide to register their ships with the flag State of their choice, including those which, under the current Kyoto Protocol, are not ‘Annex I’ nations. Measures to deliver meaningful emission reductions are, thus, much more likely to be achieved by instruments developed by governments at IMO since only about 35 per cent of the world merchant fleet is registered in Kyoto Annex I countries (ICS, 2012g).

The direct Kyoto Protocol concept of ‘common but differentiated responsibility’ (CBDR) cannot be practically applied to shipping without the danger of significant carbon leakage. The flag State with which a ship is registered or, indeed, the ‘nationality’ of the entity operating the ship, can change frequently, especially when ships are bought and sold.

IMO has, nevertheless, addressed the CBDR principle, in the regulations on technical CO₂ measures contained in MARPOL Annex VI, by providing for governments to provide technical assistance and undertake technology transfers to support developing countries, and by allowing some flexibility with respect to the dates when the new measures have to be applied.

However, the direct application of the CBDR concept – i.e. different standards being applied according to the flag of the ship – would cause gross distortion of shipping markets, reduce the efficiency of maritime transport and, thus, the smooth flow of world trade, and would not provide for environmental effectiveness. Conversely, the IMO principle of ‘no more favourable treatment’ ensures that standards adopted for shipping are applied equally throughout the world, delivering maximum environmental improvement.

Accordingly, the achievement of further reductions in CO₂ emissions will be best pursued if nations agree that the development of detailed measures, for the international merchant fleet, should be directed by governments at IMO – while respecting the outcomes agreed for the sector under any new UN climate change convention.



3.3.3 Strengthening the legal framework to effectively address aquatic invasive species

The diverse and widespread impact of aquatic invasive species means that they can affect marine and freshwater ecosystems, and the livelihoods and economies which depend upon them, virtually everywhere on earth. Invasive species threaten biodiversity, marine industries and human health. The global economic impacts of invasive aquatic species, including through disruption to fisheries, fouling of coastal industry and infrastructure, and interference with human amenity, have been estimated at US\$100 billion per year, while the projected response costs are merely in the range of four per cent of the impact (Chisholm, 2004).

Some of the major achievements since the call for urgent action from the 1992 Earth Summit include the adoption by IMO of the International Convention for the Management and Control of Ships' Ballast Water and Sediments 2004. Substantial progress has also been made in building national capacities to implement and comply with the Ballast Water Convention through the two phases of the GEF/UNDP/IMO GloBallast programme.

The Convention will enter into force after ratification by 30 States, representing 35 per cent of world merchant shipping tonnage. The

30 States which at present have ratified the Convention represent 26.44 per cent of world merchant shipping tonnage and the entry-into-force conditions are likely to be met in 2012.

However, the problem still remains. The rate of marine bio-invasions has been reported as being as high as up to one every nine weeks and over 80 per cent of the world's 232 marine ecoregions reported the presence of invasive species. On the bright side, a recent Canadian government study of invasions in the great lakes showed that, since Canada (and the US) imposed strict ballast-water management measures, there has been no documented invasion (FAOCS, 2011).

The invasion of the European zebra mussel in the North American Great Lakes, the Asian golden mussel in the inland waterways of Argentina, Brazil, Paraguay and Uruguay threatening the whole Amazon basin, the comb jellyfish in the Black and Caspian Seas are classic examples of bio-invasions, mainly mediated through ballast water and hull fouling.

The severe economic and ecological impacts of these invasions provide some of the starkest case studies of the devastating effects of aquatic invasive species. Unlike environmental impacts from pollution and habitat loss, invasive species once introduced and established, can rarely if ever be reversed and/or eradicated. Without

timely and globally coordinated measures and a legally-binding framework applicable worldwide, the impact of invasive species will only get worse over time.

IMO's adoption of an international treaty to address invasions through ships' ballast water paved the way to a global approach and demonstrated the effectiveness of Member States working together under the right auspices. This example should now be followed by a similar response to ships' hull fouling, possibly the second most significant vector for aquatic invasions, and by regulatory measures to control other means of transferring unwanted organisms from one place to another.

Global efforts need to focus on building the right legal framework to address aquatic invasions in a coordinated and consistent manner. Without such a focussed, sustained and coordinated approach, under the aegis of IMO, the significant progress achieved since Rio 1992 will not be capitalized on, and the global benefits and momentum accrued so far in addressing one of the greatest threats to the world's oceans may well be lost.

4 Conclusions and recommendations

Shipping plays a crucial role in international trade and the global economy. It operates effectively in a context of international regulations aimed at ensuring safe, secure and efficient shipping on clean oceans – one which also generates employment opportunities both onboard and ashore.

By so doing, shipping contributes towards the three pillars of sustainable development and towards a green economy. In this regard, shipping is an environmentally-friendly form of commercial transport and by far the most energy-efficient, in particular in terms of CO₂ emissions per tonne/km.

Maritime transport is already making considerable progress towards the transition to a green economy through different initiatives by the industry and through the enforcement of international regulations adopted by IMO. Further, the Organization's ITCP forms an important tool in assisting developing countries in the implementation and enforcement of its global technical standards and in the efforts towards achieving the MDGs.

A comprehensive international regulatory framework agreed by governments at IMO, which is widely enforced on a worldwide basis, has already done much to reduce various sources of pollution by shipping – both marine and atmospheric – augmented more recently by international regulations addressing atmospheric pollution and technical means of reducing shipping's CO₂ emissions.

Nevertheless, the economic, societal, environmental and reputational case for further greening of the sector is clear and is espoused by both IMO, as the sector's global regulator, and the industry itself, with the aim of:

- promoting entry into force of all of IMO's environmental treaties and their global, uniform implementation and enforcement, principally through the provision of technical assistance;
- promoting enhanced flag, port and coastal State performance to deliver further reductions in pollution caused by ships through discharges to sea and emissions to air, including through the availability of adequate port reception facilities for ship-generated wastes;
- promoting greater energy-efficiency of ships, including through the development of market-based measures, and, as a consequence, reductions in fuel consumption and in emissions of both air pollutants and greenhouse gases;
- developing global standards to ensure that the operation of ships using alternative sources of fuel is both safe and environmentally sound;
- promoting implementation, or development of global standards to prevent and control the transfer of invasive aquatic species through ships' ballast water and the fouling of ships' hulls, thereby contributing to protecting and preserving biodiversity and enhancing human health and the quality of the environment;
- addressing, through existing and/or future treaty and other instruments, the technical, operational and environmental aspects of the ever-increasing size of ships; and
- maintaining international shipping's widely-acknowledged position as the most environmentally sound mode of transport.

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MARINE-BASED RENEWABLE ENERGY

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1 Introduction: Marine-based renewable energy sector as an important sector of the Green Economy

This chapter explores how increasing investments in renewable energy, in the context of climate change and green economy policy discussions, could play out in the marine environment. It will highlight the main drivers before assessing economic, social and environmental risks and opportunities associated with the most commercially-developed technologies: offshore wind, tidal, waves and, to a lesser extent, marine-based biofuels. Based on these, an assessment is made of the enabling conditions that can support the broader marine-based renewable energy sector, followed by specific policy and financing recommendations to ensure that marine-based renewable energy options meet their potential to help power the transition to a greener economy.

1.1 Marine-based renewable energy - Overview

Energy is the driver of all economies and access to sustainable energy is a prerequisite for a sustainable economy. The marine environment has traditionally provided energy sources through coastal and deep water oil and gas reserves. However, investors are increasingly turning to the marine environment as a source of clean energy.

The ocean's potential for renewable energy resources is vast. The ocean receives more than 70 per cent of the Earth's available sunlight, and almost 90 per cent of the world's wind energy occurs over the ocean (IUCN 2010, Czisch 2005). In addition to harnessing stronger winds offshore, ocean sources of renewable energy can take many forms, including (IPCC, 2011):

- Wave
- Tidal (rise and fall)
- Tidal (currents)
- Ocean currents
- Ocean Thermal Energy Conversion (OTEC)
- Salinity gradients (osmosis)
- Marine-based biomass (algae)

The IPCC's Special Report on Renewable Energy Sources (2011), highlights that the technically exploitable potential for marine-based renewable is estimated at 7 400 EJ per year; the figure well exceeding our current energy needs. The exploitable potential is limited by the need for energy sources to be near population centres to reduce associated transmission costs, as well as on future technology developments.

However the potential for supplying the energy needs of these centres is huge. For instance, conversion of the wave energy resource alone could supply a substantial part of the electricity demand of several countries, in particular Ireland, the UK, Denmark, Portugal, Spain and Norway, especially on islands and in remote areas (EREC, 2011).

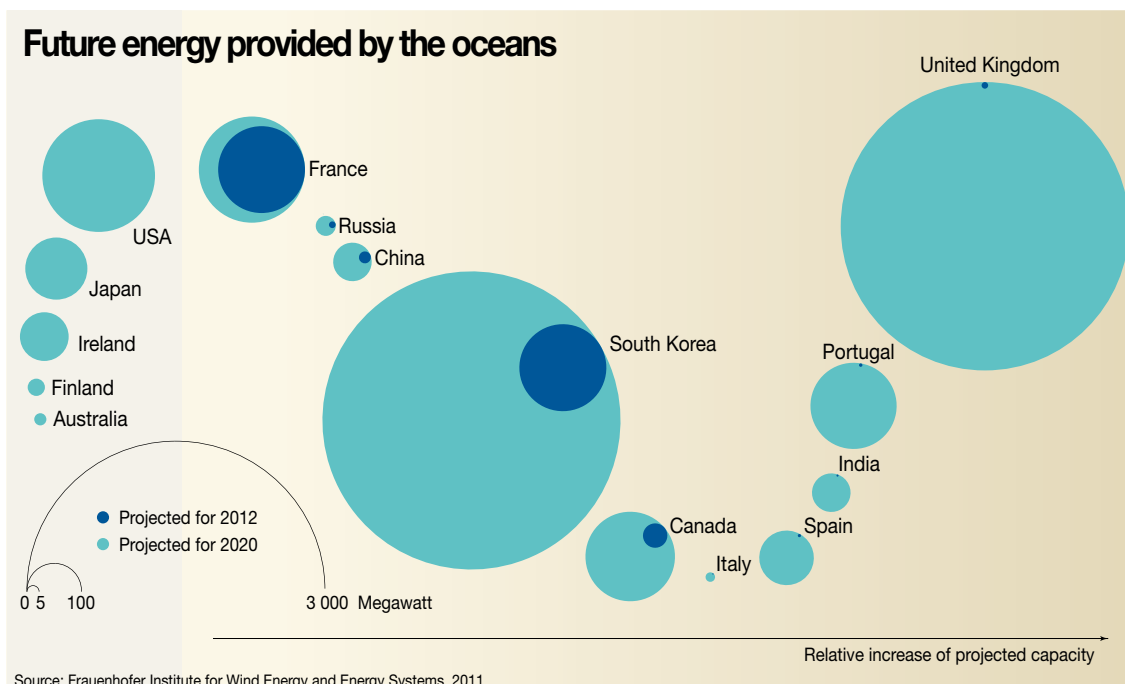
Other renewable energy technologies are more advanced in both their development and their commercialization. In 2008, marine-based renewable energy represented less than 1 per cent of total energy production of all renewable energy options, and of this, offshore wind was by far the greatest contributor. However, the marine environment does offer promising opportunities due to its more predictable circulation and untapped reserves. Additionally, there is less likelihood of conflict with other land-users which onshore renewable energy options are increasingly encountering as infrastructure levels increase.

More than 85 countries around the world have renewable energy targets in place (UNEP, 2011), with countries such as the UK, Canada, Portugal, Estonia, France, Italy and Ireland developing specific targets for marine-based renewable energy, excluding offshore wind (IPCC, 2011)¹. However, Europe currently leads the development of ocean-based energies, particularly for offshore wind, wave and marine currents, which have seen the most technological development. This development is primarily facilitated by strong renewable energy targets through the governments' directives (Renewable Energy Directive) and support for research and development, as well as investments from utility companies who are under pressure to increase their share of clean energy in their portfolio. The best ocean energy resources within European Union Member States are wave energy and marine currents, salinity gradient systems are being developed in Norway and the Netherlands (EREC, 2011).

The figure below shows projections of installed marine energy capacity for selected countries from 2012 to 2020. Marine energy sources included are: tidal barrage, tidal current, wave, OTEC and osmotic power. South Korea and France are starting with from a relatively high installed level. However, the UK, the USA and Portugal are the countries with highest relative increases projected.

The global installed wind energy generation capacity (including offshore and onshore)

1. UK: 1300 MW, Portugal: 250 MW, France: 140 MW, Estonia: 100 MW, Ireland: 75 MW, Italy: 3 MW electricity generation from marine based renewable energy.



increased more than tenfold from 18 000 MW (end of 2000) to 215 000 MW (June 2011) (WWEA). Owing to ongoing improvements in turbine efficiency and higher fuel prices, wind power is becoming economically competitive with conventional power production (Risø, DTU).

China, United States, Germany, Spain and India are among the countries producing the largest amount of (offshore and onshore) wind energy. According to the Global Wind Energy Council (GWEC) China's wind market doubled every year from 2006 to 2009 in terms of total installed capacity, and it has been the largest annual market since 2009. In 2010, China overtook the United States as the country with the most installed wind energy capacity. China wind capacity in 2010 was 41 800 MW where as that of the US in the same year was 40 180 MW (Financial Times, 2011).

Marine energy is unique because its potential varies depending on the energy source, for which there are many technology options. For example, the different concepts for wave energy conversion can be onshore, near-shore and offshore and rely on several working principles (oscillating water columns). Tidal barrage technologies are adapted to ebb and flood tides. Marine current devices are less diversified than wave energy devices, but could use a range of working principles and they can either be rigidly mounted in the seabed, pile-mounted, semi-submersible with moorings or attached to a floating structure. The technology to harness salinity gradient power uses the osmotic pressure differences between salt and fresh water or between water bodies of different salinity.

Little or no convergence has yet occurred, and is unlikely given the range of options for energy extraction (IPCC, 2011). More than 100 different marine-based energy technologies are currently under development in over 30 countries (IPCC, 2011). The four most dominant energy sources are discussed in more detail here.

1.2 Offshore wind energy

Offshore wind power is developing rapidly and creating economic opportunities in terms of its share of global energy generation. Estimates of the technical potential for offshore wind energy alone range from 160 to 1 500 million MW in a year; when only considering relatively shallow and near-shore applications; greater technical potential is available if also considering deeper water applications that might rely on floating wind turbine designs (IPCC, 2011).

Offshore wind energy is highly capital-intensive when compared to onshore wind energy. The higher offshore capital costs are due to the larger structures and the complex logistics of installing the towers that are significantly higher than onshore. For example, offshore turbines are generally 20 per cent more expensive and towers and foundations cost more than 2.5 times the price of those for a similar onshore project (EWEA, 2009). However, the higher initial capital cost of offshore wind energy is compensated by additional benefits provided by offshore over onshore wind energy. Some of these benefits are listed below:

- Greater area available for setting up large projects: due to installation at sea, there is more space available for offshore wind turbines.

- Higher consistent wind speed than onshore locations: wind-speed intensity is steadier and greater in deeper water, producing higher output per revolution. An increase of about 20 per cent in wind speed at some distance from the shore is not uncommon. Moreover wind is less turbulent at sea than over land which results in consistent energy generation.
- Close to load centres: offshore wind farms are usually located near to cities and load centres, minimizing transmission losses.
- Favourable to public acceptance: as these sites are located far from land they have less visual impact which helps with public acceptance issues. Moreover, wind turbines emit a whirring noise which has led to problems people with living nearby.

Project finances dominate the financial structure of the offshore wind-energy sector, because of the highly predictable nature of wind-farm cash flows. Over the past couple of decades, the vast majority of commercial wind farms have been funded through project finance. Project finance is essentially a project loan, backed by the cash flow of the specific project. Recently, companies' own financing has also become common for financing wind-farm projects. This means that the owner of the project provides all the necessary financing for the project, and the project's assets and liabilities are all directly accounted for at company level. Structured finance markets (such as bond markets) in Europe and North America have also been used, but to a more limited extent than project finance transactions.

Commercial-scale offshore wind facilities are currently in operation in shallow waters off the coasts, but further technology development is needed for use in the deeper waters of the high seas.

Offshore wind, currently around 3 000 MW, has mainly been concentrated in northern European countries, around the North Sea and the Baltic Sea. Europe's leadership is primarily attributed to public policy and a thriving wind energy industry. EU legislation mandates significant reductions of carbon emission, requiring, among other measures, greater usage of renewable energy resources. As of 2011, around 69 wind farms were installed or under construction in the EU. Europe has a total offshore wind-energy generation capacity of 3 000 MW (EAI). Other countries worldwide are also exploring offshore renewable energy including the Japan, USA, India and Eastern and Southern Africa (Wilhelmsson, et al., 2010).

According to the Japanese Wind Energy Association (JWEA), Japan's wind-energy

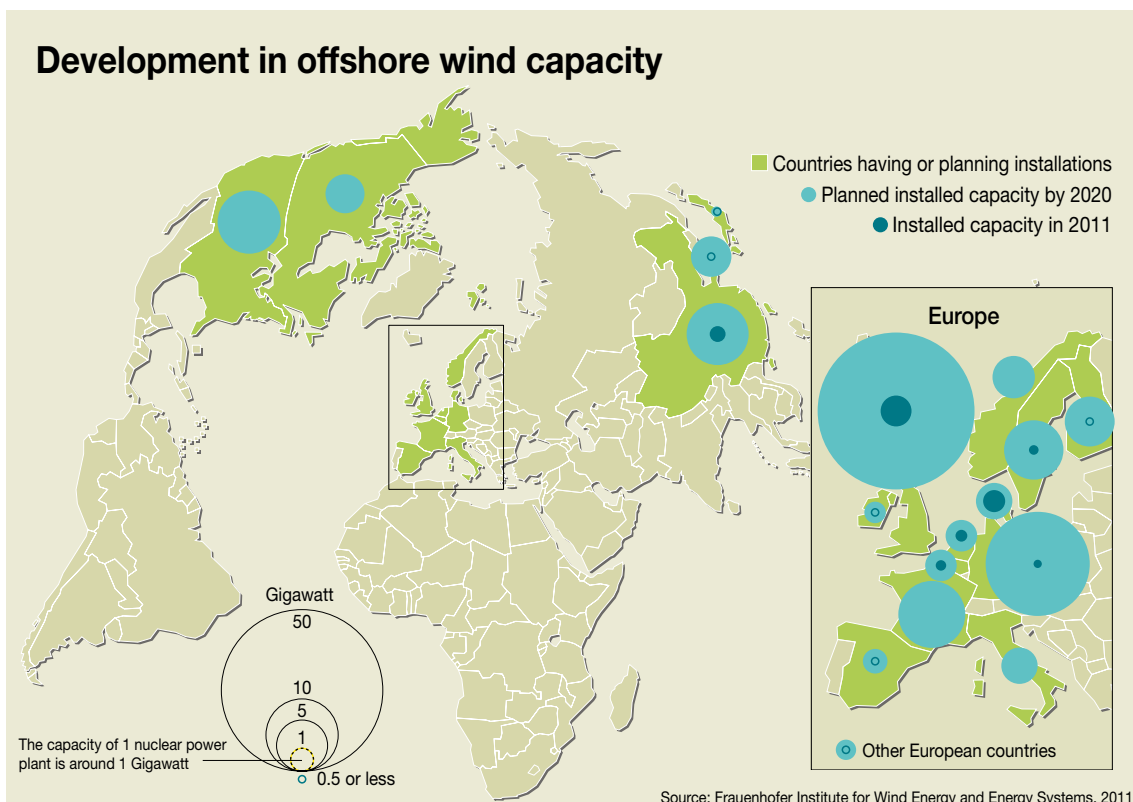
industry has surged forward in recent years; there has been an increase in installed wind-energy generation capacity from 136 MW at the end of 2000 to 2 300 MW by 2010. This is partly spurred by a government requirement for electricity companies to source an increasing percentage of their supply from renewable and partly by the introduction of market incentives, both in terms of output price subsidy and capital grants.

Similarly, wind-energy generation capacity in the US increased by a factor of 15 over the same period from 2 500 MW in 2000 to 40 100 MW in 2010 (GWEC, 2010). Wind energy now is generating around 2 per cent of US electricity needs; however the potential is much greater. In 2008, the US Department of Energy released a report, predicting that wind power could provide 20 per cent of US electricity by 2030. Offshore wind-energy generation is taking off in the US, albeit slowly. The Obama administration has unveiled a plan for fast-tracking offshore wind-energy projects, releasing US\$50 million for R&D in offshore wind energy in the USA (Ecopolitology).

The Indian wind-energy sector has an installed generation capacity of 14 158 MW (March, 2011), which is ranked fifth highest in terms of wind-power installed capacity in the world. The majority of this capacity is drawn from onshore projects. The offshore wind-power potential for India has been estimated as 15 000 MW. A huge potential remains untapped due to the high capital cost of offshore wind projects and lack of the necessary supply chain. Tamil Nadu, a southern state in India, will have the distinction to have India's first offshore wind project (EAI).

The highest country level growth rate for wind-energy generation capacity was seen in China, in the past decade. The wind-energy generation capacity in China doubled every year between 2006 and 2009, and it has been the largest wind-energy generating country in the world since 2009. There is one operational offshore wind farm in China, as of 2011.

The figure below shows the cumulated capacity of offshore wind farms in selected European countries from 2011 to 2020. It can be seen that the total capacity for offshore wind is still limited, but growth rates are high. Offshore wind farms are installed in large units – often in the order of hundreds of MW. Presently, higher costs and temporary capacity problems in the manufacturing stages, as well as difficulties with the availability of installation vessels, are causing some delays, and hence slow expansion growth. Several countries are nevertheless



showing rapid progress in offshore wind-energy installation. For instance, the UK added 90 MW in 2006 and another 100 MW in 2007 to its installed offshore wind-energy generation capacity (EWEA, 2009).

1.3 Tidal energy

Tidal range is the change in height of water level driven by gravitational forces; the difference between high and low tides. While tides' amplitude may vary during the year, depending on the relative positions of the Earth, Moon and Sun, they are regular and predictable. Tides are more predictable than wind energy and solar power and hence have the potential to generate stable income for the producer. Greater tidal ranges typically occur in estuaries and bays with the highest range being found in the Bay of Fundy, Canada (17m), the Severn Estuary, the UK (15m) and the Baie du Mont St Michel, France (13.5m). A tidal range of at least 7 m is considered to be required for economical operation and for sufficient head of water for the turbines (Ocean Energy Council, 2012)

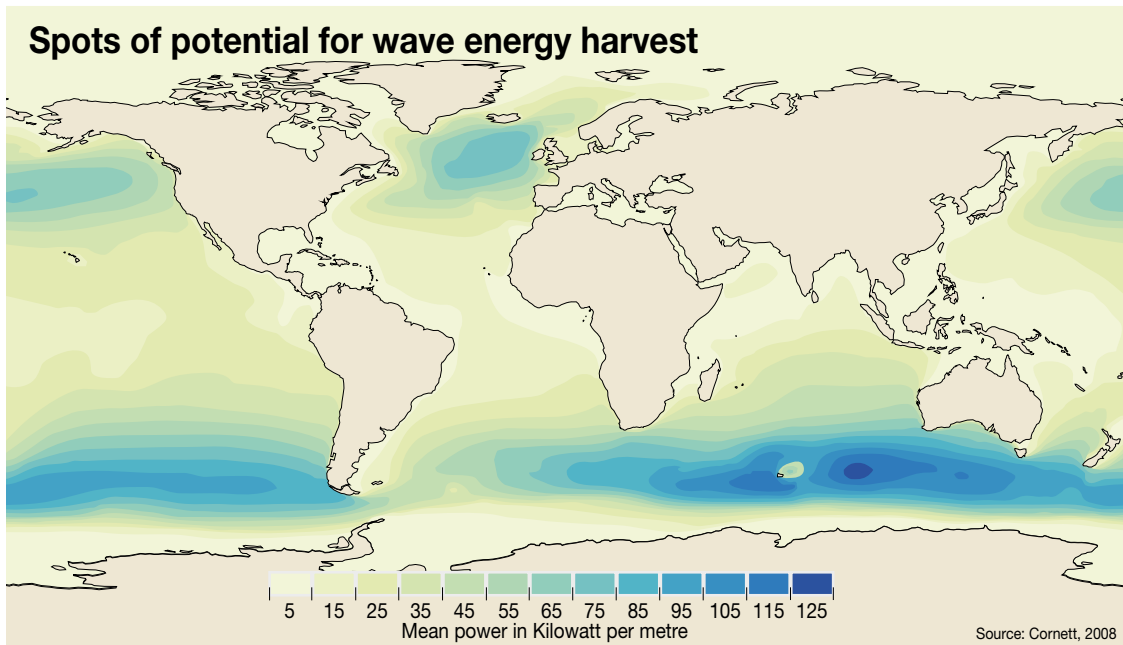
Tidal range power is a form of hydropower that converts the energy of tides into electricity. It works on the principle of turbine energy generation, where a tidal energy site consists of a storage pond, filled by the incoming tide through a sluice and emptied during the outgoing tide through a water wheel that drives turbines to generate electricity. Tidal energy can be exploited in two ways:

- By building semi-permeable barrages across estuaries with a high tidal range.
- By harnessing offshore tidal streams.

The tidal barrage in La Rance, France is the world's first tidal power station. The facility is located on the estuary of the Rance River, in Brittany, France. Opened in 1966, it is currently operated by Électricité de France (EDF), and is the largest tidal power station in the world, in terms of installed capacity, with a peak rating of 240 Megawatts, generated by its 24 turbines (Wyre Tidal Energy, 2012). Further, there is a 20 MW experimental facility at Annapolis Royal in Nova Scotia, a 0.4 MW tidal power plant near Murmansk in Russia, several locations in China since 1977, totaling 5 MW and the Sihwa Barrage in South Korea (254 MW) which is operational since August, 2011 (IPCC, 2011 and Ocean Energy Council, 2012). The UK has several proposals underway (Ocean Energy Council, 2012).

Studies point to several other promising locations, including Alaska, British Columbia, Washington, Maine, the Severn River in England, and the White Sea of Russia (Ocean Energy Council, 2012).

Tidal currents are the flow of water resulting from the rise and fall of the tides, particularly near islands or other natural constrictions. There is more potential for such resources to be harnessed, particular around headlands



or through channels. Tidal currents can be harnessed using technologies similar to those used for wind-energy conversion (horizontal or vertical-axis turbines, also known as ‘cross flow’ turbines). However, in contrast to atmospheric airflows the availability of tidal currents can be predicted very accurately, as their motion corresponds to local tidal conditions.

While still in a nascent stage of development, commercially attractive sites have been identified in the UK, Ireland, Greece, France and Italy. Outside Europe, there is potential in the Republic of Korea, China, Canada, Japan, the Philippines, New Zealand and South America. China, for instance, has estimated a tidal power current potential of 14 GW (IPCC, 2011)

Tidal energy has the potential to become a viable option for large-scale, base-load generation in some countries due to their advantageous location. However, current competitive capacity when compared to fossil-fuel based energy is still a concern.

1.4 Wave energy

Wave energy is captured directly from surface waves or from pressure fluctuations below the ocean surface. Wave power varies considerably in different parts of the world, making it more economically feasible to harness in some parts than in others, hence making wave energy a region-specific energy source. For example, strong winds variations are observed within the band between 30 and 60 degrees latitude, and circumpolar storms near the southern latitudes, which account for high-energy ocean waves in those areas (IEA, 2008). Similarly it has been

observed that annual wave power distribution is greater on the western coasts of temperate countries (IPCC, 2011). For instance in the figure above, offshore average annual wave power distribution is highlighted. It can be seen from the figure that the largest power levels occur off the west coasts of the continents in temperate latitudes, where the most energetic winds and greatest fetch areas occur.

Wave energy is predictable, because satellites can measure waves out in the ocean that will later impact on devices around the coast. This predictability will allow for less spinning reserve than is often required to support more intermittent renewable energy sources (WEC, 2007).

Many different wave energy converter types have been, and continue to be, proposed and tested but they are still at the pre-commercial phase (Holmes & Nielsen, 2010). A very few pilot projects have been translated into working prototypes, and even fewer into devices which are sufficiently robust. Some estimate that more than 50 wave energy devices are at various stages of development (IPCC, 2011), often tailored to specific site conditions. They range from small 10 kW generators standing on the seabed to large floating structures generating 1.5 MW.

The total theoretical wave energy potential is estimated to be 1 300 million MW/yr (Mørk, et al., 2010), roughly twice the global electricity supply in 2008 (700 million MW/yr). This figure is unconstrained by geography, technical or economic considerations. However the technical potential of wave energy will be

substantially lower than this figure and will depend on technical developments in wave-energy devices. Sims et al., (2007) estimate a global technical potential of 500 000 MW for wave energy, assuming that offshore wave-energy devices have an efficiency of 40 per cent and are only installed near coastlines.

1.5 Algae-based biofuels

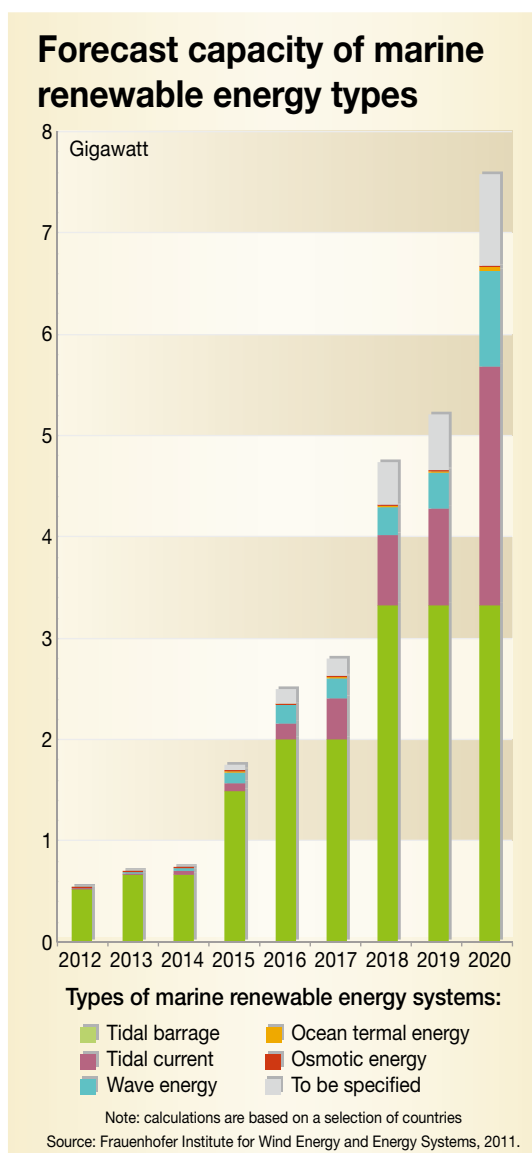
Algae-based biofuels can be regarded as a promising route to the production of future liquid transportation fuels. The typical production process benefits from the following advantages: a wide variety of input sources like combustion gas, seawater, brackish and waste water; suitability to many land and water types; availability of different production methods; likelihood of achieving good productivity levels when compared to most conventional (land-based) biomass feed stocks; and production of high grade oils that can be converted to fossil-fuel substitutes (IEA, 2011). Aside from the algal oil production and upgrading costs, which are currently high, the most significant limiting factors affecting algal biofuels are those imposed by the need for climatically favourable locations with suitable land, water and CO₂ resources.

Meaningful estimates of the potential sustainable production volumes of algae biofuels worldwide are difficult to obtain at present. However algae biofuels are unlikely to displace a large fraction of current petroleum fossil-fuel usage (IEA, 2011). The economic viability of algae biofuels is still tentative. Currently there are little or no commercial-scale examples producing algae-based biofuels. The major challenges which have been identified are high initial capital input costs for algae cultivation and processing systems (higher than agriculture), and the low value of co-products to compensate higher production costs.

2 Challenges and opportunities

2.1 Marine-based renewable energy: driving forces, pressures, state, impact, response

In order to understand the current context and challenges in the marine-based renewable energy sector, a DPSIR framework can be used to understand the links between driving forces, pressures, state, impact and responses. In short, it can be said that environmental and economic impacts associated with current fossil-fuel energy systems are driving changes that are encouraging development in renewable energy options. Within the general renewable energy context, marine-based renewable energy systems are increasingly being promoted due



to problems associated with predictability of land-based options and problems around social acceptance. In this way, the increase in demand for marine-based renewable energy can also be considered a driving force in itself for changes in the marine environment, potentially leading to conflicts with other users and the need for proactive seascape planning. Given these links, a double DPSIR framework is presented below.

2.2 The economic case for the marine-based renewable energy sector

This section highlights the respective economic cases of selected marine-based renewable energies. Given the nascent stage of most options and the lack of commercial deployment experience, commercial cost and price data is not available, hence the exact economic potential for most marine-energy technologies is difficult to assess in absolute terms. As an alternative, total expected energy generation potential and price competitive capacity compared to fossil-fuel based energy is

taken as a proxy to determine the economic case for the marine-energy technologies discussed here. To be cost-effective for energy generation and to compete against fossil-fuel based energy, marine-based renewable energy has to be cost-effective against fossil fuels. When fossil-fuel prices rise, renewable energy becomes more cost-effective, and vice versa. This trend can be seen in historical investments in renewable energy, which have coincided with high fossil-fuel prices (IPCC, 2011).

2.2.1 Economic opportunities

The figure on page 63 provides a forecast for

global installed capacity of selected marine based renewable energy sources from 2012 to 2020. Tidal current has the highest forecast increase followed by wave, based on plans and targets among all the energy technologies considered. (See section 1 for a more detailed analysis per energy type.)

2.2.2 Economic costs and challenges

The overall fossil-fuel based electricity price comprises fuel cost, operation and maintenance (O&M) costs, capital cost, including planning and site work and cost of CO₂ emissions (where

DPSIR 1 – Fossil-fuel energy sector as driver, MBRE as response

Driving Forces	Pressures	State	Impact	Response
Globalization Increasing population Increasing energy demand, especially in developing countries Economic growth	Reliance on fossil fuels Increasing energy consumption	Increasing greenhouse gas emissions Increasing land use change Air quality Hydrology	Climate change Habitat loss Water scarcity through overuse and pollution Air pollution Energy insecurity and Rising fuel prices	Renewable energy policy targets, policy framework establishments Investments in renewable energy sources (see sections 3.1 and 3.3 below)

DPSIR 2 – MBRE as driver, MBRE as response in proactive seascape planning

Driving Forces	Pressures	State	Impact	Response
Increased demand for renewable energy, including marine-based renewable energy (see section 2.3.2)	Construction of infrastructure Noise pollution Electromagnetic waves (see section 2.3.4)	Changed seabed Changed hydrographic and sedimentological patterns (see section 2.3.5)	Habitat loss/gain Disturbance of hunting/breeding grounds No fishing zones Conflict between marine users including tourism, fisheries, shipping, etc. (see section 2.3.3)	Proactive seascape planning (avoid ecologically- sensitive areas) Best practice design, construction, operation and decommissioning Stakeholder engagement (see sections 3.2, 3.4 and 3.5)

mandated). The approach in this section is to determine the price-competitive capacity of each of the selected marine renewable energies against fossil-fuel based conventional energy sources. The section also discusses costs for the latest available reference year. However, it is important to take into account trends in the costs curves, depending on where the respective technologies are on the innovation curve.

The table below provides a rough estimate of costs, with the best available data for some of the primary costs associated with selected marine-energy technologies. These costs are taken from the IPCC and, in most cases, are based on sparse information due to the lack of peer-reviewed reference data and actual operating experience. They therefore often reflect estimated costs based on engineering knowledge.

2.2.3 Economics of different marine-based renewable energy sources

Offshore wind energy

When conventional power is replaced by wind-generated electricity, the costs avoided depend on the degree to which wind-power substitutes

each of the three components: fuel cost; operation and maintenance (O&M) costs and capital cost. Wind power avoids full fuel and CO₂ costs, as well as a considerable portion of the O&M costs of the displaced conventional power plant. Henceforth, the cost comparison lies within capital costs.

The level of avoided capital costs depends on the extent to which wind-power capacity can displace investments in new conventional power plants (combined cycle natural gas power plant), and thus is directly tied to how economically viable wind energy is compared with fossil-fuel based energy. For instance, in the figure below, a reference case is depicted to compare the cost of generating wind power with conventional power.

One economic advantage of wind energy compared to conventional energy generation is the relatively constant, non-fluctuating input costs, compared to fossil-fuel price fluctuations. Although intermittent winds can mean output fluctuations, input prices for wind energy are constant at almost zero and hence the final cost of wind energy is independent of input fuel prices. The input resource costs per kWh

Summary of core available cost and performance parameters for different ocean energy sources

Marine-energy technologies	Investment costs in US\$ (2005 ec) per KW	Annual O&M costs in US\$ (2005 ec) per KW	Design life ^a (years)
Wave	6,200 – 16,100 ^b	180 ^b	20
Tidal range (using tidal barrage)	4,500 – 5 000 ^b	100 ^b	40 ^c
Tidal current	5,000 – 14 300 ^b	140 ^b	20
Wind energy	2,200 – 2 900 ^d	37- 60	20 ^e
Nuclear energy ^f	1,800	0.06 ^g	25-40
Coal energy ^h	1,000 – 1,500	0.002	35-40

Source: IPCC, IEA, EWEA and others

Notes: a) Design life estimates are based on expert knowledge. A standard assumption is to set the design lifetime of an ocean energy device to 20 years;

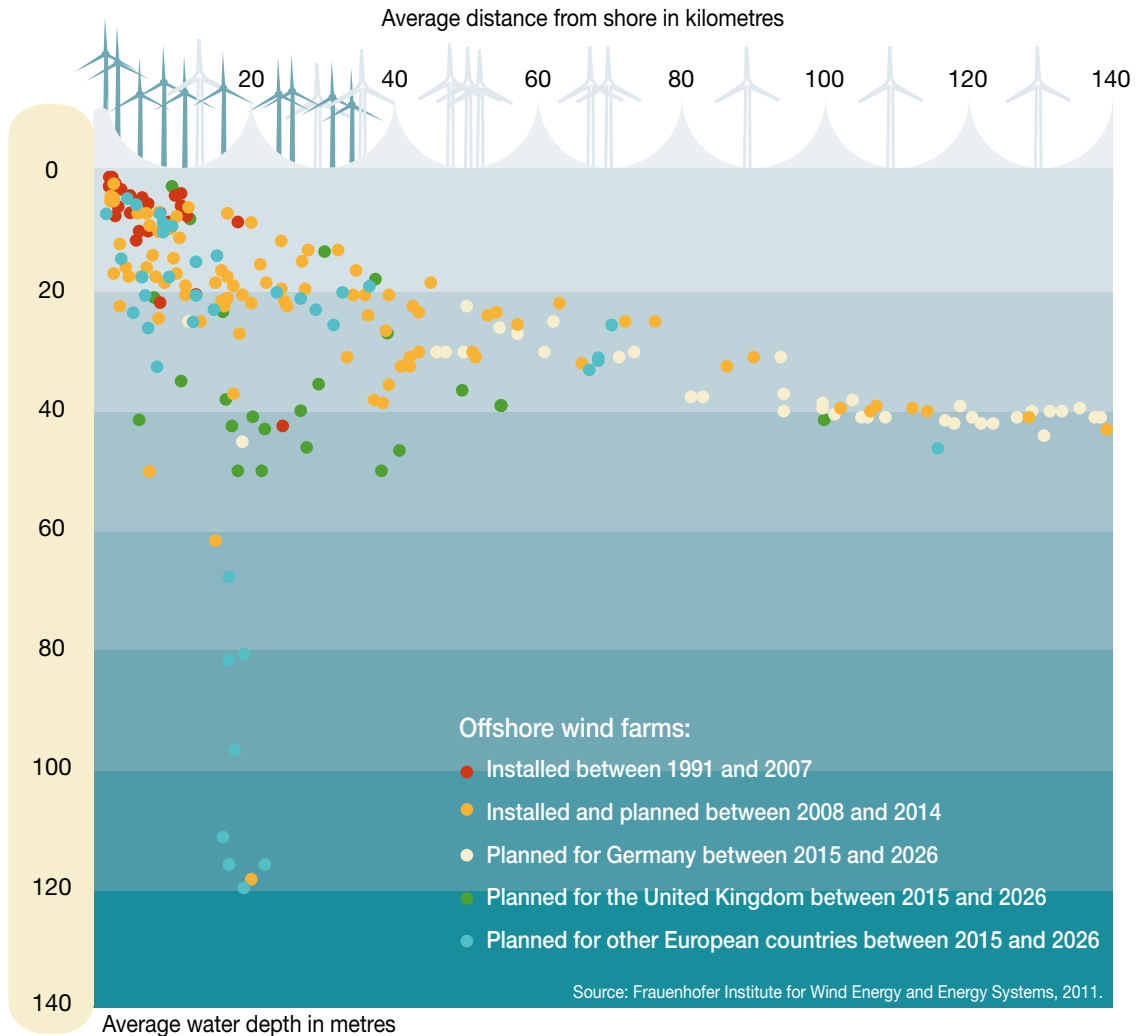
b) Based on the estimates provided by Callaghan (2006), Previsic (2004) and ETSAP (2010);

c) Tidal barrages resemble hydropower plants, which in general have very long design lives. Tidal barrages are therefore assumed to have a similar economic design lifetime as large hydropower plants that can safely be set to at least 40 years;

d) Approximate data adapted from the EWEA, 2009 for an offshore wind turbine installed in Europe, between 40 and 180 MW and reflected in 2005 USD;

e) Data taken from EWEA, (2009), f) figures are taken from a MIT report and translated into 2005 USD, g) O&M costs do not include fuel costs, h) IEA (2010)

Looking further offshore and in deeper waters



generated by wind power are almost constant over the lifetime of the turbine, following its installation. Hence, even if wind power might currently be more expensive per kWh, it is economically advantageous in the long run, since it hedges against an unexpected rise or fall in prices of fossil fuels, thereby providing more certainty to investors (Awerbuch, 2003).

A few of the main parameters governing the economics of offshore wind farm are: weather and wave conditions; water depth; type of foundation used; distance from the coast; investment costs, such as auxiliary costs for foundation and grid connection; operation and maintenance costs; electricity production against average wind speed; turbine lifetime; and the discount rate of the initial investment.

The initial setup costs for offshore wind are more than 50 per cent higher than onshore wind (EWEA, 2009). The higher offshore costs are due to associated high initial investments for larger

structures and the complex logistics of installing the towers. For instance, in Europe, the expected average investment costs for a new offshore wind farm are in the range of 2.5-US\$2.7 million (2005 ec) per MW. However, these higher costs are compensated by a higher total electricity production due to higher offshore wind speeds. For example, an onshore installation normally has around 2 000-2 300 full-load hours per year, while for a typical offshore installation this figure reaches more than 3 000 full-load hours per year (EWEA, 2009).

The high capital cost of offshore foundations bounds offshore wind energy to near shore locations. Most of the capacity has been installed in relatively shallow waters (under 20 m deep) no more than 20 km from the coast in order to minimize the extra costs of foundations and sea cables (EWEA, 2009). Most of the recently added capacity is installed in water depths of up to 40 metres, as far as 60 kilometres off the coast, as shown in the figure to the left.

Tidal energy

While technologies for tidal range are mature, tidal stream energy is not at a stage of broad deployment and is commercially immature when compared to other renewable energies, particularly wind. The table on page 65 shows US\$4 500-5 000 per KW investment costs for tidal range with a 40-year gestation period. The high investment cost and long gestation period associated with tidal energy makes it currently less economically feasible when compared to fossil-fuel based energy. However, government and public agency support for initial investment costs can improve the economic feasibility of tidal energy.

Wave energy

Cost estimates for energy produced by waves are dependent on physical factors, such as system design, wave-energy power, water depth, distance from shore, and ocean floor characteristics. Economic factors, such as assumptions on discount rate, cost reductions from a maturing technology, and tax incentives, are also critical.

As a result, the main challenges for implementing wave power are to reduce the capital costs of construction, to generate electricity at competitive prices, and to withstand extreme conditions at sea. For example, electricity from waves is currently estimated to cost seven times as much as coal-fired power (Bloomberg, 2010).

However, in certain remote locations where electricity supplies are expensive wave power is beginning to look competitive (Andrews & Jelley, 2007). This draws on the fact that the transmission and distribution cost of grid-based electricity in certain places can be higher, in locations that are farther from electricity generation centres, when compared to wave-power based electricity.

Algae-based biofuels

Algae-based biofuel development is still in its nascent phase. Despite some projections on the cost-effectiveness and imminent production volumes of algal-based biofuels, there are no commercial-scale examples of algae biofuel production (FAO, 2009). Some of the identified reasons for economic non-viability of algae biofuels are: high capital costs; biomass output is still under development (but has high potential); and the value of co-products is currently too low to achieve commercial feasibility.

In addition, knowledge gaps exist for algae-based biofuels due to several critical factors. For instance, due to a lack of industrial-scale experiments, there is insufficient knowledge

to adequately judge the economic viability; productivity data is often extrapolated from small experiments and overall analyses of energy balances, GHG balances and CO₂ abatement potential are lacking (FAO, 2009).

However, co-production of food and/or fuel has the potential to increase economic viability and can build on existing experience, with high potential in fish farming (FAO, 2009).

2.3 Social issues and opportunities

2.3.1 Employment benefits

Marine based renewable energy creates new and high return employment opportunities, due to the labour-intensive nature of production. This section here will illustrate the additional or increased employment benefits of marine based renewable energies, drawing on specific technology examples.

Compared with thermal power generation, renewable energy has a higher labour intensity and therefore acceleration in the deployment in the marine-based renewable energy sector could provide additional employment opportunities (UNEP, 2011). Lack of skilled labour is also one of the potential barriers to deployment of renewable energy (UNEP, 2011). The types and scale of opportunities will vary by national context and energy source. Marine-based renewable energy also presents a particularly relevant alternative for maritime communities who were formerly reliant on fisheries or offshore oil and gas production. In addition, energy installations can become tourist attractions in their own right, indirectly creating associated tourism and services jobs, as seen at La Rance tidal barrage in France (IPCC, 2011).

Wind energy for example provides both direct and indirect employment in the areas of wind turbine manufacturing, R&D, marketing, engineering and specialized wind-energy services. The total estimated direct and indirect jobs in Europe in 2009 are approximately 154 000 jobs. These jobs range from wind-energy manufacturers, developers, engineers, project managers, legal experts, environmental engineers, consultants, financial managers, insurers, R&D experts, constructors, etc. In terms of gender, a survey conducted by European Wind Energy Association shows that men make up 78 per cent of the workforce, due to the traditional predominance of men in production chains, construction work and engineering (EWEA, 2009).

Similarly, tidal energy is labour-intensive. For example, the envisaged Severn Barrage tidal

power station to be built across the Bristol Channel in the UK would have generated around 8 600 MW during flow and 2 000 MW on average, with a potential of creating a total of 35,000 jobs during the peak period of construction and a further 40 000 permanent jobs during the life of the project (DECC, 2010). The plan has now been shelved due to environmental concerns with destruction of marine habitats and political preference for nuclear, clean-coal and wind energy.

Moreover, the ocean wave-energy resource has considerable potential for energy production and hence contributing to economic development through employment generation. The countries with potential for wave energy such as Scotland (western coasts), northern Canada, southern Africa, Australia, and the US (northwestern coasts) have carried out roadmap scenarios for wave energy based on a few pilot projects available, to determine wave energy's approximate potential for job creation. In Scotland, for instance, the latest roadmap developed by the FREDs Marine Energy Group estimated in 2009 an overall expenditure of US\$3.75 billion to achieve 1 000 MW installed in Scotland by 2020, generating 5 000 direct jobs (Fred's Marine Energy Group (Meg), 2009). At EU level, the European Ocean Energy Association (EU-OEA, 2010) roadmap reference scenario projects total installed capacity of 3 600 MW in Europe by 2020, leading to investment of around €8.5 billion a year, which will generate 40 000 jobs. Similarly by 2050, achieving 188 000 MW could lead to an investment of €451 billion a year and the creation of about 471 000 jobs (EU-OEA, 2010).

2.3.2 Energy for development

The IPCC (2011) concluded that most theoretical renewable energy potential lies in developing countries where demand for sustainable access to energy is greatest for development needs. This is also true for marine-based renewable energy sources. However, due to the current scale and investment requirements for existing technologies, it is unlikely that marine-based renewable energy will be able to serve local community needs; other renewable energy options, such as solar and biogas, are more suitable in both scale and up-front investment.

However, electricity generated from marine-based sources could feed into the national grid of developing countries and help to offset increasingly volatile and expensive fossil-fuel imports to power the grid. This is of particular relevance for oil-importing countries in Africa, which spend on average 30 per cent, sometimes over half, of their export revenues on oil (UNEP, 2011).

Marine-based renewable energy offers the greatest potential for small island developing states, where land is often at a premium. By developing infrastructure in the marine environment, a feasible scale can be achieved, as well as avoiding conflicts with other land users. Investments are being explored in the Pacific Islands and the Caribbean (IPCC, 2011).

2.3.3 Interactions with other users

Given safety concerns around infrastructure, the areas around sites are often rendered no fishing zones. While this may serve to create benefits for biodiversity, it can cause potential conflicts with other marine users, including tourism, shipping, extractive industries and fisheries. If not addressed up-front, this conflict can cause delays to potential developments; further increasing investment costs (Wilhelmsson, et al., 2010).

Governments can also assist in preventing such conflicts through proactive marine spatial planning and zoning, ensuring that concessions are granted in zones that avoid ecologically-sensitive sites and minimize interaction with other marine users.

2.3.4 Environmental risks and opportunities

Any type of energy production – even clean and renewable options – can impact on the local and global environment. When assessing the impacts of marine-based renewable energy options, it is important to consider local impacts in the context of broader, global impacts. Climate change is an increasing threat to biodiversity. Energy generated from the oceans can substantially reduce greenhouse gas emissions, thus combating climate change. In addition, toxic pollutants associated with, for example, the burning of fossil fuels, or the local environmental impacts of large hydropower developments, could be avoided by developing wind power. These global and local advantages must however be balanced against the specific adverse effects MBRE may exert on the local marine environment.

Whilst acknowledging that research in this sector is still in its infancy, experience from other offshore sectors such as oil and gas, and alternatives such as hydropower and onshore wind indicate that the marine-based renewable energy options could have significant impacts on the marine environment. It is important to take them into account early in the planning and design phase of a development in order to reduce the risk of causing conflict with marine users who depend on the environment (see above).

While the environmental risks and opportunities of different technologies are specific to the source and design as well as the specific site, some general assumptions can be drawn. The greatest negative impacts are most likely during piling, construction and decommissioning due to noise and habitat loss. During operation, moving parts can affect birds, fish and sea mammals. But many of the potential negative impacts can be avoided if ecologically-sensitive sites are not developed, and best practice is employed for design. Furthermore, it is possible that the marine environment can benefit from the presence of the energy infrastructure through the creation of artificial habitat and the reduction of other adverse activities, like no fishing in the area (Wilhelmsson, et al., 2010).

Marine energy does not directly emit CO₂ during operation; however, GHG emissions may arise from different aspects of the lifecycle of ocean energy systems, including raw material extraction, component manufacturing, construction, maintenance and decommissioning. A comprehensive review of lifecycle assessment (LCA) suggests that lifecycle GHG emissions from wave and tidal energy systems are less than 23 grams CO₂ eq per kWh (IPCC).

It is difficult to assess the environmental impacts of wave-energy technologies, due to the limited experience of deployment. The potential effects will vary by technology and location, but may include competition for space, noise and vibration, electromagnetic fields, disruption to biota and habitats, water quality changes and possible pollution. For instance, noise and vibration are likely to be most disruptive during construction and decommissioning, while electromagnetic fields around devices and electrical connection/export cables that connect arrays to the shore may be problematic to sharks, skates and rays that use electromagnetic fields to navigate and locate prey. Chemical leakage due to abrasion (of paints and anti-fouling chemicals) and leaks, for example, oil leaks from hydraulic power take-off systems are also potential negative environmental impacts of wave energy (IPCC).

2.3.5 Potential risks and opportunities

Offshore-wind energy

Proper planning and management of offshore wind farms can help to ensure that population size and structure of marine life is not significantly disturbed and can potentially enhance levels of marine species (Wilhelmsson, et al., 2010). However, if not well-managed, significant risks for the marine environment include:

Threats:

- Piling noise/construction activities;
- Habitat loss for sea ducks and divers;
- Migration barriers for birds, sea turtles and whales;
- Bird collisions;
- Seabed changes;
- Navigational hazards/oil spills.

Opportunities:

- Exclusion of other activities, such as trawling;
- Habitat structuring.

Tidal energy

The impacts of tidal energy infrastructure vary significantly depending on the design employed. Tidal barrage systems that extract energy from ranges in tides have similar environmental impacts as traditional dams (Wilhelmsson, et al., 2010):

Threats:

- Habitat changes;
- Sedimentation (requiring dredging);
- Marine migration barriers;
- Change in estuarine water flow.

Other devices such as tidal fences or individual turbines may cause fewer negative impacts on the marine environment, compared to barrages, as their impact is spread out over a larger area. Remaining impacts are linked primarily to the effect of moving parts on marine mammals (IPCC, 2011).

Wave energy

Similar to tidal energy, the impacts of wave-energy technologies are specific to the site and type of device. For wave projects, similar concerns exist with regard to interference with fish or marine mammal migration (because wave systems are closed, entrainment is not an issue), reduction of wave height and release of lubricants used within wave systems.

Apart from offshore wind, there are few full-scale marine-based renewable energy projects deployed at full scale and as such, relatively little is known about the real impacts of newer technologies. Therefore, it is important that new developments are accompanied by appropriate monitoring and evaluation as part of environmental impact assessment procedures. Admittedly, this comes at a cost. The Ocean Renewable Energy Coalition (2011) estimates the environmental costs associated with the permitting of small marine renewable projects (under 1 MW) can make up as much as 40 per cent of the overall project cost. However, this investment is still recommended to

avoid potential increased costs in the future due to re-design and conflict over environmental issues. Governments can also help by subsidizing the costs of studies, offering funding for information collection and supporting science exchange and collaboration, including in South-South cooperation.

The UK has already undertaken strategic environmental assessments for marine renewable energy, and other European and North American governments are planning to undertake such assessments (IPCC, 2011). It is important that strategic environmental assessments are carried out to consider how the impacts of marine-based renewable energy projects combine with the impacts of other users in the marine environment, such as fisheries, aquaculture, shipping, leisure and tourism as well as other offshore energy projects.

3 Enabling conditions

The preceding analysis has highlighted the potential benefits that investment in marine-based renewable energy can bring, in terms of its contribution to low-carbon energy security and employment opportunities. However, challenges were also highlighted with respect to potential conflicts with other marine users and significant local environment impacts if proactive measures are not taken. Without taking into account negative externalities, only offshore wind is close to being cost-competitive with fossil-fuel and nuclear sources. There are many challenges to be overcome before marine-based renewable energy technologies can reach large-scale commercialization, such as high capital costs and logistics around storage capacities, etc. The greatest challenge is that many of the technologies are still in an early stage of development, with high uncertainty and associated costs around the timing and scale of the technical potential.

This section will explore the main enabling conditions to promote a rapid acceleration of this sector. They are grouped around: policies, incentives and regulation, technology and research, financing infrastructure and societal acceptance.

3.1 Policy, incentives and government regulations

Deployment of marine-based renewable energy is most likely when driven by government policy, accompanied by appropriate incentives and publicly funded research programmes (IEA, 2009). Furthermore, given the long lead times of marine-energy projects, a long-term vision

is necessary. This is because policies can help to reduce long-term uncertainty and market risk in the sector. The accompanying incentives can also offset financial risks associated with long payback periods and uncertainty (UNEP, 2011).

Governments consequently need to lead the way by establishing and maintaining renewable energy deployment targets and timelines which ideally include a specific target for specific technologies based on the local marine-energy potential. In Europe for example, the EU National Renewable Energy Action Plan (NREAP) sets ambitious, binding targets for the offshore wind sector (43 000 MW) by 2020. It is crucial that EU Member States abide by these ambitions and maintain the necessary level of support for 2020 in order to provide certainty for investors over the whole supply chain (EWEA). Non-binding targets have also been set in the UK and Canada, the US, Portugal and Ireland are following suit.

Incentive mechanisms should follow to support policy implementation. To be most effective, they need to be tailored to the stage of development of each respective technology.

- **Subsidies:** direct subsidies are particularly effective in early stages of market diffusion. They include investment support and grants to reduce capital costs and operating support. For renewable energy in general, subsidies for electricity-producing renewable technologies was between US\$1.68 billion and US\$2.52 billion for 2009. This compares to global fossil-fuel consumption subsidies of US\$312 billion in 2009 and US\$558 billion in 2008 (IISD, 2011). Subsidies should be applied carefully so that some renewable energy technologies are not supported at the cost of discouraging investment in equally promising alternatives, IISD cautions (2011). Subsidies must also achieve their policy objectives cost-effectively.
- **Taxes:** taxes can be used as an alternative to or in combination with subsidies. Tax revenue from fossil fuels or a carbon tax can be redistributed to marine-based renewable energy sources. Additionally, developers of such technologies can benefit from tax exemptions from general energy taxes, or for initial investments. These already exist for other renewable technologies in several countries; for example, the US and Sweden provide a 30 per cent tax credit for solar photovoltaics, and Australia provides rebates up to AU\$8 per watt (UNEP, 2011).
- **Performance based incentives or feed-in tariffs:** feed-in tariffs (FITs) usually take

the form of either a fixed price to be paid for renewable energy production or an additional premium on top of the electricity market price paid to RES-E producers. FITs allow technology specific promotion, as well as an acknowledgement of future cost reductions by applying dynamic decreasing tariffs. As they are usually guaranteed for a number of years, they are popular and effective with project developers as they provide long-term certainty and reduce market risk (UNEP, 2010).

It should be noted that these incentive mechanisms are most effective as and when technologies are in a position to be scaled up and more widely deployed, as seen with other forms of renewable energy. Aside from offshore wind-energy, these incentives are not as effective for marine-based renewable energy technologies which are still in the conceptual or demonstration phase. In this regard, direct funding for research is critical (see below).

3.2 Technology and research

Research and development is often highlighted as being important for a transition to renewable energy sources, but support is often inadequate (UNEP, 2011). Technical advances improve the cost-effectiveness of marine-based renewable energy technology through enhanced efficiency and capacity factors, facilitating widespread deployment. Uncertainty regarding such advances is consequently a significant obstacle to take-up in this sector.

Governments or public agencies can provide financial and legislative support for R&D of specific marine-energy technologies, and also to assist small and medium scale enterprises to set up pilot plants, for which it is hard to raise capital. For example, the European Commission's Sixth Framework Programme for research and technological development provided funding for Spain's first grid-connected wave power project, Mutriku (Bloomberg, 2011). Other examples include the Marine Renewable Proving Fund in the UK, which supports the demonstration of two wave and four tidal devices (Carbon Trust, 2011).

Other non-financial options can be used to support cooperation in this field. This is particularly important in the early phase of development where small projects are disproportionately affected by higher planning and transaction costs. International cooperation for example can also be facilitated, such as through the recently established International

Renewable Energy Agency (IRENA). This can build on other initiatives, such as the IEA's Ocean Energy Systems Implementing Agreement which is tasked with facilitating and coordinating ocean energy research, development and demonstration through international co-operation and information exchange. The European Marine Energy Centre in Scotland and other testing centres allow device developers to share the costs of testing their devices, through the use of shared infrastructure and permits (IPCC, 2011).

Given the high R&D costs involved, developing countries are not key players in the marine-based renewable energy field. However, with more than 50 per cent of potential renewable energy expected to be available in developing countries, North-South collaborations could help to speed up the transition. Producing knowledge products that can be adapted to local circumstances is another concrete action (Wilhelmsson, et al., 2010).

3.3 Financing

As illustrated above, there are financial and project specific risks associated with marine-based renewable energy, including high initial investment costs, novelty of technology and high operating and maintenance costs. Moreover, in general newer technologies have higher financial risks than conventional established ones, due to gaps in knowledge and uncertainty about results. Hence, financial support is required.

The IEA found that in its 28 member countries, financial support for renewable energy had stagnated over the last 30 years. However, there was a 50 per cent rise in 2009 despite the economic turndown, indicating resurgence in interest in this sector (UNEP, 2011). However, these are not necessarily directed to marine-based renewable energy. In 2009 new global investment in marine energy (excluding offshore wind) represented 0.001 per cent of total global investment in renewable energy (Bloomberg, 2010), reflecting the nascent stage of this sector. Finance needs to be tailored to R&D for a range of relevant option technologies.

In the early stages of development, public financial support is needed, both for R&D and then later to encourage deployment (see sections above for examples). Later, private finance can be mobilized for near-competitive technologies and demonstration projects. Public finance mechanisms can encourage the private sector to complement rather than to

need to take into account wide variability in different resources, allowing for flexibility and bulk energy storage. Offshore transmission networks also need to be established.

Given economies of scale, regional initiatives should be promoted wherever possible. For example, the European offshore super-grid is acknowledged as a good example of the benefits of moving from national to regional scope (UNEP, 2011), and can help address price volatility issues linked with offshore wind-energy.

Development of affordable installation, operation and maintenance strategies for marine-energy devices are priority areas for cost reduction. Initiating support mechanisms and framing suitable legislation to establish the required infrastructure facilities is crucial for the long-term commercial success of marine-based renewable energies.

3.5 Societal acceptance

Learning from experiences in other offshore environments, and other renewable energy technologies, it is important that societal acceptance is nurtured proactively from the beginning, thereby reducing planning time and associated development costs.

The social and environmental risks of marine-based renewable energy options are being assessed as and when projects are being deployed. In the meantime, continued and enhanced monitoring of carefully selected environmental parameters during construction and operation of marine based renewable energies using environmental impact assessments will be essential components of early deployment. In time, more reliable and adequate data will be available on both the adverse and potentially positive effects of various marine-energy technologies.

Proactive engagement of other marine users enables a balanced approach to be taken with coastal communities. Synergies should be proposed wherever feasible, such as with creating tourism ventures based on the development, or offering employment to former fishing boat operatives, for example the EU Oceans of Tomorrow programme.

Much may be learned from the proposed Severn Estuary Tidal barrage in the UK, which not only lost the support of the general public but later of government by engaging with stakeholders

once certain design decisions had already been taken. This prematurely narrowed the scope for potential tidal-energy designs, some of which could have inflicted less damage on the environment but were out of the running (Okeanos, 2011).

Governments can support proactive engagement of other marine users by undertaking strategic assessments where many developments are planned in a region. An effective consultation process with affected stakeholders must accompany any larger-scale project. Governments also need to undertake proactive strategic marine planning to offer concessions in areas with lower risk to ecologically sensitive areas and promote synergies with other marine users. The European Commission is increasingly involved in Maritime Spatial Planning, with a view to planning and regulating all human uses of the sea, while protecting marine ecosystems to ensure efficient and sustainable use of marine space and resources in Europe. It is focusing on marine waters under national jurisdiction and is concerned only with planning activities at sea, based on sound data and in-depth knowledge of the sea.

3.6 Legal issues

Offshore activities are subject to the rules of international law. Under international law there are different maritime zones each giving different rights and obligations to the coastal State and other states. The scope of the legal rights of a State to engage in specific offshore activities or establish an offshore installation will depend on the maritime zone in which the activity takes place or the location of the offshore structure.

In developing marine renewable energy production governments should carefully assess the adequacy of their legal framework. A particular issue to take into consideration is the navigational rights of foreign flagged vessels. Hence, states developing offshore marine renewable energy infrastructure should ensure the preservation of navigational rights as granted under international law. As marine-based renewable energy parks often create de-facto no-fishing, no-navigation and no-trawling areas, this highlights the need for developers to proactively engage with other stakeholders for the development of marine renewable energy. Furthermore, in cases where maritime zones overlap, governments need to cooperate with neighbouring States.

4 Conclusion and recommendations

The importance of renewable energy to drive a green economy is undisputed. Targets for renewable energy deployment and record levels of investment in renewable energy are driving this sector forward. This chapter has shown that while the theoretical marine-based potential to contribute to low-carbon energy security is significant, the currently realizable potential is much lower but still significant.

All marine-based renewable energy technologies, apart from offshore wind and tidal range are in the conceptual or demonstration stage. Offshore wind-energy is likely to expand in the coming years, while tidal range is limited by the number of potential sites and the environmental impacts associated with barrages. Technical costs are the largest barrier and are likely to remain high until a critical mass can be reached.

However, acceleration in the industry has been witnessed in regions where deployment targets are coupled with public support for research and development. To maintain this momentum, governments need to lead the way and provide the enabling conditions

outlined above to accelerate the development of the industry, reducing long-term uncertainty and market risk, and eventually mobilizing the private sector capital. Research and development needs to be maintained for all relevant marine-based renewable energy options, to ensure that subsequent breakthroughs remain possible.

In addition to relevant policy mechanisms, incentives schemes and financing options, governments, at both national and international level, also need to come up with binding targets, establish an appropriate framework and ensure smooth running of implemented policies for marine based renewable energy technologies. Countries can pass legislation similar to the European Renewable Energy Directive that requires countries to address this, more broadly for all renewable energy options.

Finally, all players in the marine-based renewable energy sector have a role to ensure that they proactively maintain and nurture civil society acceptance. Governments especially need to undertake proactive strategic marine planning to offer concessions in areas with lower risk to ecologically sensitive areas and promote synergies with other marine users.

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OCEAN NUTRIENT POLLUTION FROM AGRICULTURE, FERTILIZER PRODUCTION AND WASTEWATER MANAGEMENT SECTORS

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The chapter was reviewed by Meryl Williams of GEF STAP.



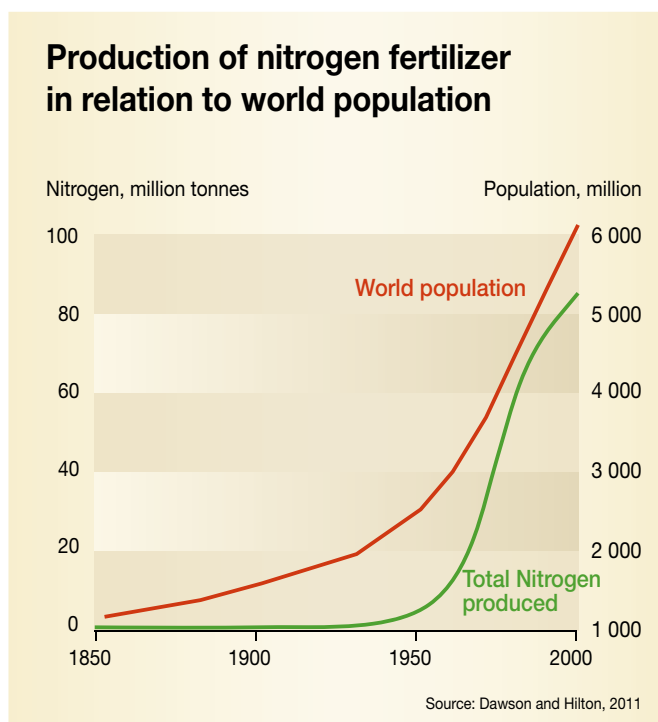
1. Introduction: ocean nutrient pollution presents an important opportunity for the Green Economy

Most human activity is conducted in the coastal zones or within river catchments that discharge to coastal zones. The consequence of these activities, be they farming, industrial production, transport, power generation or urban development, is the inevitable release of pollutants – nutrients, solids, organic chemicals, metals, etc. – to water, land and air. Over the last few decades there have been considerable efforts to reverse the historical approach of dumping wastes, including nutrients, into the oceans and to reduce the associated degradation of coastal and ocean water quality and ecosystems. This drive for pollution reduction has responded to human health concerns or preservation of the environment to protect, for example, drinking water quality or the wider ecosystem. These improvements have been driven by a combination of national or regional regulations, economic and financial instruments, and international treaties responding to wider public concerns and the need for a healthy environment. While many of the identified hazardous or persistent pollutants are controlled or in the process of being controlled (such as through the Stockholm Convention and Montreal Protocol), the issue of excess reactive nitrogen (and phosphorus) in the environment still needs to be addressed in a coherent and integrated manner.

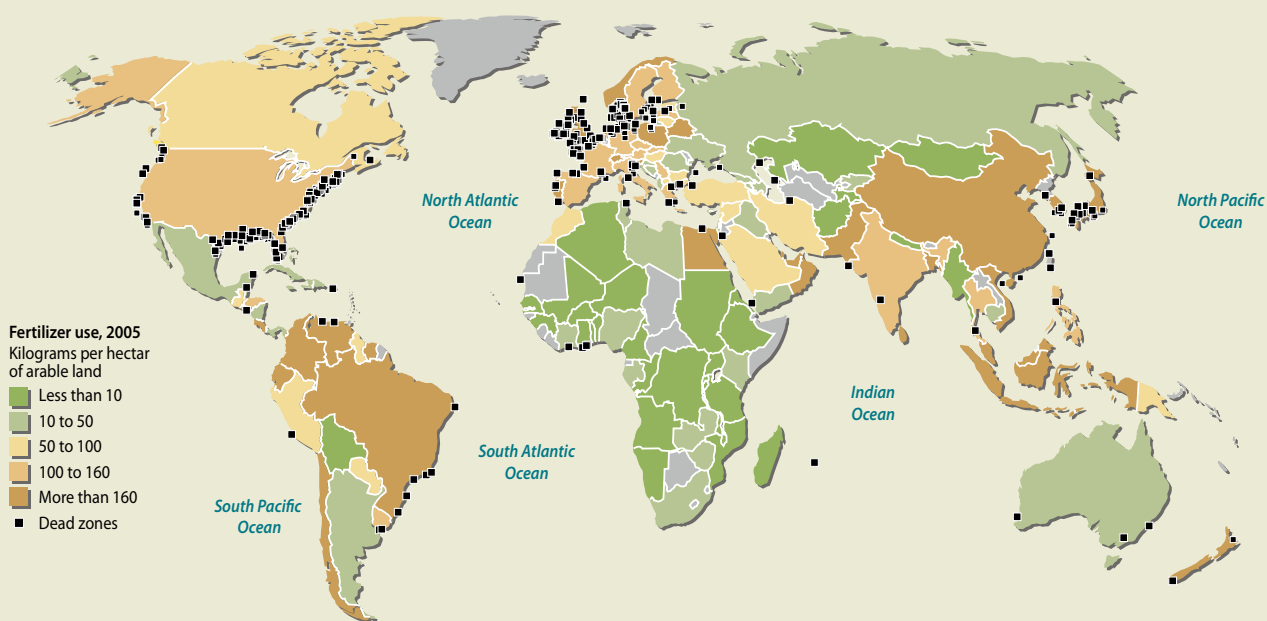
Reactive nitrogen and phosphorus are essential to all plant life, both terrestrial and marine

(including the free-living microscopic marine algae called phytoplankton), and to the animals that feed on these plant products. In most areas of the ocean, nitrogen is considered a limiting nutrient whose presence (or absence) largely determines the level of primary production (production by plankton of organic carbon via photosynthesis) and the broader level of biological activity (secondary production, fisheries biomass, etc.) in a given ocean area. Over about the last 60 years, the dependence of developed (and increasingly, many developing and/or middle-income) countries on fertilizers containing nitrogen and phosphorus to enhance agricultural productivity has led to massive increases in the production and application of fertilizers to farmed land (figure below). The often inefficient use of this fertilizer has led to substantial run-off and releases of nitrogen and phosphorus to waterways and groundwater, which, combined with comparable losses of nutrients from livestock (manure) operations, and the inadequacy of much of the world's waste-water treatment, has resulted in substantial increases in releases of nutrients both directly to the coastal zone and via rivers receiving emissions from upstream population centres and agriculture. The massive increase in anthropogenic reactive nitrogen introduced into the environment, deriving principally from the mass production of nitrogen fertilizers, has had significant negative environmental consequences (Drinkwater, et al. 2009) (Brown, 2011). The link between industrial agriculture and reactive nitrogen pollution is well established with impacts on drinking water (Powlson, et al. 2006) (Galloway, et al. 2008)

and the eutrophication of fresh water and marine ecosystems, including the proliferation of harmful algal blooms and hypoxic "dead zones" in marine ecosystems such as the Black Sea, Gulf of Mexico, Baltic Sea and elsewhere. Eutrophication occurs when excess nutrient inputs feed overgrowth of ocean plankton; dying plankton are consumed by oxygen-using bacteria which can lead to low oxygen or hypoxic conditions. This can have significant negative impacts on fisheries, food security and livelihoods, and lead to degradation of habitats which not only have important biodiversity values but, in the case for example of coral reefs, can result in the loss of natural coastal defences. The relatively recent rapid growth in the occurrence of ocean hypoxic zones has resulted from a roughly threefold increase in global loads of reactive nitrogen to the oceans compared to



Dead zones and fertilizers



Dead zones appear as a consequence of nutrient input to the oceans. Low levels of oxygen make it difficult for marine creatures to survive.

Source: World Bank, World Development Indicators database, accessed in October 2011; NASA Earth Observatory, data acquired in 2008.

pre-industrial times, from both agricultural runoff and poorly or untreated sewage.

In the US and EU levels of nitrates in groundwater in some instances are above safe levels and thus pose a threat to human health (Nolan, et al. 1988). The removal of nitrates from drinking water adds to both the costs and energy demands in treatment. This underscores the importance of preventing reactive nitrogen from agricultural sources from entering groundwater where the pollutants can have very long persistence.

The production and use of reactive nitrogen-based artificial fertilizers has had huge global benefits providing food for billions through the green revolution. The down side of the increased availability of cheap manufactured nitrogen fertilizer products has been global environment problems associated with excess nutrients, specifically the problems of eutrophication, coastal hypoxic zones and nitrate contaminated groundwater. Tracing the formation of eutrophic and hypoxic zones across the world shows a close correlation to the growth of agricultural regions, cities and coastal development (figure above); as of 2011, UNEP had identified over 500 areas of hypoxia globally (UNEP, 2011).

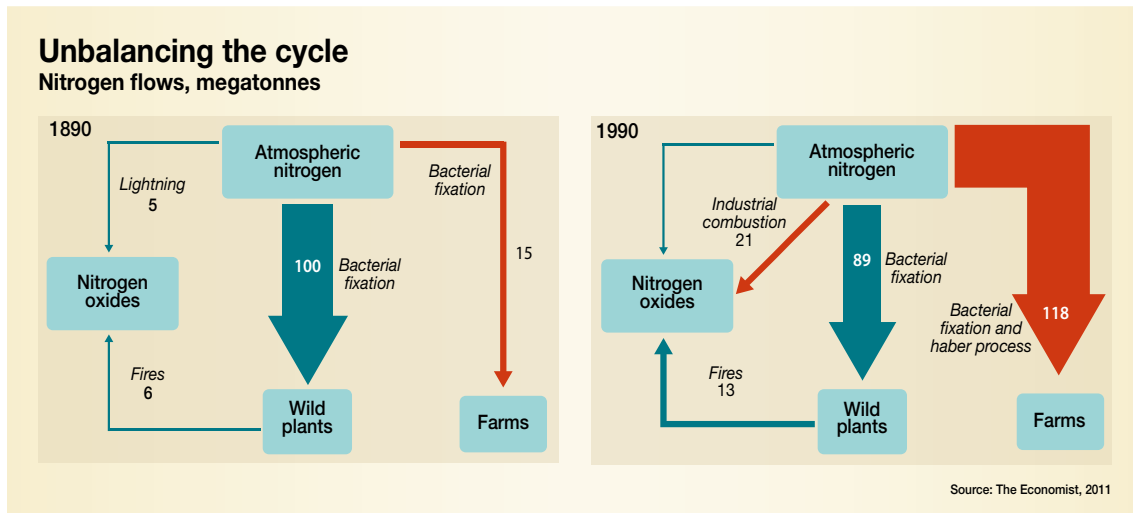
Until the early part of the 20th century, the agriculture sector and many industrial processes were dependent on limited natural reserves of reactive nitrogen, for example from Peruvian guano, Chilean saltpetre and ammonium

salts extracted from coal. In 1909, Fritz Haber identified a mechanism to produce ammonia from atmospheric nitrogen and hydrogen (from natural gas) at high temperature and pressure. This process was industrialized by a chemical engineer, Carl Bosch, resulting in the Haber-Bosch process as it is known today, with about 75 per cent devoted to fertilizer production.

The rapid increase in the production of reactive nitrogen via the Haber-Bosch process correlates closely with the increase in world population from about 2.6 billion in 1950 to over 6 billion in 2000 (figure page 78). Based on the figures from Dawson and Hilton (2011), over 2 billion tonnes of reactive nitrogen was manufactured in that period.

The enormous increase in artificial fertilizer production catalyzed by the Haber-Bosch process has altered the flow and balance of the nitrogen cycle at a global scale, representing a roughly 150 per cent increase in new reactive nitrogen added annually to the environment compared to the pre-industrial period (figure page 80). Starting in the 1940s when man-made generation of reactive nitrogen was only around 4 Mt/yr, manufacture of reactive nitrogen began rising at an exponential rate (figure page 78).

While clearly the Haber-Bosch process has delivered substantial agricultural productivity and food security benefits in terms of providing cheap nitrogen fertilizers that



played a fundamental role in catalyzing the green revolution, it is also clear that the global environmental problems and socio-economic impacts that have resulted are significant; the impacts of excess nitrogen in the EU alone are estimated at €70-320 billion per year (Sutton, et al., 2011). In addition, the energy consumption and associated environmental costs for fertilizer production are also significant: including natural gas consumption, an estimated 1-2 per cent of all global energy is consumed in the Haber-Bosch process (Smil, 2011), with substantial associated impacts on greenhouse gas emissions and climate change.

The importance of this chapter

The release of excess reactive nitrogen to the oceans, causing coastal eutrophication and increasingly frequent hypoxia and ecosystem damage, has become a problem of global scale. The estimated socio-economic costs of excess nitrogen in marine and freshwater systems run into hundreds of billions of US dollars, from losses to tourism revenue through degraded coastal locations, decimated fisheries and fish resources from hypoxia, and habitat degradation. Our current approach to managing nutrients represents a huge economic waste – tens of billions of dollars per year – via a very linear approach to nutrient management consisting of manufacture/mining, (often inefficient) use as fertilizer in agriculture, harvesting and sale of crops and livestock, consumption, and lastly, release of the majority of the nutrients via waste-water systems and agricultural runoff of nitrogen and phosphorus to coastal waters. This chapter focuses on the need to address eutrophication and ocean hypoxia by reducing global nitrogen (and phosphorus) pollution through a concerted suite of legal/regulatory, policy, economic/financial and institutional actions at local, national, regional and global levels. The benefits would be to the wider global ecosystem and the sectors

that are highly dependent on healthy marine ecosystems (fisheries, tourism, human health, etc.), but also in reduced global energy demand (and consequential reduction in CO₂ emissions), reduced GHG emissions from farming, and stimulation of innovative new business partnerships between the agriculture, waste-water management and fertilizer industries.

2 Challenges and opportunities

The global nutrient pollution and ocean hypoxia issue presents a number of significant challenges as well as opportunities. Challenges include the scale of human perturbation of the nutrient cycle; the diversity of both point and non-point sources from agriculture (fertilizer, manure), waste water and certain industries; limited adoption and implementation of available and appropriate legal, policy, and institutional mechanisms and economic instruments that promote more cyclic use of nutrients; and an only modest level of global political, public and media recognition of the scale and impact, particularly socio-economic and on livelihoods, of nutrients and hypoxia on ocean ecosystems and economies. Conversely, the availability of a fairly wide range of proven policy, regulatory and economic nutrient management tools creates a tremendous global opportunity to scale up these approaches. Such a scaling up would not only incrementally reduce global nitrogen and phosphorus pollution, begin to slow down and reverse eutrophication and ocean hypoxia, and restore healthy marine ecosystem-dependent economies and jobs, it would also create opportunities for innovative new nutrient efficiency, recovery and reuse business and investment partnerships between the key involved sectors – agriculture, waste-water management and fertilizer manufacturing. While not precisely known at present, the potential scale of new business models and opportunities that greening the

nutrient economy could generate clearly would run into many tens of billions of dollars given the breadth and scale of the concerned sectors (see Section 3.2).

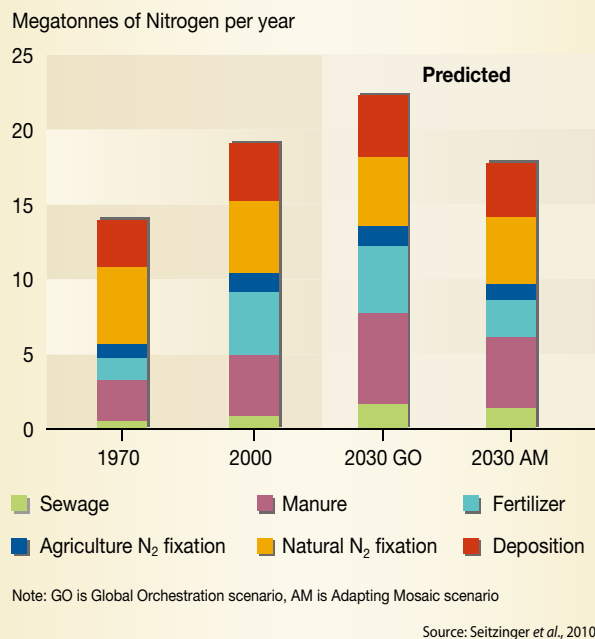
2.1 Ocean nutrient pollution sectors

Over the last 20 years, significant data and experience in understanding and addressing the sectoral drivers, pressures, sources, impacts and response to reactive nitrogen have been gathered and progress made in trying to address these issues. The key sectors that are involved include the agriculture, waste-water management, and fertilizer production sectors. As shown in the figure to the right for the year 2000, models indicate that globally, roughly equal amounts of reactive nitrogen reach the oceans from fertilizer, manure and (dominantly anthropogenic) atmospheric deposition, with smaller fractions from sewage and agricultural nitrogen fixation. However, analysis at the regional level shows somewhat different proportions with sewage less important in less developed continents such as Africa, South Asia and South America, suggesting the need to apply nutrient reduction strategies that best fit the nutrient profile of a given region or sub-region or basin. Not surprisingly, while business as usual model projections indicate relatively modest (30-40%) growth in nutrient emissions to the oceans from Europe and North America by 2050, these same models (figure on page 82) predict explosive growth in emissions from Africa (200%), South Asia (200%), South America (200%) and East Asia (100%) which would lead to significant increases in eutrophication and coastal hypoxia in each of these regions where many of the economies of coastal and island states have a particularly high dependence on marine ecosystem goods and services.

2.2 Environmental and social challenges and opportunities

Coastal eutrophication driven by excess nutrient burdens can lead to substantial environmental degradation including hypoxia (“dead zones”) and has emerged as one of the principal environmental challenges facing the sustainability of marine ecosystems and the livelihoods and economies that depend on these ecosystems. Due to the roughly threefold increase in nitrogen burdens from continents to oceans since pre-industrial times, the incidence of hypoxic zones has been increasing at a geometric rate in recent years and is projected to

Nitrogen sources to watershed exports to the oceans



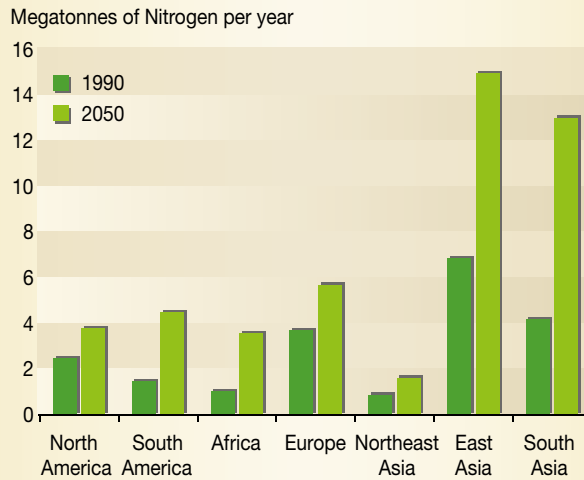
continue to accelerate in most of the developing world in business as usual scenarios (figure on page 82). The global socio-economic impacts at the present time are already many hundreds of billions of dollars and these impacts will only increase further, especially in the developing world, if new nutrient management paradigms are not soon put into place. There is also ample evidence (such as in the Black Sea with the comb jellyfish *Mnemiopsis*) that marine ecosystems already weakened by hypoxia may be more susceptible to the successful introduction of aquatic invasive species which can further disrupt ecosystem function and stability. There is also increasing scientific evidence that hypoxic conditions act as endocrine disruptors (Wu, et al., 2003) affecting reproductive success of marine organisms including decreased size of reproductive organs, low sex hormone levels, low egg counts and reduced spawning activity.

2.2.1 Description of the sectors as a business

Agriculture

The advent of agriculture dates back several thousand years so is arguably one of the oldest economic sectors in human history which, by creating food surpluses which allowed humans to shift away from hunter-gatherer societies, is widely credited with hastening the development of human civilization. After the overall service sector, today agriculture is the world's largest employer with roughly

Dissolved Inorganic Nitrogen export by rivers for world regions



one in every three workers on Earth employed in the sector. Due in part to the tremendous increases in productivity of the sector (the green revolution) due to technological innovation (fertilizer, irrigation, crop alteration, herbicides/pesticides, etc.), agriculture accounts for no more than 5 per cent of global GDP or about US\$3.58 trillion (nominal) in 2010 (CIA, 2010). However, in many developing countries, agriculture represents both the largest employer and a sizeable portion of GDP, 20 per cent in low income countries and as much as 50 per cent of GDP in some of the world's poorest countries. China has the largest agricultural output in the world, followed by the EU, India and the US. Agriculture today is one of the more widely subsidized sectors as governments seek to ensure adequate and affordable food supplies for their populations; in some cases, these subsidies can be environmentally damaging by promoting excess pesticide and fertilizer use and inefficient use of water for irrigation. Livestock production occupies 70 per cent of all land used for agriculture.

Waste-water management

Over the past hundreds of years, waste-water management has been developed and refined with a focus on dealing with larger and larger urban developments and associated waste water volumes. While data at a global level is limited, recent (2009) estimates (Owen, 2010) are that around US\$83.5 billion is spent annually on waste-water management including: US\$29.7 billion (treatment), US\$15.8 billion (sewerage rehabilitation) and US\$37.8 billion (sewerage extension). Levels of treatment vary widely across regions and countries. Globally, about

84 per cent of all municipal water and sanitation systems are publicly vs. privately owned, increasing to 93 per cent in the developing world. In the US, Canada and the EU-15, 62, 67 and 85 per cent of sewage receives secondary or tertiary treatment, respectively. In developed Asia, 67 per cent is treated to primary or secondary levels, compared with only about 25 per cent in Latin America. In the rest of the world only around 5 per cent of waste water is treated to this extent. Global needs for urban waste-water treatment and recovery projects are at least US\$52 billion per year compared with current levels of about US\$30 billion. About US\$14 billion per year of this is spent in developing and transition countries (UNEP, Executive Director, 2004) and rough estimates suggest that of the roughly US\$5

billion per year of development aid committed to water and sanitation in the developing world, only 5 per cent of this has been spent on waste-water treatment. Private sector flows to waste-water treatment in the developing world are also seen to be very low and unlikely to meet more than 5-10 per cent of projected investment needs. Per capita costs of sewage treatment go up roughly tenfold from basic latrines to tertiary treatment of collected waste water (figure to the right). The cost to remove nutrients from waste water averages around €1 per kg N (via denitrification to N₂) and €1.5 per kg P. The traditional northern approach which involves building large sewerage networks and technically sophisticated and energy-intensive waste-water treatment facilities may be prohibitively expensive for many developing countries and as argued earlier, this end-of-pipe approach is inherently inefficient as a process. These figures suggest the opportunity to incentivize, apply and scale up completely different waste-water management models for many parts of the developing world at much lower cost.

Fertilizer Production

As discussed earlier, the invention of the Haber-Bosch process in 1909 was a key milestone in modern human development as it was a prime driver in the green revolution starting in the 1950s, enabling a rapid increase in the productivity of agricultural land, and supplying sufficient food products to support significant growth in global population. It is arguable that fertilizer production and population growth were synergistic drivers that enabled both to grow exponentially over the last 60 years;

with increasing wealth and various government and donor programmes promoting smaller families, fertility rates have fallen to or near replacement levels in many developed and increasingly developing countries, so the global population growth rate has slowed somewhat and world population is projected to plateau sometime this century at around 9-10 billion. The additional 2-3 billion people will require continued enhancement in agricultural productivity and yields, particularly in Africa which to date has benefited the least from the green revolution.

At present, the manufactured fertilizer industry produces about 100 million tonnes of nitrogen in fertilizer per year; China is the largest consumer at about 25.4 million tonnes per year (2002) (FAO STAT, 2012). Industry revenues are about US\$80 billion per year (2009) with recent average after tax profit margins around 5 per cent. Annual global sales of fertilizer are projected to increase to US\$150 billion per year by 2030 and US\$227 billion by 2050. Today, 40-60 per cent of global crop yields are attributable to commercial fertilizer use and 40 per cent of all the nitrogen and phosphorus found in human food products are from artificial fertilizers. Statistics on commercial production and sales of organic fertilizer are not readily available at the global level but these are likely to be only a few per cent of the volume of manufactured fertilizer production. Notably, the fertilizer industry consumes 1-2 per cent of ALL global energy, from both the energy-intensive demand of Haber-Bosch on electricity consumption, and from the quantities of natural gas required to supply the hydrogen needed to combine with nitrogen gas and produce ammonia for fertilizer; the cost of natural gas alone can constitute up to 90 per cent of the cost of producing ammonia. Some 1-2 tonnes of CO₂ equivalent are emitted per tonne of ammonium nitrate manufactured from Haber-Bosch (Wood & Cowie, 2004). In recent years, European fertilizer producers have faced increased costs due to higher costs of imported natural gas, and higher electricity costs related to ETS emissions trading. One study estimated producer price increases of 21-34 per cent on European fertilizer companies (Strait & Nagvekar, 2010); in a highly competitive market globally these cannot be passed on to purchasers. This extra burden of carbon and natural gas costs has already significantly hurt the competitiveness of European fertilizer



manufacture; more than half of fertilizer plants in EU-15 have closed in the last 20 years.

2.3 The economic case for greening the sector

As an issue that cuts across several very large, established economic sectors – agriculture, waste-water management and fertilizer production – reversing eutrophication and ocean hypoxia presents a range of unique opportunities to create new cross-sectoral public-private and other partnerships aimed at using policy, regulatory, economic and financial incentives to move towards much more efficient and cyclic use of nutrient resources. The value of unrecovered nutrient resources (waste) that mostly end up in groundwater and our oceans is on the order of US\$15 billion per year¹, underscoring the underlying financial opportunity. Furthermore, the enormous socio-economic costs of nutrient pollution, hypoxia, and other impacts, compared to the more modest incremental costs expected to be associated with greening the nutrient economy suggests a very positive cost-benefit calculus which should further help to incentivize political support and government and other stakeholder action.

Three key sectors, agriculture, fertilizer production and waste-water management will be impacted by a transition from the current linear approach to managing nutrients to a much more cyclic approach involving substantial increases in efficiency, nutrient recovery and

1. [4 kg N/person/yr x US\$0.448/kg N + 0.5 kg P/person/yr x US\$0.508/kg P] x 7 billion people

reuse. Of the three involved sectors, agriculture at about US\$2 850 billion in gross production value (2009) (FAO STAT, 2012a) is by far the largest in terms of annual sales and contribution to global GDP. All three sectors are projected to grow substantially in the next 50 years; agriculture needs to continue to expand to feed a still growing human population and rapidly changing consumption patterns particularly in the middle-income countries. The fertilizer industry must in turn grow to meet increasing demands of agriculture and complete the green revolution by enhancing agricultural productivity in least developed countries, particularly in Africa. With only around 10-20 per cent of the developing world's waste water even receiving primary treatment, clearly substantial additional investment will be required in the sector over the next 50 years, particularly in rapidly growing coastal urban centres in these developing countries. The developed world still represents the majority of the world's hypoxia hot spots so clearly substantial additional investment, technological innovation and strengthening of nutrient management practices remains essential in the North if eutrophication and hypoxia are to be reversed. The economic case for greening the nutrient economy rests on arguments pertaining to likely

costs, benefits, cost effectiveness and potential impacts (positive or negative) on employment in each of these sectors; this issue is explored in the next section.

2.3.1 Cost-benefit analysis of greening the sectors

Most of the work done to date on costs, benefits and cost effectiveness of different strategies to reduce reactive nitrogen contamination of rivers and coastal areas has been done in Europe and the US; the European Nitrogen Assessment (Sutton, et al., 2011) is probably the most recent, comprehensive review including on issues of costs and benefits. Estimates by the latter of the economic damage from excess reactive nitrogen (to atmosphere and water) in the EU alone amount to the equivalent of €70-320 billion per year with an estimated €15-70 billion for the aquatic environment or €5-20 per kg N. The corresponding benefit of nitrogen fertilizer to farmers is estimated at €10-100 billion per year and €1-3 per kg N so this provides some initial evidence that overall benefits of improved nutrient management in the EU would exceed costs (since the avoided per-kg-N cost of nitrogen fertilizer exceeds the per-kg benefit to farmers). These figures and the similarity of sources and impacts in other parts



of the developed and rapidly developing world suggest a global damage figure several times the EU figure. Agricultural measures in the EU-27, such as the EU Common Agricultural Policy and the Nitrates Directives (part of the Water Framework Directive), have only reduced total reactive nitrogen inputs by about 15 per cent between 1980 and 2000, mainly from reduced fertilizer use and livestock numbers.

In the US, while there does not appear to be an equivalent nation-wide review for nitrogen pollution as for the ENA, a great deal of work on the science, policy and economics of managing nutrient pollution and hypoxia has been done for water bodies heavily impacted by hypoxia such as the Gulf of Mexico and Chesapeake Bay. One study for the Mississippi and Gulf of Mexico (Doering, et al., 1999) found minimal aggregate economic impacts on the agricultural sector of a 20 per cent reduction in nitrogen emissions. Above 30 per cent, however, sizeable impacts on grain exports started to become evident due to reduced production resulting from reduced fertilizer application. These analyses found that strategies based on enhancing wetlands and/or nutrient sinks were more cost effective than fertilizer reduction approaches, vegetative buffers were of limited cost effectiveness, and fertilizer restrictions were more effective than fertilizer taxes. Based on the economic value of closure of oyster beds and other shellfish losses attributed to excess nitrogen, economic costs of hypoxia to the Gulf of Mexico have been estimated at US\$1.4 billion per year. In addition, the Gulf alone is source for 72 per cent of all US-harvested shrimp, underscoring the economic risk of business as usual in the Mississippi River basin.

While there does not yet appear to be any comprehensive analysis of the aggregate economic costs of hypoxia in the Chesapeake Bay, costs for selected fisheries and other affected sectors are instructive. The decline of the Chesapeake oyster fishery has cost Virginia and Maryland more than US\$4 billion in losses in the past 30 years (Chesapeake Bay Foundation, 2010). Between 1998 and 2006, the Chesapeake Bay crab fishery experienced losses of US\$640 million due to polluted waters; Virginia and Maryland's seafood harvests declined by 30 per cent between 1994 and 2004. Total estimated costs to achieve an agreed target reduction of nitrogen loads to the Chesapeake of 40 per cent are US\$15 billion. Studies of costs and benefits for reducing nutrient pollution to Chesapeake Bay found the lowest costs associated with restoring or creating wetlands with wastewater treatment upgrades averaging 10 times higher.

Given the complexity of the nutrient economy in terms of sectoral point and non-point sources (waste water, fertilizer, manure, industry), the diversity of sectors that can be affected by hypoxia (fisheries, tourism, housing, etc.) and the wide range of unit (US\$ per kg N) costs cutting across different nitrogen abatement strategies (fertilizer use, waste-water treatment, manure management, wetland restoration, etc.), there is likely no single answer to the question of net cost or benefit of greening the nutrient economy at a global level. As will be demonstrated in the next section, the nutrient economy presents us with opportunities to pilot and scale up a number of innovative pollution reduction tools (policy, regulatory, economic) which have been successfully applied to nitrogen as well as other regional and global contaminants such as sulphur dioxide, carbon dioxide and chlorofluorocarbons (ozone depleting substances). By incentivizing nutrient efficiency, recovery and reuse, these tools provide opportunities to create new lines of business and employment with associated net positive socio-economic benefits that could well exceed the benefits associated with traditional nutrient management models such as end-of-pipe waste-water treatment and disposal.

3 Enabling conditions

As for most other pollution types, excess reactive nitrogen (and phosphorus) in the marine environment represents an environmental negative or externality whose costs of avoiding have not been fully incorporated (internalized) into the prices of the goods and services for which nitrogen represents a required input (primarily agriculture). A wide range of policy, regulatory, economic, financial and institutional tools and approaches are available which can help to internalize such externalities and many of these can be applied to nutrients across the involved sectors. This section summarizes and reviews some appropriate tools (which may be applied at local, national, regional and/or global levels) and provides examples of where they have been successful or in some cases, unsuccessful.

Building effective policy, regulatory and economic frameworks and institutions

Nutrient contamination of coastal areas and associated hypoxia can have impacts at local, national and regional levels; while not a truly global problem (like climate change is to the atmosphere) in terms of affecting all parts of the world oceans, the frequency and scale of eutrophication and hypoxic areas, combined with the geometric rate at which hypoxia

Nutrient reduction tools at different geographic scales

	Policy/Legal/Regulatory	Economic/Financial	Institutional
Local/Municipal/Provincial	<p>Local regulations that reduce nutrient pollution (limits fertilizer/ha, manure management requirements, riparian buffer zones, nitrogen vulnerable zones, etc.)</p> <p>Local nutrient management strategies/plans</p> <p>Local Good Agricultural Practice (GAP) requirements / guidance</p>	<p>Small grants to local farmers for nutrient management projects</p> <p>Local subsidies to organic vs. manufactured fertilizer to promote increased utilization</p> <p>Local taxes on point source nutrient emissions</p> <p>Local caps on point source nutrient emissions</p> <p>Local subsidies to farmers that promote application of GAP for nutrient management</p> <p>Local subsidies to promote tertiary treatment in WWTPs</p> <p>Local subsidies and other financial incentives to remove barriers to creation of nutrient recovery and reuse businesses</p>	<p>Agricultural extension services which train farmers how to optimize fertilizer use, reduce manure run-off, etc.</p> <p>Extension services which build local capacity for tertiary treatment and nutrient recovery in WWTP operations</p>
National	<p>National regulations that reduce nutrient pollution (caps on fertilizer/ha, manure management, agricultural buffer zones, nutrient budgeting, point source emission limits, etc.)</p> <p>National nutrient management strategies/plans</p> <p>National Good Agricultural Practice (GAP) requirements / guidance</p>	<p>Cap and trade on point source nutrient emissions to national rivers (primarily WWTPs and industrial point sources)</p> <p>Cap and trade on non-point source nutrient emissions</p> <p>National tax on fertilizer purchases</p> <p>National taxes on point source nutrient emissions</p> <p>Subsidies to promote tertiary treatment in WWTPs</p> <p>National subsidies to purchases of organic vs. manufactured fertilizer</p> <p>Grants/subsidies to nutrient recovery and reuse schemes from human and livestock waste streams and to promote PPP</p> <p>Guaranteed prices for fertilizer secured from nutrient waste recovery (Feed-In Tariff approach)</p> <p>Economic incentives that promote use of N fixing plants</p> <p>Economic incentives to use timed-release N-fertilizer</p> <p>Climate finance payments to farmers for reducing N₂O (a greenhouse gas) releases from fertilizer application</p> <p>Eliminate subsidies to fertilizers that promote excess/ inefficient use</p>	<p>Creating dedicated nutrient management units (agricultural, waste-water management, industrial) within Agricultural and/or Water Ministries</p> <p>Developing management techniques such as nutrient source/pathway models and strategic scenario modelling</p> <p>Engaging wider national stakeholders (policy makers, farmers, scientists, public) to formulate policy for national reductions</p>
Regional	<p>Protocols to river basin conventions that limit nutrient pollution (point source emission limits, phosphate detergent bans, etc.)</p> <p>Regional/basin level nutrient management strategies/plans</p> <p>Enhanced adoption and implementation of LBA protocols by Regional Seas Conventions/Action Plans (Baltic Sea Convention, Black Sea Convention, etc.)</p> <p>Regional scale nutrient reduction policy/legislation in regional economic blocks (EU WFD's Nitrates Directive)</p>	<p>Cap and trade on point and non-point source nutrient emissions to transboundary river basins</p> <p>Regional/basin level tax on fertilizer purchases</p> <p>Regional/basin level tax on point source emissions</p> <p>Basin level cap-and-trade on manufactured fertilizer use</p> <p>Regional/basin level subsidies to organic vs. manufactured fertilizer</p> <p>Regional/basin level fund to provide guaranteed prices (Feed-In Tariffs approach) for fertilizer sourced from human & livestock waste streams to promote innovative public-private partnerships and transition to increased nutrient recovery from waste stream</p>	<p>Strengthened nutrient management capacity in transboundary river basin institutional frameworks (Secretariat, Working Groups, Expert Advisory Groups, etc.)</p> <p>Developing common management techniques such as nutrient source/pathway models and strategic scenario modelling – enabling 'what if' options to nutrient mitigation to be explored</p>
Global	<p>Global legal framework on nitrogen management</p> <p>Global nutrient reduction strategy</p> <p>Providing Global Program of Action on Land-Based Activities (GPA/LBA) with a more formal legal basis at global level</p>	<p>Global tax on manufactured fertilizer production</p> <p>Global cap-and-trade on fertilizer production</p> <p>Global Fund for Nutrient Reduction (capitalized by global fertilizer tax or sale of fertilizer production credits)</p> <p>Global fund to provide guaranteed prices (Feed-In Tariffs approach) for fertilizer sourced from human & livestock waste streams to promote innovative public-private partnerships and transition to increased nutrient recovery from waste stream</p>	<p>Global Secretariat for Nutrient Fund and/or economic instrument(s) (tax, cap-and-trade)</p> <p>Fertilizer efficiency knowledge and capacity support units within international fertilizer industry associations</p>

has been increasing, make ocean hypoxia a global issue in terms of the level of action that may be required as well as the longer-term threat to broader ocean health under business-as-usual scenarios. Similarly, the diversity of point (untreated waste water) and non-point (fertilizer and manure run-off from farms, airborne deposition) sources of nutrient pollution demand action at all geographic levels – local (village, municipality, province), national, regional (shared river basins and Large Marine Ecosystems), and global – if the issue is to be addressed in a comprehensive manner. As such, a tool kit of nutrient management and reduction options needs to encompass options that can address both point and non-point sources at the different scales of interest.

Table 1 summarizes a range of policy, regulatory, economic/financial and institutional nutrient management tools that may be appropriate for application at these different geographic scales.

3.1 Learning from successful and unsuccessful international experiences

As Table 1 summarizes, there are a wide variety of policy, legal, financial and/or economic, and institutional tools and strategies that can help to reduce nutrient pollution at local, national, regional and global scales. A number of these have been applied in different settings; this section reviews some experiences with some of these tools.

Good agricultural practices

The EU Nitrates Directive (European Commission, 2012) (part of the EU Water Framework Directive) requires implementation of Good Agricultural Practice (GAP) by farmers including:

- Measures limiting the time when fertilizers can be applied on land, in order to allow N availability only when the crop needs nutrients;
- Measures limiting the conditions for fertilizer application (steeply sloping ground, frozen or snow covered ground, near water courses);
- Requirement for a minimum storage capacity for livestock manure;
- Crop rotations, soil winter cover, catch crops, in order to limit leaching during the wet seasons
- These measures are mandatory in Nitrogen Vulnerable Zones (NVZ)
- Application limits of 170 kg N manure per hectare per year

Between 2004 and 2007, nitrate concentrations in surface water remained stable or fell at 70 per cent of monitored sites in the EU. Despite these measures, nitrogen fertilizer consumption in the

EU has remained roughly flat since 1992 and much remains to be done to achieve desired water quality standards in many areas.

Cap and Trade on nutrient emissions to national or regional water bodies

Cap-and-trade schemes for pollutants set an overall cap on emissions, allocate pollution allowances to emitters (either free or via sale of emission credits) and then allow individual polluters to trade their emissions credits via an open market. Emitters who can reduce emissions more cost-effectively can then profit via sale of their extra emission allowances to less efficient entities. Cap and trade is widely considered to be the most economically efficient approach to pollution reduction as it lets market forces work their magic to direct capital where it can be used most efficiently. Cap and trade has been effectively applied for a number of air pollutants. For greenhouse gases the largest is the EU Emission Trading Scheme (UK Department of Energy and Climate Change, 2012). In the US there is a national market to reduce acid rain through trading in sulphur dioxide emissions, and several regional markets in nitrogen oxides

There are a number of nutrient trading programmes currently in operation in North America. The Long Island Sound trading programme administered by the Connecticut Department of Environmental Protection, for example, trades nitrogen credits between point sources, which are the main cause of excessive nitrogen levels in the sound. While not yet under implementation, a 2003 study by WRI (Greenhalgh & Sauer, 2003) assessed a variety of agricultural policy options to mitigate the hypoxic zone in the Gulf of Mexico and found that nutrient trading would be the most cost-effective solution and also would deliver improvements in farm income. The Helsinki Commission for the Baltic Sea has also conducted some technical studies on the potential for nutrient trading for both point and non-point sources but does not yet appear to have put any specific programmes into operation. Similar studies were conducted for the Danube (UNDP/GEF Danube Regional Project, 2005) under the UNDP/GEF Danube River Basin programme but also do not appear to have leveraged any follow-up action.

While nutrient emissions trading for point sources (primarily WWTPs) can be relatively straightforward due to ease of measuring emissions against a baseline, it should be recalled that 90 per cent of global nitrogen emissions are from agricultural non-point sources. Diffuse agricultural sources (manure and fertilizer run-off) present a significant measurement challenge to verify emission reductions against an agreed baseline. The uncertainties involved with non-

point source reductions can be addressed through the establishment of sound and consistent estimation tools to ensure comparability. Uncertainties within the estimation method itself can be addressed through the application of trading ratios which are discount factors related to the uncertainty associated with the actual measurement of reductions, e.g. the uncertainty associated with the effectiveness of an agricultural BMP in achieving nutrient reductions. Four of the states in the Chesapeake Bay adopted voluntary nutrient trading principles in 2001 (Wiedeman, 2001) and at least one state, Pennsylvania, appears to have put a voluntary nutrient trading programme in place (NutrientNet, 2012) (for the Susquehanna and Potomac River watersheds) which involves reductions from both point and non-point sources, one of the first in the US.

Cap-and-Trade on fertilizer production

At the global scale, the main example of a cap placed on production (as opposed to emissions) of a global contaminant is ozone depleting hydrochlorofluorocarbons under the Montreal Protocol, the latter involving a stepwise decreasing cap on production and import and permits trading between and within companies of different types (based on ozone depleting potential) of HCFCs. As noted above, the diffuse nature of the vast majority of nutrient pollution creates challenges in nutrient accounting for cap-and-trade approaches to reduce emissions, although the Chesapeake/Pennsylvania example above demonstrates it is doable, but requires highly complex nutrient accounting tools which may be subject to large error bars.

As discussed earlier, the majority of the net new nitrogen that is being systematically added to freshwater and coastal ecosystems is ultimately sourced from Haber-Bosch production of fertilizer (presently 100 million tonnes per year). A rather bold and likely controversial approach to reducing global nutrient pollution and ocean hypoxia could include application of a cap-and-trade scheme to production of artificial fertilizer at a global scale. Unlike HCFCs, the objective would not be to completely phase out fertilizer production (which will clearly continue to be required to feed a growing population) but to use market mechanisms to promote increased fertilizer use-efficiency and enhanced recovery and reuse of nutrients for fertilizer from the human and animal waste streams. Fertilizer manufacturers who sourced a portion of their N (and P) feedstock through innovative approaches (nutrient recovery) could reap additional profits by trading their issued quotas to traditional producers more dependent on manufactured sources of nitrogen.

Properly designed, such a scheme would send

a clear and predictable signal to the fertilizer industry of the need to incrementally increase the share of fertilizer produced from recovery and reuse of nutrients from the human and animal waste streams, and create completely new business partnerships between the fertilizer and waste-water-management industries. Second, it would catalyze innovation in nutrient recovery technology, from waste water collection and treatment to the separating toilets being promoted by Gates Foundation (Time World, 2011) and others that permit nutrient recovery and reuse. Third, by making manufactured inorganic fertilizer incrementally more expensive, it would promote its more efficient use in agriculture as well as increased use of existing (and emerging, via increased nutrient recovery) organic fertilizers such as manure and food waste. Fourth, it would create sizeable numbers of new jobs in both the developed and developing world as nutrients recovery would be far more labour-intensive than the much more energy, technology and chemical-intensive manufactured reactive nitrogen. However, such a scheme is likely to face industry and political opposition due to possible short-term effects on fertilizer prices as the mechanism is put into place and associated impacts on global food prices, so clearly substantial additional analysis and stakeholder dialogue would be required if such an approach were to be considered as one element of a global strategy.

Nutrient management budgets

Nutrient budgets for farms are becoming increasingly common as a number of countries, such as the US, EU, Canada and Australia, have put in place policies and regulations which require or encourage farmers to prepare and implement nutrient management budgets for their fields. Such budgets, by providing farmers with a quick measure of how nutrients are being used, give them the tools to decide on optimal fertilizer management and to evaluate increased efficiency gains against cost. In New Zealand (MAF, 2010), over 99 per cent of dairy farmers have completed such budgets under the Clean Streams Accord and such budgeting is expected to be applied more broadly across the agricultural sector.

Local, national and regional taxes on fertilizers

Fertilizer taxes have been introduced in European countries such as Finland, Norway, and Sweden with this tax revenue frequently earmarked for various environmental uses. Sweden, for instance, used its fertilizer and pesticide tax to finance environmental research and improvements; the fertilizer tax amounted to about a 20 per cent premium on fertilizer production and import in Sweden



and delivered about a 10 per cent reduction in fertilizer consumption (ECOTEC, 2001). However, analyses suggest the tax would have to be 6-8 times larger to deliver the nitrogen pollution reduction targets the Swedish government was seeking to achieve. A 2004 study (Bel, et al., 2004) of application of fertilizer taxes in Europe ranging from 3 to 70 per cent delivered negligible changes in fertilizer use with the possible exception of one country, Austria. The study concluded that fertilizer demand was far more sensitive to agricultural output demand than to fertilizer price. Other studies identified fertilizer consumption levels falling from 33 to 50 per cent for taxes ranging from 50 to 100 per cent of base fertilizer price. Clearly fertilizer taxes can be effective in sending price signals that can alter fertilizer consumption and usage patterns but application of such taxes at local, national and even regional scales can create concerns with putting farmers subject to such taxes at a competitive disadvantage.

Small grants for nutrient-reduction at local level

A number of initiatives have promoted improved nutrient management through small grants to local farmers and other relevant stakeholders. The Small Grants Programme of

the UNDP-GEF Danube Regional Project (REC, 2006) awarded 65 grants to train farmers in best nutrient management practices, build improved manure enclosures, restore vegetation (nutrient sinks) along river banks, promote organic agriculture, build constructed wetlands for waste water polishing, phosphorus detergent phase-outs, and many others. While the projects did not specifically measure and track pollution reduction against initial baselines, it seems clear that many if not most of the projects did deliver nutrient pollution reduction benefits.

Subsidies to organic farming and fertilizers

Through its Common Agricultural Policy (CAP) following the legal definition of organic farming in 1991, the EU has provided subsidies to organic farms; farmer dependency on such schemes is very high in countries like the UK, Denmark and Germany. Total subsidies to organic agriculture in the EU-25 in 2005 amounted to €660 million or 17 per cent of total EU subsidies to the sector and represented support to 46 per cent of the organically farmed land area (European Commission, 2010). Organic farms receive higher subsidies than conventional farms in both absolute terms and on a per hectare basis but this appears to be driven more by the

prevalence of organic farms in disadvantaged rural areas than targeting specific environmental improvements. In the US, only a tiny fraction (circa US\$20 million) of the annual tens of billions of dollar of subsidies to the agricultural sector go to organic farmers.

Local subsidies and other incentives to remove barriers to creation of nutrient recovery and reuse businesses

On average, humans excrete about 3.5 kg of reactive nitrogen (Germer, et al., 2009) per person per year. Currently around US\$10 billion worth of valuable nutrients is flushed down the toilet each year. Meanwhile, over a third of humanity – 2.6 billion people – still lack a safe, hygienic sanitation facility which prevents human waste from being released into local land and waterways, many of which drain into our oceans. The economic value of nutrients contained in the waste of the un-served 2.6 billion amounts to another US\$5 billion per year. Progress on the sanitation Millennium Development Goal (MDG) is among the slowest of all the MDGs (WHO/UNICEF, 2010) and this deficit has demonstrably slowed economic development in many countries (UNDP, 2012).

The Bill and Melinda Gates Foundation has recently committed to ‘reinvent the toilet’ in recognition of the urgent need to accelerate the sanitation MDG and the massive waste and unsustainability of traditional linear approaches to dealing with human waste. A pilot project funded by the Gates Foundation (Time World, 2011) is underway in South Africa to convert the urine of 400 000 South Africans into nitrogen fertilizer; an MIT team is also designing and testing toilets that allow recovery of fertilizer – and generate energy from biogas – through its Sanergy (MIT, 2011) project in Kenya.

3.2 Managing the transition

The transition to a much more closed and efficient system of nitrogen use and reuse will require significant policy, regulatory, and institutional reforms at all geographic levels and the effective adoption and implementation of a range of available economic and financial instruments. Catalyzing such changes will require substantial political will and this underscores the need to conduct further detailed analyses on the cost-benefit and job creation calculus of greening the nutrient economy as financial returns and job creation can help to motivate decision-makers and the private sector. Since nitrogen reaches the oceans as run-off from a wide range of small and very large (and most often, multi-country) river basins, partnerships

and coordination will be required between national and regional river basin organizations and downstream national (or regional) ocean and coastal management bodies. In this respect, adoption of nutrient reduction protocols to river basin conventions holds significant promise as a legal mechanism to catalyze broader reforms at national and local levels. Of course, a global legal framework on nitrogen would likely be the most effective driver of a multi-level global response, as has been demonstrated by other global environmental agreements such as the Montreal Protocol, Stockholm Convention/POPs, and Convention on Ship’s Ballast Water and Sediments.

Whether manifested through local, national, regional and/or global approaches, nitrogen reduction strategies which use market forces (taxes, cap-and-trade, smart subsidies, feed-in tariffs, etc.) present the best opportunities to truly transform each of the three key sectors by providing financial incentives for nutrient use-efficiency, recovery and reuse which should in turn help to catalyze innovation in both technology and sectoral best practice. Since greening the nutrient economy calls for substantial enhancement in the recovery and reuse of both human and animal waste, another important aspect of the transition will be to alter public perceptions regarding such re-use and assuring the public that crops grown with fertilizer sourced in this way are safe to consume.

Global reactive nitrogen (and phosphorus) releases to the coastal zone in the business as usual scenario are projected to increase two or three-fold on current levels by 2050 (Seitzinger, et al., 2010) (or six or nine times pre-industrial levels), mostly from the developing world which has the most dependence on marine and coastal economic goods and services. The global economic damage from eutrophication and hypoxia, already in the hundreds of billions of US\$ annually, would rise correspondingly. These figures suggest that a concerted effort to green the nutrient economy must commence immediately to avoid potentially irreversible damage to the ocean and coastal ecosystems upon which so much of humanity depends for food security, livelihoods and sustainable development. Preliminary evidence suggests that such a greening could catalyze a wide range of new business, investment and technology development opportunities and cross-sectoral partnerships, and associated contributions to (net) job creation.

4 Conclusions and recommendations

Humankind has arguably disturbed the global cycle of nitrogen as much as it has that of carbon, with cumulative addition of over 2 billion tonnes of new reactive nitrogen to the Earth's biosphere over the last 50 years, primarily via the energy-intensive production of fertilizer using the Haber-Bosch process. As a result, reactive nitrogen loads to the oceans are now three times pre-industrial levels and projected to triple again by 2050 in the business as usual scenario. This has led to an exponential increase in the occurrence of coastal eutrophication, and hypoxic areas now exceed 500, with associated socio-economic losses in the hundreds of billions of dollars globally. Studies suggest an upper limit of 35 million tonnes N per year should be extracted from the atmosphere into reactive nitrogen, which would ultimately require an approximate 75 per cent reduction in the production of reactive nitrogen to return to ecologically acceptable limits.

At present, most of humanity – particularly in the industrialized world but increasingly in fast developing middle income countries – practices a primarily linear approach to managing nutrients. The urgency of continued coastal eutrophication and its impacts – particularly hypoxia – on marine ecosystems and societies, underscores the need to begin a transition to much more cyclic management of nutrients whereby efficiency of fertilizer use is increased and an increasing fraction of human and livestock waste nutrients are recovered and reused for fertilizer. In parallel, some analyses project that economically recoverable global phosphorus reserves could peak and begin to decline as early as this century with unprecedented effects on global food security; whether it is this soon or somewhat longer does not negate the fact that eventually, phosphorus recovery from the waste stream needs to become the norm, not the exception, if long-term global food security is to be ensured.

A wide range of both proven and emerging nutrient reduction policy, regulatory and economic instruments need to be applied and scaled up at local, national, regional and global levels to transform the nutrient economy from a linear to much more cyclic approach over an appropriate time frame. Policymakers need to send clear regulatory and market signals to agricultural, waste-water-management and fertilizer industries of the urgent need to transition towards optimal fertilizer use-efficiency and sizeable recovery and reuse of nutrients. These actions would create the enabling conditions to catalyze innovation in fertilizer management and use-efficiency and human and livestock waste nutrient recovery technologies and strategies, creating new business partnerships between the agriculture, waste water and fertilizer industries as well as associated jobs. Gradual improvements in efficiency of fertilizer use and reduced losses from farms, including reductions in releases of associated greenhouse gases would be a key outcome of the recommended actions. Further, an increase in the volume and proportion of fertilizer produced from recovered nitrogen (and phosphorus) and the diversification of sources for fertilizer raw materials would help to moderate fertilizer prices and their volatility, enhancing global food security.

Market and regulatory mechanisms would catalyze the creation and dissemination of new nutrient recovery technologies and supply chains, creating sizeable numbers of new businesses and jobs. By incentivizing nutrient recovery and reuse and creation of associated business opportunities, these mechanisms could help mobilize substantial new sources of financing and innovative approaches for accelerating urgently needed progress on the sanitation MDG in the developing world.

Over time, decreases in the loads of reactive nitrogen (and phosphorus) entering coastal areas will ultimately reduce coastal eutrophication and hypoxia and associated impacts on ecosystems, economics and livelihoods.

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COASTAL TOURISM

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1 Introduction

This chapter reviews the major issues of relevance for the greening of tourism in the Blue World. Coastal tourism, which includes ‘the full range of tourism, leisure, and recreationally oriented activities that take place in the coastal zone and the offshore coastal (Hall, 2001), has been identified as the largest tourism market segment globally (Orams, 1999) (Hall, 2001). Tourism in coastal zones makes use of the sea, beaches, landscapes, biodiversity, food, and cultural and built heritage. It includes a diversity of activities that take place in both coastal zones and coastal waters, which involve the development of tourism capacities (hotels, resorts, second homes, restaurants, etc.) and support infrastructure (ports, marinas, fishing and diving shops, and other facilities). Marine tourism is closely related to the concept of coastal tourism but also includes ocean-based tourism such as deep-sea sports fishing and cruising (Hall, 2001).

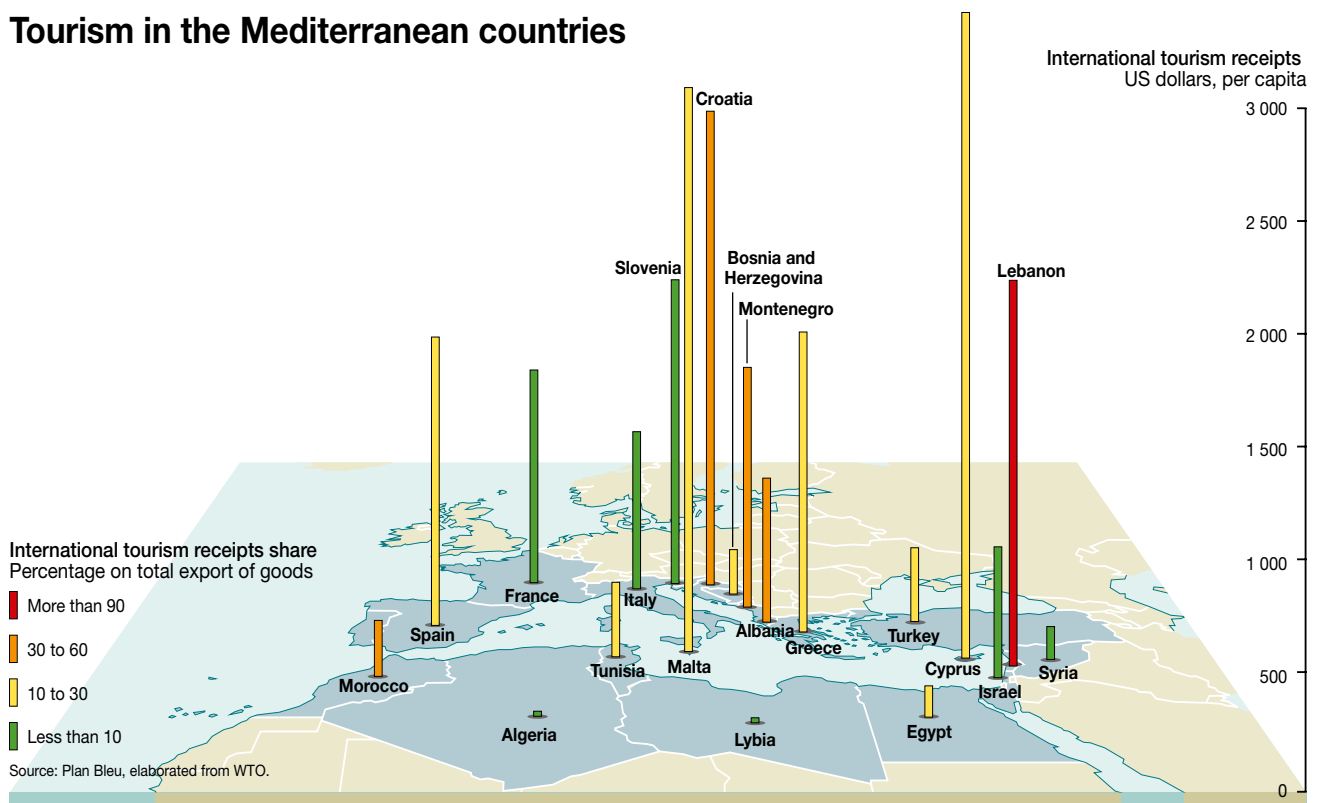
The economic importance of coastal tourism is unquestionable, although due to data limitations there is no comprehensive analysis of the sector’s contribution to the global economy. The Mediterranean Basin alone hosted some 250 million visitors in 2008. In France, tourism provides 43 per cent of jobs in coastal regions, generating more revenue than fishing or shipping. In the UK, tourism to the coast is worth £110 billion (approximately US\$171 billion)

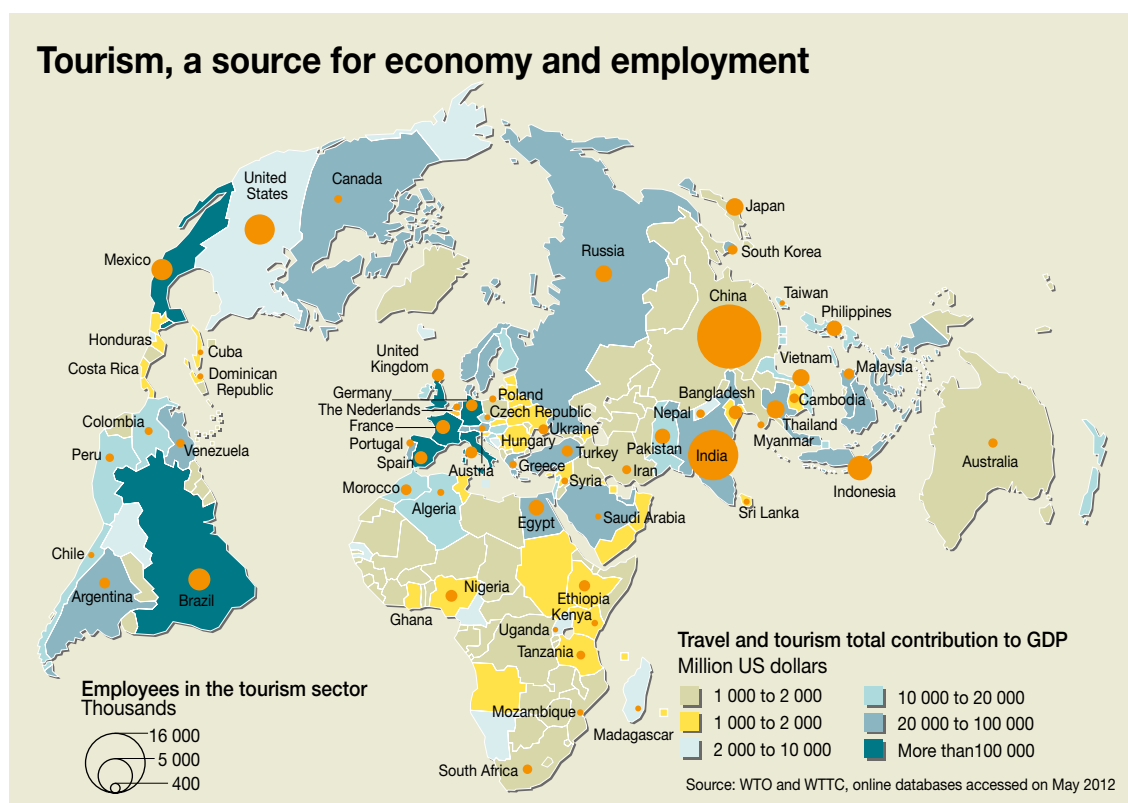
and employs more than 1.3 million people (5% labour force) (Williams, 2011). In most Small Island Developing States, coastal tourism is a major employer, such as Antigua and Barbuda, Aruba, and Anguilla, where tourism employs over 80 per cent of the labour force. Worldwide, coastal tourism is gaining importance (UNEP, 2011).

The attraction of quick economic profit from the tourism industry, brought by the investment of huge sums of capital and associated real estate speculation, is often seen as an easy way to support national and regional economies and generate employment. Many regional and national governments, especially in developing countries, have provided incentives for investment in coastal resorts via tax exemptions, low tax rates, subsidized infrastructure provision, low cost of land, land alienation, fast tracked or no environmental assessment, and/or low cost government backed investments loans (Hall, 2008). This perception has led many coastal areas to experience constant and often very uncontrolled growth of tourism activity. Because of the growing realisation that uncontrolled coastal tourism development has significant externalities and opportunity costs, increasing attention is now being given to more strategic approaches to tourism investment that is integrated with environmental and social goals.

Over recent decades, coastal zones have increasingly tended to be considered as

Tourism in the Mediterranean countries





spaces for amenity migration and tourism development. With the exception of some port and industrial areas, tourism-related pressures in coastal regions now dominate over other sectors, to the point that, in some cases, tourism can be considered unsustainable (UNEP, 2009a). In order to minimize tourism-induced problems and secure both the sustainability of the tourism industry and coastal resources used by other sectors, increased attention must be given to proper planning and the better integration of tourism in coastal development. Negative impacts and conflicts are due mainly to ignorance of coastal environments and inadequate planning and economic overreliance on a single sector, tourism.

In planning more sustainable tourism development, information must be made available to decision makers on the possible short and long-term pressures of tourism on environmental and social systems, and practical, context-appropriate tools provided with which to respond to these pressures, including growth management, activity restrictions, zoning, use rationing, economic incentives, regulation and planning and policy evaluation (Hall, 2008). Sustainable tourism development and Integrated Coastal Zone Management (ICZM) are seen as two parallel, complementary and strongly interlinked processes. A variety of tools offered by ICZM allow for a more sustainable development of tourism that in turn makes the ICZM process more effective (UNEP, 2009a).

2 Challenges and opportunities

Marine and Coastal Tourism has many important linkages to the Green Economy in a Blue World. Coastal tourism development can lead to urban sprawl, urbanization, destruction and fragmentation of habitats, the production of waste, water pollution as well as the loss of social and cultural identity and values. Many of these existing challenges will be exacerbated by climate change-induced environmental changes including, coastal inundation and erosion, biodiversity- and ecosystem loss (coral reefs and mangroves), altered wildlife productivity and distribution (sport fish, bird migrations), and changes in the availability and quality of fresh water resources. Notably, tourism is itself a major contributor to emissions of greenhouse gases and thus climate change (see below).

2.1 Current impacts of tourism

Land conversion

Tourism development leads to the conversion of land for construction, and many coastal destinations have become heavily urbanized. For example, out of 8 000 kilometres of Italian coastline, 43 per cent is completely urbanized, 28 per cent is partly urbanized and only 29 per cent of coastline could be considered 'pristine' (UNEP, 2009a). Because of the desire to locate as close to the sea as possible, much coastal tourism infrastructure has resulted in the destruction of coastal wetlands, dune complexes and

mangroves (Hall, 2011). Though it is difficult to estimate the loss of species associated with land conversion and related aspects, such as pollution, it is generally understood that tourism related land use change has led to a decline in biodiversity (Hall, 2010). Notably, the impact of coastal tourism extends beyond the narrow coastal zone, including road and rail networks, airports, housing development for employees, large shopping centres, and increasingly golf courses and other tourism amenities.

Pollution

Marine pollution can be caused by hotels, bars and restaurants and other leisure facilities releasing untreated sewage into the sea, or from the discharges from tourist yachts, excursion boats, car ferries and cruise ships. Tourism related marine pollution also consists of solid waste and often less recognized impacts from light and noise pollution in coastal environments.

Biodiversity

Although tourism can have significant negative impacts on biodiversity, when planned

and managed well tourism can also make a contribution to the protection of biodiversity. Benefits can include specific land and marine planning regulations that minimize other threats (over exploitation, pollution, habitat loss) as well as providing an economic justification for protected areas (Hall, 2011).

2.2 Climate change

Energy use and emissions

The use of fossil energy is one of the major environmental problems associated with tourism and travel. According to UNWTO, UNEP and WMO (2008), emissions from tourism (including transports, accommodation and activities) account for about 5 per cent of global CO₂ emissions and up to 12.5 per cent of global radiative forcing, i.e. the warming caused by CO₂ and other greenhouse gases. Most of this (approximately 75 per cent) is caused by transports, and in particular aviation (Scott, et al., 2010). Growth in emissions from aviation is clearly in conflict with global climate policy.

The Global Partnership for Sustainable Tourism

The Global Partnership for Sustainable Tourism (GPST) is an initiative launched in 2011 to inject sustainability principles into the mainstream of tourism policies, development, and operations. It emerged as a successor to the International Task Force on Sustainable Tourism Development (ITF-STD). The Secretariat is hosted by the United Nations Environment Programme (UNEP).

The mission of GPST is to encourage networking and cooperation to promote the long-term economic health of the tourism sector. By bringing together all actors in tourism sector, it aims to produce important and long-lasting results. The main strategies are knowledge sharing and project development.

Objectives of the partnership

- bring together and involve all tourism’s stakeholders
- encourage networking among

members

- facilitate access to information on sustainable tourism
- strengthen, coordinate and encourage the adoption and implementation of sustainable tourism policies
- convey success stories
- scale-up, adapt and replicate successful projects and initiatives
- establish and implement innovative, multi-stakeholder projects

The GPST has more than 80 members, including National governments; UN agencies and the Organization for Economic Cooperation and Development (OECD); international organizations and business associations; companies and; non-governmental organizations.

Source: GPST, 2011

Ocean acidification and coral bleaching

Marine environments are subject to large-scale degradation from climate change. Coral reefs are one of the most important marine ecosystems for tourism and also considered one of the most vulnerable to climate change. Impacts including ocean acidification, coral bleaching, and for those coral reefs located close to shore, greater land run-off and potential pollution as a result of increased storm events (Hughes, et al., 2010). With very high confidence, the IPCC (2007) concluded that a warming of 2°C above 1990 levels would result in mass mortality of coral reefs globally.

Sea Level Rise and inundation

The exact magnitude of global sea level rise (SLR) and regional variability remains uncertain, but SLR is considered one of the most certain consequences of human-induced climate change (IPCC, 2007). The impacts of SLR on coastal areas include erosion, inundation, impeded drainage and increased risk of riverine flooding, salinity intrusion into freshwater supplies, coastal habitat loss through 'coastal squeeze', and higher water tables which can adversely affect the stability of foundations of coastal infrastructure. SLR is a unidirectional hazard that once set in motion will continue for centuries, if not millennia, even under moderate scenarios of global warming.

Few regional studies of the impacts of SLR have examined potential damages in the tourism sector. The broadest multi-national study of the SLR impacts on tourism to-date examined potential inundation and erosion impacts for major coastal tourism resorts and resort front beach areas in 19 nations of the Caribbean. Using a database of over 906 major tourism resort properties, (Scott, et al., 2012) estimated that 266 would be vulnerable to partial or full inundation by a one metre sea-level rise. A far higher number of major coastal resort properties (440 to 546) would be vulnerable to coastal erosion associated with a one metre sea-level rise. A much greater proportion of resort front beaches would be lost to inundation and accelerated erosion, as beaches would essentially have disappeared prior to damages to tourism resort infrastructure.

Water Security Challenges

Global water use has been estimated to have grown at more than twice the rate of population increase over the last century (UN-Water, 2011) and is presently doubling every 21 years (US-AID, 2009) (UN-Water, 2011). Water stress already affects a large and growing share of humanity. Global water use is increasing due to

population and economic growth, changes in lifestyles, technologies and international trade, and the expansion of water supply systems. Between 2010 and 2030 water withdrawals are projected to increase by 50 per cent by in developing countries, and 18 per cent in developed countries (UN-Water, 2011). Water stress will be more prevalent among poorer countries where water resources are limited and population growth is rapid; of the 48 countries expected to experience chronic water shortages by 2025, 40 are either in the Middle East and North Africa or in sub-Saharan Africa. Climate change is anticipated to exacerbate water stress challenges in the decades ahead, in some places severely.

Tourism is both dependent on fresh water resources and an important factor in fresh water use (Gössling, et al., 2011). Great differences exist in terms of renewable water resources, desalination capacity, use of treated wastewater, and overall water use among the most important tourism countries. Consequently, community- and national-scale discussions of water security should not overlook tourism as a sector, particularly as water demand from tourism is expected to increase because of: (1) increased tourist numbers, (2) higher hotel standards and (3) the increased water-intensity of tourism activities (Gössling, et al. 2011). In the future, tourism businesses in water scarce regions will face considerably greater problems with regard to water availability and quality due to increasing competition among water users, and potentially, because of climate change.

Biodiversity

Climate change impacts on biodiversity include increasing average temperatures, changing precipitation regimes, extreme weather events, sea level rise, and changes in atmospheric, marine and terrestrial concentrations of CO₂. Climate change also interacts with other pressures such as land-use change, changes in fire regimes, ecosystem fragmentation, pollution and the introduction of invasive species. Many of the proposed strategies to adapt to climate change impacts in coastal regions use hard-infrastructure approaches (sea walls, dykes). Such structures often adversely impact natural ecosystems processes (SCBD, 2009).

Climate change will be a pivotal issue affecting tourism development and management in the decades ahead, and addressing the large information gaps regarding the climate change vulnerability of the tourism sector and better informing public decision makers as well as private sector of the attendant risks, must be a core component of any future strategy for tourism

to contribute to poverty alleviation and the United Nations Millennium Development Goals.

2.3 Social challenges and opportunities

Tourism provides a major contribution to the global economy, composing a significant share of national GDPs. According to the World Travel and Tourism Council, world travel and tourism generated close to US\$8 000 billion in 2008, expecting to rise to approximately US\$15 000 billion by 2018. Furthermore, the world travel and tourism industry generates 9 per cent of global GDP and employs as many as 220 million people worldwide. Overall, it is forecasted that the industry will grow by 4 per cent per annum (international arrivals) over the next 10 years (UNEP, 2011).

In recent years, tourism has been increasingly recognized as a potential tool to reduce poverty worldwide. In 2001, international tourism receipts to developing countries amounted to US\$142 billion while in 2005 they amounted

to US\$203 billion. It is also the primary source of foreign exchange earnings in 46 of the 49 Least Developed Countries (UNWTO, 2006). Additionally, tourism is growing much faster in developing countries than in mature developed economies. Predicted growth rates of between 5 per cent and 6 per cent per year for Africa and South Asia are considerably greater than for the world as a whole. As a labour intensive industry, tourism offers an opportunity to support traditional activities such as fishery, agriculture, and handicrafts as well as natural and cultural heritage conservation (UNWTO, 2006).

Nevertheless, there has also long been substantial criticism of what has been perceived as the negative impacts of tourism as a development strategy (Telfer & Sharpley, 2008). For example, the supposed comparative advantages of LDCs with respect to tourism are not evenly distributed. There are many developing countries, and regions within them, which have only a limited opportunity to benefit from tourism. Tourism has also been associated

Blue Carbon and Sustainable Tourism

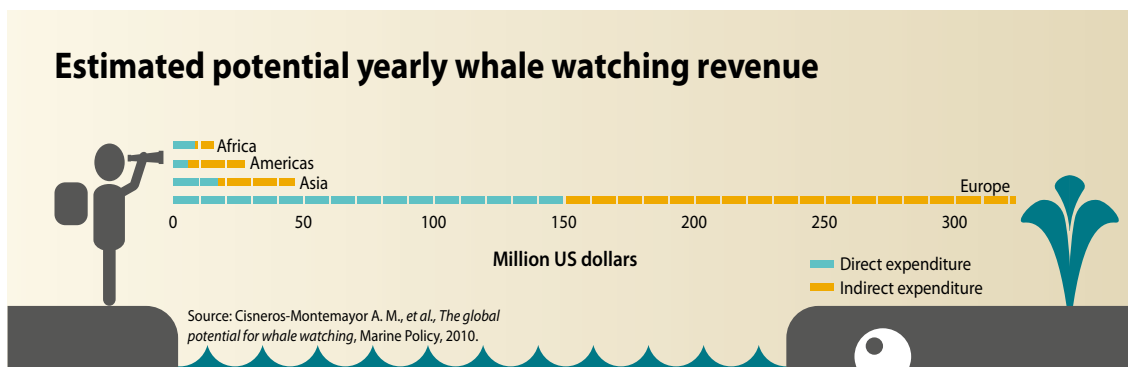
Intact coastal landscapes are the preferred target destination for much nature-based tourism. These areas, encompassing mangrove forests, sea-grass meadows, and saltwater marshlands, are recognized as important carbon sinks (IUCN, 2009) (UNEP, 2009). This means that Blue Carbon ecosystems help to remove carbon dioxide from the atmosphere, through storage in canopy biomass and subsurface roots and sediments. When these ecosystems are disturbed or degraded, much carbon is lost, resulting in increased greenhouse gas emissions. A combined Blue Carbon and sustainable tourism strategy can link tourism to bio-cultural conservation and help mitigate climate change. In addition there is a potential for financial mechanisms that result in payment for carbon sequestration from Blue Carbon areas.

Blue Carbon ecosystems are important for much coastal and marine-based tourism, such as boating, kayaking, snorkelling, fishing, guided wildlife viewing, and bird watching.

Healthy and intact Blue Carbon ecosystems provide many other valuable ecosystem services important for nature-based tourism, including roles in:

- Supporting biodiversity – coral reefs (a primary target for the tourism industry) can be connected through nutrient cycles, physical processes and plant and animal migration;
- Sustainable food supply – through functioning as fish nurseries and food sources;
- Improved water quality – through natural sediment control;
- Shoreline protection – through the buffering of shorelines from severe weather;
- Natural Beauty – maintain the aesthetics of intact landscapes and seascapes.

Source: Blue Carbon Project, UNEP/GRID-Arendal, 2011a



with substantial environmental change and degradation and cultural commodification, while economic benefits may not be as great as expected because of profit repatriation by foreign investors, relatively low wages, and underemployment because of seasonal demand. The benefit of tourism to society is thus highly complex and its contributions to poverty alleviation remain to be better substantiated.

3 The economic case for greening the sector

As outlined, marine environments are key assets for tourism, and increasingly at risk of being lost to environmental- and climate change. While there appear to be few studies assessing the global value of marine environments for tourism in its entirety, some estimates exist for marine recreational activities such as fishing, whale watching and diving (Hoyt, 2001). Unless otherwise indicated, the following sections are based on UNEP (2011).

The value of marine recreational activities was calculated by Cisneros-Montemayor & Sumaila (2010). A database of reported expenditure on marine recreational activities was compiled for 144 coastal countries, with the authors estimating that in 2003, nearly 60 million

recreational anglers around the world generated a total of about US\$40 billion in expenditure, supporting over 950 000 jobs.

Hoyt (2001) estimated that over 13 million people worldwide participated in whale watching in 2003, with expenditure reaching around US\$1.6 billion in that year (Cisneros-Montemayor & Sumaila, 2010). It is also estimated that 18 000 jobs worldwide are supported by this industry each year. Furthermore, 10 million active recreational divers and 40 million snorkelers generate over US\$5.5 billion globally in direct expenditure, supporting 113 000 jobs. In total, it is estimated that 121 million marine recreational activities participants generate US\$47 billion in expenditure annually and support over one million jobs (Cisneros-Montemayor & Sumaila, 2010). Studies have also addressed the economic value of diving for protected areas. Cesar & van Beukering (2004) calculated that more than 14.6 million snorkelling trips and 870 000 dives were sustained by coastal zones in Hawaii, corresponding to a total economic value of US\$264 million for snorkelling and US\$40 million for diving. White & Rosales (2003) report that most local and about 80 per cent of foreign divers were willing to pay user fees for diving in the Philippines, with up to US\$9 per person per trip.

Ecosystem-based marine recreational activities in 2003

Item (units)	Recreational fishing	Whale watching	Diving and snorkelling	Total
Participation (millions)	60	13	50	123
Expenditure (US\$ billions)	40	1.6	5.5	47.1
Employment (thousand)	950	18	113	1,081

Source: Cisneros-Montemayor & Sumaila (2010)

3.1 Description of the sector as a business

Tourism is a heterogeneous industry where hundreds (and sometimes thousands) of actors operate in multiple market segments, even within a single country or region. These segments include conventional mass tourism as well as more niche areas such as ecotourism¹, adventure and cultural tourism, rural tourism, sports fishing, cruise tourism and health and spa tourism. The principal businesses within the tourism industry are accommodation, tour operation, and transport (land, air, and sea). In addition, tourism has diverse linkages through several economic activities, from lodging, entertainment and recreation, to transportation, professional services and advertising, among others.

Ecotourism is the tourism industry's fastest growing sector globally. Well planned sustainable tourism can support conservation efforts such as marine protected areas (MPA). During MPA planning and implementation, positive economic, socio-cultural, environmental and climate considerations are incorporated. Healthy intact landscapes are the most desirable for sustainable marine tourism, and they also store the most Blue Carbon (UNEP/GRID-Arendal, 2011b).

Numerically the tourism industry is dominated by owner-operated and small and medium sized enterprises (SMEs) (UNEP, 2009a). Although online travel agencies and large conventional tour operators control an important share of international travel from Europe and North America, tourism destinations are characterized by the predominance of smaller businesses. For example, close to 80 per cent of all hotels worldwide are SMEs and, in Europe, this figure is 90 per cent (UNEP, 2009a). Additionally, providers of goods and services for the industry tend to be small, local businesses.

3.2 Cost-benefit analysis of greening the sector

No valuation of global coastlines and the coastal and marine environment for tourism has been made, and consequently, it is impossible to provide a relevant cost-benefit analysis at this stage. Further, no assessments exist that would point to the funding requirements for such an effort. However, as has been outlined, marine environments are key assets of global tourism, and their preservation is ultimately a precondition for the survival of marine and coastal tourism.

1. Ecotourism is nature-based tourism that conserves the environment and improves the well-being of local people.

Enabling conditions

Tourism can have positive or negative impacts depending on how it is planned, developed and managed. A set of enabling conditions is required for tourism to contribute to social and economic development within the carrying capacities of marine ecosystems and socio-cultural thresholds. As outlined in UNEP (2009), this will require overcoming barriers in the areas of

- private-sector orientation;
- destination planning and development;
- fiscal and government investment policies; governance and investment; and
- local investment generation.

3.3 Private-sector orientation

While all tourism stakeholders can and should benefit in the medium to long term from greater sustainability in the sector, greening will require very different actions and investments. A coherent strategy for green tourism growth must, therefore, cover all segments and activities, and the ways in which they interact.

Enabling conditions for engaging the industry

Tourism promotion organizations, environmental management agencies and destination management organizations (DMOs) should link marine and coastal tourism products more closely with market positions and destination branding. This will ensure a consistent selling position in world tourism markets based on high-value experiences at natural and cultural sites.

Tourism industry associations and wider industry organizations play an important role in engaging tourism businesses in sustainability. Still, measures such as triple-bottom-line (environmental, social and economic) reporting, environmental management systems and certification appears to be prevalent only within a selection of larger firms. Tools to educate and support action by SMEs are critical, and most effective when accompanied by scale and place-specific, actionable items. Programs that foster peer-to-peer experience sharing and knowledge transfer among SMEs and local communities have large potential.

International development institutions, such as multilateral and bilateral cooperation agencies, and Development Finance Institutions (DFIs) should engage directly to inform, educate and work collaboratively with the tourism industry to integrate sustainability into policies and management practices, and secure their active participation in developing sustainable tourism.

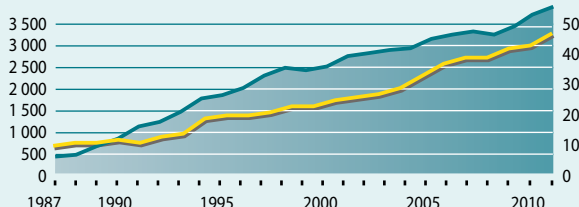
Blue Flag up!



Number of blue Flag certifications by country
Total beaches and marinas



Number of Blue Flags



Source: Blue Flag International Coordination.

The Blue Flag is a certification assigned towards sustainable development of beaches and marinas through strict criteria dealing with Water Quality, Environmental Education and Information, Environmental Management, and Safety and Other Services.

The increased use of industry-oriented decision support tools through capacity building efforts would help speed the adoption of green practices (Hotel Energy Solutions, TourBench and SUTOUR).

The promotion and widespread use of internationally recognized standards for sustainable tourism is necessary to monitor tourism operations and management. The Global Sustainable Tourism Criteria (GSTC) provides a promising current platform to begin the process of grounding and unifying an understanding of the practical aspects of sustainable tourism, and prioritising private sector investment. Promoting the adoption and implementation of voluntary codes of conduct and initiatives will bring added value in this context.

Economies of scale in the tourism sector could be achieved by means of clustering. A high environmental quality is a key input by those companies that pursue competitive advantages based on sound environmental management. In the case of tourism, the conservation of the natural capital of a country has a chainable effect and complementary influence on many firms.

3.4 Destination planning and development

Advancing greening goals through tourism planning and destination development requires the ability and institutional capacity to integrate multiple policy areas; consider a variety of natural, human and cultural assets over an extended time frame; and put in place the necessary rules and institutional capacity. A destination cannot successfully implement a green tourism strategy without laws, and regulation and private sector incentives, or the appropriate governance structure to enforce them.

Enabling conditions for greener destination planning

Higher-level government, community and private tourism authorities must establish mechanisms for coordinating action with regard to zoning, protected areas, environmental rules and regulations, coastal zone modification, labour rules, agricultural and fisheries standards, and health requirements. Create a regulatory framework conducive to green tourism investment.

Organizations engaged in developing tourism methods and tools encompassing economic,

environmental and social approaches for sustainable development need to better enable stakeholders from different components of the value chain understand their environmental and socio-cultural impacts. SMEs should be a particular priority for assistance.

Tourism Master Plans or Strategies provide a supply side approach for developing a tourism destination. Environmental and social issues must be included in these plans in order to manage the critical assets and promote greener outcomes. Green transformation programmes will be more effective if produced by a multi-stakeholder participatory planning process, as well as through the development of partnerships at local, national, regional and international levels. Public, private and civil society stakeholders should consider which kind of tourism they want to consolidate in the longer term, considering the possible impacts on the natural resource base.

When promoting sustainable tourism, a coherent destination planning policy is necessary to create a sound international reputation, a country brand that differentiates and positions the country competitively.

Assessment of carrying capacity and social fabric should be considered to take into account external and internal impacts of tourism at destination. While it is difficult to evaluate due to great differences from one destination to another, maximum thresholds could be agreed on so as to provide guidance for the development of planning policies.

Importantly, the lifecycle of most coastal tourism resort infrastructure is approximately 25-30 years and much of the development that occurred in the coastal tourism boom of the 1970 and 1980s with limited controls in developing countries is approaching a period where major retrofits or demolition is required. With the salient need for planning to adapt to sea level rise that will transform coastal tourism in the decades ahead emerging at the same time, there exists a vital window of opportunity to advance sustainability of coastal tourism in many destinations in the next 20 years.

3.5 Fiscal policies and economic instruments.

The greening of tourism will require a more sophisticated and innovative use of instruments within government purview, such as fiscal policy, public investment, and pricing mechanisms for different public goods. Incentives should be consistent with both socio-environmental sustainability and value added creation. Market

trends and competitive advantages need to be mutually reinforced. From a national perspective, sustainable tourism policy should address market failures (including externalities). Selected interventions must provide incentives for more efficient allocations of goods and resources than would occur in the absence of government action. Where appropriate, the use of incentives should be based on market instruments that foster investment in green tourism rather than command and control measures. Some forms of market failures deserve special attention, particularly those that prevent learning how new sustainable tourism businesses can produce profitably (self-discovery externalities), impede simultaneous and integrated investments which decentralized markets cannot coordinate (coordination externalities), and missing public inputs (legislation, accreditation, transport and other infrastructure).

Enabling conditions in fiscal and government investment policies

In the case of tourism, policy intervention towards investment sustainability can be justified as far as enabling conditions promote the sustainable use of natural resources and therefore create positive externalities for the society. Alternative, less productive uses of natural resources (i.e. unsustainable agriculture) or possible depletion activities (i.e. coral or offshore sand mining) could be compensated (for their opportunity cost) with policy instruments that increase profitability for sustainable tourism businesses and generate positive environmental externalities. Non-compliance by companies should be avoided with an effective performance monitoring and impact evaluation mechanism. There is a need to conduct periodic evaluations and impact analysis of tourism incentives, from an economic, social and environmental perspective.

Defining and committing to critical government investments in the green enabling policy frameworks plays a central role in determining private sector investment and direction. Government investments in protected areas, cultural assets, water, waste management, sanitation, transportation and energy infrastructure investments play a critical role in private sector investment decisions toward greener outcomes.

Appropriate taxation and subsidy policies should be framed to encourage investment in sustainable tourism activities and discourage unsustainable tourism. Use of taxation is often resorted to for keeping developments in limits (for instance, taxes on use of resources and services at the destinations) and controlling the specific inputs and outputs (like effluent charges and waste services).

Tax concessions and subsidies can be used to encourage green investment at the destinations and facilities. Subsidies can be given on purchase of equipment or technology that reduces waste, encourages energy and water efficiency, or the conservation of biodiversity and the strengthening of linkages with local businesses and community organizations.

Establish clear price signals to orient investment and consumption. The price for such public goods as water production and supply, electricity and waste management send important signals to the private sector. Governments frequently price these goods at very low levels (frequently even free) to encourage investment, only to find that low prices encourage waste, place a drain on communities and make it very costly (financially and politically) to raise prices.

3.6 Financing green tourism investments

Environmental and social investments are relatively new, and remain outside the mainstream of financial markets. In many cases, barriers are based on misperceptions or lack of knowledge. For example, for many green investments, payback periods and amounts are not clearly established (due to limited experience

with them), creating uncertainty for banks or other investors that can jeopardize financing. Also, the return on many green investments includes easily measurable components (such as energy savings), combined with more difficult to measure components such as “guest satisfaction”. Another situation found in many developing countries is that the financial regulatory systems classify “environmental” investments as “non-productive assets”, requiring banks to hold greater reserves, resulting in higher interest rates and less investment.

Enabling conditions for finance

The single greatest limiting factor for SMEs in moving toward greener tourism is lack of access to capital for this type of investment. Green investments must be seen as value-adding and made on their economic and financial merits, without prejudice. This will require greater private sector awareness of the value of green investment, and also policy coordination with Ministries of Finance and Economic Development and regulatory and banking authorities.

Regional funds for local tourism development could help overcome financial barriers for green investments where investments also

Ecotourism funding for community marine management in the Indian Ocean

For nearly a decade, ecotourism revenue has contributed substantial funding to community-based conservation efforts in southwest Madagascar. International volunteers sign up for 6-week diving expeditions with marine conservation NGO Blue Ventures, and are trained to conduct underwater assessments of coral and fish health.

Funds raised from the volunteers are used to support the development and management of one of the Indian Ocean’s largest locally managed marine areas (LMMA). Called Velondriake – ‘to live with the sea’ in Malagasy – this marine conservation initiative encompasses 24 coastal and island villages, and is largely

managed by an association of local fishers and village elders (SEED, 2005).

Ecotourism provides a reliable flow of funding to the Velondriake LMMA. Unlike many conservation initiatives that are solely dependent on short-term grants, Velondriake can be assured long term funding as needed. This model has achieved numerous international awards for responsible tourism, as well as being the first European-based organization to win the SEED award, founded by UNEP, UNDP and IUCN in recognition of innovative entrepreneurial solutions for sustainable development (SEED, 2005a).

Source: Kame Westerman, Blue Ventures, n.d.

generate public returns (through positive externalities). Foreign Direct Investment (FDI), private equity, portfolio investment, and other potential funding sources should be aligned with sustainable projects and strategies for the tourism industry.

Mainstream sustainability into tourism development investments and financing. In this regard, the Sustainable Investment and Finance in Tourism (SIFT) network is working to integrate the expectations of private investors, the leveraged strength of the financing and donor community, and the needs of developing destinations.

Establish partnership approaches to spread the costs and risks of funding sustainable tourism investments. In the case of small and medium enterprises, for example, besides sliding fees and favourable interest rates for sustainability projects, in-kind support like technical, marketing or business administration assistance, could help to offset the cash requirements of firms by offering them services at low cost. In addition, loans and loan guarantees could include more favourable grace periods, soften the requirements on personal asset guarantees or offer longer repayment periods. Loans for sustainable tourism projects could be set up with guarantees from aid agencies and private businesses, lowering risk and interest rates.

3.7 Local investment

Sustainable tourism creates additional opportunities to increase local economic contribution from tourism. An often-overlooked aspect of these linkages is that they also offer opportunities for increased investment in local communities. Capitalized and formalized businesses in the tourism value chain enhance local economic opportunity (through employment, local contribution and multiplier effects) while also enhancing local competitiveness among tourists demanding greater local content. This win-win situation is recognized in the UNWTO's Sustainable Tourism for Eliminating Poverty (ST-EP) initiative. This promotes a greater number and variety of excursions in a given destination, a "buy local" movement in food and beverages sector, and growth of specialized niches. Efforts by tourism businesses to include local communities within value creation, public and private initiatives of local workers training, and the development of infrastructure and supporting industries, creates new conditions for business development, more equitable growth and less leakage. These businesses require investment, and can expect substantial growth opportunities in successful destinations.

Enabling conditions for increasing local contribution

Strengthen tourism value chains to back SME investment. Destination tourism is usually stable enough to provide sufficient guarantees for investors and bankers. Long-term contracts for products and services to hotels or other "anchor" businesses create suitable conditions, and simple mechanisms to monitor performance.

Expand the use of solidarity lending mechanisms to permit groups of local suppliers to access credit and build capital. Solidarity lending (guarantees provided by a peer group) has proven successful in fisheries, agriculture, and handicrafts – all industries of critical importance to successful sustainable tourism destinations.

Enhance development bank access to individuals and small businesses that are not eligible for credit, or are involved in the provision of public services (such as protected areas management, guiding, waste management, infrastructure construction, among others).

Establish seed funds to permit new green industries to develop locally. For example, solar collectors and photovoltaic systems can be imported as complete systems, or can be assembled locally from imported components. The latter encourages local investment and promotes local economic contribution. It also permits adaptation of the technologies to better suit local tourism needs.

The UK's Travel Foundation model of collaborative support for sustainable tourism could be expanded and adapted as required to all other major outbound nations (current and emerging). This would provide critical capital from tourists themselves to support the transition of tourism to the green economy.

4 Conclusion and recommendations

Tourism is a leading global industry, responsible for a significant proportion of world production, trade, employment, and investments. In many developing nations, it is the most important source of foreign exchange and foreign direct investment. Tourism can contribute towards a green economy transition through investments leading to energy and water efficiency, climate change mitigation and adaptation, waste reduction, biodiversity and cultural heritage conservation, and the strengthening of linkages with local communities.

Making tourism businesses more sustainable will foster the industry's growth, create more

Linking Tourism & Conservation at UNEP/GRID-Arendal

The tourism industry is the largest sector supporting protected areas financially (UNEP, 2009a), and the world's biggest service industry. Both foreign and domestic tourists make use of protected areas and these experiences can make tourists engage in conservation. Sustainable tourism has major potential to raise investments for conservation.

The Linking Tourism & Conservation (LT&C) initiative was first developed at UNEP/GRID-Arendal in 2007. The aim of this initiative is to highlight examples of international best practice in tourism that supports the development and management of marine and terrestrial protected areas. Success factors of functioning cases have been identified and the initiative is now focused on increasing the worldwide understanding of LT&C models, their functioning and potential for replication. The initiative is supporting the strategic goals and specific targets of the UN Convention on Biological Diversity (CBD) (SCBD, 2007)

and (SCBD, 2011). LT&C is a recognized project of the GPST and will continue to work in cooperation with partners within the network.

The initiative can create incentives for positive change to benefit protected areas by:

- Proactively considering the role of tourism in the development of (new) protected areas so scarce funds for effective management can be increased through financial flow from tourism.
- Encouraging tourism businesses to include nature conservation in their management plans.
- Increasing awareness among visitors to protected areas that can lead to direct financial contributions and support for relevant organizations and policies.

Source: Linking Tourism & Conservation, UNEP/GRID-Arendal, 2011c

and better jobs, consolidate higher investment returns, benefit local development and contribute to poverty reduction, while raising awareness and support for the sustainable use of natural resources. Evidence shows that demand for traditional mass tourism has reached a mature stage whereas the demand for more responsible forms of tourism is booming. Tourism market tendencies indicate that main drivers towards investment in sustainable tourism relate to consumer demand changes, actions to reduce operations costs and increase competitiveness, coherent policy and regulations, technology improvements, and stronger efforts for environmental and social responsibility and natural resource conservation. These are leading the transformation of the industry and determine the future returns on investments.

Targeted research is needed to better understand the value of intact ecosystems to tourism. Further, models specific for coastal

and marine tourism on the necessary funds, as well as economic and social opportunities would support strategic decision-making and investment by both the private and public sector.

In a business-as-usual (BAU) scenario up to 2050, overall tourism growth will imply increases in energy consumption (111 per cent), greenhouse gas emissions (105 per cent), water consumption (150 per cent), and solid waste disposal (252 per cent) (UNEP, 2011). In comparison, the green investment scenario is expected to undercut the corresponding BAU scenario by 18 per cent for water consumption, 44 per cent for energy supply and demand, and 52 per cent for CO₂ emissions (UNEP, 2011). This will result in potential avoided costs that can be reinvested in socially and environmentally responsible local activities—such as local transportation and staff capabilities and skills—increasing the indirect and induced effects of tourism expenditure on local development.

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METALS IN THE DEEP: PREPARING FOR A NEW FRONTIER IN MINING

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GREEN economy
in a Blue World

1 Introduction: Marine mineral resources potentially supporting a Green Economy

We examine the factors driving the interest in deep-sea mineral extraction and look at the possible challenges and opportunities related to this new industry. We also look at the financial instruments and other factors which need to be developed to ensure social, environmental and economic equity from resource revenue. Finally, we discuss the policy implications of deep-sea mining and the attributes of good regulatory frameworks.

In the past, mainstream policy-making has tended to treat thematic areas such as fiscal policy, environmental sustainability, natural resource extraction, trade and social impacts separately. The aim of this chapter is to examine a more integrated framework for sustainable management of non-living resources which considers ecological and new economic thinking in the planning and regulation of these industries.

1.1 Minerals and society

Minerals, and the metals they contain, are an essential component of the modern high-tech world. Global stocks of raw mineral resources continue to dwindle, leading to increased pressures to access new sources and maximize resource efficiency. Despite increased innovation and recycling, continued increase in material consumption, has led industry to seek access to previously unattainable mineral deposits.

According to Captain Nemo in Jules Verne's epic novel *Twenty Thousand Leagues Under the Sea*, 'in the depths of the ocean, there are mines of zinc, iron, silver and gold which would be quite easy to exploit'. Though not quite as described by Verne, deep-sea mineral deposits have been scientifically studied for decades in all ocean basins of the world (see Map 2) and recently have received renewed attention from commercial interests.

1.2 A brief history of deep-sea minerals.

There are three main classes of deep-sea minerals – manganese nodules, manganese crusts and seafloor massive sulphides (SMS) (for a more detailed description see Rona, 2008). Manganese nodules were first discovered lying on the deep ocean floor during the oceanographic expedition of HMS Challenger, 1872-76. Research into their recovery stretches back to the 1970s. The first hydrothermal sulphide systems were discovered on the

Galapagos Rift in 1977 (Corliss, et al., 1979) and the first expedition devoted solely to the study of manganese crusts occurred in 1981 (Halbach, et al., 1982).

Over the last few decades there has been an increase in scientific research into the origin, composition, and distribution of seafloor minerals. Recognizing the economic potential of these mineral occurrences, exploration companies have been mapping and sampling the seafloor across the Pacific region. SMS deposits have been discovered in the Exclusive Economic Zones of several Pacific Island countries (Glasby, 1982 and Hein, et al., 2005). These deposits contain copper, lead and zinc, and some have very significant amounts of gold and silver. Other deposits have manganese nodules and crusts which contain nickel, copper, cobalt, and rare-earth elements (REEs). Particularly high concentrations of REEs have also been documented in muds on the bottom of the northeast Pacific Ocean (Kato, et al., 2011). REEs are used in a variety of high-tech products such as mobile phones (cerium), digital cameras and batteries (lanthanum) (Long, 2011).

The refinement of deep-sea mining technology, the continued rise in global demand (hence prices) for metals (UNEP, 2011), the high grades of ores associated with some marine mineral deposits and increased clarity in the legal frameworks governing exploration and extraction rights, have led industry to consider deep-sea mining as a commercially viable prospect. Some states have shown interest in exploiting mineral deposits beyond national jurisdiction. These rarer metals alone may not be commercially viable, but when coupled with downstream production of consumer goods requiring these metals, may provide a market advantage. However, there is a legitimate concern regarding both our understanding of the different ecosystems associated with deep-sea mineral sites, and the economic and social consequences of any development.

2 Challenges and opportunities

2.1 Environmental Challenges

There are environmental challenges with any resource development such as mining, logging or fishing. Experience from land-based mining shows that poor environmental management can result in extensive ecosystem destruction and permanent damage to the livelihoods of local communities (Weeramantny, 1992). In considering the development of deep-sea minerals, it is essential to safeguard associated natural capital and resources and to avoid

degrading the environmental resources on which local communities and future generations might depend. Today this resource may be fishing, for future generations it may include the biopharmaceuticals which could be discovered from deep-sea species. The challenge is to adequately safeguard environmental values including biodiversity so that future generations have the opportunity to benefit from these resources.

It is important that nations fully consider both the economic benefits and potential costs of deep-sea mineral extraction. The benefits of deep-sea minerals derive from the sale of refined metals. The costs comprise two main components: (i) direct costs – the financial costs of mining, transporting, processing, and marketing the metals, and (ii) external costs – the cost of environmental impacts (environmental costs) and opportunity costs such as those arising from the displacement of other uses of the ocean. Notably, some of the external costs might involve the loss of non-market values, such as those attributable to clean water or the existence of a unique ecosystem or species.

Deep-sea mining is a new industry with many unknowns, but there are lessons which can be learned from onshore mining and offshore oil and gas extraction. These industries share the need to manage physical habitat destruction, the potential loss of biodiversity and the

dispersal of toxic waste. The technology required for deep-sea mining is still evolving and must be able to operate at great depth and subject to the vagaries of wind, waves and currents. These difficult conditions will require expert management and maintenance of equipment to ensure that accidents do not occur. In addition, due to the uncertainties surrounding this new venture, adaptive management strategies are required which incorporate the new information and knowledge which will arise as the industry advances.

Seafloor massive sulphides, manganese crusts and manganese nodules are found in very different geological and ecological environments which involve different technological challenges and may necessitate different conservation approaches.

The ecosystem services which exist in these potential mining sites may include important fish habitat, scientific research opportunities (especially apparent in the case of hydrothermal systems which offer the chance to study the evolution and adaptation of life under extreme conditions) and potentially valuable genetic resources and chemical compounds. While the mining footprint on hydrothermal massive-sulphide sites is expected to be small in comparison to land-based operations (Scott, 2006), there are still large knowledge gaps in our understanding of the ecosystems

Rare minerals for new technology

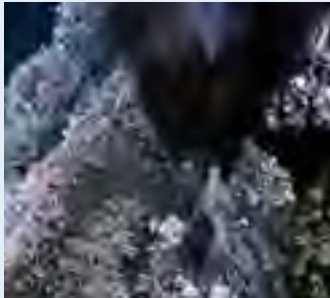





Deposits commonly known as manganese crusts, cobalt-rich crusts or iron-manganese crusts occur on seamounts and other ocean highs. Their mode of formation favours the absorption of many rare metals in high concentrations. This includes tellurium, cobalt, bismuth, zirconium, niobium, tungsten, molybdenum, platinum, titanium and thorium (Hein, et al., 2010) The high enrichment values of many of these metals compared to the concentrations mined on land, coupled with their general scarcity, may make them an economic proposition in the deep-sea. Currently these metals are used in the production of super alloys

and a number of new and developing technologies such as solar panels and wind turbines, storage cells and batteries and electronic devices. The rare metals market tends to be dominated by a few players, for example 95% of the world's supply of tellurium comes from China. Problems with the supply of tellurium have slowed the development of the high performance cadmium – tellurium photovoltaic cell (Hein, et al., 2010). The future of photovoltaics may hinge on the supply of rare metals such as tellurium and in this instance developing states may be able to play a significant role in the greening of global energy production.

Mining massive sulphides, an example from the planned Solwara 1 deposit

In order to characterize the environmental and opportunity costs of deep-sea mining, it is helpful to outline the steps involved in the extraction and recovery of minerals from a seafloor massive-sulphide deposit. When mining begins at Solwara 1, in Papua New Guinea, indications are that extraction will be undertaken with mining machinery remotely operated from a vessel anchored above the mining site. Surface sediments will be scraped and removed from the deposit. The deposit will be cut by a bulk-mining machine and reduced to a particle size which can be pumped as a slurry through a riser and lift system (a pipe) to a surface production-support vessel. The slurry

will then be dewatered on the vessel, and the water filtered and returned for discharge near the seafloor. Dewatered ore will be transported by barge to an unloading and storage facility on land. It will then be transported by truck to a concentrating facility, where it could be partially processed into concentrated copper and zinc ore. Because Papua New Guinea, like most countries in the region, does not have an industrial-scale smelting facility, the concentrate would be trucked again to a port and shipped to an overseas smelter or shipped there directly. Only the initial mining, lifting, dewatering, and shipping of the ore would be novel mining industry activities in Papua New Guinea.

	Seafloor Mining	Rise/Lifting	Mining Support Vessel
Environmental Costs	<p>Mechanical aspects of seafloor mining could result in damage to poorly understood species and habitats.</p> 	<p>The Risers and Lifters could allow chemicals, sediments, or metals to leak from the pipes into the ocean</p> 	<p>Mining support activities could result in dumping of mine tailings or waste.</p> 
Opportunity Costs	<p>Seafloor Mining could damage future scientific, medicinal, or recreational opportunities in the unique vent ecosystems.</p> 	<p>Accidental contamination could affect seafood safety and production</p> 	<p>Mining support vessel activity could displace local fishing.</p> 

The deep-sea mining technique proposed destroys the physical habitat of the sea floor and associated biota. One of the main concerns voiced regarding deep-sea mining is the potential for the release of large amounts of particulate matter into the water column, both from the collection process and the return of turbidity-laden seawater from the ship-board dewatering of the ore (Halfar & Fujita, 2007 and Sharma, 2011). This may be detrimental to organisms living close to the mine site and potentially those further afield (in response to concerns about pelagic fish, Nautilus has developed a solution to return the water to the seafloor). Mining may also affect surrounding organisms through the

introduction of invasive species, toxic substances from the deposit, spilt ore and pollutants (such as hydraulic fluid, etc.) and vibration. In addition, mining introduces light into an otherwise dark world, which could potentially interfere with the feeding and reproductive behaviour of organisms (Nautilus, 2008).

Deep-sea mining activity at the lift/riser site and also the increase in support vessel traffic could cause some displacement of artisanal or industrial fishing. It is also possible that mining activity could prevent future use of the mining site for bioprospecting, deep-sea tourism, or research science.

Ship Concentrate

Processing

Market

Shipping the concentrate causes carbon emissions as well as the risk of polluting the ocean with toxic metals

Metals processing is highly polluting

Shipping to market causes carbon emissions as well as the risk of polluting the ocean



Shipping activity may disrupt fishing activity.

May require new facilities if seafloor metals differ significantly in processing needs from terrestrial minerals

Policy focus may be drawn away from non-exhaustable resources such as tourism



associated with these deposits, including spatial connectivity within and between bioregions (larval dispersal, recruitment, gene flow, etc.) and the resilience of the ecosystems (Van Dover, et al., 2011 and Nautilus, 2008).

In principle, destruction of ecosystems associated with deep-sea minerals might involve the loss of 'existence values'¹, or 'bequest values', or there may be future-use values of which we are currently unaware (also known as 'option values'). In practice, passive and option values (existence and bequest values) are likely to increase for three reasons: 1) people will become more aware of these habitats, especially the specific habitats where mining is proposed; 2) any future mining activity will decrease the number of available mining sites, and thereby potentially increase their value; and 3) potential non-extractive uses of deep-sea habitats including medicinal applications, bio-engineering, or even tourism may become relevant. Given that current passive and option values for these habitats are exceedingly small, as mining operations and associated research expand, these values are only likely to grow as we learn more about these habitats. Consequently, in addition to prudent management there needs to be a programme of scientific research, dissemination of results and ongoing public consultation.

Getting marine minerals from the seafloor to market requires a life cycle which affects a wide range of environments, not only those directly associated with the deposit (see textbox above). Onshore operations, which may include infrastructure development, ore transfer, crew transfer, minerals processing and transport, etc. have the potential to affect local water and air quality, and will result in carbon emissions. The potential economic cost of these environmental damages has not been estimated. A reduction in local environmental quality may also pose a public health risk to local communities.

Although deep-sea mining does not face the same landowner issues as many land-based developments, there is still a need to consult with local communities as the exploitation of resources may impinge on customary rights and connections to the ocean, including economic, cultural, social, political and religious rights.

At present there is no track record on which to judge the performance of companies

1. Existence value can be defined as the benefit derived from simply knowing something exists even if it is never used. Existence values are often associated with marine biodiversity (Hageman, 1985). Bequest value is the value placed on the knowledge that resources and opportunities will be available to future generations (Beaumont et al. 2007)

involved in deep-sea mining, but the impacts and changes evident to the environment from on-land mining signal the need to apply the precautionary principle² to development.

2.2 Environmental Opportunities

It may at first glance appear that deep-sea mining offers very few environmental 'opportunities' but advocates of deep-sea mining have argued that focusing mineral exploration on the deep sea is significantly better for the environment than the continued exploitation of minerals on land (Branan, 2007 and Schrope, 2007). The reasons put forward include less waste, smaller mine footprint, reusable infrastructure, lower greenhouse gas generation and easier site remediation. The trend of terrestrial mining to exploit ores of increasingly lower grades results in larger and larger amounts of waste material being generated. The comparatively high grade of deep-sea ores and the general absence of overburden means that, in comparison to on-land mining, there is likely to be a much smaller mine footprint and much less waste generation (Scott, 2001). Historically mining waste has often caused serious pollution – contamination of waterways, increased sedimentation and acid mine drainage – but due to the minimal amount of waste theorized to be generated at deep-sea mine sites, toxic waste is considered to pose less of a problem with marine mining. Deep-sea mining is not likely to displace most land-based mining, however, unless policy actions are implemented to limit or at least charge for environmental impacts associated with mining (see text box).

Deep-sea mining activity may provide environmental spin-offs, which include increased knowledge of deep-sea biological communities. For example, private company funded research in the Manus Basin, Papua New Guinea, has already produced a significant body of literature on vent communities and the physio-chemical conditions surrounding hydrothermal systems. The value of these scientific discoveries is difficult to quantify, but it is clear that the costs of conducting such research in the absence of commercial exploration would be high and therefore may not occur. Increased knowledge assists with the management and conservation of deep-sea environments. Deep-sea mining activity and the habitat-mapping data it could generate can be used to define meaningful marine protected areas in regions of the deep sea where there is currently very sparse information.

2. Principle 15 – the Precautionary Principle, contained in the 1992 Rio Declaration on Environment and Development, states that, "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."

Will deep-sea mining reduce terrestrial mining?

Deep-sea mining is proposed as a more environmentally sound alternative to terrestrial mining for similar minerals. It is unlikely, however, that deep-sea mining will displace terrestrial mining activity unless other policies are implemented. Left only to the market, deep-sea mining would replace terrestrial mining only in those cases where deep-sea mining is less costly and thus more competitive than rival terrestrial sources. On the

other hand, deep-sea mining could displace terrestrial mining if policies are put in place which would make mining companies pay for the full environmental costs of their commercial activities – making deep-sea mining the lower cost alternative. Similarly, environmental regulations which limit environmental damage could increase the cost-competitiveness of deep-sea mining relative to terrestrial mining.

2.3 Social Challenges

Many academics have studied the link between mining and political instability³. In general, these studies have indicated that the presence of natural resources may increase risk of conflict in four ways: by affecting a country's performance in other economic sectors; by making government weaker, less accountable and more prone to corruption; by giving the populations of resource-rich regions incentives to seek independence from central government; and by providing financial resources to support political (armed) conflicts. The presence of natural resources can therefore become part of a complex set of factors which may ultimately affect political stability.

The contribution of deep-sea minerals to development goals will depend on a nation's

current state of development, its marine-mineral endowment, and other living, non-living and human capital endowments. The key for each country, and in some cases regions, is to determine where deep-sea minerals fit in a larger development framework and whether the extraction, processing, and marketing of marine minerals provides a net advancement in achieving development goals.

Countries also need to consider the degree to which they can meet development goals without exploiting marine minerals. In many cases, developing countries are beginning to tap emerging markets which generate income directly from ecosystems. These income streams come from fisheries, tourism, and increasingly direct payments to protect marine biodiversity and the carbon held in coastal habitats. Nations around the world are also finding new

3. Examples include Professor Michael Ross of UCLA and Professor Paul Collier of Oxford University.

Environmental guidelines for marine mining

A recent publication by the International Seabed Authority (Van Dover, et al., 2011) on the environmental management of deep-sea chemosynthetic ecosystems (associated with SMS) put forward (the Dinard) guidelines designed to protect natural diversity, ecosystem structure,

function and resilience of chemosynthetic ecosystems, while enabling rational use. These guidelines call for a network of conservation reserves, which may also be an applicable strategy for protecting ecosystems associated with the other types of deep-sea mineral environments.

opportunities in service and technology sectors, as well as trade and finance. Still, for many countries, non-extractive resources and human capital may be insufficient to meet development targets. For these countries, deep-sea minerals may offer an opportunity to meet these goals and help economies transition to higher levels of development.

2.4 Social opportunities

A thorough cost-benefit analysis should be undertaken before any mining operation commences. The cost-benefit analysis should include careful accounting of the likely monetary and non-monetary costs and benefits which might accompany a deep-sea mining endeavour. Additionally, such an analysis should provide a clear accounting of how these costs and benefits are distributed across society with special attention given to costs and benefits which accrue to the host country and to (national, regional, and local) components of society within the host country.

The benefits enjoyed nationally and locally from deep-sea mining will depend on a host of factors. At a minimum, States can charge fees, taxes and royalties which can be reinvested locally. Deep-sea mining might also provide direct employment opportunities for the host country, but such employment depends

on the degree to which the administration, transport and technical operations related to mining are based locally. Potential employment could be created directly in industries such as shipping, aviation, warehousing, maintenance, construction, regulation and monitoring (including laboratory services), although highly skilled or technically specialized positions may be filled by foreigners. Indirect employment, for instance in hospitality, lodging and provisioning industries, could occur if mining operations source goods and services locally. Mining operations may also require the development of new local infrastructure (roads, ports, power plants) which could serve to support or spur needed infrastructural development in host countries.

Mining companies may also provide direct philanthropy and community support services for host countries. Such philanthropy could include health and education services. The mining company currently engaged in offshore mine development in Papua New Guinea has established a skills-building programme, which is providing vocational training to local geologists, geophysicists and environmental scientists and also support for selected students to pursue studies in marine-science related fields at an international University. Industry-provided philanthropy, however, will be case-

Dutch disease and resource curse

Papua New Guinea has seen three resource booms since independence in 1975. Wealth from these developments has not been shared widely and the country is unlikely to meet the Millennium Development Goals (Morris, 2011). So will new marine mining ventures break with the past and contribute to economic, social and political development? Many resource-rich developing states like Papua New Guinea are seen as victims of the 'resource curse' because despite their resource wealth, they have exhibited slow economic growth. The resource curse is often associated with 'Dutch disease', a phenomenon which arises when local currency appreciates due to increases in resource exports. This makes it difficult for other sectors, such as manufacturing and

agriculture to compete internationally and consequently they decline. Once the boom is over it may be difficult for these industries to start up again. In addition, it has been noted which when a new income possibility arises it can lead to increased rent seeking by powerful individuals or groups. The more people are involved in rent seeking, the less total income increases (Torvik, 2009). There has been considerable research aimed at understanding the causal relationship between resource abundance and slow economic growth. Although the relationship is still not clear, it appears which good governance is fundamental and which states need to move from simple resource extraction to integrated resource management (Pedro, 2006).

specific and the longevity of the effect of such activity is unclear.

2.5 Economic Challenges

Too often mining appears to increase a country's poverty (Sachs & Warner, 1997). In contrast to sectors such as agriculture where economic gains are often well distributed among a wide percentage of the population, the economic benefits of mining activity tend to be concentrated in the hands of a 'lucky few'. Moreover a few individuals are often vested with decision-making power over projects which can represent tens to hundreds of millions of dollars. This may explain the seemingly high positive correlation in several countries between mining activity and socio-political instability – though it should be recognized which the discovery of oil, gas and minerals per se may not lead to instability, but could worsen existing social tensions, particularly in the absence of strong governance systems.

The five S's of natural-resources revenue management

Fulfilling the potential of natural-resources wealth is neither assured nor automatic. With sudden inflows of natural-resources revenues, governments face a number of questions: How to deal with the variability of tax income related to fluctuating commodity prices? How to address the issue of Dutch disease and domestic inflationary pressures? How to ensure that a portion of the revenues are saved for future generations and that governments will not be tempted to access the accumulated savings in the future? How to balance these savings with the immediate needs for socio-economic development and investment in health, education and infrastructure and how to resist political pressures to use natural-resources revenues for non-priority elements?

The truth is that too often mining revenues have been used not for positive social transformation but for short-term or narrowly focussed political agendas. Sound revenue management will ensure that the correct balance is struck between saving revenue for future generations, and spending current mining revenue on projects with long-term benefits.

In order to better guide governments in the most appropriate way to collect, manage and disburse natural-resources revenues, five issues are of particular importance and need to be taken into account to ensure sound revenue management. These issues are stabilization; sterilization; savings; socio-economic growth; and safety.

Stabilization refers to the need to protect against mineral-resource price fluctuations and require that incremental revenues be set aside in a Fund when the commodity prices are high and taken out when the prices drop, so that governments have a stable revenue stream.

Sterilization involves keeping a large part of the revenue collected out of the local economy to avoid Dutch disease and excessive inflationary pressure.

Saving for future generations: since the resources are limited and will eventually be exhausted, some of the revenues should be saved in view of intergenerational equity. Examples of savings funds include Norway and more recently Timor-Leste

Safeguarding revenue: protecting saved revenue is not always easy. It is necessary to have a separate funding vehicle for savings which is governed by non-discretionary rules, so that Governments are less tempted to spend these savings.

Socio-economic development: although revenue should be set aside for future generations, long-term investments in infrastructure and socio-economic projects should be made while mining is going on. Making good investments in health, education, roads, technology, etc. is also investing in future generations

One of the main challenges for Governments receiving substantial additional revenues from mining activity is how to properly manage a significant increase in budget and to avoid waste. Public demands may put government under pressure to increase expenditure in various areas. Although some socio-economic projects may have long-term benefits, spending and investment decisions can become highly politicized. In this climate, short-term benefit projects, rather than long-lasting ones, can often become the norm.

One common mistake is to underestimate the long-term financial and human resource requirements for maintaining new projects, such as upkeep and repair costs for infrastructure, schools or hospitals, or budgetary provisions to cover the salaries of teachers, nurses and doctors. Too often governments have spent considerable sums of money on ambitious projects which have rapidly become 'white elephants' because of the high, unaccounted-for costs of operation and maintenance (Dumas, 2010).

2.6 Economic Opportunities

None of the negative economic consequences of resource development outlined above are inevitable. Examples such as Botswana, Trinidad and Tobago and, historically, Canada and Australia demonstrate that it is possible to use natural resource wealth to transform society for positive ends. Botswana today – with mineral exports comprising almost 90 per cent of the country's total exports – has one of the highest rates of GDP per capita in sub-Saharan Africa and the smallest number of people living below the poverty line. Looking at these and other successful countries, what is clear is the importance of ensuring successful oversight of mining activity (Ballard & Banks, 2003). This can be achieved by well-enforced legislative and regulatory frameworks, strong institutions with adequate capacity, and good governance according to widely-shared principles.

A key success factor in managing mineral wealth is to separate the decision of *how much to spend* from *on what it should be spent*. Some of the most successful Funds have achieved this by transferring a single amount to the overall State Budget. Budget allocations and spending decisions are then governed through the regular budgetary process. In fact, some argue that a Fund which would develop its own spending programme would divert important spending decisions and priorities to non-elected officials. As the amounts involved may become significant this would basically create a 'state-within-a-state'.

The remaining question is therefore how much to spend. The level of discretion should be related to the country's level of governance and the strength of its institutions. In theory, the amount spent each year could be left entirely to the discretion of policy-makers, current and future, to be set indicatively (as in Norway) or be determined entirely by law (such as the recent cases of Sao-Tome and Timor-Leste.) recognizing that few countries benefit from the same level of good governance as Norway.

3 Enabling Conditions

While States are given legal rights over deep-sea minerals by the UN Convention on the Law of the Sea, the Convention and other international and regional instruments also impose obligations on State parties. These legal standards apply regardless of a State's individual economic status or capacity, and include obligations to protect and preserve marine resources and marine scientific research, to conserve living marine resources, habitats and rare or fragile ecosystems, to monitor risks or effects

of pollution, and to minimize pollution and accidents to the fullest possible extent (UNCLOS Articles 61, 117, 192, 194, 204). If States do not fulfil their obligations under international law they will be liable for any damage occurring as a result (UNCLOS Articles 139, 235). States must also take measures to secure compliance with these international law standards by any third-party private entities within their control – that is, undertaking mining activities on that State's continental shelf, or in the International Seabed Area under the State's sponsorship.

The implementation of a robust national legal framework to regulate deep-sea mining, before mining activity commences, will greatly assist a State in the effective discharge of its obligations under international law.

3.1 Attributes of an effective regulatory regime

Due diligence: to meet international obligations, States must conduct appropriate checks and research into the contractor and its proposed work plan, before issuing a permit for any mining activity. The degree of due diligence may vary according to the risks of the activity (which will depend on the area, activity, mineral, and technology to be used). At the application stage, the State will wish to review evidence of the company's ability to perform mining activities in a timely, safe and efficient manner (company financial information, a plan of work, insurance documentation). The regulatory regime should require the mining applicant to conduct an Environmental Impact Assessment (EIA) as soon as the mining project is sufficiently defined to permit meaningful analysis, and before any mining activity takes place (UNCLOS Article 206). The outcome of that EIA will inform the State's decision as to whether mining can proceed, and if so, within what parameters.

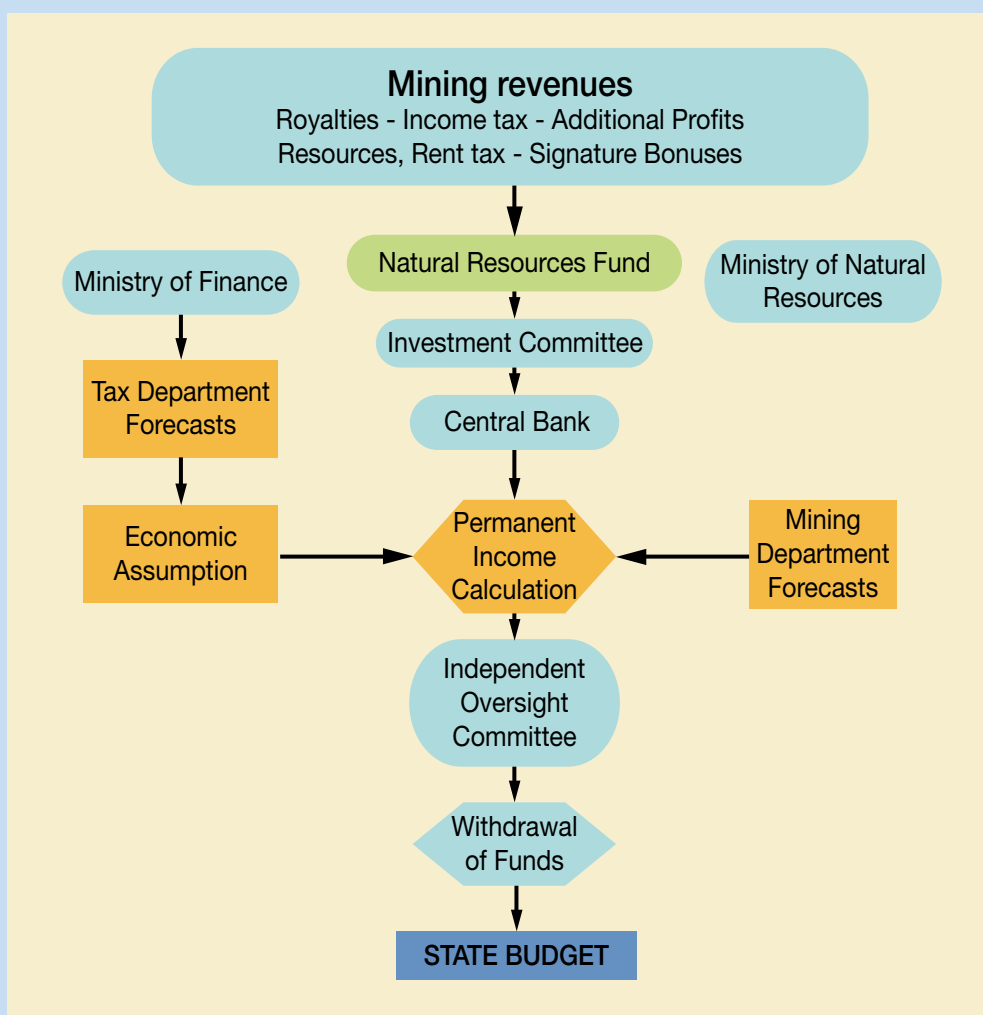
Compliance: the regulatory regime must establish clearly the rules with which entities in the State's control or jurisdiction must comply. This can be done by way of legislation, and by the issue of a licence by the State to the mining company. The licence will give express rights to the company for mining activity in the designated area, setting operational parameters and performance standards. It will contain undertakings, guarantees and indemnities on the part of the contractor, and penalties for breaches.

Monitoring: international legal requirements would not be met by a State merely putting rules and measures in place: it must also exercise further vigilance in monitoring these (Pulp Mills case, 2010). This will require a national regulating body. The regulator may

Design of a mineral fund

A simplified structure for a Natural Resources Fund, its actors and functions:

- The revenues received are paid directly into the funds and are invested in secure financial assets, mostly outside the country.
- Investment strategies are determined by an Investment Committee and funds can be managed by the Central Bank.
- Each year, the Ministry of Finance or Economy determines the amount which can be withdrawn and transferred to the Government's consolidated account.
- Governance is assured by an Independent Oversight Committee (IOC), which reviews payments, calculation of the PIH-based withdrawal amount and accuracy of published information.
- The IOC should also be responsible for auditing the Funds' activities and transactions and should be accountable to the highest instances such as the Parliament.



require regular reporting by a mining company on its activities, expenditure, and environmental issues, in order to be able to verify progress against the plan of work. Such information may

be published to promote accountability to the public. Self-reporting from the mining entity can be supplemented with other methods of oversight, including site visits by the regulator.

Enforcement: an effective regulatory regime both provides incentives for compliance and sets sanctions against non-compliance. The incentive for a contractor to adhere to a State's deep-sea mining regulatory regime will be permission to explore and exploit the designated area of sea for minerals. Regulatory sanctions for breaches or poor performance by the mining company should be proportionate and transparent, with triggers and procedures clearly set out in the legislative regime and the individual agreement. Sanctions may include suspension, termination

or amendment of the licence. Financial penalties may also be imposed. The regime may also include criminal offences, and recourse should be available within legal systems for prompt and adequate compensation or other relief in respect of damage caused by pollution of the marine environment.

3.2 Inter-linked components for successful oversight of resource development

Successful management of resource development requires a combination of

Pacific Regional Policy development approach

Surrounded by vast ocean spaces, most Pacific Island countries (PICs) and territories rely for their livelihoods upon sustainable use of the sea and its resources. Varied mineral occurrences on the seabed have been identified within the jurisdictional waters of many PICs. Nauru and Tonga have been the first developing countries to take steps towards sponsorship of private companies to undertake deep-sea mining activities in the area. The Pacific region therefore finds itself at the forefront of this pioneering industry, and with an opportunity to set a precedent for responsible and sustainable marine mineral industry development, for the benefit of its citizens, and of future world populations.

Recognizing that the trans-border nature of the marine environment supports a regional approach, the Secretariat of the Pacific Community in 2011 commenced a four-year EU-funded project entitled Deep Sea Minerals in the Pacific Islands Region: a Legal and Fiscal Framework for Sustainable Resource Management. The project aims to strengthen systems of governance and capacity of Pacific Island countries in managing their potential deep-sea mineral resources, and in so doing, ultimately to expand the economic resource base of the 15 participating States in the region. The project provides technical assistance for the development and subsequent implementation of regional policy regimes, legislation and

Countries participating in the Project are: Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, Papua New Guinea, Tonga, Samoa, Solomon Islands, Timor Leste, Tuvalu, Vanuatu. There are numerous other interested partners to the project, from international organizations, academia, private sector, and civil society

regulations governing deep-sea mining.

The Pacific Regional Legislative and Regulatory Framework will be designed in consultation with Project participants and stakeholders to provide a user-friendly 'road map' for national level policy and legislation. It will encompass: safety, licensing processes, due diligence measures, contractor prerequisites, performance standards, contract content, transfer of technical knowledge and capacity-building of State nationals, mining standards and practices, application of precautionary principles, conservation of resources and protection of the environment, social responsibilities, good governance and transparency, fiscal regime, and administrative procedures (including reporting, monitoring and enforcement).

adequate regulatory frameworks and the existence of appropriate and strong institutions with the expertise and authority to perform a clearly defined role.

3.2.1 Adequate frameworks

Legal and contractual

There are several reasons why comprehensive and well-implemented legislative and regulatory frameworks are essential to the governance of mining activity. As a first step, investors require a minimum of rules before making a positive investment decision, because of 1) the long-term nature of the investment; 2) the extremely high capital intensity of the industry, especially in mining; and 3) the immobility of assets once built.

In devising legal and contractual frameworks, it is important to entrench internationally accepted standards and practices concerning natural resource sector administration and management. This includes making appropriate provisions

in legislation which reflect best international practices for transparency in decision-making, together with measures which are designed to uphold accepted standards of corporate responsibility for companies, as well as enhancing the developmental benefits for local communities.

Fiscal framework⁴

Arrangements for the fiscal framework must balance international competitiveness (in order to attract and sustain investment in the natural resources sector) with fiscal benefits for the host country. This is not an easy balance to strike, though at least one important feature of an adequate fiscal regime is its progressivity. A progressive regime ensures that the government will be in a position to capture a higher share of fiscal benefits generated from mining activity as a project's profitability increases.

4. For a full discussion of different fiscal frameworks in mineral-rich countries, see Minerals Taxation Regimes: A review of issues and challenges Commonwealth Secretariat and International Council on Mining and Metals, 2009.

ISA regulations and policy under UNCLOS

Under the 1982 United Nations Convention on the Law of the Sea the seabed and ocean floor beyond national jurisdiction (i.e. beyond the outer limit of the continental shelf) is known as the 'Area'. A special legal regime applies to the Area, which is considered to be the common heritage of mankind. The resources of the Area are to be used for the benefit of mankind as a whole. The Convention also establishes an international organization – the International Seabed Authority – to manage and control mineral prospecting, exploration and exploitation in the Area. These activities may only be carried out under a contract with the Authority. Contracts may be awarded to States Parties, state enterprises sponsored by States Parties or to natural or juridical persons having the nationality of States Parties and sponsored by States Parties. This element of sponsorship is fundamental to the international regime, as it is designed to ensure that, ultimately, a State Party to the Convention has international responsibility for the activities of contractors with the Authority.

Whilst the primary function of the Authority is to regulate seabed mining in the Area, it also has broad responsibilities (under article 145 of the Convention) to take measures for the protection of the marine environment of the Area from the harmful effects of seabed mining, as well as to conduct, as well as to promote and encourage, marine scientific research in the Area for the benefit of developing States (article 143 of the Convention). The measures taken by the Authority to date include regulations which require exploration contractors to collect and submit to the Authority environmental data which will help to establish environmental baselines for the conduct of environmental impact assessments. The Authority has also developed a provisional environmental management plan for the seabed of the Clarion-Clipperton Zone of the Central Pacific Ocean, which is the main area of interest for nodule mining.

Experience suggests that, in general, one-on-one negotiations between governments and companies have generally led to more favourable terms for the companies. This in turn implies that governments would serve the interests of their countries more effectively by moving towards fixed terms for investors, and conducting negotiations on an open and transparent basis.

Environmental frameworks

Decision-makers in the natural resources sector should apply internationally accepted best practice in environmental management and proactively account for the value of natural capital when considering acceptable trade offs for a given project. This includes legal and policy measures which underpin environmental safeguards such as environmental impact assessments as a prerequisite for the granting of rights to companies to engage mineral exploration and development, as well as measures to support effective environmental monitoring and the mitigation of environmental damage.

Further, potential for transboundary impacts both horizontally (in neighbouring countries waters) and vertically (on the water column beyond national jurisdiction) should be taken into consideration.

In developing their polices, States should ensure consistency with the wealth of pre-existing initiatives, laws, policies, and guidance, including (among others): UN Convention on the Law of the Sea (UNCLOS), Noumea Convention (SPREP), Madang Guidelines, Pacific Island Regional Ocean Policy (PIROP), Oceanscapes Initiative, Convention on Biodiversity (CBD), Pacific Plan, International Seabed Authority's Mining Code, February 2011 Advisory Opinion from the International Tribunal of the Law of the Sea, IMO Conventions (MARPOL), Extractive Industries Transparency Initiative (EITI), International Marine Minerals Society (IMMS) Code for Environmental Management of Marine Mining; as well as work already undertaken in relation to national deep-sea mining regimes in the region by individual states – including that supported by the World Bank and the Commonwealth Secretariat.

3.2.2 Strong Institutions

In many countries, adequate legislative and regulatory frameworks already exist, but implementation has been a challenge due to a lack of public administration capacity. Strong institutions are particularly important to the oversight of mining activity and they need to cover the same broad categories as the frameworks: legal and contractual (management of licensing and mineral rights); fiscal (tax and

customs); and environmental (health and safety, waste disposal and mine rehabilitation).

Unfortunately, institutions are often the weak link in the concept of 'frameworks-institutions-governance'. Institutions often lack the moral or practical authority to monitor compliance and enforce the frameworks in place. They may also have insufficient resources to operate and effectively ensure that the frameworks are implemented and often find themselves burdened with prescribed inter-institutional competition for vital operational resources.

4 Conclusions and recommendations

With mineral resources becoming increasingly valuable, the deep-sea reserves of developing states may provide a new source of revenue to support development goals. Although there are many examples of poor performance of land-based mining operations which have resulted in negative consequences for developing countries, there are also examples which show it is possible to reconcile mining activities with environmental sustainability, equitable development and the maintenance of communities. For developing states to benefit from their mineral resources, both economically and socially, the development of these resources needs to be managed in a way which takes advantage of the best practices being implemented for sustainable mining. But making the extraction of a finite resource sustainable is a real challenge. It requires good governance and transparency across a whole spectrum of interconnected areas of the mining process, including the initial decision on whether to mine or not. There are often trade-offs made in order to achieve a benefit from one activity, such as resource development, but decisions on the acceptability of these trade-offs need to be made in consultation with all stakeholders. The issues which need to be resolved include potential environmental impacts and liability, and social impacts. Mining operations need to provide better environmental and social outcomes with increased certainty and consistency. Where there are uncertainties the precautionary principle should be applied.

The deep-sea minerals sector must be encouraged to support developing states by implementing voluntary codes which promote best practice. Industry can respond to the sustainability challenge by developing indicators which can be used to gauge performance and develop improvements. Many international companies have accepted that the landscape has changed over the last decade and

that adopting sustainable practices including comprehensive sustainability reporting is necessary. But ultimately it is up to governments to ensure that deep-sea mining meets the expectations of communities and consumers both to support sustainable development and to produce the commodity in a way which meets acceptable environmental and social standards.

Managed properly, resource development can build wealth for both current and future generations, but it requires long-term thinking by governments and constituents. The timeframe for development must allow for the establishment of a proper regulatory and legislative framework

and appropriate mechanisms for the creation and management of wealth. The central requirement for resource-development success appears to be good governance. This includes integrated systems which ensure standards of compliance and responsible fiscal management. Deep-sea mining could even be a driver for improved governance, helping to build strong and capable institutions.

When evaluating a policy course of action in relation to non-renewable natural resource extraction, all states should be encouraged to explore progressive approaches which may be better suited to their respective goals.

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CONCLUSIONS





GREEN economy
in a Blue World

Healthy oceans are invaluable for human development. Human activities in the marine environment, and on the landmasses which drain into it, have damaged ocean ecosystems, the services they provide and the economic values they generate. We see costs which arise from having to substitute ecosystem services such as coastal protection, and lost revenues in sectors dependent on ecosystems, such as the fisheries 'sunken' US\$50 billion per year reported by the World Bank and FAO. But beyond these measurable effects, we see decreased values such as beauty, when we walk along a beach polluted by waste, let alone oil. Lost potential values such as pharmaceutically active substances are the consequence of the loss of biodiversity. Access to free market and non-market ecosystem services such as the provision of food and coastal protection, are of greatest importance to those who cannot pay – here, greening the blue economy becomes a question of security and equity. For these and many other reasons, greening our ocean economies is a matter of enlightened self-interest.

Are we enlightened yet? While major achievements have been made in the spheres of both private economic and public governance, marine and coastal ecosystems and biodiversity remain under imminent pressure. We do not yet fully recognize and incorporate the importance of ecosystem services in planning and investment. Many parts of the ocean, particularly the deep sea, are virtually unknown. The myriad links and

dependencies in the marine environment are still far from being understood. Strengthening marine science and raising awareness are needed to increase our comprehension and maintenance of ecosystem services. Where we do not know enough, the Precautionary Principle must guide our decision-making.

Governance in the marine environment faces particular challenges. The fluid nature of the oceans makes the management of fisheries or pollution more difficult than on land. Further, few property or tenure rights exist in the ocean, leading to what has been termed the Tragedy of the Commons. In truly global sectors such as shipping, and also those two thirds of the oceans beyond the limits of national jurisdiction, single governments have limited power to protect the environment. Regional and global frameworks are consequently essential tools and must become more effective to fill this role. Globally, subsidies which perpetuate unsustainable 'brown' economies must be shifted to greening, and environmental externalities must be reflected in the pricing of ocean-based goods and services. The transfer of new technologies which help greening must not be hindered.

Shifting the purpose of the economy away from exclusively GDP-measured production of market values raises new questions about society's broader goals, such as equity, security and the maintenance of natural capital. This is particularly true for emerging sectors such as



deep-sea mineral production, for which the direction of development is largely open. This can be a challenge to decision makers who have grown used to simplistic formulations which view economic growth as a *sine qua non*. At the same time, such a shift grants modern governance tools a greater role. Ecosystem-based management, a relatively recent approach receiving growing attention and application, recognizes that human welfare and ecosystem health are linked. It calls for integrated management across sectors and aims to harmonize all human activities with one another and with ecosystems. The involvement of relevant public and private actors and the application of marine spatial planning can help to ensure optimal coexistence of uses, users and the marine environment.

Ecosystem valuation, a growing field in academia, helps us create new opportunities for reconciling use and protection of the coastal and marine environment. Payment for Ecosystem Services represent one of these opportunities, whereby the protection of valuable services such as clean water is financially supported by the beneficiaries of those services, often at much lower cost than more technology-driven approaches to service provision. Mobilizing financial capital through innovative funding mechanisms can be a prerequisite to enable enterprises to make green investments. In coastal and marine tourism for example, the majority of businesses are small and medium sized enterprises. Governments, investors

as well as global private and public donor organizations need to provide the necessary funds to those actors who have a high potential for greening, but are hampered by lack of access to capital and capacity. Public private partnerships, tax exemptions and reduced interest rates are fiscal measures which can unleash that potential. At the other end of the spectrum, renewable-energy production often needs support to make the effort to shift from prototypes to pilot plants. Public investment in green infrastructure, in education and capacity building, but also in protected areas can reduce the private costs of greening. Cap-and-trade mechanisms are established tools to catalyze technological innovations towards greener productions; their application in new sectors such as fertilizer production should be explored.

Greening our ocean economies is a challenge which demands commitment by all of us – as individual consumers, investors, entrepreneurs or policy-makers. This report shows how investment in a Green Economy in a Blue World pays off. A less energy-intensive, more labour-intensive, less destructive, more sustainable, less exclusive, more integrative approach will lead to more jobs, strengthen intra-and inter-generational equity and empower people to economic participation and greater self-determination. For countries, greening their marine economies means diversification, stronger resilience to economic or environmental shocks and sustainable prosperity.

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