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The Ocean Economy in Mauritius

Making it happen, making it last



Raffaello Cervigni, Pasquale L. Scandizzo, editors

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Pasquale Lucio Scandizzo, editors



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to integrate physical hazard and vulnerability models into a coastal risk assessment for Barbados. She holds an M.S. in Agricultural and Applied Economics from the University of Illinois Urbana-Champaign.

List of Acronyms

| | |
|------|--|
| ADO | additional development options |
| AFRC | Albion Fisheries Research Centre |
| BOI | Board of Investment |
| BPO | business process outsourcing |
| CCGT | combined cycle gas turbine |
| CDM | clean development mechanism |
| CEB | Central Electricity Board |
| CGE | computable general equilibrium |
| CHCL | Cargo Handling Corporation Ltd |
| CPUE | catch per unit of effort |
| DOWA | deep ocean water application |
| ECS | extended continental shelf |
| EDP | existing sector development plans |
| EEMO | Energy Efficiency Management Office |
| EEZ | Exclusive Economic Zone |
| EIA | environmental impact assessment |
| EPZ | export processing zone |
| EU | European Union |
| FADS | fish-aggregating devices |
| FIMS | fisheries information management systems |
| FMM | Ferme Marine de Mahébourg |
| FTE | full-time equivalent |
| FTTH | fiber to the home |

| | |
|----------|---|
| GCF | Green Climate Fund |
| GDP | gross domestic product |
| GIS | geographic information system |
| GPS | global positioning system |
| ICT | information and communications technology |
| ICTA | ICT regulatory agency |
| ICZM | Integrated Coastal Zone Management |
| IOC | Indian Ocean Commission |
| IoT | “Internet of Things” |
| IOTC | Indian Ocean Tuna Commission |
| IRENA | International Renewable Energy Agency |
| ISP | Internet service provider |
| ITQ | individual transferable quota |
| IUCN | International Union for the Conservation of Nature |
| JICA | Japan International Cooperation Agency |
| JMA | Joint Management Area |
| LCOE | levelized cost of electricity |
| LLU | local loop unbundling |
| LNG | liquefied natural gas |
| LPG | liquified petroleum gas |
| MAIFS | Ministry of Agro Industry & Food Security |
| MaPP | Marine Planning Partnership |
| Mbit/s | megabit per second |
| MCT | Mauritius Container Terminal |
| MEXA | Mauritius Export Association |
| MEY | maximum economic yield |
| MMS | Mauritius Meteorological Services |
| MMTA | Mauritius Maritime Training Academy |
| MOE | Ministry of Energy |
| MoEHR | Ministry of Education & Human Resources |
| MoESDDBM | Ministry of Environment, Sustainable Development, Disaster and Beach Management |
| MoFED | Ministry of Finance and Economic Development |

| | |
|--------|---|
| MOI | Mauritius Oceanography Institute |
| MPA | Mauritius Port Authority |
| MRC | Mauritius Research Council |
| MRIC | Mauritius Research and Innovation Council |
| MSCL | Mauritius Shipping Corporation Ltd |
| MSP | Marine Spatial Plan |
| MSY | maximum sustainable yield |
| MVNO | mobile virtual network operators |
| NOC | National Ocean Council |
| NPV | net present value |
| O&M | operations and maintenance |
| OE | ocean economy |
| O-RET | ocean-renewable energy technology |
| OTEC | ocean thermal energy conversion |
| PMIS | Port Management Information System |
| PV | present value |
| R&D | research and development |
| SACReD | Systematic Analysis for Climate Resilient Development |
| SAM | social accounting matrix |
| SEMPA | South East Marine Protected Area |
| SEZ | Special Economic Zone |
| SIOFA | Southern Indian Ocean Fisheries Agreement |
| SME | small and medium-size enterprise |
| TFP | total factor productivity |
| UoM | University of Mauritius |
| URA | Utility Regulatory Authority |

Overview

Key Messages

The focus of this book is on the big picture and on a few key sectors.

The book aims at assessing the overall potential of the Ocean Economy (OE) to contribute to Mauritius' development, at identifying key sectoral and cross-cutting challenges to be overcome in order to seize that potential; and at evaluating ways to ensure the OE's longer-term sustainability, addressing in particular environmental and climate change concerns. While the book discusses specific projects in selected sectors, this is intended only to illustrate opportunities and challenges (including in terms of resource mobilization); an appraisal of the technical and financial feasibility of individual projects would go beyond the scope of this work and would have to be conducted as part of separate follow-on activities. This book reflects data and information available as of March 31, 2017.

Doubling Mauritius' ocean economy is possible and worthwhile, but it will take time.

Based on a macroeconomic modeling of the country developed in partnership with the Government of Mauritius, the book finds that doubling the GDP share of the OE (the "O2" strategy) is possible; but achieving such a target is likely to take to at least 15 years. Attempts to pursue the O2 target over a shorter period may well result in undesirable economic outcomes, such as diseconomies of scale, price increases, excessive use of natural resources, and fiscal imbalances.

The required investments are large but achievable.

Over the next 10 years, with investments on the order of US\$580 million per year, the O2 strategy can yield considerable growth results, including an increase in the OE GDP of 62 percent in absolute terms and 38 percent in terms of its share of the national total (rising from 12.6 percent to 17.5 percent). Such an extra investment push would be large, being equivalent, on average, to an additional 1.6 percent of GDP going every year toward investment (compared with the last 10 years' average of investment as a share of GDP). While large, such an increase would not be unconceivable, since it would mean lifting total investment back to the levels observed in the early 2000s. Full achievement of the O2 target in the longer term is estimated to require investments of around US\$8.2 billion.

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Key Messages *(continued)*

Investing in the OE sector could support inclusive growth, with the right enabling factors in place.

Compared to a plausible alternative scenario, which involves distributing the additional investment of US \$580 million per year across the economy in proportion to the historical sector shares (rather than concentrating them in the OE sectors), the O2 strategy would boost returns on investment by 20 percent; improve diversification of the OE away from tourism (a 20 percent increase in diversification); create 36 percent more jobs; improve the trade balance by 60 percent; reduce poverty and inequality; and strengthen the government's finances (a 2 percent reduction in the debt/GDP ratio). Successful pursuit of the O2 strategy requires key enabling conditions, including stable macroeconomic and exchange rate policies (to encourage investment inflows), investment in human capacity (to avoid mismatch between demand and supply of skilled and semi-skilled labor); and conservation of the high-quality natural capital on which the OE depends.

To complement the top-down analysis of the OE expansion as a whole, the book assesses opportunities and constraints for OE development from the individual perspective of four sectors, representing the OE's established sectors (fisheries, ports), as well as the emerging ones (marine energy and marine information and communications technology or ICT). The book also highlights a number of innovative strategies, to be further studied, to foster OE strategic development. These include: (i) developing a Maritime Digitization Platform (which could leverage big data and decision analytics) to turn Mauritius into a maritime knowledge hub; and (ii) turning Mauritius into a decoupling point in the global supply chain/logistics corridor for Africa.

Fisheries: Reduce over-exploitation and carefully manage underused resources.

Enabling the sector to meet its true potential would require a reduction in over-exploitation and environmental stresses in the lagoons and coastal fisheries; careful management in the development of underused resources such as the Banks fisheries; and an enhanced investment climate for expansion of aquaculture and the seafood hub. Additional investments of US\$331 million over 10 years could increase the sector's revenues by US\$380 million per year and generate an additional 3,500 jobs. The benefit/cost ratios vary across the components of the development scenarios, ranging from 1.2 for aquaculture to over 3.6 for the Banks fisheries. Similarly, the investment cost per permanent job created varies between US\$32,000 per job for the Banks fisheries to \$170,000 per job for aquaculture.

A range of cross-cutting measures are needed to backstop sustainable investments, ensure their long-term economic viability and effective social inclusion, and restore the environmental health of marine and coastal resources. Fisheries sector audits have criticized the poor implementation of previous plans. The existing plans will require updating and the inclusion of financing modalities and monitoring of key milestones (both of which are often lacking).

Port: Attract investment to boost transshipment.

Strategically located at the crossroads of Asian and African sea routes, Mauritius' seaport has the potential to play a key role in OE development, primarily through the expansion of Mauritius' role as a hub of global trade flows, including container transshipment, re-exported petroleum products, and the transshipment of fish. The book evaluates two development scenarios, the first including various projects identified by the recent Port Master Plan that are already under active discussion, requiring just under US\$1.1 billion of investment (conservative scenario), and the second requiring an additional US\$0.24 billion of investment for other projects that might be undertaken in the next 10 years or beyond (optimistic scenario). The economic modelling shows these projects to have a positive net value added in aggregate, which is even larger once multiplier effects are accounted for. However, the financial feasibility of some projects—such as the Island Container Terminal and the oil terminal at Albion—needs to be further investigated, including the option of undertaking them as public-private partnerships. The Mauritius Port Authority (MPA) has a central role to play in the efforts of "Mauritius Inc." to attract inward investment, but it needs further capacity building in the areas of marketing, customer relationship management, project appraisal, and ICT. The additional human resource needs are small, but the key personnel need to be carefully selected and given customized, on-the-job training.

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Key Messages *(continued)*

Marine energy: Pursue deep ocean water applications and position Mauritius as a future leader in off-shore wind and wave energy.

An integrated assessment of the longer-term potential of ocean-renewable energy technology (O-RET) in the context of Mauritius's overall energy system finds that currently Deep Ocean Water Cooling holds the greatest economic potential, and offshore wind shows extensive potential with concessional finance (such as carbon financing). Wave energy, on the other hand, would require higher levels of supporting finance. The modelling suggests that expansion scenarios are technically feasible and are likely to generate sizable economywide benefits, with benefit-cost ratios well in excess of 2. In addition, expanding the use of marine energy can reduce the country's dependence on fossil fuels (especially coal) and lower its greenhouse gas (GHG) emissions—with potential import reductions of 3 to 19 percent and GHG emissions reductions of 3 to 18 percent through O-RET deployment. For large deployment of O-RET to happen, there will need to be a combination of clear longer-term vision, human capacity development, standards adoption, comprehensive tariffs, and targeted opportunities to attract private investment.

ICT: Improve cable connectivity and promote innovative ocean solutions to data storage and off-shore communication.

There are strong two-way synergies between the OE and the ICT sector: ocean resources enable the ICT sector to function and expand (through undersea cables, the provision of cooling services for offshore data centers, and new market opportunities in the area of offshore communications services to mariners). Conversely, ICT applications can also be a key ingredient in the development of many ocean activities, especially in terms of enhancing the future competitiveness of Mauritius. Investment of some US \$300 million (for additional cable capacity, a deep water data storage pilot, better management of spectrum to allow more offshore mobile communication, and downstream ICT applications in selected OE clusters) could deliver a considerable benefit/cost ratio for the economy as a whole (in excess of 3.6) and the potential to create some 3,500 permanent jobs. Investments in this area generate significant spillovers into the wider economy, as confirmed by the lower values of the benefit/cost ratio at the project level.

Make the ocean economy last...

Any OE expansion is likely to entail larger pressure on the environment, including pollution of water and coastlines, in turn affecting coral reefs, lagoon habitats, and biodiversity; and higher exposure to the risks posed by current climate variability and future change.

... through marine spatial planning (MSP) ...

Mauritius has recently initiated an MSP process as a key instrument to reconcile multiple ecological, economic, and social objectives in the use of coastal and ocean resources. An overarching, strategic decision to be made early in the process concerns the level of ambition of the MSP. Two options can be envisaged: Either (i) develop a high-level strategic framework for management of marine resources, with zoning to be defined only after an initial pilot phase of some five years; or, alternatively, (ii) develop a decision-making framework and comprehensive zoning design simultaneously or sequentially, but without a period of adaptation prior to implementing the complete MSP. Either way, the MSP process will need to address key challenges in the areas of inter-institutional coordination; upgrading of the legal and regulatory framework; definition of how the planning process would engage with Rodrigues and the outer islands; engagement with Seychelles, if the MSP includes the Joint Management Area; and coordination with Indian Ocean countries and associations or commissions (in relation to international pelagic resources).

... and by addressing risks of large shocks to the economy from climate change.

Climate change is being increasingly recognized as a threat to the development potential of the OE in Mauritius. The country has made important progress on the understanding of impacts, including sea-level rise, coastal erosion, tropical storm intensification, intensified rainfall patterns, increased temperatures, and ocean acidification); it

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Key Messages *(continued)*

has also made progress on practical adaptation responses, such as guidelines for coastal setback, formulated in anticipation of sea level rise risks to coastal assets. However, more can be done to better understand and mitigate the increased risks that climate change may pose to the entire OE and, in fact, to the economy as a whole. In particular, we find that under certain climate change scenarios, the risk of large GDP losses from tropical cyclones could significantly increase: for example, a cyclone or a series of cyclones causing a long-term GDP loss of 7.5 percent (over a 40-year horizon) has a 10 percent probability of occurring under current climate conditions; under climate change, this probability increases to 30 percent on average.

Strengthening the ocean economy governance.

The current OE governance system, based on a dedicated ministry and a consultative body (the National Ocean Council or NOC), has been instrumental in promoting the OE agenda over the last few years. To fully turn the OE's potential into reality, there is a need to strengthen it, both in terms of technical capacity and in terms of decision-making mechanisms. Mauritius could consider establishing a highly qualified Ocean Economy Unit (OEU), staffed with full-time top professionals in the different OE clusters, to be housed at the Ministry of Ocean Economy to strengthen the ministry's capacity; or alternatively, at the Office of the Prime Minister to provide the unit with stronger clout across sectors. At the institutional and political level, the work of the OEU would be vetted and validated by the National Ocean Council, the Minister of Ocean Economy, or other ministries. For decisions of particular strategic significance, the formation of an Ocean Inter-Ministerial Committee could also be considered.

Recommendations

In addition to the establishment of the Ocean Economy Unit, Mauritius could consider the following actions for the short term (6 to 18 months). (A longer list of recommendations is provided at the end of this Overview).

- Prepare a draft National Ocean Policy paper, including an action plan with short- and medium- term targets
- Prepare a draft unified regulatory framework, gradually expanding to cover the different OE sectors
- Develop a comprehensive training action plan to develop technical capacity in selected priority OE areas
- Develop a governance and legal framework for the next steps of the MSP process
- Develop a financial protection strategy against climate disasters, based on a diagnostic of economic and fiscal impact of disaster shocks
- Formulate a high-level policy commitment on lagoon rehabilitation
- Develop a three-year business plan for Banks fisheries development
- Establish an integrated energy planning process through an inter-sectoral coordination panel
- Develop a more ambitious cable program, looking eastward (toward Asia) and northward (to Europe and the Gulf); and
- Strengthen the commercial functions of the Mauritius Port Authority through suitable capacity building.

A New Role for the Ocean Economy in Mauritius

Mauritius is an upper-middle-income country, with a successful record of sustained growth, a stable macroeconomic environment, and solid institutions. The country boasts abundant ocean resources and natural capital, has a vast exclusive economic zone (EEZ) under its management (or jurisdiction), and is reliant on a healthy ocean for a host of socioeconomic activities. Thanks to forward-looking policies with the right mix of private-sector orientation and promotion of social inclu-

sion, the country has evolved over a few decades from a land-based, mono-cropped, inward-looking economy into an export-oriented and diversified economy, producing textiles and services in tourism, finance, and ICT.

The recent economic history of Mauritius starts with a colonial legacy characterized by specialization in agricultural production and limited processing of sugar. This single commodity dependence accentuated the vulnerability of a small island economy, with a limited population and land base and exposure to many sorts of outside shocks. Yet, in spite of the many unfavorable factors, Mauritius has achieved a remarkable economic performance since its independence in 1968, with high and consistent growth rates—ranging from a high in excess of 6 percent during boom years to lows of still above 3 percent during recent years, against the backdrop of sluggish global growth. Its performance has included an exemplary transition path from commodity dependence to a diversified industrial and, more recently, service-based economy that is highly productive and fully integrated in global value chains. Between 1980 and 2007, total factor productivity (TFP) grew over 1 percent a year, including a faster spell (in excess of 1.3 percent a year) between 1980 and 1990. This solid performance was achieved thanks to the following key factors: strong democratic institutions, a well-crafted economic strategy, careful macroeconomic governance, and international negotiating ability.

However, as the country aspires to rapidly achieve and maintain high-income status, it faces a number of important challenges. These include its reliance on foreign capital and technology, the relative decline of its traditional sectors (such as the sugar and textile industries), concerns as to the sustainability of recent growth drivers like tourism and high-end real estate development, and a degradation of both the land and ocean environment. Shortages of highly skilled labor and job mismatches are also the consequence of the country's ongoing structural transformation to a modern service economy and the employment structure of the declining textile industry, which is mostly based on low-skilled and difficult-to-retrain workers. More recently, following the global economic recession that affected most of its export markets, Mauritius also experienced lower growth (at 3 to 4 percent, down from the historical averages of 5 to 6 percent), falling saving and investment rates, and pressures on government finances from a combination of capital import dependence and low domestic taxation.

Against this backdrop, the various governments that have held office since the release of *The Ocean Economy: A Roadmap for Mauritius* (PMO 2013), hereafter referred to simply as the *Roadmap*, have identified the OE as a key development opportunity for the coming

decades and endorsed the goal of rapidly increasing the overall economic importance of the OE. The *Roadmap* sets a target of doubling the OE's share of GDP over a 12-year time horizon (2013–2025), creating some 35,000 jobs in the process. The government created a new Ministry of Ocean Economy, Fisheries, Marine Resources and Outer Islands in 2015, aimed at consolidating the several different entities that existed with stronger coordination mechanism as well as promoting a stronger ownership and accountability. Mauritius has also committed to meet the UN Sustainable Development Goals, the Convention of Biological Diversity targets, and the UN Framework Convention on Climate Change to improve ocean management, strengthen marine protected areas, and make its development less carbon-intensive and more climate-resilient.

In articulating its commitment to OE expansion, the government has adopted a cluster approach, whereby selected OE sectors have been identified as having the highest potential to achieve and contribute to overall growth. These sectors include both some traditional sectors (such as fisheries and marine transportation services), as well as some new sectors and inter-sectorial projects (such as maritime digitization, big data and logistics, sea bed explorations, and ocean based energy) that appear to hold the potential for leapfrogging development.

Currently, the OE contributes about 10 percent to GDP (Table 1), but the contribution is likely to be larger when the full range of direct and indirect interactions with the rest of the economy are properly taken into account.

Objectives, Structure, and Limitations of the Book

The Ocean Economy in Mauritius has the following objectives: (i) assessing the overall potential of the OE to contribute to Mauritius's development (in terms of economic growth and diversification, trade balance, reduction of poverty and inequality, and effects on the government's finances); (ii) identifying key sectoral and cross-cutting challenges to be overcome in order to seize that potential; and (iii) evaluating the prospects to ensure the OE's longer-term sustainability, especially in terms of conservation of the environment and of the risks posed by climate change.

The approach taken combines a top-down analysis of a doubling of the OE's share of GDP in the medium to longer term, with a bottom-up analysis consisting of four deep dives in specific sectors that are representative of the OE's traditional sectors (fisheries and ports), and emerging ones (marine energy and marine ICT). The book is organized in three parts, as visualized in Figure 1. Part A, "The Big Picture,"

Table 1. GDP Share of Each Sector Included in Mauritius' Ocean Economy^a

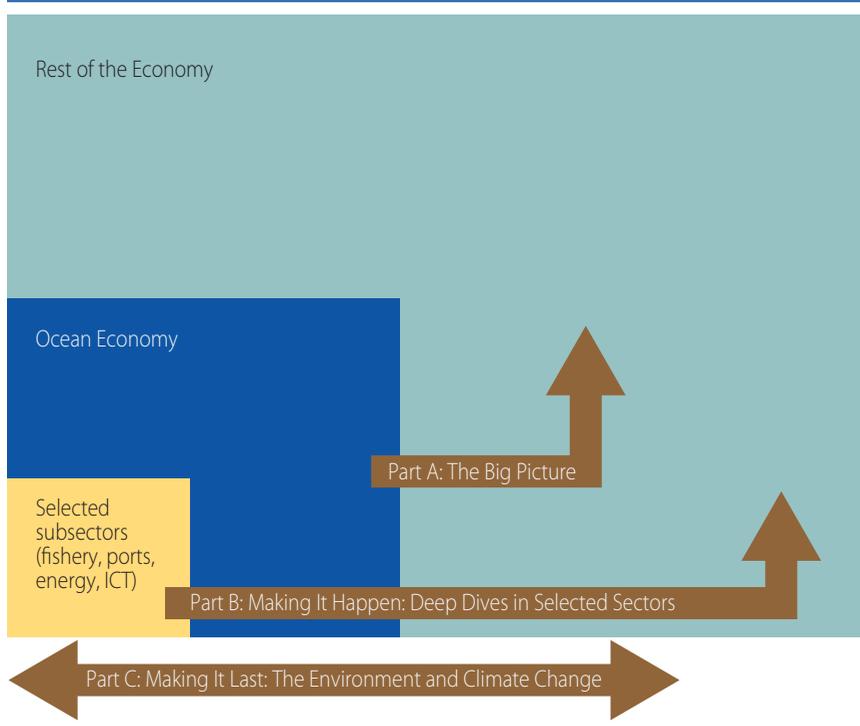
| Sectors | Average GDP share (2012–14) |
|---|--------------------------------|
| A. Seafood fishing and processing^b | 1.43 |
| B. Port-related activities | 1.97 |
| Sea transport | 0.05 |
| Services allied to transport | 1.58 |
| Ship building and maintenance | 0.12 |
| Storage | 0.22 |
| C. Tourism and related activities | 6.86 |
| Freeport activities | 0.54 |
| Hotels and restaurants | 4.88 |
| Leisure boat activities | 1.18 |
| Ship store and bunkering | 0.26 |
| D. Government bodies related to the OE^c | 0.19 |
| Total | 10.45 |

Source: Statistics Mauritius.

Note: (a) The selection of the sectors included in the OE is consistent with UN guidelines, and reflect criteria currently being used by Statistics Mauritius. However, there are a number of new sectors that are too small to be accounted for at present, but are considered in the rest of the book, in particular in the CGE model (these include, among others, several ICT subsectors and ocean energy). (b) Includes aquaculture, fishing other than aquaculture, and fish processing. (c) Includes Beach Authority, External communications division, Fisherman Welfare fund, Mauritius Oceanography institute, Ministry of Fisheries, National Coast Guard, Shipping division (of Ministry of Land Transport and Shipping), and Tourism Authority.

provides an evaluation of the ability of the OE as a whole to contribute to the country's overall development. Part B, "Making It Happen," contains deep dives into selected OE sectors. Part C, "Making It Last," is a discussion of two key issues related to the OE's long-term sustainability: the options for developing marine spatial planning (MSP), which is key to ensuring the conservation of the natural capital on which the OE depends; and the significance of the threats posed by climate change to several OE sectors.

While the top-down analysis in Part A covers the OE as a whole, the book does not analyze the development prospects of all OE sectors. Notably, tourism is not included, since it is a mature and relatively large sector and thus likely to run into diminishing returns as it expands, as confirmed by the economywide analysis. As a result, an important part of the impulse for the longer-term growth of the OE can arguably be expected to come from emerging OE sectors, or from smaller traditional ones, which are less likely to be affected by diseconomies of scale. Seabed mining of minerals and hydrocarbons is also not analyzed;

Figure 1. How This Book Is Organized

in this case, the reason for the omission is that there are currently few hard facts on that sector's potential.

An important caveat is that the book is intended to provide a big-picture, strategic assessment of the OE; specific investment opportunities at the individual project level are discussed in Part B of the book (the bottom-up analysis), mostly to exemplify opportunities and challenges, and to assess the order of magnitude of investment resources required to promote the growth of the OE. Any appraisal of the technical and financial feasibility of individual projects would go beyond the scope of the book and will have to be conducted as part of separate follow-on activities.

The Big Picture: Doubling the Ocean Economy

While there is no shortage of examples of investment opportunities related to the OE that have generated economic benefits in other countries and also appear promising in Mauritius, to date there has been no systematic assessment of the OE's ability to become a fundamental driver of the country's economy for the foreseeable future.

Box 1. Tools for Analyzing Economywide Effects of Developing the Ocean Economy

The social accounting matrix (SAM) is a system of national/regional/sub-regional accounts represented in a matrix format (Stone, 1962, 1981). It includes the inter-industry linkages through transactions typically found in the input-output accounts and the transactions and transfers of income between different types of economic agents (such as households, government, firms, and external institutional sectors) from national accounts and other statistical sources. A typical computable general equilibrium (CGE) model is able to generate solutions that are consistent with a SAM. The model can thus be calibrated using a SAM for a base year or a set of base years. For Mauritius, the SAM estimated for 2015 was used to calibrate the CGE model so that the CGE solution reproduces the 2015 data as a baseline reference; and to replicate the actual performance of the Mauritius economy during the period 2006–14.

The SAM built for Mauritius aims to represent a coherent, integrated, and structured framework that accounts for the economic potential of marine natural resources and uses or activities (such as ship routes and energy sources from the oceans). It distinguishes between ocean-based and non-ocean-based activities, as well as “blue” (marine ecosystems) and “green” (terrestrial ecosystems) natural resources. The critical ocean-based activities are sustainable fisheries and aquaculture, renewable marine energy, marine bio-prospecting, maritime transport and infrastructure, and marine and coastal tourism. Water treatment and decontamination activities are also considered, while the coastal activities represent a critical interface between the blue and green economies.

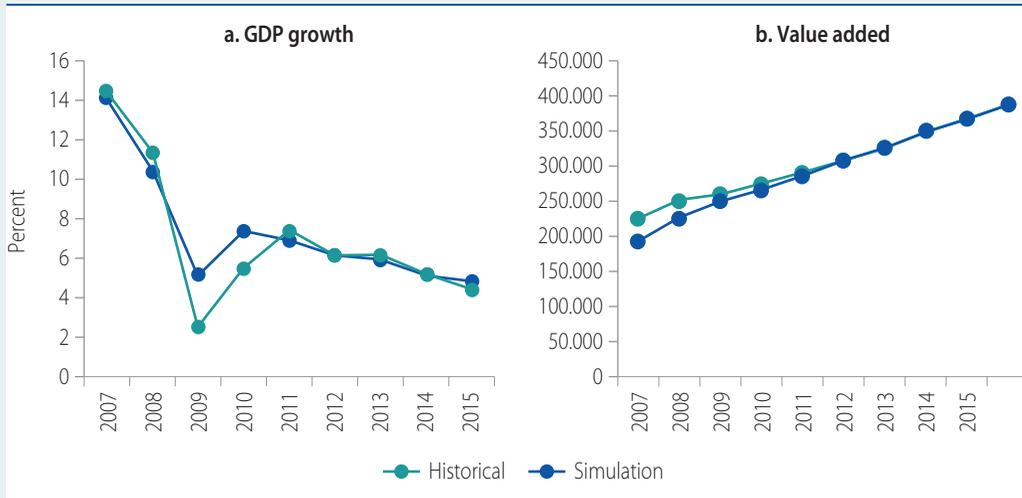
CGE models use actual economic data to represent the functioning of an entire economy and estimate how it might react to changes in policy, technology, or other external factors. The model developed for Mauritius is a dynamic recursive one. Dynamic models trace each variable through time, often at annual intervals (unlike static models, which look at the reactions of the economy at only one point in time). Dynamic models assume that behavior depends only on current and past states of the economy. CGE models always contain more variables than equations, so some variables (known as exogenous variables) must be set outside the model, a process known as closure. They also typically assume as exogenous important drivers of socioeconomic change, such as global economic growth and global trade, climate changes, and other major factors. For our purposes, we have used a closure rule based on the hypothesis that the official exchange rate is fixed and that investment financing in excess of domestic savings can be secured by foreign capital inflow.

To assess the OE potential and evaluate the volume of investment required to seize it, it is necessary to represent in a rigorous and coherent way the functioning of Mauritius’ economy. The study team has therefore developed a dynamic computable general equilibrium (CGE) model, which is based on a social accounting matrix (SAM) estimated in full partnership with Mauritius government institutions (in particular, Statistics Mauritius and the Ministry of the Ocean Economy). These tools (Box 1) have made it possible to reliably reproduce the

Box 2. Ensuring the Accuracy of the Model

The CGE model was calibrated to replicate the actual performance of the Mauritius economy during the period 2006–14. The results show that the model is able to achieve a close representation of the economy. In the case of the rate of GDP growth, the model’s simulation does not deviate more than 5 percent from the historical data, as shown in Figure 2, Panel A. In the case of value added, the historical data are perfectly replicated by the model for the last six years, with only a slight underestimate for the first three years (Panel B).

Figure 2. Trends in GDP Growth and Value Added, 2007–15: CGE Simulation vs. Historical



Source: World Bank simulations; data from Central Statistics Office Mauritius.

past behavior of the economy (Box 2) and address, for the first time in Mauritius, the following key questions:

- Is the doubling of the OE achievable?
- If so, over what time horizon?
- How much would it cost?
- Is such a doubling desirable?
- What structural obstacles would need to be overcome?

The approach used to answer those questions included the following steps:

1. Define and evaluate a future scenario where the size of the OE (as a share of GDP) doubles over the next decade or two—what we call the *O2 scenario*—including the quantification of the investment that

- would need to be channeled to key sectors that depend (directly or indirectly) on ocean resources.
2. Define and evaluate an alternative scenario, where the same investment resources required in the O2 scenario are not concentrated on the OE but instead are distributed across sectors according to the same pattern observed in recent years. This alternative scenario is called the *counterfactual scenario*, and its purpose is to provide a reference against which the relative merits of investing in the OE can be evaluated.
 3. Compare the O2 scenario to the counterfactual scenario to quantify the merits of the former, in terms of outcomes such as growth, return on investment, income distribution, job creation, balance of trade, and fiscal balance.

Doubling the OE is possible, but will take time...

The analysis suggests that doubling the GDP share of the OE is possible; but achieving such a target is likely to take at least between 15 and 18 years. Attempts to pursue the O2 target over a shorter period of time may well result in undesirable economic outcomes, such as diseconomies of scale, price increases, excessive use of natural resources, and fiscal imbalances. Nevertheless, already within the first 10 years, the O2 strategy can yield considerable growth results (Table 2), including a 62 percent increase of the OE GDP, in absolute terms, and an increase of 38 percent in OE's share in the national total (from 12.6 percent to 17.5 percent).

... it will require a major boost in investment ...

The total additional investment required to set the country on the O2 trajectory is estimated to be on the order of US\$8.2 billion. Specifically, over the next 10 years (where the model produces more detailed results), the average annual investment is estimated to be on the order of US\$580 million/year. This is equivalent to an increase in investment of 1.6 percentage points of GDP over and above the share of GDP going to fixed investment over the decade 2005–15 (Table 3).

This increase in investment is feasible and is in line with a reasonable objective of a 30 percent GDP share going toward fixed capital formation, in order to finance the OE as a major contributor to Mauritius' transformation into a high-income economy. It would, however, require a reversal of the recent declining trend in both private and public investment, and it could only be achieved by increasing productivity and competitiveness throughout the Mauritius economy.

... and will result in an expansion of non-traditional sectors.

At the sub-sectoral level, the results point to the less than proportional expansion of some of the traditional sectors (like coastal hotels and restaur-

Table 2. Performance of the Economy Over 10 Years: O2 Scenario versus Counterfactual Scenario

| Indicator | O2 Scenario (doubling of the OE) | Counterfactual scenario |
|--|--|----------------------------|
| Base-year proportion of OE GDP to total GDP | 12.6% | 12.6% |
| Additional total investment required for the O2 path (Year 1–10, US\$ billion) | 5.8 | 5.8 |
| End-year proportion of OE GDP to total GDP | 17.5% | 14.7% |
| End-year OE GDP (base year = 100) | 162 | 147 |
| NPV (5%) GDP increase/additional investment | 1.49 | 1.23 |
| NPV (5%) export-import increase over 10-year period (US\$ million) | 45.2 | 28.5 |
| Average contribution to growth rate | 3.17% | 2.93% |
| Government debt as percent of GDP, average for years 1–10 | 60.7% | 61.45% |
| Natural resources contribution to value added (cumulative, years 1–10, US\$ million) | 128.2 | 114.02 |
| Net jobs created (years 1–10), for jobs lasting 10 years | 25,452 | 18,648 |
| Net jobs created (years 1–10), for jobs lasting 20 years | 12,726 | 9,324 |
| Index of diversification of the OE (year 10) ^a | 52% | 46% |

Note: (a) The index of diversification is given by one minus the Gini coefficient.

Source: World Bank analysis.

Table 3. Value of Investment Resources Required to Promote OE Growth

| Variable | Value |
|--|-------|
| 1 Total additional investment required to set Mauritius on O2 growth path (Year 1–10, US\$ million) ^a | 5,800 |
| 2 Total additional Investment required to double the OE (achieve O2 over 18 years) (US\$ million) ^b | 8,200 |
| 3 Average annual additional investment required for O2 growth path (for Years 1–10, US\$ million) | 580 |
| 4 Average annual additional investment required for O2 growth path (for Years 1–10, % of GDP) | 4.2% |
| 5 Historical average annual investment (fixed gross capital formation 2006–15, US\$ million) | 1,770 |
| 6 Total annual average investment as percent of GDP required (including the additional OE investment) | 23.1% |
| 7 Historical average annual investment (FGCF 2006–2015, share of GDP) ^c | 21.6% |
| 8 Investment surge (share of GDP) to set country on O2 path (line 6 minus line 7) | 1.6% |

Source: World Bank analysis

Notes: (a) Figures include only fixed investment (gross fixed capital formation as per national account statistics). (b) "Additional" means that the investment indicated will be directed to the OE2 sectors, unlike in the case of the counterfactual scenario; part of the investment (about 2.63% of GDP on average) would substitute for investment that would be undertaken by other sectors. The estimated investment is indicative, as the full dynamic trajectory of growth has been estimated only for the years 1–10 of the simulation. (c) Historical figures are at current prices, which may over- or under-estimate investment ratios, depending on differences between GDP and investment deflators.

rants), and the more than proportional growth of both some of the traditional activities with high expected project returns and wider economic complementarities (like fishery and sea food processing, and the services allied to marine transport), as well as the emerging OE subsectors.

This result reflects several factors. First, while it is expected to remain a pillar of the economy, tourism is now already a mature sector, with relatively lower rates of return to incremental capital. Second, because of the already large proportion of the OE economy that it accounts for, tourism is affected by diseconomies of scale to a larger extent than other sectors starting from a smaller sector base. Third, tourism is still characterized by a value chain largely reliant on imported intermediary goods, hence with limited spillover benefits on the rest of the domestic economy. Fourth, while tourism is a labor-intensive sector and an important source of jobs, its ability to drive further sustained high-quality job growth is challenged by seasonality. These considerations suggest that investment in tourism should be aimed more at improving the quality and the performance of the sector than at increasing its size.

Investing in the OE is preferable to plausible alternatives ...

The analysis also shows (Table 2) that compared to the alternative scenario (the counterfactual), the O2 strategy will achieve returns on investment (the ratio between incremental GDP and incremental investment) of 1.49 (a 20 percent gain compared to the ratio of 1.23 estimated in the counterfactual); improve diversification of the OE away from tourism (a 20 percent gain in diversification); create more jobs (a 36 percent gain); improve the trade balance in net present value (NPV) terms (a 60 percent gain); reduce poverty and inequality; and strengthen the government's finances (a 2 percent reduction in the debt/ GDP ratio).

... and it will only deliver if supported by adequate conditions in terms of financing, labor productivity, and environmental quality.

Additional investments are necessary but not sufficient for the OE to fulfill its promises. Three areas should be considered as key prerequisites for solid OE performance.

First, macroeconomic policies need to remain prudent and foreign exchange rates need to be stable in real terms. Otherwise, there might be an overall slowing down of foreign capital inflows, which could lead to a suboptimal performance of the OE. If the capital supply were to become more rigid (for example, with a one-third reduction of supply elasticity), the model estimates that the contribution to growth would decline by 42 percent, from 3.17 percent to 1.83 percent.

Second, the O2 strategy requires an ample supply of skilled and semi-skilled labor —especially in the new sectors of ICT, energy, and port and allied transportation services. At the moment, there is already evidence of a significant skill mismatch between demand and supply, in part because of the low-skill labor freed-up by the contraction of the textile industry. This is resulting in imported labor at the lower and higher ends of the skill distribution. A skill mismatch, simulated in the model through a sharp decrease (from 1 to 0.1) in the elasticity of skilled labor supply to wage, would result in curtailing the potential contribution to growth of the O2 scenario by more than half, bringing that contribution down from 3.17 to 1.77; and would lead to a mere 1 percent cumulative return on investment over the 10-year period considered (as opposed to the 49 percent estimated in the absence of a skill mismatch).

Third, conservation of high-quality natural capital is a necessity for the expansion of the OE. Indeed, increases in the investment requirement in natural resources (proxied by their non-remunerated contribution to value added) are significant in absolute terms, at more than US\$21 million in the 10th year of the simulation, and some 20 percent larger in the O2 than in the counterfactual scenario (Table 2). A deteriorating environmental quality of the marine ecosystem, resulting from insufficient public and private investment in conserving natural resources (in particular ocean, blue water, green water, and wetlands), is captured in the model by a lower elasticity of supply: that is, less natural capital is mobilized for any given increase in its marginal return.

If the elasticity were to become very small (about 1 percent of the baseline value), resource use could be expanded only by depleting the resources available, effectively leading to a gradual demise of the OE. In that case, the model simulation shows that the OE's overall contribution to growth would fall to 2.75 percent (compared to 3.17 percent in the base case of the O2 scenario) and cumulative returns to investment to 26 percent. Because the use of blue natural resources is more intensive in O2 and indeed is a condition necessary for its success, the aforementioned model simulation is also the only case where the counterfactual appears to outperform the O2 scenario, although only in terms of average contribution to growth.

In summary, and simply put, the accelerated development of the OE would occur not in isolation but as part of a wider policy framework, one that maintains a conducive macroeconomic backdrop for investment and growth and avoids potential bottlenecks, crucially including labor and skills. Finally, placing the OE at the forefront of Mauritius' development strategy only makes long-term sense if strong emphasis is placed on conserving the natural assets underlying increased economic activity in Mauritius' marine environment.

Making It Happen: Sectoral Deep Dives

The top-down analysis in this book shows that a substantial expansion of the OE is possible and desirable, and that it will require scaled-up public and private investment, a conducive environment for investment, adequate policies for obtaining the needed skills, and support for natural resource conservation. To complement these big-picture insights, the book assesses opportunities and constraints for OE development from the individual perspective of four sectors, representing the OE's established sectors (fisheries, ports), as well the emerging ones (marine energy and marine ICT).

The analysis defines investment scenarios based on projects currently under discussion in Mauritius, but does not seek to assess their technical or financial feasibility. Instead, the objective is to evaluate, from a bottom-up perspective, the order of magnitude of the investment financing required; to test the use of the CGE model to evaluate the merits of investment (from both an individual project- and an economywide perspective); and identify policy or capacity bottlenecks to be overcome.

In terms of the quantitative evaluation, the analysis has been conducted by estimating each project component in terms of capital and operational costs, as well as foreseeable revenues and proceeds from market-related activities. This information has further been analyzed through the CGE model and ultimately led to two sets of indicators of investment worthiness (including NPVs and benefit-cost ratios).

The first set (project-level measures) reflects the point of view of a likely stakeholder (that is, a private party undertaking the project in full or in part with government assistance). The second set (economywide measures, EWMs) aims to address, however imperfectly, the broader question of the social and economic desirability of projects from the point of view of the Mauritius economy as a whole. Economywide measures take into account the input-output structure of the Mauritius economy and track any given expenditure through its direct and indirect impact along value chains that are active in the economy. The economywide measures of project worth are not directly comparable with the project-level measures, but are presented as a complementary set of indicators that may be useful to evaluate project outcomes from a “big picture” economy point of view.

Traditional Ocean Sectors: Fisheries and Aquaculture

The fisheries sector—which includes both gear fisheries and aquaculture—is a critical part of the Mauritius economy (Table 4). It represents about 1.5 percent of GDP and employs up to 22,000 people, including in fish processing and services to the fisheries sector. Fisheries produc-

Table 4. Status of the Priority Fisheries Development Targets in Mauritius, 2014–15

| Indicators ^a in priority fisheries | Coastal & Lagoon | Offshore banks | Aqua-culture | Seafood Hub |
|--|------------------------|----------------|------------------|------------------------------|
| State of the fish stocks (and marine environment in the case of aquaculture) | Overfished | Healthy | lagoons degraded | Some tuna species overfished |
| Production | Declining ^b | Declining | Increasing | Stable-increasing |
| Employment (numbers) | 11,520 | 202 | 115 | 7,207 |
| Value of production (US\$ million) | 43.71 | 6.75 | 2.87 | 273.35 |
| Operations and maintenance (US\$ million) | 19.3 | 5.74 | 3.90 | n/a |

Source: World Bank analysis.

Note: (a) Details are provided in the fisheries chapter of the full book. All values are estimates are based on 2014–15 data. (b) Except in Rodrigues, where production is increasing.

tion is valued at more than US\$580 million per year and accounts for about 22 percent of Mauritius' exports in value terms (US\$400 million). Currently, fishing and maritime transport are the only significant marine economic activities in Mauritian jurisdictional waters, which cover 1,400 times the land area of Mauritius. The reef and lagoon environment and coastal fisheries make a vital social and economic contribution (particularly in Rodrigues) by not only providing incomes and food security but also supporting tourism and livelihoods. The tuna cannery is the single largest employer in Mauritius, and Port Louis is the port of choice for many industrial fleets fishing in the region because of its relative efficiency and availability of services. Offshore banks and seamounts offer untapped fishing potential, while an infant aquaculture industry has attracted investor interest.

However, in recent decades, the lagoons, coral reefs, and associated coastal habitat (especially around Mauritius island) have been progressively degraded and damaged, threatening the long-term viability of fisheries in Mauritius. While some of the loss of ecosystem function may be attributed to natural causes, the study team considers anthropogenic stresses, such as overfishing and agricultural runoff and urban pollution, to be the primary causes. Moreover, coastal and fishing communities are in the front line of climate change, threatened by cyclones, coastal erosion, and sea-level rise.

Enabling the sector to meet its true potential will require a reduction of over-exploitation and environmental stresses in the lagoons and coastal fisheries; carefully managed development of underused resources such as the Banks fisheries; and an enhanced investment climate for expansion of aquaculture and the seafood hub. The book identifies four investment scenarios (Table 5) to revitalize and develop the sector in each of these areas.

Table 5. Key Investment Areas and Expected Benefits of Fisheries Development Scenarios

| Development scenario | Areas of Investments | Expected benefits |
|-----------------------|---|---|
| Lagoon Rehabilitation | <p>Scheme to monitor the state of the coastal environment and the fisheries</p> <p>Development of a marine spatial plan</p> <p>Reduction of fishing effort, effective management of selected fisheries, such as the octopus fishery, regulation of “amateur” fishing</p> <p>Support to communities for creation of non-fisheries economic opportunities (e.g. in marine leisure activities)</p> | <p>Increased revenues in tourism and marine leisure</p> <p>Reduction of coastal erosion</p> <p>Reduction of damage caused by cyclones</p> <p>Recovery of selected fisheries</p> |
| Banks Fisheries | Private investment for up to 16 modern fishing vessels | <p>Increased revenues from banks fisheries</p> <p>Revenues from a blue carbon scheme^a</p> <p>Additional jobs at sea and in marine science</p> |
| Aquaculture | <p>Inshore investments (finfish, invertebrates)</p> <p>Offshore investments (including shore facilities)</p> | Increased revenues |
| Seafood Hub | <p>Investment in:</p> <ul style="list-style-type: none"> • longline vessels • cold storage • chill fish handling | <p>Increase of vessel calls per year and the corresponding sale of services</p> <p>Increase of fish landings</p> <p>Productivity gains from regional economic cooperation on tuna</p> |

Note: (a) Blue carbon is the carbon captured by the world’s oceans and coastal ecosystems. The carbon captured by living organisms in oceans is stored in the form of biomass and sediments from mangroves, salt marshes, seagrasses, and potentially algae. The carbon emissions avoided by conserving oceans coastal ecosystems can be traded in carbon markets or other regulatory mechanism.

Lagoon Rehabilitation

Restoring the declining health of the lagoons and reefs is a “no-regrets” investment, creating significant sustainable benefits for coastal fisheries, for the tourist industry, and by mitigating coastal erosion. Healthy reefs and lagoons are a vital coastal defense against typhoons and coastal erosion. They protect the coral sand beaches essential to the tourist industry, support sustainable small-scale fishing, tourist diving, and sport fishing—and are emblematic of Mauritius’ reputation as an environmentally responsible and pristine tourist destination. Rehabilitation and conservation of the lagoons will require a combination of marine spatial planning, mitigation of land-based sources of pollution, and attention to the social issues arising from reduced fishing effort in the lagoons. Rodrigues Island offers some lessons in lagoon restoration and spatial management. Lessons from the management of the Rodrigues octopus fishery are already being applied in Mauritius Island.

Table 6. Economic Assessment of the Four Fisheries Development Scenarios

| | Investment and financing | | | Measures of worth | | | | |
|-----------------------|--------------------------|--------|---------|-----------------------|------|-------------------|------------------------|------|
| | (US\$ millions) | | | Economywide measures | | | Project-level measures | |
| | Total | Public | Private | NPV (US\$millions) | B/C | Jobs ^a | NPV (US\$millions) | B/C |
| Lagoon rehabilitation | 23.75 | 23.75 | | 51.89 | 3.54 | 250 | 23.05 | 1.13 |
| Banks | 27.45 | 14.45 | 13.00 | 59.97 | 3.59 | 860 | 30.09 | 1.77 |
| Aquaculture | 245.00 | 0 | 245.00 | 104.48 | 1.19 | 1,450 | 345.67 | 1.63 |
| Seafood Hub | 34.90 | 3.40 | 31.50 | 81.99 | 3.65 | 1,000 | 12.80 | 1.69 |
| Total | 331.10 | 41.60 | 289.50 | 298.33 | 1.53 | 3,560 | 411.61 | 1.16 |

Source: World Bank analysis.

Note: (a) Job creation is defined as the labor income stream that would support a worker continuously employed for 20 years. B/C = benefit-cost ratio.

Offshore Banks

The offshore Banks include the vast Mascarene underwater plateau and several undersea ridges, which are about 50 times the size of Mauritius' land area. Part of the extended continental shelf is shared with the Seychelles. Production from the high-value deep water Banks fisheries has been declining, partly as a result of an aging fleet and regulatory changes. The way forward requires investment in a modern Banks fishing fleet, backed by a management regime of access to fisheries founded on sound economic principles, as typically these remote deep-water fisheries suffer from economic overfishing long before the resource is biologically depleted. Economic performance will depend on improved fishing technologies and cooperation between operators in terms of safety-at-sea, logistics, and export marketing. Increased maritime surveillance will reduce suspected illegal foreign fishing and assert Mauritius' jurisdiction over these remote fishing areas.

Aquaculture

This industry can expand significantly through farming of invertebrates (like oysters, crabs, or sea cucumbers) and the cage culture of finfish. But expansion will hinge on demonstrated profitability and mitigation of the high risks associated with aquaculture, along with public investment to create a more robust enabling environment for private investors and to attract finance. Limited space within the lagoons means that expansion will require some farms to be located in more exposed sites outside the reefs. While these technologies exist, the risks and the capital and operating costs are likely to be significantly higher and financing more difficult. Offshore farm size and investment tend to be high, in order to achieve

the economies of scale needed to justify establishment of hatcheries and shore infrastructure. Expansion of aquaculture may be the most challenging development scenario due to competition for inshore space, the weak economic performance of the existing large-scale farms, and the risks and financing difficulties offshore. Planned offshore site surveys and expedited approval processes may provide needed incentives.

Seafood Hub

Less than 10 percent of the tuna landed or transshipped in Port Louis is caught in Mauritian waters. In particular, the important canning and loining activities rely on imports. This underscores the importance of regional cooperation on tuna, not only for resource management but in support of value added processing of the region's raw material. In this regard, the experiences of the Parties to the Nauru Agreement in the Western Central Pacific provides a useful model that can be adapted to the needs of the region's coastal states, while local industry-led fisheries improvement projects can complement public initiatives. Investments aimed at improving the productivity of existing port and fisheries infrastructure can improve the comparative advantage of Mauritius as a regional seafood hub. Existing regional fleets could increase their use of the port, increase landings of raw materials for processing, and expand purchases of services and supplies. The Mauritius-based longline fleet is also expanding to take advantage of markets for fresh tuna and the efficient air services to Asian and European markets.

Economic Assessment

An analysis of the four investment scenarios using the CGE model shows that additional investments of US\$331 million over 10 years could increase the sector's revenues by US\$380 million per year and generate an additional 3,500 jobs (Table 6). The benefit/cost ratios vary across the components of the development scenarios, ranging from 1.2 for aquaculture to over 3.6 for the Banks fisheries. Similarly, the investment cost per permanent job created varies between US\$32,000/job for the Banks fisheries to \$170,000/job for aquaculture. In addition to creating new jobs, the investments also contribute to retention of existing ones, particularly in coastal fisheries, seafood processing, and indirectly in tourism.

A range of cross-cutting measures are needed to backstop sustainable investments, ensure their long-term economic viability and effective social inclusion, and restore the environmental health of marine and coastal resources. Fisheries sector audits have criticized the poor implementation of previous plans. The existing plans will require updating and the inclusion of financing modalities and key milestones (both of which are often lacking). Other needed measures include these:

- Performance-based realignment of staff, budgets, and institutions to help meet changing priorities;
- Improved fisheries governance informed by a modern fisheries information management system;
- Expanded monitoring of reef and lagoon health to: (i) clearly identify the impact of different stressors; (ii) justify remedial actions upon which a comprehensive lagoon rehabilitation program can be based; and (iii) develop synergies with investment in climate action, tourism, and MSP;
- Public support for private business initiatives to draw on the lessons of previous loan and grant schemes in fisheries; and
- At the international level, continued effort by Mauritius to sustainably manage the tuna resources for the benefit of the region, lead blue economy innovation and development, and press for resources for a proposed Africa Ocean Economy Platform.

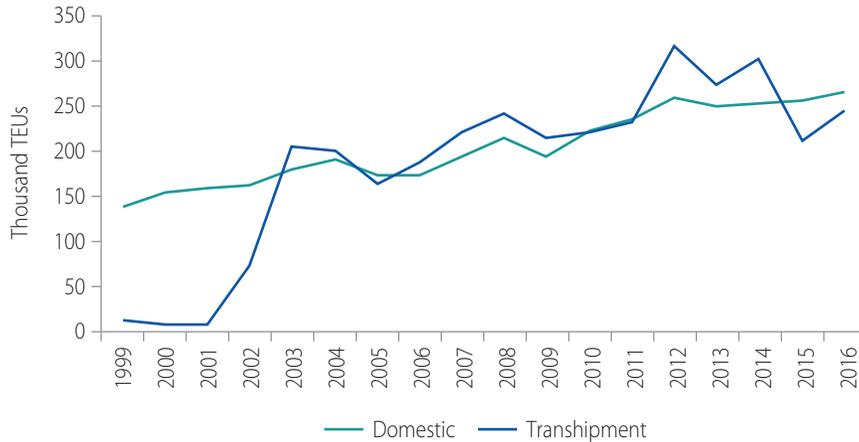
Consolidating and sustaining these diverse initiatives suggests that a robust public information strategy can increase public support and understanding. Preparation of regular state of the fisheries or state of the OE reports can inform public opinion and the political processes at national and local levels. Universities and nongovernmental organizations (fisher and industry associations) will all have a role to play in informing and supporting these initiatives.

Traditional Ocean Sectors: Ports

Strategically located at the crossroads of Asian and African sea routes, Port Louis, the main seaport of Mauritius, handles 99 percent of the country's external trade and has become an important hub for the transshipment of containers moving between other countries. Port-related activities account for around 2 percent of the country's GDP (Table 1) and around 9,000 jobs.

Over the past two decades, major investments have transformed Port Louis into an efficient, modern seaport. The government is now planning to reposition the port as a regional trade hub, with the focus on boosting transshipment activities, including containers (Figure 3) and petroleum products, as well as seafood processing, bunkering, and cruise activities. This is intended to bring in substantial additional income from outside of Mauritius, as well as serving the needs of an expanding domestic economy.

Responsibility for the provision of port infrastructure and services rests primarily with two state-owned organizations: Mauritius Port Authority (MPA), which is the main body responsible for port planning, infrastructure investment, pilotage and towage, and port administration;

Figure 3. Domestic and Transshipment Container Traffic, 1999–2016

Source: Mauritius Port Authority.

Note: TEU = Twenty-foot equivalent unit, representing the dimensions of a standard shipping container.

and the Cargo Handling Corporation Ltd (CHCL), which is responsible for cargo handling, mainly of containers. Some private companies own or lease their own dedicated facilities within the port and provide their own handling services for specific bulk cargoes, such as wheat.

Port traffic reached 8.4 million tons in 2016 and is dominated by containers (52 percent), but there are also sizeable movements of dry and liquid bulk cargo (22 percent and 24 percent, respectively), and smaller movements of general cargo and fish. Frequent, competitively priced container services to multiple destinations are an important plus point in attracting footloose foreign investment, and they have allowed Mauritius to expand and diversify its economy by seeking export opportunities overseas. In 2015, imports of goods and services were equivalent to 59 percent of GDP, while exports of goods and services were equivalent to 49 percent of GDP.

However, Mauritius-based trade (both imports to and exports from the country) accounts for only 60 percent of port throughput. The rest comes from facilitating global trade between third countries, made up of container transshipment (27 percent), re-exported petroleum products such as bunkers and liquefied petroleum gas (LPG) (12 percent), and the transshipment of fish (2 percent).

The key question for Mauritius is how it can further increase the external component of port traffic. Two scenarios have been identified (Table 7):

- **Conservative scenario:** This scenario would require just under US\$1.1 billion of investment and is based on projects actively under

discussion. The projects include a new gate complex for the existing container terminal, a second oil jetty at Fort George, a breakwater with a new “island” container terminal on its shore side, a cruise terminal, a new oil jetty and tank farm at Albion, and a small breakwater in the Caudan area to provide shelter for marine-type activities.

- **Optimistic scenario:** This scenario would require an extra US\$0.24 billion of investment, and is based on additional projects that might be undertaken in the next 10 years or beyond. The projects include a further extension of the Albion tank farm, the reconstruction of Quay 1 for dry bulk cargo, a marina, fishing harbor facilities, and a third ship-repair yard.

Some of the projects, such as the gate complex, breakwaters, and fishing harbor, are not directly revenue-generating but are required to improve operational performance and support other port activities. In other cases, such as the oil jetties at Albion and Fort George, the financial returns on public investment will be relatively low because of public sector pricing policies. However, these facilities are expected to draw in significant amounts of private investment, which would not otherwise have come to Mauritius.

The CGE modeling work shows these projects to have a positive net value added in aggregate, which is even larger once multiplier effects are accounted for. However, the financial feasibility of some projects—such as the island container terminal and the oil terminal at Albion—needs to be further investigated, including the option of undertaking them as public-private partnerships. In addition, the public sector may have to make investments in the port that do not show a positive financial return in order to attract the necessary private investment. Thus, the port expansion projects needed to reposition Port Louis in the market warrant further investigation to validate the result of this preliminary analysis regarding their worth from the point of view of the economy as a whole.

Because many of these projects rely on capturing mobile third-party business in a globally competitive market, rather than servicing the needs of a captive domestic economy, they are relatively high risk. Several of the larger projects are also capital-intensive, with relatively few linkages to other sectors of the Mauritius economy. This explains why the ports sector is shown in Figure 8 as generating a lower benefit/cost ratio and fewer jobs per \$1.0 million of investment than some of the other sectors of the OE.

Whether or not to go ahead with the projects in the two scenarios will depend on the creation of a more favorable environment for private investment in port-related infrastructure; and on the implementation of a series of measures to “make it happen.” The OE investments being

Table 7. Investment Costs and Benefits of Two Port Development Scenarios

| Development scenario | Investment costs (US\$ millions) | | | | Project-level measures of worth | | Economywide worth | | |
|-------------------------|----------------------------------|----------------|-------|-----------------|----------------------------------|---------------------------------|---------------------|---------------------------------|--------------|
| | Public sector | Private sector | Total | PV ^b | NPV (US\$ millions) ^c | Benefit/cost ratio ^d | NPV (US\$ millions) | Benefit/cost ratio ^d | Jobs created |
| Conservative | 591 | 492 | 1,083 | 842 | 142 | 1.17 | 495 | 1.59 | 1,440 |
| Optimistic ^a | 56 | 187 | 243 | 188 | 408 | 3.52 | 75 | 1.44 | 230 |

Source: World Bank analysis.

Notes: (a) Incremental investments undertaken in addition to the conservative scenario. (b) Investment costs 2017–27, discounted to present values (PVs) at 5%. (c) Annual increases in value-added 2017–40 discounted to PVs at 5%, minus PV of investment cost. (d) Annual increases in value-added 2017–40 discounted to PVs at 5%, divided by PV of investment costs. PV = present value; NPV = net present value.

planned for the future are larger and more complex than those undertaken in the past; also, these planned investments seek to attract investors and customers from outside of Mauritius rather than within. Thus, a more pro-active approach to project development will be required, with the joint development of comprehensive investment packages by MPA and other government bodies such as the ministries of Finance and Ocean Economy and the Board of Investment.

The MPA has a central role to play in the efforts of “Mauritius Inc.” to attract inward investment, but it needs further capacity building in the areas of marketing, customer relationship management, project appraisal, and IT. The additional human resource needs are small, but the key personnel need to be carefully selected and given customized, on-the-job training. Key issues to be addressed include these:

- Helping existing customers to grow and, if needed, prioritizing long-term economic considerations over MPA’s short-term financial objectives. Possible measures include continuous research into the needs of the port’s main users, strategic planning meetings with customers, expansion of government-funded training schemes for port service providers, and government procurement policies that favor local suppliers.
- Actively seeking out new customers overseas. OE objectives should lie at the center of any future port marketing strategy, with the provision of suitable incentives for private investors in the port that have forward and backward linkages to the rest of the economy. The impact of new investments on established (potentially competing) businesses should also be considered.
- Measures to expand port services, such as bunkering, ship repairing, crew changes, and ships’ supplies. These are low-profile port services that require further investigation.

Table 8. Potential Economic Impacts of a New SEZ at Riche Terre

| | Time scale (years) | Site area (acres) | Investment (US\$ millions) | Revenues (US\$ millions p.a.) | Local value- added (US\$ millions p.a.) | Permanent jobs |
|------------------|-------------------------------|------------------------------|---------------------------------------|--|--|---------------------------|
| Phase 1 | 5–10 | 130 | 100–250 | 50–100 | 20–40 | 1,500–3,000 |
| Full development | 15–25 | 325 | 300–600 | 125–250 | 50–100 | 4,000–8,000 |

Source: BDO 2016.

- The development of Riche Terre Special Economic Zone (SEZ). Although this is not the direct responsibility of MPA, it could become an important center for port-related distribution activities, with strong backward and forward linkages into the rest of the economy (Table 8).
- Improved project evaluation procedures that will encourage faster processing of new proposals while ensuring that they still provide value for money, especially in respect of public sector investment.
- Design of tariff structures, leases, and concession agreements to keep as many of the benefits of new projects as possible within Mauritius.
- Improved monitoring of port performance, including better statistics integrated into a Port Management Information System (PMIS) and further upgrades to the Port Community IT system to reduce transaction costs and allow big-data analysis of cargo flows through the port.

For the ports sector, the future holds a mixture of opportunities and challenges. Seizing the former and addressing the latter can turn Mauritius into the Singapore of the South West Indian Ocean. In particular, there will be an increasing need to be well-informed about port and shipping developments elsewhere in the world, and for MPA to expand its role from that of a landlord port authority into a facilitator of economic development with a leadership role within a cluster of broadly-based port-related activities—as is currently happening in progressive European ports such as Rotterdam.

Emerging Ocean Sectors: Energy

As Mauritius looks for ways to meet its commitments to the UN Sustainable Development Goals and national targets for renewable energy, encouraging the use of renewable and clean energy to reduce the country's dependence on fossil fuels and decrease greenhouse gas (GHG) emissions, ocean-renewable energy technology (O-RET) is being explored as a promising option. The country has a total area of close to 2 million square kilometers of Exclusive Economic Zone (EEZ)

and is geographically well positioned to harness ocean energy, in the form of offshore wind, ocean wave, ocean current, ocean thermal, and ocean saline energy. Currently, the Mauritian energy sector is carbon intensive and dependent upon imports such as oil and coal. Nationally, the power sector fuel input is split between 20 percent renewable bagasse, 26 percent oil, and 54 percent coal. Just over 5 percent of generation is from hydro, and small quantities of electricity are generated by wind and waste (CEB 2014; World Bank 2015). Coal is cheap, imported, and GHG-intensive. It is the lowest-cost option for further expansion of the power system (OECD 2015).

The potential expansion of the energy system is split into conventional land-based and new ocean-based options. Recent national analyses indicated that the renewable options—which include bagasse, wind, solar, and hydro power, but not O-RET—might contribute as much as 35 percent by 2030 (Dhununjoy and Ramparsad 2015; Soonarane 2016)). Wind and solar energy are expected to play an increasingly important role, but they are intermittent and will require other power plants to “balance” the system, the grid to be strengthened, and market rules to change. Globally, the use of offshore wind power is growing—with one recent study noting that in 2015 the European Union (EU) represented 14 percent of the total wind power installations, up 4 percent from the previous year; by 2020, present capacity is expected to grow threefold (Khoodaruth et al. 2017).

Ocean renewable energy technology, or O-RET, is an emerging technology and could make a significant contribution to reducing dependency on imported fuels. How much of a role can O-RET play in supplying energy in Mauritius? At this point, the newly launched Mauritius Renewable Energy Agency (MARENA) is actively coordinating and promoting investment to harness the potential of O-RET, and activities are accelerating (Box 3).

This analysis assesses the medium to longer-term potential of O-RET using the cost minimizing Open Source energy Modelling System (OSeMOSYS) and considering different assumptions of key exogenous variables such as carbon pricing and efficiency gains driven by technological progress. Of the options available to Mauritius, three stand out, as follows:

- ***Deep water ocean cooling.*** This is a cost competitive technology, with current application focused on buildings with central chiller systems, close to deep water. A pilot in Port Louis is being considered that might reduce electricity demand by 2 to 4 percent. The process involves extracting deep cold ocean water and using it to chill water that, in turn, cools air in modified central air-chillers. Note, however,

Box 3. A Snapshot of Government Steps to Support Renewable Energy

A renewable energy agency. Under the Ministry of Energy (MOE), the Mauritius Renewable Energy Agency (MARENA) is synthesizing analysis to inform national renewable energy technologies targets, grid integration, and the role of the ocean. To assist integration, a document setting up norms and standards for the importation, installation, maintenance, and recycling of RET devices has been drafted.

Promotion of renewables. Recent efforts include funding photovoltaic farm deployment (such as a 15 MW facility in 2014), net-metering, and deployment of subsidies for photovoltaic under green energy schemes (Mauritius 2017). Seed funding for wave based mini-grid generation has been attracted. Green Climate Fund support for the operationalization of MARENA and improving the readiness of the electricity grid to receive greater quantities of distributed renewable energy generation has also been secured (GCF, n.d.).

Bilateral wave energy collaboration. Collaboration with Australia on wave energy development is expected to yield an actionable wave sector development roadmap. For wind, a call for an expression of interest in a 10–20 MW offshore farm is being drafted. Given growth potential in wind, wave, and deep ocean water applications (DOWAs), an ocean technology incubator has been identified as a facility to be jointly developed with the Central Electricity Board (CEB).

A regional wave database. The Mauritius Oceanography Institute (MOI) has developed a referential wave database for the entire Indian Ocean Commission (IOC) region. It has collaboratively deployed wave observation buoys and undertaken extensive satellite-based assessments. Being situated in a location with limited coral barrier, it intends to demonstrate wave potential with a small, low-cost pilot plant during 2017. It has also been the recipient of requests for information on water temperature profiles by potential ocean thermal energy conversion (OTEC) project developers.

that access to a cold water stream has multiple potential uses—such as for the cooling of surface ICT data-centers and improving the efficiency of industrial freezing, aquaculture (like abalone farming) thalasso, bottling, and others. These non-air-conditioning uses may increase the revenue and provide a space for new product development. It is assumed that with dynamic expansion, as much as 4 percent¹ of power demand may be reduced by taking advantage of DOWA. Related options not included, which may hold future potential, include deep water pumped storage (*Economist* 2016) and OTEC electricity generation.

¹ This is expert judgment, based on an assessment that at least 15 percent of the island's commercial and industrial energy is used for cooling (AFD 2012) and assuming that as much as 30 percent might be captured by DOWA. The percentage cooling is likely to rise with increased air-conditioning and processing requirements. Clearly, however, a deeper analysis would need to be made around the potential spatial evolution of cooling demand. For example, if low cost district cooling were available, it would likely attract activities with high cooling requirements.

- **Offshore wind.** At present this is not cost-competitive compared to producing electricity from coal or even land-based wind (although the latter is restricted by limited siting space). But it could become competitive if costs were to drop; or if reduction of emissions were to be incentivized through a carbon market. One possible technology is fixed turbines, which are cheaper (per kW) but require shallow water, which exists in and around the lagoon. If this technology were adopted, careful marine spatial planning (MSP) would be required to trade off social, environmental, and economic considerations. The other possible technology is floating turbines, which can be situated further from land; however, they are expensive and the technology is immature (Martin n.d.).
- **Wave.** The potential for wave appears high, although it is not economic at present. However, it has advantages. The electricity that this technology provides is not as intermittent as wind.² In addition, while the technology is immature, its costs are decreasing, and it is subject to aggressive learning. Wave could become economic if paired with carbon finance. Some companies are developing pilot sites internationally—and Mauritius may be an excellent site for a highly subsidized pilot (CWE 2016).

O-RET technologies that were not analyzed in the model scenarios, but are worth noting, include: (i) use of algae-based biofuel; this appears to hold potential, but recent estimates indicate important uncertainties concerning its economic potential (IRENA 2016a); (ii) electricity generation from OTEC; the technology is still in its infancy and expensive, and existing demonstration projects are small³; and (iii) desalination of

² The consistency of wave energy results from the ability of waves to travel long distances with little loss of energy. This means that many sites for wave farms will be receiving significant swell waves created by winds out to sea, even when there is little or no local wind. This extra persistence of swell waves gives wave energy a significant advantage over wind energy. Wave energy is also more forecastable than wind energy, allowing for easier integration into power grids. Typically, wave sizes can be accurately forecast three to five days in advance (McArthur and Brekken 2010).

³ By 2016, the largest was a 0.1 MW plant in Honolulu, which was built at a reported cost of more than \$5 million, about 50 percent higher than the current cost of wave energy (Vyawahare 2015). At this point, leading organizations like the International Energy Agency do not yet include current or projected costs of OTEC power generation in their reference cost projection publication (IEA 2016), but costs may fall quickly as deployment increases. China is building a 10 MW machine on Hainan island, and the associated scale and learning may lead to significant cost decreases (Power Technology n.d.). A watching brief should be kept on the technology and its potential in Mauritian waters.

Table 9. Three Development Scenarios for Expansion of Marine Energy

| Technology | Metric | Baseline ^a | Existing development plans | Additional development options |
|---------------|---|-----------------------|----------------------------|--------------------------------|
| DOWA | Share of electricity demand displaced by 2030 | 0% | 1% | 4% |
| Offshore wind | Share of electricity generated by 2030 | 0% | 2% | 19% |
| Wave energy | Share of electricity generated by 2030 | 0% | 1% | 8% |

Note: (a) The baseline scenario includes a high level of land-based renewable energy technologies – 8 percent wind, 17 percent bagasse, and 4 percent photovoltaic by 2025; but no marine-based energy.

ocean water; this is becoming increasingly important as a use of electricity that can be switched on and off to match the intermittency of variable RET (including O-RET), and demand for it is increasing.

Combining these with other options available for energy sector expansion, the analysis describes two development scenarios. One reflects options for O-RET development already identified; and the second one (“additional development options”) focuses on a plausible upper end of expansion (Table 9).

Our results show that currently DOWA holds the greatest economic potential, already being explored for air conditioning in Port Louis. Next, offshore wind shows extensive potential with appropriate concessional finance (such as carbon financing), which would likely only need to be modest thanks to rapid cost and performance improvement. Wave energy, on the other hand, would require higher levels of supporting finance. The modeling suggests that both scenarios are technically feasible and are likely to generate sizable economywide benefits, with benefit-cost ratios well in excess of 2 (Table 10). The more ambitious scenario also has a high pay-off in terms of employment generated per unit of investment. This is due in part to the prevalence of the higher labor intensity sectors (wind and wave) and in part to the fact that the optimistic additional-development-options scenario is more intensive in construction work.

In addition to the growth and employment benefits, expanding the use of marine energy can reduce the country’s dependence on fossil fuels (especially coal) and lower its GHG emissions—with potential import reductions of 3 to 19 percent and GHG emissions reductions of 3 to 18 percent through O-RET deployment (Figure 4). These benefits will also assist Mauritius in meeting commitments made under the UN Sustainable Development Goals and other agreements.

In sum, the proposed DOWA project should be started, pursuing at the same time an audit of the costs (and benefits) and further development of the appropriate supporting policy. And it would make economic sense for Mauritius to position itself as a desired location for

Table 10. Ocean Energy Development Scenarios (Present values at 5% discount rate)

| Development scenario | Total investment cost (US\$ millions) | | Financing (US\$ millions) | | | Economywide measures of worth ^a | | |
|--------------------------------|---------------------------------------|---------------|---------------------------|----------------|----------|--|------|---------------------------|
| | Total cost | Present Value | Public Sector | Private Sector | Combined | NPV value added (US\$ millions) | B/C | Jobs created ^b |
| Existing development plans | 152 | 127 | — | — | 152.0 | 239 | 2.88 | 476 |
| Additional development options | 619.5 | 463.9 | — | — | 619.5 | 666.2 | 2.44 | 5,472 |

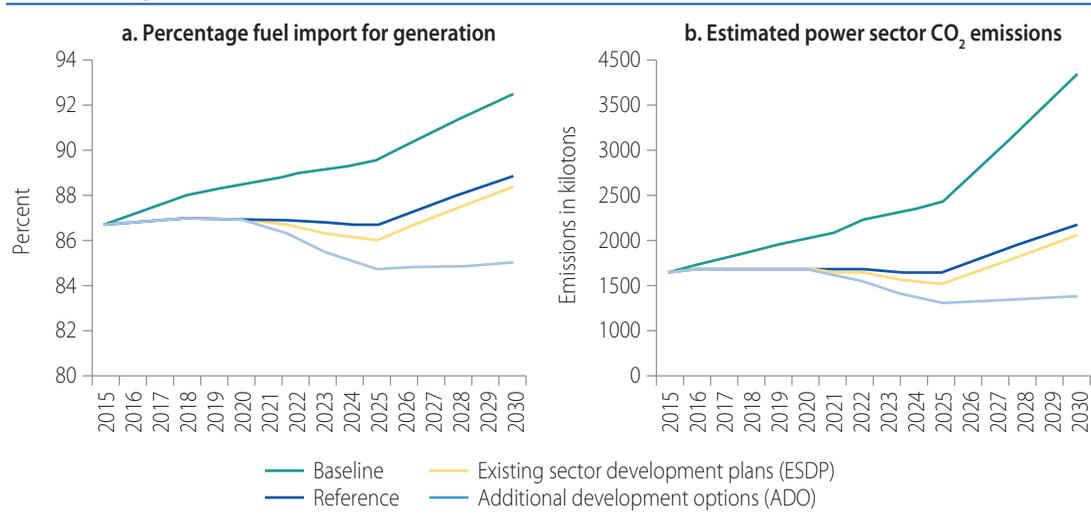
Source: World Bank analysis.

Notes: (a) The merits of the development scenarios are assessed only from the point of view of the economy as a whole. At the project level, the projects are viable to the extent that an adequate rate of remuneration of capital is built into system of electricity tariffs. (b) Job creation is defined as the production of a labor income stream that would support a worker for 20 years. BC stands for benefit-cost ratio.

pilot demonstration projects of the other technologies, namely offshore wind and wave energy, that could later be scaled up because they would attract external co-financing from developers and others.

For large deployment of O-RET to happen, there will need to be a combination of clear longer-term vision, human capacity development, standards adoption, comprehensive tariffs, and targeted opportunities to attract private investment and realize the sector’s potential. This would include but not be limited to:

Figure 4. Projected Fuel Importation and CO₂ Emissions for the Power Sector, by Year, 2015–30



Source: World Bank calculations based on AFD (2012), CEB (2014), Duke (2016), Howells et al (2011), IRENA (2016), Mauritius and IRENA (2015a, 2016b), OECD (2015), OffshoreWind.biz. (n.d.), Saboori et al (2011), World Bank (2015, 2016), and Vyawahare (2015); as well as personal communication with Emmanuel Andre, CEO of SOTRAVIC, 2016.

- Establishing an integrated energy planning process through an inter-sector coordination panel meeting regularly, so as to accommodate changes in costs and circumstances;
- Carrying out a grid stability and ancillary service analysis to determine technical requirements for increased RET penetration on the island;
- Developing an appropriate market design to facilitate high RET penetrations (and associated ancillary service remuneration) in the Mauritian context;
- Developing new risk mitigating business models to support DOWA and energy efficiency, within the context of the market re-design; and
- Undertaking an assessment of potential concessionary finance and support mechanisms available to low carbon O-RET pilot (and potentially scaled-up) projects.

In the short term, a pragmatic master plan might involve a limited set of pilot demonstration projects that might later be scaled up. Those chosen should show positive benefit-cost ratios, or high potential of longer-term benefits. Offshore wind and wave pilots should be considered on a case-by-case basis, following negotiations with suppliers and a full assessment of the integration, supplementary revenues, and in-kind contributions associated with setting up demonstration projects.

Emerging Ocean Sectors: ICT

The ICT sector now contributes some 5.6 percent of national GDP, of which perhaps just under 10 percent is related in some way to the OE. But there are strong synergies between the OE and the ICT sector that, if properly exploited, can contribute to both growing the ICT sector as a whole and to reinforcing its ocean component. These complementarities go in both directions. On the one hand, ocean resources enable the ICT sector to function and offer opportunities for ICT market expansion (Box 4) through undersea cables, the provision of cooling services for off-shore data centers, and new market opportunities in the area of off-shore communications services to mariners (mainly leisure users, but also coastal fisheries). On the other hand, ICT applications can also be a key ingredient in the development of many ocean activities (Table 11), especially in terms of enhancing the future competitiveness of Mauritius.

At the moment, there are investment and policy constraints that prevent Mauritius from fully taking advantage of the potential synergies. For example, limits to competition in the access to international bandwidth received through a submarine cable results in relatively poor internet experience for Mauritian consumers (Table 12). Specifically,

Box 4. How the Ocean Supports ICT Development

The ocean supports the ICT sector in three main ways, all of which are based on investing in infrastructure directly in the ICT sector and using Mauritius's island location to generate revenue and future growth.

The first linkage is through the **global network of undersea cables**, which provide the "first mile" of the internet to a majority of the world's population. Mauritius was an early beneficiary of such a global network when the Cable and Wireless Trans Indian Ocean cable reached Mauritius (from Durban) and Rodrigues (from Zanzibar) in 1901. In more recent times, the first fiber optic cable (SAFE) arrived in 2002, and a second landing came in 2009 (LION), although these cables are now limited by capacity and competitive constraints. Two further cables are planned, and Mauritius is open to further investment, but there is perhaps a need for greater ambition.

A second potentially important linkage comes from the use of **offshore data centers**. Several companies already have data centers on oceangoing ships, such as the Google Barges,^a and now Microsoft has gone a step further by experimenting in Project Natick^b with an undersea data center, at a depth of 30 meters in trials. The logic is to reduce costs for space rental and cooling, both of which make up a significant part of the budget for a data center. Mauritius, with its abundance of cold, deep water close to shore, is an obvious candidate to host such floating and underwater data centers.

Thirdly, **cellular mobile services**, which constitute the largest segment of the ICT sector worldwide, can be extended offshore to provide services to mariners, mainly leisure users but also coastal fisheries. Mauritius's success in being one of the first countries in Africa to complete the digital switchover from analogue TV broadcasting has released a large swathe of valuable spectrum (below 1 GHz), much of which is earmarked for mobile cellular use. The future allocation of this spectrum, which is particularly useful for offshore services because of its long range and low attenuation, could generate significant income, especially if allocated using market mechanisms (such as auctions).

^a See https://en.wikipedia.org/wiki/Google_barges.

^b See <http://natick.research.microsoft.com/>.

international bandwidth is not being converted to higher speeds for users because of a low level of competitive efficiency compared to other countries using the same cables.

This book identifies illustrative scenarios of investment to strengthen both ends of the OE/ ICT synergistic relationship, focusing on expansion of the capacity of submarine cables, on the development of offshore data storage, on the market for off-shore mobile services, and on selected marine ICT applications. The scope of the assessment is limited to development options where sufficient information could be obtained during the timeframe of the study.

The main opportunity lies in the expansion of Mauritius's network of international undersea communications cables. There are great benefits in having a coastline for access to fiber-optic submarine cables. In Africa, the average price per megabit per second (Mbit/s) of bandwidth per month is more than US\$200 cheaper in coastal countries than in land-locked countries. Mauritius is currently served by two undersea cables

Table 11. Downstream ICT Applications Supporting the Ocean Economy: Selected Examples

| Ocean clusters | Examples of ICT applications |
|--|---|
| Offshore wind, tidal, and wave energy | Telecommunications, banking, financial services and insurance, fintech, IOT. |
| Marine aquaculture | Banking, financial services and insurance, IT application development and maintenance support. |
| Marine biotechnology | Analytics and big data, app development, content and mobility, cloud services. |
| Ocean-related tourism and leisure activities | Banking, financial services and insurance, IT application development and maintenance support; business process outsourcing (nonvoice and voice). |
| Ocean monitoring, control, and surveillance | Telecommunications, banking, financial services and insurance, IT application development and maintenance support, business process outsourcing (nonvoice and voice), fintech, analytics and big data, app development, content and mobility, cloud services. |
| Port services | Telecommunications, banking, financial services and insurance, IT application development and maintenance support, business process outsourcing (nonvoice and voice), fintech, analytics and big data, content and mobility, cloud services. |
| Ship registration, monitoring, and control | Analytics and big data, app development, content and mobility, cloud services; development of a full-fledged open ship registry should help with the ripple effect of ICT in the wider marine economy. |
| Marine sensor networks | Using existing marine furniture (such as meteorological stations and buoys) to support a network of sensors that could be used, for instance, for early warning of the arrival of tsunamis. |
| Ocean meteorology | The setting up of a Regional Ocean Modelling System should improve regional ocean climate forecasting, as well as general weather forecasting. |

Source: World Bank, based on PMO (2013).

Note: Similar ICT services would also apply to tourism and leisure.

(SAFE and LION-1) (Map 1), and it hosts many meetings of international cable consortia (notably, Seacom and Liquid Telecom). But the existing cables suffer from drawbacks and constraints, hampering Mauritius' ability to fulfill its true potential either as an international connectivity hub for the southern Indian Ocean or as an exporter of ICT-based services, such as in business process outsourcing (BPO). Concerning the two current undersea cables, the following is relevant:

Table 12. Internet Bandwidth Speed and Efficiency for Mauritius and Selected Countries

| Country | Population | International bandwidth (Gbit/second) | Bandwidth per pop. (kbit/second) | Average speed (Mbit/second) | Competitive Efficiency Index |
|--------------|---------------|---------------------------------------|----------------------------------|-----------------------------|------------------------------|
| Mauritius | 1,249,151 | 41.3 | 33.08 | 5.6 | 0.17 |
| Kenya | 45,545,980 | 228.3 | 5.01 | 7.3 | 1.46 |
| India | 1,267,401,849 | 3,014.3 | 2.38 | 3.5 | 1.47 |
| South Africa | 53,139,528 | 512.5 | 9.65 | 6.5 | 0.67 |

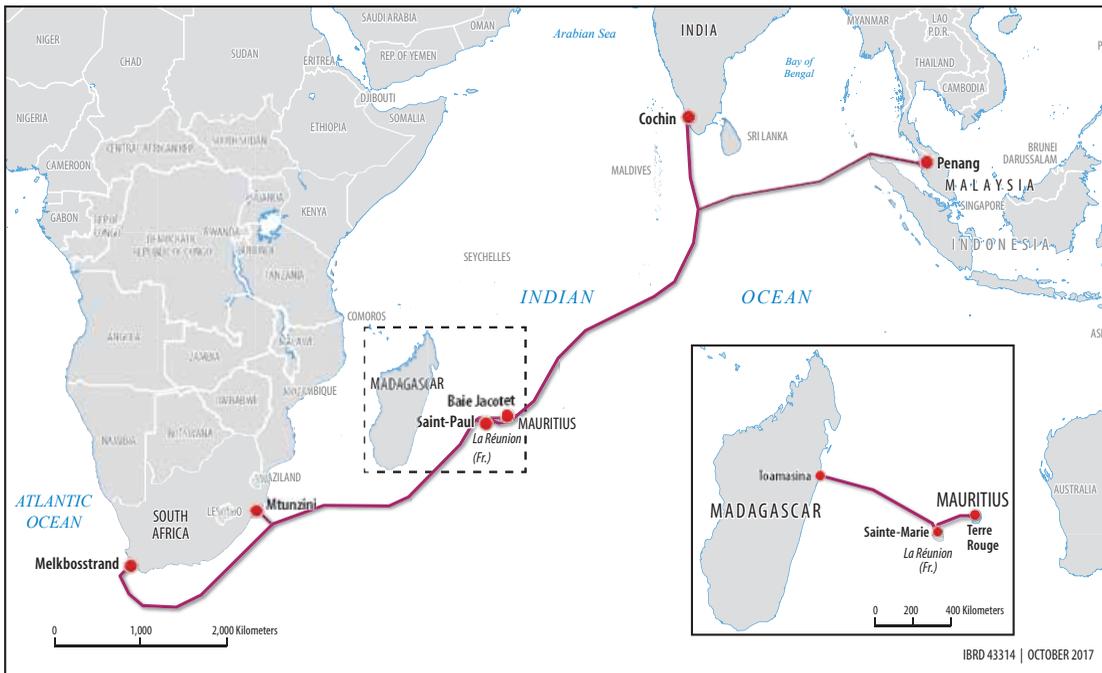
Source: World Bank analysis, based on data from TeleGeography, Akamai, and World Bank.

Note: The Competitive Efficiency Index is a measure of how well higher international capacity is converted into faster speeds for users.

- **SAFE cable (South Africa – Far East).** This was one of the first fiber optic networks to serve Africa when it was launched in April 2002. It joins South Africa with the SAT-3 cable, of the same vintage, that links to West Africa and Europe. It is a “club cable”—that is, owned by a consortium of some 30 telecom operators, of which Mauritius Telecom, is one—but it is not an “open access” cable, in the sense that capacity can only be sold through its members, which restricts scope for price competition. Furthermore, it represents the technology of its day, carrying only 2 lit (that is, usable) fiber pairs with a maximum capacity of 440 Gbit/s. It cannot easily be upgraded, and it is approaching the end of its expected lifespan.
- **LION-1 cable (Lower Indian Ocean Network).** This is a more recent cable (in service since November 2009) with a much greater potential capacity, 1,280 Gbit/s, though as of mid-2016 only 20 Gbit/s (1.6 percent) is actually lit. It is effectively a proprietary owner’s cable, belonging to Orange (formerly France Telecom), though the ownership is formally divided with its subsidiaries, Telecom Mauritius and Orange Madagascar. LION-1 connects to the LION-2 cable, from a branching unit off the coast of Madagascar, and from there to Mayotte and Nairobi, where it links with four other cables. The LION-1 cable has landfall in Terre Rouge, in the north of the island. Thus, the only connection between the SAFE and LION-1 cables is via Telecom Mauritius’s domestic network, enabling Mauritius Telecom to maintain its stranglehold over prices. Furthermore, even though EMTEL (Mauritius’s second operator) has purchased capacity on LION-1, the terms of its license prevent it from increasing that capacity. Thus, LION-1 is not a true open-access cable and it brings very little price competition to Mauritius.

As for internet bandwidth, Mauritius ranks third in Sub-Saharan Africa (after Ghana and Malawi) for having the lowest prices. However, its US\$26.09 per Mbit/s monthly price is still much higher than international competitors for OE activities, especially when expressed in terms of purchasing power parities (US\$46.77). By contrast, economies such as Hong Kong (a shipping and port competitor) offer rates as low as US\$1.06 per Mbit/s per month, and the Bahamas (a tourism competitor) offer rates of US\$3.92—while even Vietnam (a fisheries and seafood competitor) is able to offer rates at around US\$26.06 per month, or just over half the price of Mauritius.

The challenge to Mauritius is to develop a new generation of under-sea cables that will service its aspirations to be a global player in the information society. This requires a global rather than a purely regional perspective.

Map 1. Location of Mauritius' Submarine Cables

Source: TeleGeography.

A second area of potential growth is in pilot programs for offshore data centers that are either undersea or floating. The advantage here is that deep ocean water can provide low-cost cooling for the huge amounts of power consumed by data centers. This is an approach that is both “green” (using less energy) and “blue” (making the best use of Mauritius’s natural resources).

There are also a number of other options that were not possible to include in the analysis, particularly in the domain of ICT applications in support of OE clusters. Several of them appear promising, though at relatively small scale, and could be examined further through separate, follow-on work (Box 5).

The results of the CGE analysis reported in Table 13 refer to an optimistic development scenario. This scenario includes a more ambitious expansion of submarine cable capacity, investment in pilot programs for deep-water data storage, auctioning of spectrum for offshore mobile communication, and various initiatives to boost downstream ICT applications in selected OE clusters (like GPS tracking, ship registries, radio-frequency identification (RFID) monitoring, and safety of life services).

They suggest that an investment of some US\$300 million could deliver a considerable benefit/cost ratio for the economy as a whole (in

Box 5. Using Big Data to Support Trade Logistics

An informal working group formed by the experts of the Ministry of Ocean Economy, Ministry of Finance, and Statistics Mauritius has been consulting on the design of a major program on Big Data and Maritime Digitization. This appears to be a promising initiative, and the government may wish to formalize the arrangement and further develop the program, which would help the transition from a mere industrialization to an innovation policy centered on the OE. The program would include activities on: (i) ocean-going research- and marine-security vessels; (ii) satellite remote sensing, communications, and global positioning; (iii) submersible and fixed platforms and systems; (iv) in-situ sensors; (v) modelling and computational infrastructure; and (vi) “big data” storage and management. It would generate ocean monitoring, security, and surveillance components, encompassing a mix of diverse sectorial infrastructures that serve a variety of purposes.

The program could cover a range of modern services that can be digitized to support global trading, which is constantly expanding—such as the application of big data in the digitalization of international trade and supply chain data in Africa (emerging continent) and the China/Asia sourcing region for the trading/business community worldwide and locally. It could also expand to digitalization of the remaining ocean clusters’ scientific and technical data to better understand their challenges and opportunities.

excess of 3.6) and the potential to create some 3,500 permanent jobs. The benefits of the investment are larger from the economy-wide perspective than from the project level one (which exhibits a benefit/cost ratio below 2). This is due to several reasons:

- The ICT projects all include public good components in the form of infrastructure that can be shared by virtually all sectors and economic agents (such as the submarine cables).
- The construction activities activate several other sectors through their linkages with the rest of the economy.
- The telecommunications sector, the ultimate destination of the investment, has multiple important linkages with most service activities, especially financial services and tourism.

A constrained availability of skilled labor may be particularly important for the ICT sector. A sensitivity analysis conducted under an assumption of lower elasticity of labor supply to wage suggests that the investment program identified would still be worth pursuing from the point of view of the economy as a whole, but it would deliver lower economic returns and fewer jobs.

Table 13. Economywide and Project-level Worth of ICT Investment Under Two Scenarios

| | Economywide worth | | | | | Project-level worth | | | |
|-----------------------------------|--------------------------------|---|-------------------------|---------------------|------|---------------------------|-----------------------|---------------------|------|
| | PV value added (US\$ millions) | Total investment cost and incremental O/M (US\$ millions) | PV cost (US\$ millions) | NPV (US\$ millions) | B/C | Job creation ^a | PV Va (US\$ millions) | NPV (US\$ millions) | B/C |
| Optimistic scenario | 939 | 302 | 259 | 637 | 3.62 | 3,478 | 479 | 91 | 1.84 |
| Constrained scenario ^b | 537 | 302 | 259 | 278 | 2.07 | 2,243 | | | |

Note: (a) Job creation is defined as the number of labor income streams that would support a worker for 20 years. (b) The simulation of the constrained scenario is based on the hypothesis that the elasticity of supply of workers with more than secondary and with tertiary education are, respectively, 1 percent and 0.1 percent in the short term, so that either an important increase in the education budget will have to be undertaken or a substantial amount of skilled labor will have to be imported (or both).

In summary, ICT could play a much bigger role in transforming the Mauritian economy, but for that to happen, there will need to be a well thought out strategy of stepped-up investments and progressive policy reforms. A top priority is boosting investment in submarine cables, while rethinking their geopolitical orientations—that is, whether the focus should be regional (the current case) or global in ambition. Mauritius also needs to invest more in its domestic backbone network (by expanding domestic fiber optic capacity on an open access basis and ensuring the existing Internet Exchange Point is better utilized) to ensure greater connectivity—and explore new areas like hosting floating and underwater data centers.

But new investments must be backed by policy reforms, led by ICTA (the ICT regulatory agency), to improve the sector’s competitiveness—ranging from privatizing the government’s majority share in Mauritius Telecom to encouraging measures (like local loop unbundling) to deliver high-speed internet services at an affordable price.

Making the Ocean Economy Last

What needs to happen to ensure the longer-term sustainability of the OE? Any OE expansion is likely to entail larger pressure on the environment, including pollution of water and coastlines, in turn affecting coral reefs, lagoon habitats, and biodiversity. Coastal erosion resulting from land use change and climate variability and change is also increasing. A more active use of the OE requires technical and institutional mechanisms to reconcile, across sectors and time, competing claims over ocean resources; and to increase the resilience of ocean and coastal resources to climate variability and change.

Marine Spatial Planning

As Mauritius weighs how to balance OE development with conserving the very ocean on which that development depends, a relatively new management tool—marine spatial planning (MSP)—stands out as especially promising to address the challenge. The expansion of the OE will necessarily require improved management of the coastal and marine environment, reduced pressures on key natural resources, and ensuring long-term sustainability of natural capital or ecosystem services

In recognition of this need, the Prime Minister’s Office announced in December 2016 the intention to develop an MSP for the country’s EEZ, to address increasing demand for marine space, in particular, fisheries and aquaculture, tourism, and leisure. Since the MSP process is in its early stages, there is an opportunity to build on international experiences to inform the next steps, including definition of objectives, the geographic boundary of the plan, expected timeline of results, data to be gathered, modalities of stakeholder involvement, and implementation.

An MSP is different from the usual way that decisions are made in the marine environment in that it is an integrated process to reconcile multiple ecological, economic, and social objectives. UNESCO defines it as “a practical way to create and establish a more rational organization of the use of marine space and the interactions between its uses, to balance demands for development with the need to protect marine ecosystems, and to achieve social and economic objectives in an open participatory and planned way.”(Ehler and Douvere, 2009). MSP is usually specified through a political process and involves stakeholder participation.

Globally, 22 countries have completed, approved, or implemented MSPs, and plans are under way in 12 more countries. These plans range from unregulated MSPs that provide policy direction to regulated ones that are supported by legislation or regulations. One of the key lessons learned over the last 10 years is that there are tangible benefits to multi-objective, integrated MSPs over single-sector management plans. Benefits include reduced permitting times for new development; increased coordination between government agencies, resulting in reduced time for decision-making; and improved stakeholder buy-in for new marine protected areas and management reforms.

In Mauritius, the benefits of a comprehensive approach are particularly evident, where several drivers of pressure on the marine environment will need to be addressed and managed with strict policies and regulations to ensure that the financial investment in the OE is supported by a healthy ocean. Of greatest importance are restoring coral reefs to ensure adequate coastal protection from cyclones and to support lagoon fisheries; restoring mangroves and addressing shoreline

hardening to control beach erosion; improving water quality by controlling pollution of the marine environment from wastewater and agricultural run-off; and ensuring lasting results by using robust stakeholder engagement processes to site new marine uses like aquaculture, renewable energy, and deep sea mining to avoid or minimize conflicts with existing uses.

Mauritius is well positioned to get the MPS process going. A recent high-level analysis of the feasibility of creating one for Mauritius finds that eight of nine key enabling conditions are present to some degree (Table 14).

Indeed, the country's preparedness is relatively strong in that there are relevant legal instruments that may apply to an MSP, spatial data and scientific institutions that can develop or create new data, and government champions. There is also an urgency in the need to address land-based sources of pollution, protect the coastal areas from erosion, and allocate space for new activities—against a backdrop of overlapping authorities that manage the coastal area.

What is the best way for Mauritius to proceed with planning and implementing an MSP? An overarching, strategic decision to be made

Table 14. High-level Analysis of Enabling Conditions for MSP in Mauritius

| Criteria | Analysis | Summary |
|--|----------|---|
| Driver | Present | Aquaculture, marine renewable energy, deep sea mineral exploration, coastal beach erosion, land-based pollution, climate-change adaptation |
| Government authority | Present | Prime Minister's Office (PMO), Maritime Zones Act; Ministry of Environment, Coastal Zone Management Plan |
| Government champion | Present | PMO and Ministry of Environment |
| Financial resources | Unknown | Government (total funding need not known) |
| Local Staff capacity | Present | Government, institutes, academia, and consultants with experience in land-use planning, data management, geographic information systems, policy and stakeholder engagement |
| Spatial data | Present | Government, Mauritius Oceanographic Institute, University of Mauritius, and Mauritius Fisheries Institute retain spatial data. Needs assessment and gap analysis need to be undertaken. |
| Scientific information and local knowledge | Present | Numerous published scientific studies for the marine environment in Mauritius. Stakeholders have strong local knowledge. |
| Legal instruments | Present | Maritime Zones Act is a key piece of legislation for the authority to plan. At least 15 Acts or Regulations pertaining to MSP could be applied. New MSP legislation may need to be developed. |
| Stakeholder consultations | Present | Enthusiasm for participation. Some sectors have associations. Needs assessment for capacity and engagement support. |

Source: The Nature Conservancy/TNC Canada.

early in the process concerns the level of ambition of the MSP—for example, what will be accomplished, and how long will it take? Answering these questions is critical to the success of the process and will require careful selection of priority objectives, a governance framework for making decisions and receiving stakeholder input, and deciding upon the plan outputs. All of this needs to be considered within the context of available funding and capacity. There are two main options that can be considered with respect to these considerations, as follows.

Option 1: First, develop a high-level strategic framework for decision-making and management of marine economic sectors. The framework will guide development and future marine investments, identify the top environmental issues that need to be addressed, and identify future development that is likely to create spatial conflicts with existing uses. Next, implement and monitor the strategic plan for five years, revise and adapt where necessary, and then develop a spatial plan with zones and management considerations. During the five-year monitoring period, spatial data would be gathered, systematic conservation planning and other analyses would be undertaken to identify high priority conservation areas, stakeholder engagement would be organized and funded, and governance structures would be developed. Such an approach is similar to the one that Norway used to develop a comprehensive MSP. It has the advantage of ensuring that the decision-making framework is robust, tested, and adapted based on government and stakeholder feedback before the spatial planning begins. It also has the advantage that more spatial data are likely to be available in the second phase. It has the disadvantage that allocation of space for new activities might not occur for up to 10 years and the urgency of an MSP may be lost.

Option 2: Develop a decision-making framework and comprehensive zoning design simultaneously or sequentially, but without a period of adaptation prior to implementing the complete MSP. This approach has the advantage of planning for future activities within the next six years, planning for increased marine protection to meet the UN Convention of Biological Diversity 10 percent by 2020 goal, immediately starting to address climate change impacts, generating momentum with stakeholders without any disruptions, and completing the whole plan before undertaking monitoring and a five-year review. It has the disadvantage that spatial data may not be available for all decisions, and it may exceed resources available in the short-term (that is, more time might be needed for fundraising).

Challenges

Whichever option is chosen (and there are other possibilities as well), there are at least five challenges that should be tackled as the MSP process progresses in Mauritius.

Defining the role and responsibilities of each institution. There are a multiplicity of public sector agencies that are actively engaged in the marine space and that will need to find ways to cooperate effectively to advance the MSP process and ensure successful implementation. These include the Prime Minister's Office, the Ministry of Environment and Sustainable Development, the Ministry of Ocean Economy, MOI, the National Ocean Council (NOC), the University of Mauritius (UoM), and the Mauritius Research Council (MRC).

Upgrading the legal and regulatory framework. Despite the existence of no fewer than 25 Acts or other legal instruments in Mauritius that are relevant to MSP, there are key gaps that should be addressed in order to implement an MSP. These include the absence of a proper mechanism to resolve conflict among users of marine resources; the unclear definition in the 2007 Fisheries and Marine Resources Act of the characteristics a particular area requires to have the status of a Marine Protected Area; and the framework for integrating coastal zone management.

Coordination with Rodrigues. This relates to the fact that back in 2007, Rodrigues took the steps to protect its marine ecosystem through the creation of four marine reserves (no-take zones) in the north of the island, and it has been engaged in multi-sector marine planning.

Joint Management Area with Seychelles on the Mascarene Plateau. There are ongoing discussions by Seychelles and Mauritius for a political and strategic framework for decision-making and management of the Joint Management Area (JMA).⁴ While this is a distinct institutional and political planning process from either the Mauritius or Seychelles MSP, it will be important to figure out effective coordination mechanisms and planning objectives, because of crucial information that may influence the location of zones adjacent to the JMA and allowable activities within the national EEZs.

⁴ Mauritius-Seychelles Joint Commission of the Extended Continental Shelf, draft Strategic Plan 2016–2018.

International pelagic resources. Several pelagic resources (notably tuna) are managed jointly with international bodies and also require regional coordination (for example, the Indian Ocean Tuna Commission). Pelagic resources require careful consideration in terms of an MSP process because additional stakeholders may need to be involved in discussions about objectives, conservation targets, zone locations, and allowable uses, and the timeline for those discussions may be affected by other agreements.

Making an MSP happen in Mauritius will involve deciding on the process structure (options 1 and 2 above) and then developing a budget, and identifying financial and staff resources. An MSP can be thought of as occurring in several phases, each with approximate timelines, such that it can take 4 to 10 years for a complete MSP. The timing depends on whether phases are done sequentially or simultaneously:

- Pre-planning: identify need, authority, financial support, and spatial boundary—1 to 2 years.
- Phase 1: MSP as a framework for decision-making—2 to 3 years.
- Phase 2: MSP as a zoning design and approved legislation—3 to 5 years.

One of the lessons learned from other MSP processes is the need to carefully think through implementation plans, including applicable regulations, financing, timing, and governance structures, and building these into the work plan from day one.

In sum, an integrated and comprehensive MSP is an important strategy for expanding the OE in Mauritius in an orderly fashion, including proper siting of new activities and addressing environmental pressures from traditional marine sectors. An MSP should result in clear guidelines for developing across space emerging sectors (like marine renewable energy and aquaculture), thus providing the business certainty needed to attract investors to these industries and developing enduring mechanisms to resolve conflicts amongst users. Finally, an MSP process will necessarily engage stakeholders, bringing local knowledge and contributed information about social values into the design of the plan, which will increase buy-in and ownership of the plan for successful implementation of OE investments.

Climate Change

Climate change is likely to endanger much of the development potential of the OE in Mauritius. Important climate-related stressors include

sea-level rise (including increases in coastal erosion), tropical storm intensification (including storm surges and changes in wave dynamics), intensified rainfall patterns, increased temperatures, and ocean acidification (which can affect fishery resources). Table 15 lists the OE clusters and the climate change shocks and stressors most likely to pose a significant risk.

Building up a growing body of studies (Box 6), the Government of Mauritius has taken important steps already to interpret the relevant climate science for the island and the South West Indian Ocean region. In many cases, it has used this knowledge to better understand key physical effects, such as ocean acidification and the impact of sea temperature changes on fisheries resources. In a few cases, it has quantified and monetized these impacts. For example, Mauritius' Second National Communication states that over the last decade, 18,500 square meters of beach have eroded in Mauritius, land with a rental value conservatively estimated at MUR 1.2 million and an ecosystem and protection value of potentially millions of rupees more.

However, significant work remains to be done to gain a more comprehensive understanding of the full range of possible climate change impacts and to identify priority actions to buffer the OE from climate stressors and shocks.

This book contributes to a fuller understanding in two ways: (i) reviewing the latest projections on changes in temperature, precipitation, and intensity/frequency of extreme events such as intense storm rainfall and tropical cyclones; (ii) assessing, for the first time, the incremental economic impact of tropical cyclones, compared to historical climate patterns, using the CGE model developed for this book.

Latest projections. An analysis of the latest climate change scenarios shows that maximum daily temperatures in Mauritius are expected to rise significantly by mid-century—with the median changes in maximum daily temperatures under RCP4.5 (a high greenhouse gas mitigation effort scenario) and RCP8.5 (a low greenhouse gas mitigation effort scenario) reaching 1.3 and 1.7 degrees C, respectively. Localized precipitation projections through the year 2050 are highly variable, ranging from a decline of more than 25 percent to an increase of more than 25 percent, compared to historical rainfall. This variability results from uncertainties in global efforts to mitigate carbon emissions and in climate science. This stressor may be critically important to Mauritius, given that more intense rainfall could greatly exacerbate inland flood risks.

Moreover, a Mauritius-specific storm simulation modeling conducted for this book shows that climate change could also substantially increase

Box 6. Existing Studies on Climate Change Impacts in Mauritius

The impacts of climate change on the OE clusters have been previously studied in Mauritius and other similar contexts, and while several clusters are predicted to see large impacts of climate change with high confidence, impacts on other clusters require more research (Nurse et al. 2014).

Fishing, seafood processing, and aquaculture are vulnerable to: (i) coral bleaching leading to reduced fisheries production (Hoegh-Guldberg et al. 2014); (ii) ocean acidification affecting mollusk shell formation and the oyster and pearl industry (De Silva and Soto 2009); (iii) severe weather, erosion, and storm surge infrastructure damage (De Silva and Soto 2009); and (iv) changing species distribution induced by rising ocean temperatures (Nurse et al. 2014).

Threats to **seaport related activities** include damage to port infrastructure, change in navigability of access channels, and interruptions in business activities and movements (World Bank 2016). More frequent extreme weather events may disrupt complex supply chains, while sediment from coastal erosion may increase dredging costs (UNCTAD 2008). Thus, integrated investment, planning, and operation will be needed for ports to adapt (Becker et al. 2013).

The **tourism sector** may be impacted by water shortages exacerbated by rising temperatures and more variable rainfall (Mauritius 2012). Altered seasonality could impact the tourism industry via heat stress for tourists, increased cooling costs, changes in wildlife populations, and infectious diseases (MAIFS et al. 2012). And beach erosion is also a concern.

Other sectors of the economy, while potentially vulnerable to climate change, lack the needed historical evidence of impacts and research support. For example, while the most significant ocean warming has been observed at surface levels, deep ocean waters (700 to 2,000 meters) are also experiencing similar, yet less significant changes (Hoegh-Guldberg et al. 2014). However, the impact of climate change on deep sea environments is difficult to observe because of access issues and lack of long-term data (Smith, Jr. et al., 2009).

the rainfall (Figure 5), wind speed, and landfall patterns associated with tropical cyclones. As a result, we estimate that total tropical cyclone damage (from wind, storm surge, and inland flooding) in the worst-case climate scenario could increase by about a factor of two.

Virtually all storms would be stronger with climate change, and the frequency overall would also increase. An important result from this analysis is that the once-in-100-year storm, with climate change, could be characterized by peak wind speeds 30 km/hour higher than the historical baseline. For reference, Cyclone Hollanda, which struck Mauritius in 1994, was roughly a once-in-100-year storm—climate change would make that storm much more damaging.

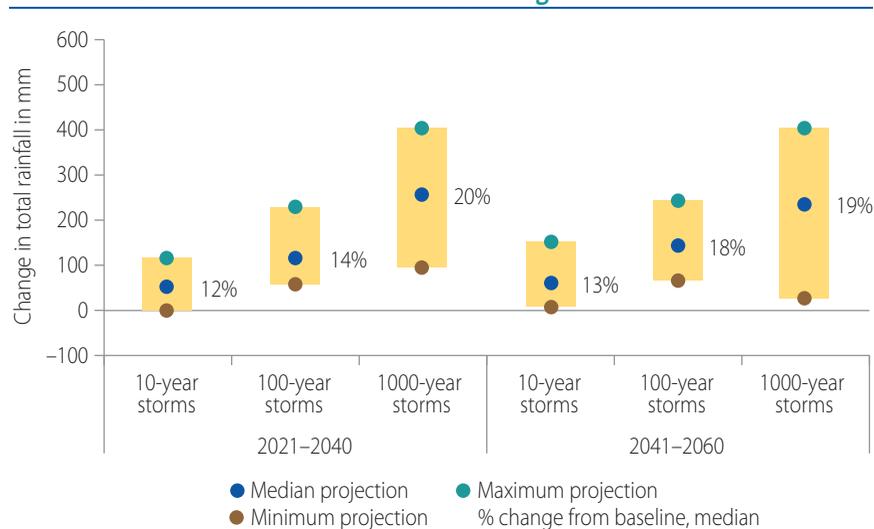
As a “deep-dive” illustration of just one impact of climate change, the economic effects of changes in cyclone strikes on Mauritius are shown to reduce the cumulative GDP (in present value terms) by more than 10 percent by the end of a 40-year simulation period, relative to a scenario that simulates historical storm occurrence. In addition, if a single 100-year return period storm of the sort anticipated with climate change

Table 15. Potentially Vulnerable OE Clusters and Their Climate Change Shocks and Stressors

| OE clusters | Climate change shocks and stressors | | | | |
|--|-------------------------------------|--------------|-------------------|-----------------------------|--------------------|
| | Sea level rise | Storm surges | Tropical cyclones | Non-tropical Cyclone Floods | Other ^a |
| 1. Seabed Exploration for Hydrocarbon & Minerals | | | + | | + |
| 2. Fishing, Seafood Processing and Aquaculture | | | ++ | | ++ |
| 3. Deep Ocean Water Applications (DOWA) | | | | | + |
| 4. Marine Services: | | | | | |
| a. Marine Tourism and Leisure | ++ | ++ | ++ | ++ | ++ |
| b. Marine ICT | | | + | | |
| c. Marine Finance | | + | + | + | |
| d. Marine Biotechnology | | | | | + |
| e. Ship Registration | | | + | | |
| 5. Seaport-related Activities | ++ | ++ | ++ | + | |
| 6. Marine Renewable Energies | | | + | | |
| 7. Ocean Knowledge | + | | | | + |

Source: World Bank analysis.

Note: (a) Other shocks and stressors include ocean acidification, and ocean and air temperature change. + indicates potential for risk; ++ indicates demonstrated risk.

Figure 5. Projected Change in Total Storm Rainfall During Two Future Eras Under Intense Climate Change Scenario

Source: World Bank estimates based on a review of IPCC models.

Note: The figure shows the range of changes in rainfall associated with specific magnitudes of storms under future climate conditions, using six climate models whose results are published by the UN IPCC, relative to rainfall for comparable storms in the historic record. The results are presented for one global greenhouse gas emissions scenario, RCP 8.5, which is a higher emissions pathway. The edges of the box show the maximum and minimum projections, and the green triangle shows the median projection; the median value is shown as percent change from the baseline.

were to occur in the next 10 years, the effect would be to cause GDP to shrink for a time, and to reduce GDP growth rates by about 2 percentage points for at least the following five years. This simulation is based on the same CGE model used in Part A of this book to assess the OE's potential for boosting GDP for the entire Mauritius economy (Box 7).

The CGE simulations also show that while average annual losses to be expected under climate change are larger than the historic baseline, a potentially more significant change will be seen in the risk of rare but large-scale losses. For example, under current climate conditions, a storm or a combination of storms causing a loss of 7.5 percent of GDP (that is, a reduction of GDP compared to what would have happened with no cyclones) has, on average, a 10 percent probability of occurring; under climate change, this probability increases to 30 percent on average (Figure 6). This is because of the higher destructive power of cyclones with any given return period and/or because for any given intensity of impacts, cyclones are expected to happen more frequently.

Box 7. How the CGE Model Simulates the Impact of Climate Change

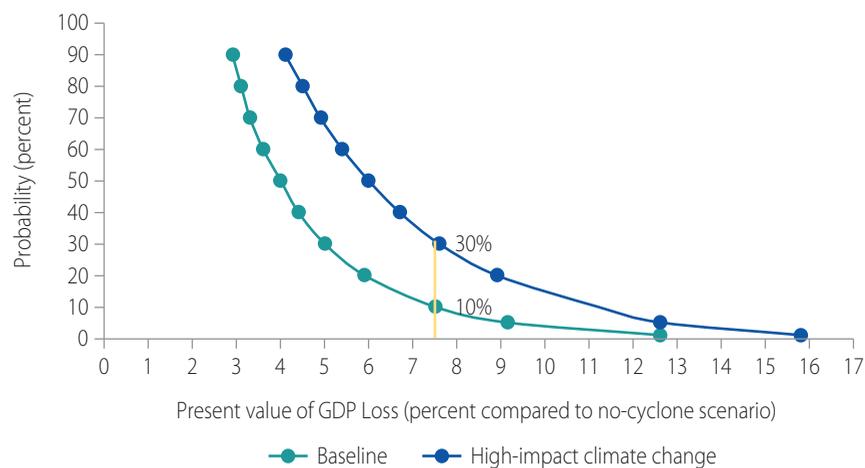
The CGE model incorporates storm damages as a fraction of the capital assets destroyed in a particular sector as a result of storm strike. Among the extreme meteorological events, tropical cyclones were singled out as the most likely events to be affected by climate change in a major way. In order to simulate their economic impact, we focused on four future scenarios:

- No tropical cyclones;
- Tropical cyclone frequency and severity consistent with historical patterns;
- Tropical cyclones expected under a high-impact climate scenario; and
- Tropical cyclones expected under a low-impact climate scenario.

Storm damage input to the CGE is identified using two probability distributions based on a Mauritius-specific storm simulation (MSS) modelling conducted for this book. These distributions are: (i) a Poisson distribution of storm frequency as defined by the parameters projected in the MSS model; and (ii) a gamma function of storm damage defined by output produced and maximum wind speed.

For each year from 2020 to 2060, the CGE model randomly selects the number of events from the Poisson distribution, and then assigns damages of each selected event from the gamma damage distribution. The damages associated with tropical cyclones under both historical and future climate conditions are identified in five categories of loss: residential, commercial, infrastructure, industrial, and public. Each type of loss is attributed to the 112 sectors by category. The model enters the "reconstruction mode" once hit with an extreme event, where the expected damages enter the CGE as a shock to capital in the designated sector(s). For a set number of years following the event or events, a defined proportion of GDP is directed to restore the damaged capital in a manner that maximizes a national welfare function, which weighs exponentially the incomes of the different households in inverse proportion to their levels. This process is repeated for the high impact climate scenario, the low-impact climate scenario, and the historical climate scenario.

Figure 6. Projected GDP Losses from Tropical Cyclones: Baseline vs. High-Impact Climate Change



Source: World Bank estimates.

Note: the chart represents the relationship between the deciles of the distribution of the model simulation's results (vertical axis), and, on the horizontal axis, the corresponding present value of GDP loss (expressed as percentage of GDP in the no-cyclone scenario) over a 40 years-time horizon. For each decile, the value of loss shown in the chart is an average across a distribution of intra-decile values. Further details are available in Appendix 5.

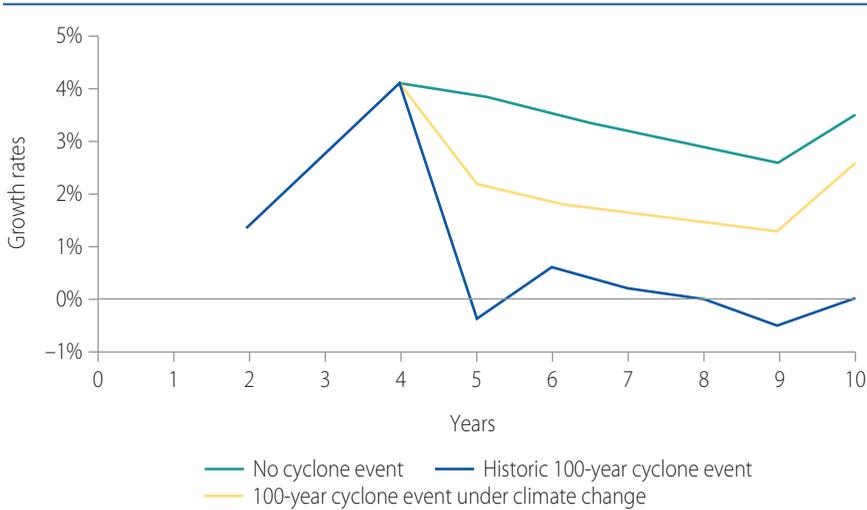
In a comparison of direct damage with the projected climatic conditions in the South-West Indian Ocean, a 100-year storm will cause almost double the damage as a storm with the same return period in the baseline. This effect is seen across a variety of return periods, and it is even more pronounced in relatively frequently occurring storms, with 5-year storm damage nearly tripling.

To further illustrate the effects of climate change on GDP, compared to both a no-cyclone scenario and a scenario of cyclone occurrence but without the additional strength induced by climate change, the team assessed the situation where a once-in-100-years cyclone occurs in the middle of a 10-year simulation (Figure 7).

Over the 10-year period, the net present value of the GDP loss due to a climate-change-amplified event is about 6.2 percent, relative to the no-event baseline, or 3.3 percentage points more than the historical event scenario. As Figure 7 shows, this total loss would be equivalent to losing more than 2 percentage points on average of GDP growth per year in the climate change scenario (the difference between the green and red lines in the figure, after the event occurs in year 4 of the simulation).

Already, Mauritius has taken steps to address climate change vulnerability, both at the policy level (for example, the 2012 National Climate Change Adaptation Policy Framework) and at a more operational level

Figure 7. Impact of 100-Year Cyclone Event on GDP Growth Over Three Scenarios



Source: World Bank estimate.

Note: The chart illustrates the behavior of GDP growth rates over 10 years in three scenarios, namely: (a) with no cyclone taking place; (b) with a “historical” 100-year cyclone event taking place in year 4, with an intensity in line with 1-100 cyclones recorded in the past; and (c) with a 100-year cyclone event taking place in year 4, with a stronger intensity caused by climate change. A 100-year cyclone event is defined as the type of cyclone that happens once in a hundred years, on average.

(through the 2016 guideline for coastal setback, formulated in anticipation of sea-level rise risks to coastal assets). Our book highlights that more can be done to better understand and mitigate the increased risks that climate change may pose to the entire OE and in fact to the economy as a whole. The possibility that high-impact cyclones could become more frequent and intense is very real. To mitigate the resulting social and economic impacts, there is a need to consider both

- **Structural responses** – such as a review of building codes to assess the resilience to stronger cyclones. In the port sector, it is important to fully integrate climate change projections in the design of the breakwater project to ensure its ability to withstand the additional stress from waves and wind caused by climate change; and
- **Disaster risk financing options**, such as the sovereign insurance scheme developed by Africa Risk Capacity, the World Bank Catastrophe Deferred Drawdown Option (CAT-DDO) or the Green Climate Fund—under which Mauritius is particularly well positioned to prepare an application for adaptation investments as a member of the Small Island Developing States (SIDS) group, which represents a preferred class of potential Green Climate Fund grant recipients.

Other climate change impacts that would need to be looked at more closely to identify adequate responses include those on fisheries and aquaculture and those affecting coastal erosion.

Good Governance

This book has found that, overall, making the OE a larger driver of growth is both possible (in the medium to longer term) and desirable—and that there is no shortage of specific project ideas to turn the OE's potential into reality, certainly in the four sectors analyzed in detail and most likely in other sectors as well (Box 5). But achieving the objective will be no small feat, particularly considering the sizable volume of investment resources required and the fact that the OE spans across multiple areas of institutional responsibility.

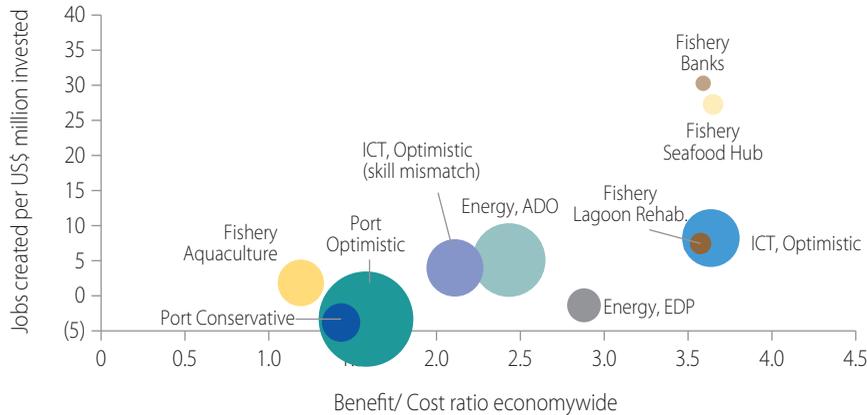
The question then arises: Who will actually move the overall agenda forward? Developing the OE entails assessing investment opportunities across sectors and using different evaluation criteria. To illustrate, Figure 8 summarizes the findings of the sectorial analysis, mapping the development scenarios identified in Part B of this book along the two dimensions of the benefit/cost ratio (for the economy as a whole) and of the ability of investments to create permanent jobs; the size of each bubble in the figure is proportional to the corresponding investment cost.

While all scenarios are found to be worth pursuing from the economy-wide perspective (their benefit/cost ratio exceeds 1 in all cases), some scenarios have higher payoffs in terms of employment generation per unit of investment, and some have higher opportunity costs in terms of scarce public and private investment resources that will need to be mobilized.

Of course, there are a number of other evaluation criteria that can be considered. One example is that some investments might have positive externalities that would add to their economic benefits—such as the breakwater, which will help protect the port (and, indirectly, other sectors, too) from the negative effects of climate variability and change. Another example is that marine energy may be able to deliver additional benefits not illustrated in the diagram, such as energy security. Even in the case of the two criteria utilized to build the diagram (benefit/cost ratio and employment generation), the results should be considered as purely indicative, and subject to various caveats, as further discussed in the full book.

As a result, Figure 8 has no ambition to serve as a prescriptive tool for recommending any particular investment decision. Instead, it purports to underscore a key challenge that Mauritius will face as it pursues the

Figure 8. Job Creation and Economywide Benefit/Cost for Various Ocean Economy Sectors



Source: World Bank analysis.

Note: The size of each bubble is proportional to the corresponding investment cost. ADO = additional development options; EDP = Existing sector development plans.

ambitious objective of making the OE a pillar of its future economic development—that is, the need to orient a major program of investment (some US\$580 million per year, according to this analysis) that will, by necessity, entail choices and trade-offs across sectors and across time. Simply summing the investment needs identified for the projects discussed in the Deep Dive section of this book adds up to about US\$3 billion, or 50 percent of the total investment required for the O2 scenario; whereas currently these four sectors account for less than 30 percent of the OE GDP.

Clearly, it will not be possible to finance them all, especially given that in some cases, different projects may compete for the same scarce inputs, such as private capital and skilled labor. In other words, developing the OE will require not only the ability to develop good projects in different sectors; but also the ability to evaluate them across sectors, and select the best ones based on clear evaluation criteria. In addition to supporting OE development through individual sectoral investments, there is a need to address a number of key cross-sectoral aspects (Box 8) that are essential to ensure both that the country offers an attractive business environment for domestic and foreign investors and that development remains inclusive and friendly to natural resources.

This brings us to a key area, namely of the institutional model required for addressing this challenge. The current OE governance system is based on a ministry, recently entrusted with a special mandate (the Ministry of Ocean Economy, Marine Resources, Fisheries and Shipping) but with limited technical capacity beyond its original

Box 8. Cross-sectoral Policies to Support the OE Strategy

The OE sector cluster approach illustrated above needs to be complemented by several cross-cutting policies. These policies are necessary to ensure that the country offers an attractive business environment for domestic and foreign investors and, at the same time, that development remains inclusive and friendly to natural resources.

First, complementary reforms and investments are needed to address bottlenecks and improve the quality and capacity of infrastructure in **Energy, Transport and Water and Sanitation**. These policies are important to ensure a level of basic services commensurate to Mauritius' economic development status and ambitions. They are also crucial to provide an adequate background of basic services to enhance the attractiveness of the business environment and the efficiency of production from the newly formed capital.

Second, **education** requires special attention, both in terms of resources and institutional enhancements, to address the emerging skills gap and improve productivity and innovation capacity. These policies should focus on strengthening primary education and improving quality and access to Technical, Vocational, Education and Training (TVET) and Tertiary education, as well as research capacity in science and technology.

Third, **environmental policies** become ever more necessary as there are clear signs of stress both on land and water resources. Sewage and water treatment, as a primary form of infrastructure, should be expanded in line with the growth of population and economic activity. Forward-looking forms of land use planning and conservation policies for natural resources and biodiversity should also be adopted.

Fourth, **boosting productivity** should be a key policy objective at the core of the economic growth and competitiveness agenda. Achieving this goal depends critically on the speed of technology adoption and further improvements in the business environment. Two important sets of actions and policies in this respect concern logistics and marine digitalization.

Improving logistics may be the most effective way to increase productivity, since, as a small island highly dependent on international trade, Mauritius' national economy is critically affected by all forms of transport. Better logistics requires the development of a series of smart services, such as precision delivery, management of materials, services and information, and integrating technology and innovation capabilities. It goes hand in hand with the development of Mauritius as an important maritime and shipping hub with dynamic port-related industries including seafood, cruises, etc.

Fifth, **investments in big data and digital technologies** also appear to be a very promising line of action to increase total factor productivity. For the OE, Mauritius could play an important role as a big data hub for B2B transactions including products, services and marketing and generating valuable information to know the contribution of different companies in the relevant value added chains.

area of competence (fisheries); and a consultative body (the National Ocean Council or NOC), established “administratively” (and thus with no autonomous legal status and no political decision-making power) to carry out various duties.

NOC's duties include formulating a National Ocean Policy Paper, including a unified regulatory framework and a National Ocean Authority; promoting the development of the various OE clusters; and formulating action plans in specific areas such as shipping industry, ship financing, and ICT. NOC is formed by representatives of several government departments and the Joint Economic Council on behalf of the

private sector. While it receives organizational and administrative support from the Ministry of Ocean Economy, it has no dedicated budget, and thus it has no dedicated technical staff to prepare its deliberations.

While instrumental to get the process started over the last few years, the current model is likely to require considerable strengthening, both in terms of technical capacity and in terms of decision making mechanisms. The emerging international experience (Box 9) suggests that achieving progress on the OE agenda requires a clearly defined strategy, stakeholder engagement, a comprehensive regulatory framework, seed funding to leverage private resources, business intelligence, and policies and investment for long-term environmental sustainability and climate change resilience. Several of these ingredients are being put in place in Mauritius.

To accelerate progress, Mauritius could consider establishing a highly qualified Ocean Economy Unit (OEU), staffed with full-time top professionals in the different OE clusters, to be housed at the Ministry of Ocean Economy (to strengthen the ministry's capacity); or alternatively, at the Prime Minister's Office (to provide the unit with stronger cross-sectoral clout). The OEU would be responsible for all the technical work required to rapidly move the OE agenda forward, and to prepare and inform decisions to be made at the political level. Its duties could include these:

- Prepare, in consultation with NOC, a draft National Ocean Policy Paper, including an action plan with short and medium term OE-wide targets (such as contribution to GDP and employment generation), based on sound economic analysis and using quantitative tools such as those developed for this book, suitably expanded and regularly updated (Box 10).
- Prepare a draft unified regulatory framework for the OE for discussion by NOC and adoption by the Cabinet (and submission to Parliament, as appropriate).
- Coordinate investment initiatives/projects promoted by different government departments to achieve OE development objectives—rigorously evaluating their contribution to achieving the action plan's targets and making recommendations for financing to the Ministry of Finance.
- Interact with national and international private sector representatives to identify and promote innovative business opportunities.
- Prepare an annual “State of the Ocean Economy” report to document progress made in developing the OE, and organize a high-level event where the book would be presented to stakeholders, including current and prospective investors.

Box 9. Key Aspects of Ocean Governance: The International Experience

A review of selected country and regional experiences in Ocean governance (including the European Union, Grenada, Ireland, New Zealand, Norway, Portugal, Singapore, and the United Kingdom) points to a number of key conditions for making progress on the Ocean agenda (see Appendix 6 for further discussion).

Successful ocean economies have developed clearly articulated strategies and governance approaches that assure that the relevant sectors have visibility, are fully engaged in the governance process, and have access to support and seed funding, in particular during early development stages. Science, innovation and conservation are critical components of these strategies.

However, while the public sector acts as facilitator, investment decisions are ultimately taken by private business, and funding beyond the early technology stage is provided through existing commercial and other avenues in the normal way. Successful ocean economies tend to also have a range of other supporting institutional features, including experienced bureaucracies, established public-private partnership mechanisms, deep capital markets and longer-term planning horizons.

Sector choices and priorities reflect broader societal choices, reflecting for instance the shift from extraction to a renewable and circular economy. Whilst coastal tourism will remain in many places a large component of ocean sector revenues, it will critically depend both on protection of the marine biodiversity and development of sustainable coastal infrastructure, while traditional activities such as fishing and shipping will require help with the transition to long-term sustainability.

Ocean energy will take time and significant investment before it becomes a larger part of the energy mix, while ocean data and ocean biotech are still small but offer exciting growth opportunities, provided they can be embedded into a supportive science and innovation technology policy framework.

Successful open economies with clear regulatory structures, government strategies and support mechanisms for innovation are also likely to have successful marine sectors that make an important contribution to sustaining livelihoods, diversifying economic activity, and managing environmental resources, even if the contribution to output is small in the context of the overall economy.

A strategic emphasis in the form of a national ocean plan (e.g., as in Ireland), supported by a dedicated Minister for the Sea (e.g., Portugal), targeted support for and investment in marine innovation (e.g., Norway), funding support for research and infrastructure (e.g., European Union), including at regional and local levels (e.g., Canada), and a comprehensive analysis of the specific future challenges (e.g., New Zealand) are identified here as key components for sustainable blue growth.

- Provide specialized advisory services on the preparation and financing of selected strategic OE projects.
- Evaluate and assess key programs and projects at critical junctures in their lifecycle, ensuring that they are worth realizing and, once selected, can progress successfully to the various stages of start-up and implementation.

At the institutional and political level, the work of the OEU would be vetted and validated, depending on the case, by the National Ocean Council, the Minister of Ocean Economy, or other ministries. For decisions of particular strategic significance, the formation of an Ocean Inter-Ministerial Committee could also be considered.

Box 10. Further Use of the CGE Model Developed in This Book

One tool that could help policy makers craft measures to invest in human and natural capital would be the dynamic CGE model developed for this book, which could be further refined to answer specific policy questions.

From the point of view of the underlying accounting system and as a statistical tool, the model has already been instrumental in prompting a fruitful dialog between the World Bank team and a local team composed of several Mauritius statisticians and economists from the Central Statistical Office, the Ministry of Ocean Economy, the Ministry of Finance and the University of Mauritius. Both the input-output and the SAM accounts have been developed as a joint product with the local team and can be the basis for a systematic data collection and systematization effort in the future.

The CGE model can also be updated and extended, as the O2 strategy and other government policies are deployed, with improved estimates of the model parameters. Behavioral and technical equations could be revised to reflect new data, including data on and costs and benefits of specific projects. The model can also be used for training and can contribute to empower the government's statisticians and economists, who have already produced an exemplary set of methodologies, statistics, and economic accounts for the country.

Recommendations

What are the overall recommendations for Mauritius to move forward now on enabling the OE to play a bigger role in the country's future development? Table 16 summarizes short-term recommendations on governance (based on the above discussion) and other cross-cutting issues. Table 17 summarizes selected sector-specific recommendations, with the full list (including for the longer term) provided in the rest of the book. In both cases, the identification of actors is purely indicative, and subject to further discussion with the Government of Mauritius, to better realign action areas to the comparative advantages and attributions of the different institutions.

Table 16. Cross-cutting Recommendations for the Shorter Term (6–18 months)

| Area/Action | Actors |
|--|--|
| Overall governance | |
| Establish a highly qualified Ocean Economy Unit (OEU) | Ministry of Ocean Economy, Prime Minister office |
| Prepare, in consultation with NOC, a draft National Ocean Policy Paper, including an action plan with short and medium terms OE-wide targets (e.g. contribution to GDP, employment generation, etc.), based on sound economic analysis, and using quantitative tools such as those developed for this book | BOI, OEU, NOC, Ministry of Ocean Economy |
| Prepare a draft unified regulatory framework for the OE, for discussion by NOC and adoption by the Cabinet (and submission to Parliament as appropriate) | BOI, OEU, NOC, Ministry of Ocean Economy |
| Develop a comprehensive action plan to develop technical capacity in selected priority OE areas, through technical, vocational, education and training (TVET) and tertiary education | BOI, OEU, NOC, Ministry of Ocean Economy |
| Marine spatial planning | |
| Develop a legal framework to outline the structure and legal implications required to implement MSP | PMO, MoESD |
| Develop a conflict resolution mechanism, such as an Arbitral Tribunal; or confer a suitable mandate to the Environment and Land Use Appeal Tribunal | PMO, MoESD |
| Revise the Fisheries and Marine Resources Act (2007) to make it more explicit about what characteristics a particular area requires to have the status of a Marine Protected Area | MoOEMRFS, MOI |
| Finalize the Integrated Coastal Zone Management Framework | MoOEMRFS, MOI |
| Climate change | |
| Develop a financial protection strategy against climate disasters, based on a diagnostic of economic and fiscal impact of disaster shocks | Ministry of Finance, Ministry of Environment |
| Review potential financial protection instruments (including sovereign level insurance solutions) to mitigate the socioeconomic damage of high impacts cyclones | Ministry of Finance |
| Fully integrate a wide range of climate change projections in the feasibility study and design of the breakwater being considered for the port | MPA |

Note: BOI = Board of Investment; CEB = Central Electricity Board; EEMO = Energy Efficiency Management Office; ICTA = ICT regulatory agency; MARENA = Mauritius Renewable Energy Agency; MEXA = Mauritius Export Association; MoESDDBM = Ministry of Environment, Sustainable Development, Disaster and Beach Management; MoFED = Ministry of Finance and Economic Development; MOI = Mauritius Oceanography Institute; MoOEMRFS = Ministry of Ocean Economy, Marine Resources, Fisheries and Shipping; MPA = Mauritius Port Authority; NOC = National Ocean Council; OEU = Ocean Economy Unit; PMO = Prime Minister's Office; UoM = University of Mauritius; URA = Utility Regulatory Authority; WWMA = Wastewater Management Authority.

Table 17. Sector-specific Recommendations for the Shorter Term (6–18 months)

| Sector | Action | Actors |
|-----------|---|--|
| Fisheries | Formulate a high-level policy commitment on lagoon rehabilitation | MOE, Min Environment, M. Agriculture, WWMA |
| | Develop a 3-year business plan on the development of Banks fisheries, building on the specific recommendations of this book's fisheries chapter | BOI, MOE and Min. Finance in consultation with industry |
| | Establish a Seafood Hub logistics unit in MPA to optimize vessel logistics to increase efficiency in day-to-day operations | BOI, MEXA or MPA |
| | Design an OE/ fisheries business promotion facility | BOI, MOE/ MF/ Business Mauritius/ banks |
| Energy | Develop a DOWA demonstration project | BOI, MARENA, MoEPU, CEB, MoFED, EEMO, URA, Ministry of Environment |
| | Establish an integrated energy planning process through an inter-sector coordination panel | MoEPU, CEB, MARENA, EEMO, URA, MoFED, MoESDDBM, UoM |
| | Carry out a grid stability and ancillary service analysis | MoEPU, CEB, MARENA, URA. |
| ICT | Encourage use of alternative infrastructures (e.g., CEB), unbundling the local loop, constructing an IXP, and enforcing open access rules | ICTA |
| | Develop a more ambitious cable program looking eastwards (towards Asia) and north (to Europe and the Gulf) | Private sector, ICTA, Board of Investment |
| Ports | Introduce new procedures for project evaluation (possibly involving other ministries) | MPA in collaboration with other relevant ministries |
| | Strengthen MPA commercial functions (capacity building) | MPA |

Note: BOI = Board of Investment; CEB = Central Electricity Board; DOWA = deep ocean water application; EEMO = Energy Efficiency Management Office; ICTA = ICT regulatory agency; MARENA = Mauritius Renewable Energy Agency; MEXA = Mauritius Export Association; MOE = Ministry of Energy; MoESDDBM = Ministry of Environment, Sustainable Development, Disaster and Beach Management; MoFED = Ministry of Finance and Economic Development; MOEPU = Ministry of Energy and Public Utilities; MPA = Mauritius Port Authority; UoM = University of Mauritius; URA = Utility Regulatory Authority.

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PART A

Promoting the Ocean Economy: The Big Picture

Setting the Stage

Raffaello Cervigni, Lucio Scandizzo, and Yuvan Beejadhur

Key Messages

- As Mauritius looks for ways to spur growth and move into the high-income category, it is increasingly focusing on its ocean economy (OE) as a new frontier for development.
- Currently, the OE contributes about 10 percent to GDP, although the contribution is likely to be larger when the full range of direct and indirect interactions with the rest of the economy is properly taken into account. Back in 2013, the Government of Mauritius announced the goal of doubling the OE's share of GDP share in 12 years and creating 35,000 jobs in the process.
- The government has made considerable progress in defining a governance framework for the OE, in particular through the establishment of a dedicated ministry and a high-level National Ocean Council. Important challenges still remain, however, particularly in terms of intersectorial coordination and technical capacity for investment planning, implementation, and monitoring
- This book aims to assess the overall potential of the OE to contribute to Mauritius's development (in terms of economic growth and diversification, trade balance, reduction of poverty and inequality, effects on the government's finances); to identify the challenges to be overcome to seize that potential; and to evaluate the prospects of ensuring the longer-term sustainability of the OE, in particular from the environmental point of view and taking into account the risks posed by climate change.
- The approach used combines a top-down analysis of a doubling of the OE's GDP in 10 years with four bottom-up deep dives in specific sectors representative of both the OE's traditional sectors (fisheries, ports) and its emerging ones (marine renewable energy and marine information and communications technology [ICT]).
- The analysis is intended to provide a big-picture strategic assessment of the OE. Specific investment opportunities at the individual project level are discussed in the second part of the book (the bottom-up analysis), mostly to exemplify opportunities and challenges and to assess the order of magnitude of investment resources required to promote the growth of the OE. Appraisals of the technical and financial feasibility of individual projects would go beyond the scope of this book and will have to be conducted as part of separate follow-on activities.

Introduction

Since the launch of its first National Dialogue on the Ocean Economy (OE) and subsequent launch of its *Roadmap* in July 2013, Mauritius has been a fertile laboratory—a testing ground in the Indian Ocean articulating a vision that promotes the OE as one of the main pillars of a country’s economic development. Although it is a Small Island Developing State in terms of land mass, Mauritius stands among a handful of countries that have exclusive economic zones (EEZs) of at least 2 million square kilometers.

The Government of Mauritius demonstrated greater stewardship of the complex OE agenda when in 2015 it dedicated a new Ministry of Ocean Economy, Fisheries, Marine Resources, Shipping and Outer Islands (the Shipping and Outer Islands mandates were moved to other ministries in 2017). The government’s initial vision was to pool all ocean-related activities under one roof and consolidate mandates, create deeper coordination, set clearer directions, and have greater ownership and accountability. In 2015, this ministry established a National Ocean Council (NOC), which was expected to be the driving force for the ministry and be at the heart of all ocean-related projects and development (See Box 1.1). Some of the immediate objectives of the NOC have been to formulate a National Ocean Policy Paper (defining clearly the short-, medium-, and longer-term strategy for the new ministry) and to create a white paper for the setting up of a National Ocean Act and an National Ocean Authority.

What exactly does an “ocean economy” mean? The concept involves taking a new perspective on sources of sustainable economic growth and has made a recent contribution to the debate on the desirable characteristics of global development policies. While the basic definition centers on identifying the set of activities whose inputs depend on the ocean, its interpretation by international institutions hinges on opportunities to identify and pursue a strategy of green, inclusive growth. As UNCTAD (2014) puts it:

...The concept of the oceans economy, also referred to as the blue economy, is one that simultaneously promotes economic growth, environmental sustainability, social inclusion and the strengthening of oceans ecosystems.

It embraces the same desired outcomes as the Rio+20 green economy initiative:

[achieving] improved human well-being and social equity, while significantly reducing environmental risks and ecological

scarcities. In its simplest expression, a green economy can be thought of as one which is low carbon, resource efficient, and socially inclusive. (UNEP 2015).

Thus, an OE, from the point of view of its definition and concerns, appears to have a distinctive dual nature, reflecting both a new attention to the potential contribution of ocean resources to economic growth and the perception of the ocean as an endangered ecosystem. For example, technological advances and greater capacity and scope for deep-water marine research have led to increased awareness of greater opportunities for undertaking commercial extraction of deep-water living and non-living resources. But the same advances have also shed a new light on the fragility of deep-water systems. The very potential for commercial use of the deep seas, in turn, has both furthered concern about eco-systemic vulnerability and advanced the development of marine research technologies.

In its 2013 Roadmap, Mauritius spelled out how it hopes to take advantage of the economic, social, and environmental potential of its oceans and defined as targets doubling the OE share of GDP in 12 years and creating 35,000 jobs in the process. The strategy involves harnessing the untapped value of the exclusive economic zone (EEZ) by ensuring sustainable and coordinated use of living and non-living resources. Business opportunities are also expected to develop in four key clusters:

- marine services (marine tourism and marine pharmaceuticals);
- petroleum, minerals and ocean energies;
- fisheries and aquaculture; and
- seaport-related activities.

Moreover, the plan for deep ocean water applications (DOWAs) includes pumping cold water of about 5° C from depths of around 1,000 meters to the surface to cool buildings. This emphasis on the OE is further enshrined in the country's Vision 2030, launched in 2015, which calls for fundamentally transforming the economy from an upper-middle-income one to a high-income one.

The Ocean as a New Frontier

The economic history of Mauritius starts with a colonial legacy characterized by specialization in agricultural production and the limited processing of sugar. This single-commodity dependence accentuated the vulnerability of a small island economy with its limited population and land base and exposure to many sorts of outside shocks. Yet, despite

so many unfavorable factors, Mauritius has achieved a remarkable economic performance since its independence in 1968, with high and consistent growth rates, ranging from a high in excess of 6 percent during boom years to lows of more than 3 percent during the latest years of world recession. Its performance included an almost ideal transition path from commodity dependence to a diversified industrial and, more lately, service-based economy, highly productive and fully integrated into the global value chain. Between 1980 and 2007, total factor productivity (TFP) grew by more than 1 percent a year, and in excess of 1.3 percent a year between 1980 and 1990. This solid performance was due to the four main factors discussed in turn next.

Strong Democratic Institutions

The country enjoyed a somewhat unique and favorable institutional set-up, with an open and democratic political system that has thrived since independence along with stable and robust institutions in the parliamentary, executive, and judicial branches. This set-up helped unify civil society behind a national project that was outward oriented, economically ambitious, and appropriately inclusive. Successive governments placed strong emphasis on education for all, health programs, and freedom of the press, religion, and expression.

A Well-Crafted Economic Strategy

The economic strategy centered on export-led growth supported by the creation of “export processing zones” (EPZs), which ensured a favorable fiscal and regulatory treatment of export industries and their value chains. The creation of EPZs was combined with targeted development of key industries, which helped diversify the economy out of its original dependence on the sugar sector. This was accomplished by first developing the apparel industry and then several areas of the service sector, such as the tourism cluster and, more recently, a range of specialized activities that have made the island an international hub of offshore financial and banking services.

Export growth and industrial policies went hand in hand with a fiscal policy of low taxation on capital and low or zero tariffs on intermediate imports, although this was combined with high import protection for consumption goods. Together with a friendly system of regulations for business (Mauritius ranks no. 1 in Africa and no. 49 overall in the World Bank Ease of Doing Business index) and a liberal and efficient financial environment, this helped create attractive conditions for foreign investment. Moreover, throughout various economic development phases, important structural reforms were undertaken to engender self-sustaining growth. A major reform modernized the sugar sector by phasing

out part of the labor force and concentrating investment in the sugar mills. The EPZ was another major innovation, entailing several reforms to meet changing market conditions. It provided a package of fiscal concessions and other benefits to attract industries to locate their labor-intensive activities. More recently, legal and regulatory reforms have been undertaken in education, financial reporting, corporate governance, the insolvency regime, the tax structure, and public debt management.

Careful Macroeconomic Governance

Macroeconomic governance was based on a wise combination of monetary and fiscal policies, cautiously conservative in the boom periods and moderately expansive during recessions. This resulted in low inflation rates (below 3 percent), and was supported by clever exchange rate management with limited floating, which kept the economy competitive and helped to reconcile stability and growth.

International Negotiating Ability

Mauritius' governments proved to be both skillful and forward-looking in negotiating mutually beneficial trade agreements with other countries, paving the way for long-term partnerships and concrete advantages in strategic sectors of the local economy. Successful negotiations included preferential quotas for exporting sugar to the European Economic Community, which not only secured a large and stable market but also allowed Mauritius to achieve prices that were three to four times above world prices. A similarly advantageous deal was reached for textiles in the Multi-Fiber Agreement, resulting in a spectacular expansion of the industry and further diversification of the economy.

In sum, Mauritius' success in recent decades seems to have depended on policy foresight, social cohesion, and structural causes—notably, the capacity to innovate, increase productivity, and respond to development challenges by pursuing growth and equity targets within a well-functioning democratic system.

In 2018, Mauritius will be celebrating the 50th anniversary of its independence. As a still young nation-state, it has much to celebrate. But there are important challenges the country now faces. These stem from structural imbalances that reflect a pattern of growth heavily reliant on foreign capital and technology, as well as difficulties in facing the demise of some traditional sectors (such as the sugar industry and textile manufacturing) and the stagnation of other sectors, like tourism. Shortages of highly skilled labor and job mismatches are also the consequence of the country's ongoing structural transformation to a modern service economy and the employment structure of the declining textile industry, which is mostly based on low-skilled and difficult-to-retrain workers. More

recently, following the global economic recession, which affected most of its export markets, Mauritius has also experienced lower growth (3 percent, down from the historical averages of 5 to 6 percent), falling rates of saving and investment, and pressures on government finances from a combination of capital import dependence and low domestic taxation.

Against this backdrop, the government has identified the OE as a key development opportunity for the coming decades. While the complexities of the sector and its potential for growth are a novel venture for policy making, the government's move is in line with the historical record of the country in pursuit of new opportunities with foresight and resolve. In fact, the OE appears to open the possibility of a new frontier of development that could boost the country's comparative advantage and growth, spurred by Mauritius' unique position as a small island with the widest ocean platform, a plurality of ocean-dependent activities, and a well-established record of successful industrial policies. Other critical factors include the country's natural resource base; its experience in key sectors such as marine tourism, ancillary services to sea transport, infrastructure, and cross-purpose technologies (like ICT and renewable energy); and its intention of becoming an international hub for advanced service activities, based on innovative technologies, smart infrastructure, ICT, logistics, and finance.

Getting a Handle on the Ocean Economy

The boundaries of the OE can be defined with reference to both the international literature (Table 1.1) and Mauritius' own strategy documents, such as the Office of the Prime Minister's 2013 publication of *The Ocean Economy: A Roadmap for Mauritius* (PMO 2013). The OE includes a large number of promising sectors where current activities can expand and new activities can be created, depending on ongoing and future innovation in technologies and modes of production. Industrial organization, competition, and trade are also likely to evolve in response to the expansion of the ocean sectors and the innovation engendered by many emerging technologies and investment opportunities.

How large is the OE in Mauritius? According to official statistics¹ updated to 2015, the OE accounts for more than 10 percent of GDP, with tourism and marine leisure together accounting for more than 70 percent of that amount (Table 1.2). It is quite possible that the true contribution of the oceans to Mauritius's economy is in fact larger:

¹ The latest official version of the Social Accounting Matrix refers to 2007 data; an updated version of this matrix with 2015 data has been developed for this book, through a partnership between the World Bank and Statistics Mauritius.

Table 1.1. Sectors Included in the Ocean Economy

| Ocean Sectors | Definition |
|---|---|
| Marine fishery | Includes mariculture, marine fishing, marine fishery service industry, and marine aquatic processing. |
| Offshore oil and gas industry | Refers to the production activities of exploring, exploiting, transporting, and processing raw oil and natural gas in the ocean. |
| Ocean mining industry | Includes the activities of extracting and dressing beach placers, beach soil chloride and sand, submarine geothermal energy, and coal mining and deep-sea mining. |
| Marine salt industry | Refers to the activity of producing salt products with sodium chloride as the main component by utilizing seawater, including salt extracting and processing. |
| Shipbuilding industry | Refers to the activity of building ocean vessels, and offshore fixed and floating equipment with metals or non-metals as the main materials, as well as repairing and dismantling ocean vessels. |
| Marine chemical industry | Includes the production activities of chemical products of sea salt, seawater, sea algal, and marine petroleum chemical industries. |
| Marine biomedicine | Refers to the production, processing, and manufacturing activities of marine-based medicines and marine health care products by using organisms as raw materials (or by extracting these organisms' useful components). |
| Marine biotechnology | Refers to the production, processing, and manufacturing activities of marine-based biotech products, including pharmaceuticals, dietary supplements, health-care products, and nutraceuticals. |
| Marine engineering and building industry | Refers to the architectural design, project construction, and preparation in the sea, at the sea bottom, or on seacoast of facilities and infrastructure for such uses as marine production, transportation, recreation, and protection—including construction of seaports, coastal power stations, coastal dykes, marine tunnels and bridges, and land terminals of offshore oil and gas fields, as well as building processing facilities and installing submarine pipelines and equipment (but not house building and renovation). |
| Marine electric power | Refers to the activities of generating electric power in the coastal region by making use of wave energy and off-shore wind energy. It does not include thermal or nuclear power generation in the coastal area. |
| Seawater utilization | Refers to activities for the direct use of seawater and seawater desalination—including the production of desalinated water and the use of seawater for industrial cooling, urban domestic water, and water for fire fighting (but not the multipurpose use of seawater chemical resources). |
| Marine communications and transportation (and) Marine ICT | Refers to the activities of carrying out and serving sea transportation with vessels as the main vehicles—including ocean-going passenger transportation; auxiliary activities of water transportation; pipeline transportation; and loading, unloading, and transport—along with a whole new wave of ICT innovations (including radar, sensor, and satellite-based ship and deep-sea applications). |
| Coastal tourism | Refers to the tourist-related activities that take place in the coastal zone and on sea islands, as well as recreational activities that use the ocean (including water-based sports and marine mammal and bird watching). |

Source: Adapted from Zhao, Hynes and Shun He (2013).

based on an analysis of the country's Social Accounting Matrix (SAM), once the full range of indirect effects of the ocean sectors on the rest of the economy are properly taken into account, the GDP contribution of the OE is close to 20 percent of the total.

Another way to capture the importance of the ocean sectors is by looking at their linkages with the other sectors—a proxy of the OE's potential to mobilize the rest of the economy and, in turn, spur

Table 1.2. Contributions of Ocean Economy Activities to GDP, 2012–14

| | Contribution to GDP (MRU million) | | | Contribution to GDP (percent) | | |
|--|-----------------------------------|---------------|---------------|-------------------------------|-------------|-------------|
| | 2012 | 2013 | 2014 | 2012 | 2013 | 2014 |
| GDP at basic prices (million MRU): | 302,617 | 322,937 | 342,179 | | | |
| Activities/organization | | | | | | |
| Salt production | 12 | 11 | 10 | 0 | 0 | 0 |
| Seafood fishing and processing | 4,314 | 4,833 | 4,687 | 1.43 | 1.5 | 1.37 |
| <i>of which:</i> | | | | | | |
| <i>Aquaculture</i> | 28 | 30 | 37 | 0.01 | 0.01 | 0.01 |
| <i>Fishing other than aquaculture</i> | 281 | 398 | 754 | 0.09 | 0.12 | 0.22 |
| <i>Fish processing</i> | 4,005 | 4,405 | 3,896 | 1.32 | 1.36 | 1.14 |
| Ship building and maintenance | 292 | 433 | 471 | 0.1 | 0.13 | 0.14 |
| Storage | 689 | 698 | 753 | 0.23 | 0.22 | 0.22 |
| Sea transport | 141 | 152 | 132 | 0.05 | 0.05 | 0.04 |
| Services allied to transport | 4,776 | 5,007 | 5,473 | 1.58 | 1.55 | 1.6 |
| Hotels and restaurants | 16,181 | 14,773 | 16,134 | 5.35 | 4.57 | 4.72 |
| Leisure boat activities | 3,442 | 3,801 | 4,174 | 1.14 | 1.18 | 1.22 |
| Ship store and bunkering | 920 | 842 | 717 | 0.3 | 0.26 | 0.21 |
| Freeport activities | 1,596 | 1,735 | 1,884 | 0.53 | 0.54 | 0.55 |
| Shipping division (of Ministry of Land Transport and Shipping) | 16 | 19 | 20 | 0.01 | 0.01 | 0.01 |
| Mauritius Oceanography Institute | 17 | 32 | 21 | 0.01 | 0.01 | 0.01 |
| External communications division | 6 | 8 | 9 | 0 | 0 | 0 |
| Ministry of Fisheries | 120 | 141 | 149 | 0.04 | 0.04 | 0.04 |
| Tourism Authority | 24 | 43 | 45 | 0.01 | 0.01 | 0.01 |
| Beach Authority | 15 | 19 | 19 | 0 | 0.01 | 0.01 |
| Fisherman Welfare fund | 2 | 4 | 4 | 0 | 0 | 0 |
| National Coast Guard | 324 | 389 | 419 | 0.11 | 0.12 | 0.12 |
| Total | 32,887 | 32,939 | 35,122 | 10.9 | 10.2 | 10.3 |

Source: Mauritius Office of Statistics.

overall development. These characteristics can be measured by using two indexes derived from an estimate of a Social Accounting Matrix for 2015 (see Chapter 2 and the Appendix for details) and a disaggregated representation of national accounts. The two indexes refer, respectively, to the backward and forward multipliers.

The backward multiplier depends on the activation process caused by the spillover effects and is a function of the length and depth of the value chains activated by OE expansion. It indicates the increase in the value

produced by all sectors in response to a unit increase of expenditure of the ocean industries in a specific sector of the rest of the economy.

The forward multiplier measures the increase in the value created by each sector, in response to a unit increase in expenditure in all sectors of the OE. This expresses the degree of participation each sector has in the activation process caused by OE expansion, and it depends on the inputs that each sector contributes to the different value chains activated by OE growth. It is thus a function of both the number of value chains activated by this growth and the capacity of each sector to contribute to them.

Table 1.3 presents the measures of forward and backward linkages (or multipliers) of the total of all OE sectors with respect to other sectors of the economy. A forward multiplier measures the extent to which OE benefits from a boost in the demand of another sector, which in turn depends on the OE linkages with sectors that buy its services, including domestic consumers. For each sector of the economy, backward multipliers, following an increase in OE demand for that particular sector, measure the extent and the depth of the sector's response as a component of a supply chain. For instance, the telecommunication (TLC) sector has an average multiplier of 0.435, suggesting that a 10 percent increase in OE demand for TLC induces a 4.35 percent increase in the demand for intermediate inputs directly and indirectly linked to the TLC supply chain.

Because of forward linkages, in fact, OE expansion requires the growth of each sector as a supplier of intermediate goods in proportion to its forward linkage strength (the amount of its supplies and the number of different supply chains to which it contributes). Thus, for example, an increase of \$1 billion in a single OE sector tends to activate production in all sectors for an average of \$435 million through backward linkages of related value chains. On the other hand, an increase of \$1 billion in all OE sectors demands production increases of intermediate inputs for an average of about \$246 million per sector.

Government's Policies to Support the Ocean Economy

The Government of Mauritius has demonstrated continued leadership and stewardship in the development of the OE and in sustainable development generally over the last few years. From the "Maurice Ile Durable Commission" to the National Dialogue on the OE in 2013 and its first *Roadmap*, Mauritius has spearheaded efforts to make the OE a reality.

At the international level, Mauritius has been among the strongest stewards of the sustainable OE and has been steadfast in championing this blue economy concept in international forums and key processes. These have included the African Union Decade of Seas and Oceans; Agenda 2030 on Sustainable Development; the Barbados Programme

Table 1.3. Backward and Forward Production Multipliers in Ocean Economy Value Chains

| Activities | Forward linkages | Backward linkages |
|---|------------------|-------------------|
| Construction and construction services | 0.233 | 0.442 |
| Education services | 0.323 | 0.435 |
| Electricity distribution services; gas and water distribution services through mains | 0.126 | 0.451 |
| Financial intermediation, insurance, and auxiliary services | 0.787 | 0.441 |
| Health and social services | 0.271 | 0.432 |
| Knitted or crocheted fabrics; wearing apparel | 0.216 | 0.438 |
| Land, air, supporting and auxiliary transport services | 0.188 | 0.421 |
| Live animals and animal products | 0.060 | 0.442 |
| Lodging; food and beverage services | 0.173 | 0.431 |
| Meat, fruit, vegetables, oils and fats, grain mill products, starches and starch products, and beverages | 0.242 | 0.413 |
| Ores and minerals | 0.040 | 0.427 |
| Other business services | 0.507 | 0.436 |
| Other manufactured goods | 0.267 | 0.440 |
| Other services | 0.131 | 0.431 |
| Products of agriculture, horticulture and market gardening, forestry and logging products | 0.080 | 0.438 |
| Public administration and other services to the community as a whole; compulsory social security services | 0.377 | 0.437 |
| Real estate services | 0.495 | 0.441 |
| Recreational, cultural and sporting services | 0.139 | 0.412 |
| Services of membership organizations | 0.042 | 0.435 |
| Sewage and refuse disposal, sanitation and other environmental protection services | 0.080 | 0.437 |
| Sugar | 0.032 | 0.457 |
| Sugar cane | 0.126 | 0.436 |
| Telecommunications services; information retrieval and supply services | 0.346 | 0.438 |
| Wholesale and retail trade services | 0.799 | 0.433 |
| Yarn and thread; woven and tufted textile fabrics | 0.066 | 0.440 |
| <i>Average</i> | 0.246 | 0.435 |

Source: World Bank analysis.

of Action; COPs; the Johannesburg Summit; Mauritius Strategy; Sustainable Development Goal (SDG) 14 on the conservation and sustainable use of the oceans, seas and marine resources for sustainable development; the UN Conference on Implementation of SDG 14; and the UN Conference on Sustainable Development/Rio+20. More recently, the World Bank and the Government of Mauritius co-organized the

conference entitled, Towards COP22: African Ministerial Conference on Ocean Economies and Climate Change, where a ten-point action plan high-level “Mauritius Communique” was agreed by countries.² This African ocean economy and climate action agenda was brought forward to the ‘Oceans Day’ at the COP22 in Marrakesh, Morocco.

At the domestic level, in 2015 the Government of Mauritius created a dedicated Ministry of Ocean Economy, Marine Resources, Fisheries, Shipping and Outer Islands (hereafter referred to simply as the Ministry of Ocean Economy), and it later appointed a Senior CEO as the apex official of the ministry. In 2017, the portfolio of Outer Islands was moved to another ministry. A consultative body (the NOC) was also established, “administratively” (and thus with no autonomous legal status, and no political decision-making power) to carry out various duties (Box 1.1).

Box 1.1. National Ocean Council: Structure, Mandate and Key Areas of Work Undertaken by Member Institutions

The National Ocean Council (NOC), established by the Cabinet in 2015, is formed by representatives of the Prime Minister’s Office, the Ministry of Tourism, the Ministry of Energy, the Ministry of Ocean Economy, Fisheries, Marine Resources, Shipping and Outer Islands (hereafter referred to as the Ministry of Ocean Economy), Mauritius Oceanography Institute, Mauritius Port Authority (MPA), Mauritius Research Council (which has now become the Mauritius Research and Innovation Council), and the Joint Economic Council. NOC’s Terms of Reference include the following:

- Coordinate technical cooperation and assistance between the government and international institutions and foreign experts to ensure the formulation of a National Ocean Policy Paper that will include the creation of a unified regulatory framework and a National Ocean Authority;
- Set up and drive a government–private sector working group to assess and promote economic activities, capacity building, and marine good governance as well as other developmental needs of the individual sectors of the OE to ensure sustained development, job creation, and wealth generation in the relevant industries;
- Assess the provision of modern logistics infrastructure and services for the development of the maritime and shipping industries;
- Formulate a new action plan for the shipping industry that would include developmental opportunities for the maritime training academy, the flag ship registry, super yachts, ship repair, and ship maintenance and refurbishment;
- Recommend action plans to develop the maritime financial services such as ship financing, insurance, and ICT; and
- Carry out any other advisory and developmental responsibilities as may be requested from time to time by the Minister of Ocean Economy.

(continued on next page)

² www.climatesmartoceans.org.

Box 1.1. National Ocean Council: Structure, Mandate and Key Areas of Work Undertaken by Member Institutions *(continued)*

NOC's activities are organized in thematic clusters, including Fisheries & Aquaculture; Logistics, Shipping, Ports, and Port and Other Services; Business Facilitation; Environment Protection & Maritime Governance (Director of Environment); Regulatory Framework & Institution Building; Skills Development, Training & Employability; and Seabed Exploration, Renewable Energy, Marine Research & Development. Selected key areas of work undertaken to date by the NOC or its member institutions include the following.

Fisheries and Aquaculture (Seafood Hub)

- Allocation of 21 concession sites and initial promotion for land-based aquaculture
- Promotion of Banks fishing and financial subsidies for purchase of fishing vessels (small and semi-industrial), through Marine Finance
- Help and guidance to new entrepreneurs provided by MAUBANK
- Planning of several private sector projects and foreign direct investment (FDI), including Grow Fish, UNIMA, and Afrintex
- For the Mauritius Maritime Training Academy (MMTA), reduction in course fees (from MUR 11,000 to MUR 2,000) and medical test fees (from MUR 10,000–15,000 to MUR 2,000)
- Development of the OE sector in tandem with the World Bank, Board of Investment (BOI), and Mauritius Export Association (MEXA)
- Promotion of the concept of sustainable fishing concept, including through assistance for better monitoring and surveillance of catches.

Logistics, Shipping, Ports, Port and other Services

- Partnership between Virgin Oil and Mauritius Shipping Corporation Ltd (MSCL) to recycle used ship oil and oil slippage from pumping and refining
- Shipbuilding: Chantier Naval de l'Océan Indien (CNOI) – IBL Group – Land in port areas allocated by MPA in consultation with NOC for shipbuilding activities
- LHF Fishing Port Development Quay – MPA and NOC have held consultations
- Purchase of surveillance vessel and subsidy for bank fishing (through budgetary measures)
- A 100% income tax exemption has been introduced for local sailors
- Relocation of AFRINTEX headquarters from Africa to Mauritius, with the Board of Investment (BOI) and MPA – a multibillion investment
- Tuna derogation and multibillion-Rupees export contract (facilitation with MEXA), 4,000 tons per annum.

Port Sector

- Development of port, with port masterplan finalized by MPA after consultations with NOC; the masterplan is now ready for implementation
- Important MPA projects in the pipeline to increase port efficiency, attractiveness, and competitiveness, including new passenger terminal, fishing quay and petroleum jetty

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Box 1.1. National Ocean Council: Structure, Mandate and Key Areas of Work Undertaken by Member Institutions *(continued)*

- BOMIN (bunkering hub) – fourth largest bunker trading company in the world today present in Mauritius since 2016, and
- Cargo handling given policy instructions to increase port productivity to attract more business.

Commercial Shipping Services (MSCL)

- Restructuring of Mauritius Shipping Corporation Ltd (MSCL), a 100% government-owned enterprise currently providing services to Rodrigues, Agalega, and Reunion, and in the future to service other locations in the Africa region. The restructuring has resulted in a complete turnaround of MSCL, which went from heavy losses (of an average of MUR 53 million in 2009–13) to profits (estimated to be MUR 52 million, 10 million, and 110 million in 2015, 2016 and 2017, respectively), and
- A brand new vessel in the process of being acquired and aggressive development of ship agency and ship related new services.

Education and Maritime Training for Prospective Seamen

Target established: i.e. the creation of 18,000 jobs in five years

At the Mauritius Maritime Training Academy (MMTA):

- Reduction in tuition and medical fees: From MUR 11,000 to MUR 2,000
- Allowing recourse to foreign lecturers
- Reorganization of MMTA with the help of international experts

License granted to private-sector institution (Acropolis)

AEL/DDS (a logistics and transportation company) offering courses on Designated Person Ashore (DPA) and Company Security Officer (CSO)

Maritime and OE courses offered by the University of Mauritius.

Business Facilitation for Private Sector Investment

Projects in the pipeline include:

- Aquarium: land has already been allocated by MPA
- Ship building and repair (CNOI) – land has been already allocated
- Deep ocean water application (DOWA) – urban cooling project
- Aquaculture and seafood (Grow Fish, UNIMA and AFRINTEX)
- Enhancement of Disaster Risk Management
- Ocean energy (wave) project (Led by MRC)
- Marine pharmaceutical project in North (with BOI)
- Finalization of regulatory framework for oil and gas exploration and commercialization
- Recycling, refining, and commercializing used marine/ship oil (Virgin Oil Co.) to help reduce marine pollution in the lagoon

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Box 1.1. National Ocean Council: Structure, Mandate and Key Areas of Work Undertaken by Member Institutions *(continued)*

International Partnerships, Consultations and South-South Learning

- Roundtable discussion on Mauritian OE held by NOC with UK Investors in Mayfair, London – Sept 2015. Organized by the British High Commission and Mayor of London
- Africa Ministerial Conference with World Bank held in Mauritius, Sept. 2–3, 2016 (300 foreign participants, more than 20 countries present as well as a dedicated Journalism Training for African journalists); a 10-point-action high-level “Mauritius Communique” was agreed upon, and
- Mauritian officials supported to participate in South-South Learning Exchange Learning Overseas Tour on topic of Renewable Energy and Oceans to Hawaii (USA).

The topic of OE features prominently in the country’s policy-making process, as exemplified by decisions made as part of the 2017–2018 Budget (Box 1.2).

The emerging international experience (Box 1.3 and Appendix 6) suggests that achieving progress on the OE agenda requires a clearly defined strategy, stakeholder engagement, a comprehensive regulatory framework, seed funding to leverage private resources, business

Box 1.2. Excerpts from the 2017–2018 Budget of Mauritius

...the validity of the fishing rights permit will be extended from one year to five years for fishing vessels flying the Mauritian flag, subject to all their catch being unloaded and processed in Mauritius. This should make it easier for them to access finance.

...provision to upgrade and equip the Maison des Pêcheurs at Cap Malheureux, Tamarin, and Mahebourg. Our aim is to provide the fishermen cooperatives with the facilities to transform their fish catch into value-added fish products.

...extension of 2016’s fishermen cooperative societies to acquire semi-industrial vessels until 2018.

... grants to the fishermen cooperative societies for the acquisition of refrigeration vehicles.

...promotion of coral farming by fishermen and SMEs; Government is making provision for the setting up of sea-based coral farms for developing ornamental corals for the tourism sector, aquarium market, and high-end jewelry manufacturing.

...appropriate amendments will be made to the Maritime Zone Act to cater to marina development.

...the Mauritius Shipping Corporation Ltd, in collaboration with the Royal Institution of Naval Architects, will set up a new Maritime Training Institute that will focus on training our youths for jobs on cruise ships and in the maritime sector.

Box 1.3. Key Aspects of Ocean Governance: The International Experience

A review of selected country and regional experiences in ocean governance (including European Union, Grenada, Ireland, New Zealand, Norway, Portugal, Singapore, and the United Kingdom) points to a number of key conditions for making progress on the ocean agenda (see Appendix 6 for further discussion).

Successful ocean economies have developed clearly articulated strategies and governance approaches that ensure that the relevant sectors have visibility, are fully engaged in the governance process, and have access to support and seed funding, in particular during early development stages. Science, innovation, and conservation are critical components of these strategies.

However, while the public sector acts as facilitator, investment decisions are ultimately taken by private business, and funding beyond the early technology stage is provided through existing commercial and other avenues in the normal way. Successful ocean economies also tend to have a range of other supporting institutional features, including experienced bureaucracies, established public-private partnership mechanisms, deep capital markets, and longer-term planning horizons.

Sector choices and priorities reflect broader societal choices, reflecting for instance the shift from extraction to a renewable and circular economy. While coastal tourism will remain in many places a large component of ocean sector revenues, it will critically depend both on protection of marine biodiversity and the development of sustainable coastal infrastructure; traditional activities such as fishing and shipping will require help with the transition to long-term sustainability.

Ocean energy will take time and significant investment before it becomes a larger part of the energy mix, while ocean data and ocean biotech are still small but offer exciting growth opportunities provided they can be embedded into a supportive science and innovation technology policy. Government and the public sector will need to continue to offer a supportive infrastructure, while it will in the end depend on the private sector to build a resilient economy.

Successful open economies with clear regulatory structures, government strategies, and support mechanisms for innovation are also likely to have successful marine sectors, but these may be small in the context of the overall economy.

A strategic emphasis in the form of a national ocean plan (e.g., Ireland), supported by a dedicated Minister for the Sea (e.g., Portugal), targeted support and investment in marine innovation (e.g., Norway), funding support for research and infrastructure (e.g., European Union), including at regional and local levels (e.g., Canada), and a comprehensive analysis of the specific future challenges (e.g., New Zealand) are identified here as key components for sustainable blue growth.

intelligence, and policies and investment for long-term environmental sustainability and climate change resilience. Several of these ingredients are in place in Mauritius; but there are important areas where further progress is needed.

In particular, the Ministry of Ocean Economy has in-house expertise on fisheries, but more limited capacity in areas such as aquaculture, shipping, marine resources, and outer islands. In addition, other key OE areas, such as energy, tourism, environment, disaster risk reduction, beach erosion, sustainable development at large, education, and ports, are outside the mandate and jurisdiction of the Ministry of Ocean Economy. There is no clear mechanism for interministerial coordination

at the day-to-day administrative level, beyond what a consultative body like the NOC could facilitate.

The NOC faces significant challenges, too. The council can boast high-level expertise across the full spectrum of the OE areas; its members often play key roles in national debates on policy priorities and economic opportunities. However, while the NOC receives organizational and administrative support from the Ministry of Ocean Economy, it has no dedicated budget and thus no dedicated technical staff to prepare its deliberations. Perhaps more importantly, it does not have a mandate for making policy decisions or recommending them formally to Cabinet.

Finally, there are other key pillars of ocean governance that have been envisaged in different occasions by the NOC and the government but are not yet in place. These include:

- Developing a unified regulatory framework for the OE
- Preparing a National Ocean Policy Paper
- Preparing a National Oceans Bill/Act, and
- Establishing a National Ocean Authority.

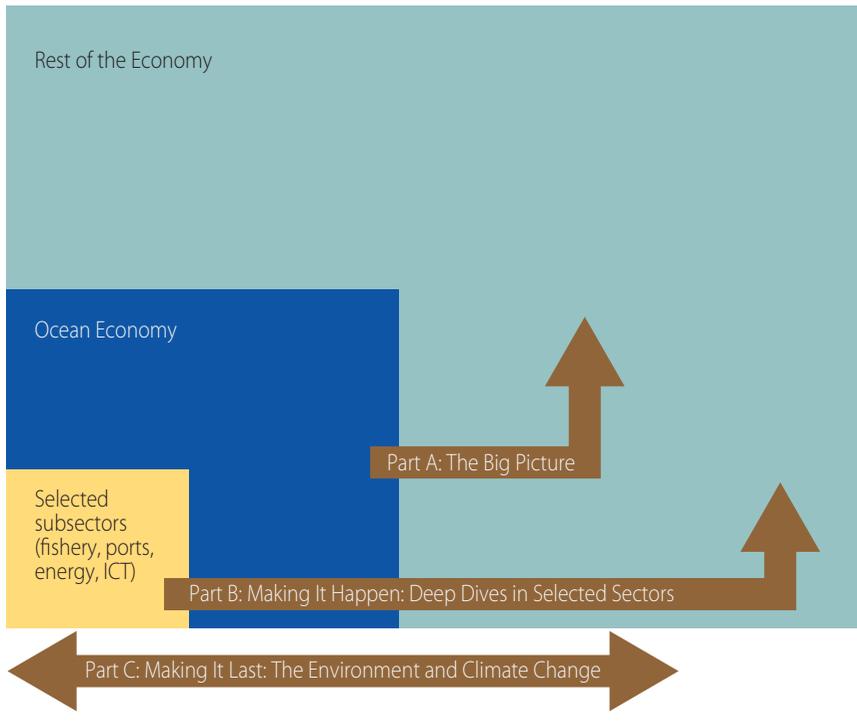
Objectives, Structure, and Limitations of this Book

This book aims at assessing the overall potential of the OE to contribute to Mauritius's development (in terms of economic growth and diversification, trade balance, reduction of poverty and inequality, effects on the government's finances); at identifying the challenges to be overcome to seize that potential; and at evaluating the prospects to ensure the longer term sustainability of the OE, in particular from the environmental point of view and taking into account the risks posed by climate change.

The approach used here combines a top-down analysis of a doubling of the OE's GDP in 10 years with four bottom-up deep dives in specific sectors representative of both the OE's traditional sectors (fisheries, ports) and its emerging ones (marine energy and marine ICT). The book is organized in three parts, as visualized in Figure 1.1.

The first part of the book, "Promoting the Ocean Economy: The Big Picture," offers a top-down analysis of a doubling of the OE's GDP in 10 years (the O2 scenario) by using a dynamic computable general equilibrium (CGE) model based on a highly disaggregated social accounting matrix (SAM) for 2015, which was developed by the task team in collaboration with Statistics Mauritius and the Ministry for Ocean Economy.

This part of the book evaluates the ability of the OE, taken in its entirety, to contribute to the growth of the rest of the national economy. It first identifies the amount of investment required to double the size

Figure 1.1. How this Book Is Organized

of the OE over ten years (a reasonable proxy of the overall goal of the 2013 roadmap), and then it assesses the merits of investing those resources into the OE, as opposed to investing them in a plausible alternative scenario. While this part of the analysis does not evaluate investment priorities across OE components, it does assess the ability of the OE to serve as an overall engine of growth; and it identifies cross-cutting constraints to be addressed in the process. These include in particular the need to build adequate human capital, to ensure the conservation of the natural capital on which the OE depends; and to create favorable conditions to attract the resource flows required to finance the expansion of the OE.

Part B of the book, “Making It Happen: Deep Dives into Selected Sectors,” consists of a bottom-up analysis of four sectors (fisheries, ports, marine energy, and marine ICT) to assess their financing needs (from public and private sources), revenue generating potential, and institutional or capacity bottlenecks to be overcome to fulfill the promises of the OE. This part of the book includes estimates of the merits of investing in the selected sectors, both from the project-level perspective and from the point of view of the economy as a whole. Given the

study's time and budget constraints, the analysis does not intend to be comprehensive, but rather illustrative of the opportunities and challenges of expanding traditional OE sectors (e.g., fisheries, ports), as well as emerging ones (marine energy, marine ICT).

Part C of the book, "Making It Last," asks what needs to happen to ensure the longer-term sustainability of the OE. Any OE expansion would also entail the need to cope with environmental threats coming from a combination of anthropogenic influences and the effects of climate change. Damage to the local biotopes and biodiversity from climate change is already significant, as is damage to coral reefs and lagoon habitats from water pollution. Coastal erosion and vulnerability to weather extreme events are both increasing. A more active use of the OE requires technical and institutional mechanisms to reconcile, across sectors and time, competing claims over ocean and coastal resources. This is the reason why at the end of 2016 Mauritius has embarked on the process of developing a Marine Spatial Plan (MSP). The book outlines options that could be considered in the next stages of the MSP preparation. The analysis is based on a review of international MSP experiences and takes into account Mauritius-specific issues and challenges, in terms of both the current legislative framework and the sources of environmental pressure to be mitigated.

Another key aspect of longer-term sustainability of the OE is climate change. The final chapter of the book reviews climate risks, both those that are well known and those that are less well known; and illustrates how the CGE model developed by the study team for Mauritius could be used to quantify the socioeconomic risks (notably, in terms of growth and jobs) of climate change, focusing on a particular class of climate shocks, namely tropical cyclones. This can help in assessing the merits of investing in preventive adaptation measures.

One important caveat is that the analysis is intended to provide a big-picture, strategic assessment of the OE. Specific investment opportunities at the individual project level are discussed in Part B of the book (in the bottom-up analysis), mostly to exemplify opportunities and challenges and to assess the order of magnitude of investment resources required to promote OE growth. However, an appraisal of the technical and financial feasibility of individual projects would go beyond the scope of this book and will have to be conducted as part of separate follow-on activities.

While the top-down analysis in part A covers the OE as a whole, the book does not analyze the development prospects of all OE sectors. Notably, tourism is not included, since it is a mature and relatively large sector and thus likely to run into diminishing returns as it expands, as confirmed by the economywide analysis. As a result, an important

part of the impulse for the longer-term growth of the OE can arguably be expected to come from emerging OE sectors or from smaller traditional ones, which are less likely to be affected by diseconomies of scale. Seabed mining of minerals and hydrocarbons is not analyzed either; in this case, the reason for the omission is that there are currently few hard facts on the sector's potential.

Most of the chapters contain specific recommendations for seizing the opportunities afforded by the OE and for ensuring that these opportunities last over time. A summary of the top recommendations, focused on the shorter term (6–18 months), is included in the Overview to this book.

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Prospects for Doubling the Ocean Economy

Lucio Scandizzo and Raffaello Cervigni

Key Messages

- Based on a model of Mauritius' economy developed in partnership with Statistics Mauritius and the Ministry of Ocean Economy, Fisheries, Marine Resources, Shipping and Outer Islands (referred to hereafter as the Ministry of Ocean Economy), this book finds that it is a smart decision for Mauritius to invest in *doubling the gross domestic product (GDP) share of its OE* as a way of moving up the economic development ladder, and in an inclusive, sustainable manner. We call this the *O2 strategy*.
- While it is unlikely that the doubling target can be achieved in less than 18 years, already within 10 years the O2 strategy can yield considerable growth results, including a 62 percent increase of the OE GDP in absolute terms, and an increase of 38 percent in its share of the national total (from 12.6 percent to 17.5 percent).
- The analysis also shows that, compared to a plausible counterfactual, such a strategy will boost returns on investment (a 20 percent gain), diversify the OE so it no longer relies on tourism alone (a 20 percent increase in diversification), create more jobs (36 percent more in O2 than in the counterfactual), improve the trade balance, reduce poverty and inequality, and strengthen the government's finances (2 percent reduction in debt/GDP ratio).
- However, this investment will need to be complemented by a joint public-private sector effort to boost labor productivity, ensure adequate inflow of financing, and invest in training and education.
- Also vital will be additional investment (an extra 19 percent compared to the counterfactual) to conserve and improve the natural resources of the ocean and coastal areas, given that additional pressure is expected to be placed on these resources as the O2 strategy is implemented if it is to be sustained over time.

Introduction

So far, this book has introduced the concept of an ocean economy (OE) and discussed why Mauritius is increasingly interested in it as a new frontier for development. While there is no shortage of examples of investment opportunities related to the ocean that have generated economic benefits in other countries and appear promising in Mauritius too, until now there has been no systematic assessment of the ocean's ability to become a fundamental driver of the country's economy for the foreseeable future.

This chapter illustrates how economic modeling techniques can be used to fill that knowledge gap. It takes a big picture perspective, focusing on the government's goal to make the OE a driving force of the economy as a whole. Here, the key questions are: Is the doubling of the OE in as little as 10 years achievable? Is it desirable? What does it take to make it happen? These questions are then asked in subsequent chapters from the individual perspectives of four critical sectors of the OE: fisheries and aquaculture, ICT, energy, and ports.

Our basic approach to assess the overall prospects of the OE is as follows:

- Define a scenario where the size of the OE (in GDP terms) doubles over the next decade—the O2 scenario—by quantifying the investment that would be needed to be channeled to key sectors that depend (directly or indirectly) on ocean resources;
- Evaluate an alternative scenario where the same investment resources required in the O2 scenario are not concentrated on the OE but are instead distributed across sectors according to the same pattern observed in recent years. This alternative scenario uses a counterfactual to assess the relative merits of investing in the OE; and, finally,
- Compare O2 and the counterfactual to assess the merits of the former, in terms of outcomes such as growth, return on investment, income distribution, job creation, balance of trade, and fiscal balance.

The results of the analyses show that investing in doubling the size of the Mauritian OE could be a powerful way to transform the economic fundamentals of the country and could do so in an inclusive, sustainable manner. But this will only occur if Mauritius also adopts complementary policies to boost labor productivity, consolidate government finances, further enhance the investment climate, invest in training and education, and restore and conserve the ocean's natural resources. What

this means in more specific terms is examined in detail in the four sector-level “deep dive” chapters that follow.

A Guide to the Economywide Approach

The approach adopted to study Mauritius’ OE relies on two main analytical tools: a social accounting matrix (SAM) and a computable general equilibrium model (CGE). Both were developed in full partnership with Mauritius government institutions (in particular, Statistics Mauritius and the Ministry of the Ocean Economy). These tools are a way of linking Mauritius’ national accounts to investment scenarios and policy changes in order to estimate their impacts on growth, jobs, incomes, exports, and other key economic and social indicators that help inform decisions. More specifically:

- The CGE is one of the most rigorous, cutting-edge quantitative methods to evaluate the impact of economic and policy shocks—especially policy reforms—on the economy as a whole. It can be calibrated using a SAM, which is a consistent and complete data system that captures interdependencies that exists within a socioeconomic system; and
- The SAM includes transaction estimates across all sets of economic agents, which are grouped into producing sectors (activities), products and services, factors of production (such as labor by skill, capital of various forms, and natural resources), and institutions (government, households, and firms).

Both the SAM and the CGE are economic tools that are useful for systematizing and interpreting aggregate and sector statistics from a variety of sources in the framework of national accounts and for simulating the impact of alternative strategies of growth on the economy for a given year and over time (see Box 2.1). The dynamic CGE model aims to capture some of the relevant features of the Mauritius economy today and their potential evolution over time. As Figure 2.1 shows, our CGE model of Mauritius does a good job of tracking the past performance of the economy in terms of aggregate economic values such as GDP growth, value added, and household consumption. (However, as a simulation tool, there are important limits to what it can do, which should be carefully taken into account in the interpretation of the results).

Using the approach described above, the analysis carried out for this book has identified a plausible scenario—the O2 scenario—of a government-led doubling of the OE’s share of GDP, based on a highly disaggregated model of Mauritius’ economy. This model for the first time quantifies the investment resources required to achieve

Box 2.1. SAM and CGE Models for Mauritius

According to the United Nations, the OE is an economy that simultaneously promotes economic growth, environmental sustainability, social inclusion, and the strengthening of oceans ecosystems (UNCTAD 2014). The social accounting matrix (SAM) built for Mauritius aims to represent a coherent, integrated, and structured framework that accounts for the economic potential of marine natural resources (such as ship routes and energy sources from the oceans). It distinguishes between ocean-based and non-ocean-based activities, as well as blue (marine ecosystems) and green (terrestrial ecosystems) natural resources. The critical ocean-based activities are sustainable fisheries and aquaculture, renewable marine energy, marine bio-prospecting, maritime transport and infrastructure, and marine and coastal tourism. Water treatment and decontamination activities are also considered, while the coastal activities represent a critical interface between the blue and green economies.

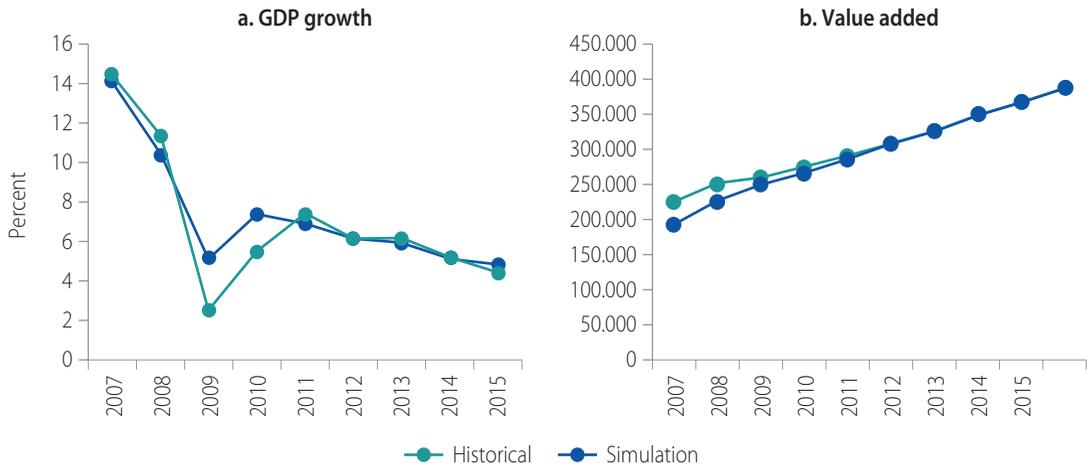
The SAM is a system of national/regional/sub-regional accounts represented in a matrix format (Stone and Brown 1962; Stone 1981). It includes the inter-industry linkages through transactions typically found in the input-output accounts and the transactions and transfers of income between different types of economic agents (such as households, government, firms, and external institutional sectors). A typical computable general equilibrium (CGE) model is calibrated using a SAM. For Mauritius, the SAM estimated for 2015 was used to calibrate the CGE model so that the CGE solution reproduces the 2015 data as a baseline reference.

The CGE model is a dynamic recursive one. Dynamic models trace each variable through time, often at annual intervals (unlike static models, which look at the reactions of the economy at only one point in time). Dynamic recursive models are those that can be solved sequentially (one period at a time). They assume that behavior depends only on current and past states of the economy. CGE models always contain more variables than equations, so some variables must be set outside the model (known as exogenous), a process known as closure. These models also typically assume that the outside framework of the model (for example, global growth, climate changes, and other major events) are exogenous. For our purposes, we have used a closure rule based on the hypothesis that the official exchange rate is fixed and that investment financing in excess of domestic savings can be secured by foreign capital inflow.

CGE models are useful as simulation tools to explore the implications of alternative economic policies and other exogenous events on an integrated economic system, taking into account the market structure and the income formation mechanisms. They have important limitations, however, since they are based on the assumption that markets are capable with maintaining or restore equilibrium between demand and supply and that they can do that efficiently and without transactions costs.

that target and explicitly accounts for the macroeconomic and structural constraints to growing the OE sectors. The analysis identifies a reasonable trajectory of growth of the OE that leads to the achievement of the O2 target over the longer term (15–18 years). It also suggests that attempts to pursue the O2 target over a shorter period are likely to result in undesirable economic outcomes, such as diseconomies of scale, price increases, excessive use of natural resources, and fiscal imbalances.

To provide insights into the features and merits of the O2 scenario over a time horizon of greater relevance for policy making purposes, the rest of this chapter focuses on a shorter snapshot (10 years) of the

Figure 2.1. GDP Growth and Value-Added: Historical vs. Dynamic CGE Simulation, 2007–15

Source: World Bank simulations; data from Central Statistics Office Mauritius.

path leading to the doubling of the OE. Even over such a time horizon, which falls short of the time needed to meet the doubling target, the importance of the OE nevertheless grows considerably, due to both the increase in overall OE output (+88 percent) and the increase in output of nonconventional OE sectors (+131 percent). It is also important to note that the measurement of the OE growth is sensitive to the share of certain sectors attributed to the ocean. For example, a broader definition of ocean-related ICT, energy, and water treatment sectors would lead along the growth path identified by the model to an even faster doubling of the OE share (that is, over a 10-year period).

How greater OE investment would affect the Mauritian economy. To shed light on how greater OE investment would affect the whole economy, we first asked what would happen if the government took steps to double the size of the OE over a suitable period. This objective could conceivably be achieved with different trajectories, ranging from a “big bang” attempt concentrated in a small number of years to more gradual investment paths distributed over a longer period. A first round of simulations showed that “big bang” solutions, where investment was concentrated over a small number of years, tended to be unsustainable because of their macroeconomic imbalance and to be ultimately ineffective because of diseconomies of scale. We thus ran the model under alternative, gradual paths of resource and finance deployments, using as criterion of choice the maximization of the present value of cumulative consumption by households over the simulation period,

Table 2.1. Projected Impact Under Both O2 and Counterfactual Scenarios, Using Best Investment Trajectories (Change Between Year 1 and Year 10)

| Indicator | O2 Scenario | Counterfactual Scenario |
|--|-------------|-------------------------|
| Base-year (2015) GDP (US\$ million) | | 10,878 |
| Base-year proportion of OE GDP to total GDP | | 12.66% |
| Percent increase of total OE production to year 10 | 88% | 47% |
| End-year proportion of OE GDP to total GDP | 17.5% | 14.7% |
| End-year OE GDP (base year = 100) | 162 | 147 |
| Average contribution to growth rate | 3.17% | 2.93% |
| Additional investment (US\$ million) | | 5,836 |
| GDP growth (US\$ million) | 3,005 | 2,457 |
| NPV (5%) GDP increase (US\$ million) | 6,018 | 4,714 |
| NPV (5%) additional OE2 investment (US\$ million) | 4,046 | 4,046 |
| NPV (5%) GDP increase/additional Investment | 1.49 | 1.23 |
| FOB export in 2015 (US\$ million) | | 93,290 |
| CIF imports in 2015 | | 168,203 |
| NPV (5%) export-import increase over the 10-year period (US\$ million) | 45.2 | 28.5 |

Source: Mauritius National Statistics Offices and model simulation results

Note: The additional investment is calculated as the minimum autonomous (that is, government-planned) investment dedicated to the sectors of the OE economy over the 10-year period that would result, over a longer time horizon (15–18 years), in a doubling of the OE's GDP share. The O2 strategy is the one leading to a longer-term doubling of the OE. The counterfactual scenario is one in which the same investment resources required under O2 (about \$5.8 billion) are allocated to sectors in the same proportions observed in the recent past. NPV = net present value.

with weights inversely proportional to the households' consumption levels.¹

The results (summarized in Table 2.1) indicate that with a cumulative investment of \$5.8 billion over 10 years, the OE share of GDP increases by almost 40 percent (rising from 12.6 percent to 17.5 percent total GDP), and by over 60 percent in absolute value. The investment stimulus defined by the simulation increases gradually from US\$25 million, or 2.37 percent of total investment, to US\$2.5 billion, or about 39 percent of the total in the 10th year of the simulation. The OE share of GDP (including the indirect effects) increases from 12.6 to

¹ This function, which is used in project evaluation to take into account income distribution, similarly to a progressive tax schedule, gives a higher weight to consumption increases of poorer versus less poor/richer households. Use of this function makes the solutions found roughly equivalent to realistic dynamic equilibrium, partially driven by short-term expectations from decentralized agents and partly determined by planning behavior guided by longer-term foresight on the part of the government.

Table 2.2. Projected Macroeconomic Impact Under O2 Scenario, Using Best Investment Trajectories

| | Year 1 | Average, Year 1–Year 10 |
|---|---------------|--------------------------------|
| Government deficit (US\$ million) | 178.70 | 177.42 |
| Government debt as percent of GDP | 61.63% | 61.40% |
| Government debt increase (US\$ million) | 177.14 | 177.42 |
| Government debt as percent of GDP | 61.63% | 60.69% |
| GDP growth | 0.58% | 5.53% |
| GDP real growth | 0.30% | 5.18% |
| Implicit GDP deflator | 0.28% | 0.35% |

Source: Mauritius National Statistics Offices and model simulation results.

20 percent, because of the expansion of the rest of the economy, which proceeds at an average rate of about 3.2 percent. The impact on GDP growth of the simulated investment is high and increasing over time, with very little inflation. Foreign exchange (Table 2.1) and government balances (Table 2.2) also appear to be positively affected, and although these effects are not large, they are significant and steady.

The O2 scenario can be compared (Table 2.1) with a counterfactual² that assumes a continuation of the historical pattern of investment in Mauritius. In the counterfactual scenario, the same amount of investment resources required to double the OE are mobilized, but they are distributed across sectors in the same proportions observed in recent years.

The O2 scenario appears to outperform the counterfactual over all the macro indicators considered, with differences tending to increase over time. The average contribution to growth of the O2 scenario is significantly higher (3.17 percent) than the counterfactual scenario (2.93 percent), and the cumulative return, as measured by the ratio of the present value of additional GDP and investment, is more than twice as large under the O2 scenario (49 percent) as it is under the counterfactual (23 percent). In other words, there is a 20 percent gain from

² The results of the counterfactual “business as usual” scenario are not based on an optimization, but are simply taken to represent the likely results of the possible and maximum crowding-out of resources that could follow the implementation of the O2 strategy. The amount of such crowding out, in turn, is assumed to be given by the most likely allocation of the same resources and along the same trajectory, according to the pattern of distribution across sectors realized historically. The counterfactual scenario represents the most likely trajectory of resource commitment under an alternative and completely decentralized equilibrium, without rational expectations on the part of the planner.

Table 2.3. Net Present Value of Incomes Under O2 and Counterfactual Scenarios, by Recipient Income Group

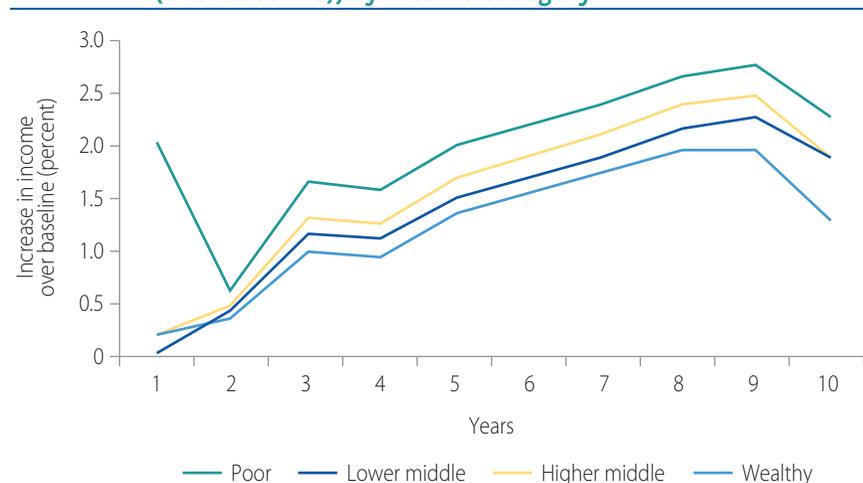
| | NPV (at 5% discount rate (in US\$ million)) | | |
|---------------------|---|-------------------------|--|
| | O2 scenario | Counterfactual scenario | Ratio (O2 value divided by counterfactual value) |
| Poor | 30 | 29 | 1.03 |
| Lower-middle income | 295 | 275 | 1.07 |
| Upper-middle income | 602 | 575 | 1.05 |
| Wealthy | 359 | 358 | 1.00 |
| Total | 1,286 | 1,238 | 1.00 |

Source: World Bank model simulation results.

Note: Income groups are defined consistently with Mauritius national accounts and, in particular, their definition for the 2002 and the 2007 SAM. Poor households comprise 7.7 percent of all households with the lowest level of equalized income. *Lower-middle* income group: comprises the next 42.3 percent of households when ranked according to their level of equalized income, and comprise nonpoor households in decile 1 and all households in deciles 2 to 5. *Upper-middle* income group comprises the next 40.0 percent of households when ranked according to their level of equalized income, from deciles 6 to 9. *Wealthy* households comprise the 10 percent of households with the highest level of equalized income, from decile 10.

investing the same amount of resources (\$5.8 billion over 10 years) in the OE, instead of investing them in accordance with the historical pattern of investment across sectors.

The O2 scenario tends to benefit the lower-income groups more (Table 2.3 and Figure 2.2). In addition, its effects on factor incomes (value added) and job creation are also larger than the effects under the counterfactual scenario (Table 2.4, Table 2.5, and Figure 2.3).

Figure 2.2. Change in Personal Income Under O2 Scenario (over baseline), by Income Category

Source: World Bank model simulation.

Investment costs and environmental costs. The O2 scenario shows an increase in the capital income component of GDP, and environmental costs (and the implicit investment costs to neutralize them) are much

Table 2.4. Value-Added Impact Under Both O2 and Counterfactual Scenarios, by Education Level and Employment Status

| | Baseline | O2 scenario | Counterfactual scenario |
|-------------------------------|----------|-------------|-------------------------|
| | Year 1–2 | Year 9–10 | Year 9–10 |
| Primary education | 4.29 | 2.22 | 2.14 |
| Less than Secondary education | 3.09 | 66.08 | 47.41 |
| Secondary education and above | 2.27 | 19.57 | 32.55 |
| Tertiary education | 4.20 | 44.63 | 76.13 |
| Own account | 6.20 | 65.81 | 127.85 |
| Employer | 1.54 | 2.85 | 19.76 |
| Operating surplus | 11.51 | 2,171.81 | 1,719.94 |
| Total VA | 33.44 | 2,372.97 | 2,025.78 |
| Ocean | 0.25 | 5.19 | 3.80 |
| Green water | 0.07 | 7.25 | 6.28 |
| Blue water | 0.04 | 4.20 | 3.68 |
| Wetland | 0.00 | 4.47 | 3.93 |
| Natural resource costs | 0.37 | 21.10 | 17.69 |

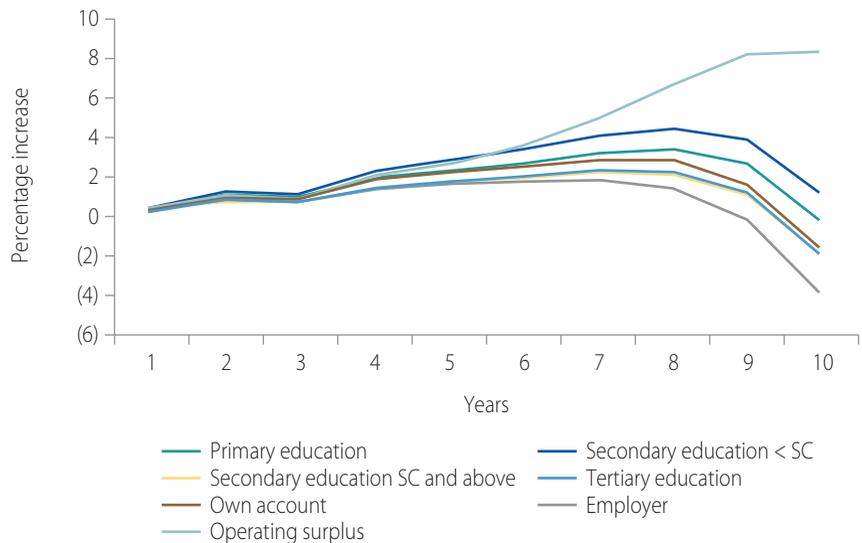
Source: Mauritius National Statistics Offices and model simulation results.

Table 2.5. Increases in Labor Real Income and Jobs Under O2 and Counterfactual Scenarios

| | Labor real income increases (US\$ million) | | Number of jobs created | |
|-------------------------------|---|-------------------------|------------------------|-------------------------|
| | O2 scenario | Counterfactual scenario | O2 scenario | Counterfactual scenario |
| Labor qualification/education | Year 1–10 | Year 1–10 | Year 1–10 | Year 1–10 |
| Primary education | 188 | 239 | 2,388 | 3,032 |
| Less than Secondary education | 231 | 173 | 2,936 | 1,649 |
| Secondary Education and above | 96 | 129 | 1,215 | 981 |
| Tertiary education | 212 | 298 | 2,694 | 2,271 |
| Own account | 275 | 456 | 3,492 | 1,390 |
| Total | 1,002 | 1,295 | 12,726 | 9,324 |

Source: Mauritius National Statistics Offices and model simulation results.

Note: Own account denotes self-employed workers. Jobs created are defined as the number of labor income streams that would support a full-time worker for 20 years.

Figure 2.3. Change in Value-added Components, by Employee Education and Status

Source: World Bank model simulations.

Note: Own account denotes self-employed workers.

higher for O2 than for the counterfactual (Table 2.4). Because of its reliance on ocean resources, even though its pressure on the small land area of Mauritius is low, the O2 strategy is likely to result in sizable environmental costs.

These costs are not easy to measure, but the model is able to generate estimates that can be considered as reasonable proxies. In particular, the model estimates the contribution to value added (and value added increases) of different factors of production (such as unskilled and skilled labor and capital). It also estimates the share of value added that is not attributable to the conventional factor of production, and the way in which this residual portion of value added can be attributed to different forms of natural capital, in particular blue water, green water, wetlands, and oceans.

It is reasonable to argue that as the contribution of natural capital to value added increases, so will the need to allocate resources to conservative and/or defensive expenditures to prevent the degradation of natural capital and the decrease in its ability to contribute to value added creation. The model results indicate that toward the end of the simulation period, the contribution of natural capital to value added is 20 percent higher in the O2 scenario compared to the counterfactual. While this result cannot directly be used to quantify the amount of investment required to conserve environmental quality, it points clearly to the fact

Table 2.6. Sector Production Value and Shares under the Best O2 Trajectory, Year 1 and Year 10

| | Year 1 | | Year 10 | | Increase (from year 1 to year 10) | |
|------------------------------------|----------------|---------|----------------|---------|--------------------------------------|---------|
| | (US\$ million) | Percent | (US\$ million) | Percent | (US\$ million) | Percent |
| Fishery and seafood processing | 509.24 | 18 | 1,149.44 | 22 | 640.20 | 26 |
| Sea transport and related services | 288.14 | 10 | 699 | 13 | 410.86 | 17 |
| Marine ICT | 195.58 | 7 | 446.11 | 8 | 250.53 | 10 |
| Tourism | 1,820.99 | 64 | 2,913.26 | 55 | 1,092.27 | 44 |
| Sewage and water treatment | 53.49 | 2 | 122.42 | 2 | 68.93 | 3 |
| Total | 2,867.45 | 100 | 5,330.23 | 100 | 2,462.78 | 100 |
| Index of diversification | 46% | | 52% | | | |

Source: Mauritius National Statistics Offices and model simulation results.

Notes: The statistical definition of the OE used in this table differs from the official definition, because it includes an estimate of marine ICT (mainly the economic value of the traffic generated by the submarine cable) and part of the sewage and water treatment sector. As a consequence, the weight of the tourism sector is lower than in the official figures. The index of diversification is given by one minus the Gini coefficient.

that investment is likely to be higher in the O2 than in the counterfactual scenario, other things being equal.

At the subsectoral level, the results point to the less than proportional expansion of some of the traditional sectors (like coastal hotels and restaurants) and the more than proportional growth of both some of the traditional activities (like fisheries, sea food processing, and the services allied to marine transport) and relatively new activities, such as ICT and ocean energy (Table 2.6).

This result depends on several factors. First, tourism is a relatively mature sector, with recently declining demand and relative low rates of return for incremental capital. Second, because of the already large proportion of the OE economy that it accounts for, tourism is affected by diseconomies of scale to a larger extent than other sectors that start from a smaller sector base. Third, tourism is still characterized by a value chain largely relying on imported intermediates, especially for the key sectors. Fourth, although tourism is a labor-intensive sector with a high capacity for job creation, it is also plagued by seasonality and low productivity of labor and capital. Thus, investment in tourism should aim more at improving the quality and the performance of the sector than at increasing its size. Overall, the O2 strategy results in a more

diversified OE, with an increase of some 13 percent of the selected index of diversification (one minus the Gini coefficient).

Conditions for Success

The dynamic simulation results suggest that the O2 strategy may be beneficial to economic growth on several fronts, including diversification, productivity increases, job creation, and income distribution. These effects also persist if comparison is made with an equivalent counterfactual scenario reflecting historical growth. However, doubling OE may create several tensions on three main fronts: foreign exchange provision, labor skill availability, and natural resource deterioration. This section aims to assess the conditions that could interfere with seizing the full potential of the O2 strategy and, in some cases, make O2 less desirable than the counterfactual scenario.

Foreign exchange provision. Foreign exchange has generally been available for Mauritius at good conditions to fill the gap caused by a declining saving rate (which fell from 25 to 15 percent of GDP between 2000 and 2013) and a stable investment rate (at 25 percent of GDP). Deteriorating external conditions and a widening foreign exchange account could make it more costly to obtain foreign capital to finance growth. The simulation is based on the hypothesis that foreign capital may become less readily available (see the technical appendix for details). Yet it still indicates that the O2 strategy would be able to increase the OE share of total production to almost twice its initial level and would yield better results than the counterfactual scenario (Table 2.7). In absolute terms, however, the O2 results would be considerably lower than the main scenario explored before, with an average contribution to growth of only 1.83 percentage points and a cumulative rate of return of only 32 percent.

Labor skill availability. The OE2 strategy—especially in the new sectors of ICT, energy, and port and allied transportation services—requires

Table 2.7. Economic Impacts Under O2 and Counterfactual Scenarios, Assuming Unfavorable International Finance Terms

| | O2 scenario | Counterfactual scenario |
|---|-------------|-------------------------|
| Total percent increase in OE production | 83% | 47% |
| Average contribution to growth | 2.84% | 1.49% |
| NPV (5%) GDP growth (US\$ million) | 5,356 | 4,405 |
| NPV (5%) Investment growth (US\$ million) | | 4,046 |
| NPV GDP/NPV INV | 1.32 | 1.09 |

Source: World Bank model simulations.

Table 2.8. Economic Impacts Under O2 and Counterfactual Scenarios, Assuming a Constraint on the Supply of Skilled Labor

| | O2 scenario | Counterfactual scenario |
|---|-------------|-------------------------|
| Total percent increase in OE production | 69% | 32% |
| Average contribution to growth | 1.77% | 1.65% |
| NPV (5%) GDP growth (US\$ million) | 4,076 | 3,339 |
| NPV (5%) investment growth (US\$ million) | 4,046 | |
| NPV GDP/NPV INV | 1.01 | 0.83 |

Source: World Bank model simulations

Note: This scenario assumes elasticities of only about 10 percent for the supply of medium- and high-skilled labor (secondary education and above). This means that an increase in wages of 10 percent is met with only 1 percent increase in labor supply.

an ample supply of skilled and semiskilled labor (Table 2.5). At the moment, there is already evidence of imported labor at both the lower and higher ends of the skill distribution, and there is evidence of significant skill mismatch because of the low skill and difficult-to-train labor liberated by the contraction of the textile industry. So what would happen with a significant skills mismatch, that is, when the supply of labor would not be responsive to increased demand and wages due to the lack of availability of skilled human capital? As Table 2.8 shows, the effect of what amounts to a constraint on labor supply would be to curtail the potential contribution to growth of the O2 strategy by more than half, bringing it from 3.17 (Table 2.4) to 1.77, for a mere 10 percent cumulative return on investment over the 10-year period considered. Compared to the growth scenario without a labor constraint (Table 2.8), this would amount to a *loss* of almost US\$2 billion, which suggests that investment in education would indeed be not only profitable but also necessary.

Natural resource deterioration. High-quality natural resources are a major ingredient for the expansion of the OE. Indeed, increases in the natural resource investment requirement (proxied by their non-remunerated contribution to value added) are significant in absolute terms, at more than US\$21 million in the 10th year of the simulation, and some 20 percent larger in the O2 than in the counterfactual scenario. These amounts are likely to reflect loss of efficiency to the extent that resource costs are not internalized by the economic agents who exploit them, which in turn would result in underinvestment in natural capital. Resource uses unmatched by adequate maintenance and renewal activities are likely to cause resource deterioration—in the form

Table 2.9. Economic Impacts Under O2 and Counterfactual Scenarios, Assuming Deterioration in Natural Resources

| | O2 scenario | Counterfactual scenario |
|---|-------------|-------------------------|
| Total percent increase in OE production | 81% | 43% |
| Average contribution to growth | 2.75% | 2.89% |
| NPV (5%) GDP growth (US\$ million) | 5,083 | 4,900 |
| NPV (5%) investment growth (US\$ million) | 4,046 | — |
| NPV GDP/NPV INV | 1.26 | 1.21 |

Source: World Bank model simulations.

of pollution, loss of biomass, and other negative changes in productivity (Table 2.9).

Deterioration in the environmental quality of the marine ecosystem, resulting from insufficient public and private investment in conserving natural resources (in particular ocean, blue water, green water, and wetlands), is captured in the model by a lower elasticity of supply; that is, less natural capital is mobilized for any given increase in its marginal return. If the elasticity were to become very small (about 1 percent of the baseline value), resource use could be expanded only by depleting the resources available, effectively leading to a gradual demise of the OE. In this case, the model simulation shows that the OE's overall contribution to growth would fall to 2.75 percent (compared to 3.17 percent in the base case of the O2 scenario) and cumulative returns to investment to 26 percent. Because "blue" natural resource use is more intensive in O2 and is a condition necessary for its success, the aforementioned model simulation is also the only case where the counterfactual appears to outperform the O2 scenario, although only in terms of average contribution to growth.

The bottom line is that a movement away from the base case of O2 expansion to less favorable conditions shows no clear tendency for O2 to become less attractive than the counterfactual, except for natural resources (Table 2.10).

Benefits of Taking a Big-Picture View

As Mauritius looks into ways to foster a new phase of inclusive growth, the idea of centering its investment strategy on the OE appears to be a good one for several reasons. To begin with, many small island economies depend on the ocean and the related system of inland waters as key natural resources for crucial sectors (such as the tourism value chain, fisheries, and numerous marine transportation and related services). In addition, there is the sheer size of Mauritius' seabed platform

Table 2.10. Economic Impacts Under O2, Relative to Counterfactual Scenario, Assuming Sequential Introduction of Exogenous Constraints

| Performance metric | Base case (no constraints) | A. Unfavorable international finance | B: A plus constrained skilled labor supply | C: B plus natural resource constraints |
|--------------------------------|----------------------------|--------------------------------------|--|--|
| Average contribution to growth | 108.19 | 190.60 | 107.27 | 95.26 |
| NPV (5%)GDP growth | 127.66 | 121.58 | 122.06 | 103.75 |
| NPV GDP/NPV INV | 121.14 | 121.10 | 121.69 | 104.13 |

Source: World Bank model simulations.

Note: All the values in the table are normalized to the corresponding value in the counterfactual scenario, which is made equal to 100.

and its potential for catalyzing development and technological progress in the areas of ICT, renewable energy, fisheries, marine biotechnology and many accessory activities based on ocean resources. Further, many of these subsectors appear to offer a way to combine productivity and employment growth, with positive effects on inclusiveness, poverty reduction, and income distribution.

For that reason, this book developed the dynamic CGE model discussed in this chapter, to test what would happen if Mauritius undertook a near doubling of the OE over a 10-year time horizon (the O2 strategy). The above findings are the result of comparing this set of CGE simulations with a counterfactual strategy based on the same amount of government-led investment allocated across sectors according to historical investment shares.

By most accounts, the O2 strategy appears to perform better than the counterfactual. In particular, the simulations suggest that, given a fixed amount of investment over 10 years, the O2 strategy, compared to the counterfactual, has the potential to (i) deliver a higher return on investment (and in the process diversify the OE away from tourism); (ii) generate more jobs; (iii) improve the net trade balance; (iv) reduce poverty; (v) improve income distribution; and (vi) improve the fiscal balance.

However, the simulations also suggest a number of caveats to these promising conclusions, underscoring the need for complementary policy measures to ensure better results—a task that could be informed by a deeper analysis of the programs needed for human and natural capital development (Box 2.2) and institutional reform.

Boost productivity. The average rate of growth achieved with the O2 strategy, at about 3.2 percent even under the best external conditions and no crowding-out of alternative investments, would fall short of realizing the 5 percent target rate of sustained growth that Mauritius can aspire to achieve on the basis of its past success and reasonable ambi-

Box 2.2. Next Steps for Mauritius' Dynamic CGE Model

The dynamic CGE model can help policy makers craft measures to invest in human and natural capital, and it can be tuned to answer specific policy questions as required by Mauritius. In fact, it already has been instrumental in prompting a constructive dialog between the World Bank team, Mauritian experts, and statisticians and economists from the Central Statistical Office, the Ministry of the Ocean Economy, the university, and business leaders. Both the input-output and the SAM accounts have been developed as a joint product with the local team, and they have formed a solid basis for future systematic data collection and analysis.

Mauritius could update and extend the CGE model to evaluate different scenarios as the OE strategy and other government policies are deployed. Mauritius' understanding of the relationships between key parameters—for example, investment and income distribution—could be improved upon by collecting new data to better analyze the costs and benefits of specific projects. The model can also be used for training to further empower the government's statisticians and economists, who have already produced an exemplary set of methodologies, national statistics, and economic accounts.

tions for the future. Thus, once again, the country will need to significantly increase its average rate of total factor productivity growth—this time, by about 1.8 percent under the O2 strategy, which is a relatively large amount, even though less than the 2.7 percent under the counterfactual strategy.

Total factor productivity increases are largely exogenous in the model, since they depend on several factors that go beyond the scope of general equilibrium simulations. These factors include successful adoption of technological innovation, research and development, and adequate investment in human capital that depend on external conditions, such as technological progress and increases in knowledge.

Strengthen the fiscal picture. The simulations show that the O2 trajectory would rely heavily on foreign capital, given the country's low-tax internal environment and a relatively low and falling domestic saving rate. The worry is that less favorable financial conditions—that is, higher interest rates—would turn this financial picture into a vulnerability. Thus, some fiscal consolidation, with somewhat higher saving rates, lower government expenditure, and higher reliance on private domestic investment, appears to be necessary to secure a firmer base for growth.

Invest in education and training. While O2 promises a high degree of job creation, its reliance on new and technologically more sophisticated sectors also threatens to worsen the skills mismatch that already

plagues the economy. At present, for example, the country is suffering from the problem of industrial conversion, with a surplus of low-level labor coming from the shrinking textile industry and a lack of skilled labor in the more highly technological sectors. Thus, there is an urgent need for investments in training and education and other policies that encourage the accumulation in human capital if Mauritius is to increase labor productivity and avoid having employment opportunities turn into bottlenecks. The public sector should lead the way by focusing on improving the school system and reforming vocational education. But the private sector can help by facilitating retraining and special skill transfers through privately financed programs.

Conserve and improve natural resources. Even though the O2 strategy lessens some of the pressure on land-based activities that rely on natural resources, the simulations show that its end use of ocean and internal waters turns out to be much more intensive than the counterfactual. Moreover, much of the country's natural resources are now being exploited at no charge, maintenance and renewal activities are low, and pollution and other forms of degradation appear to be a concern. Thus, investments in ocean environmental goods are essential. This means replacing the current model of rent exploitation with significant investment in the conservation and improvement of natural resources. Possible solutions include marine spatial planning and lagoon rehabilitation, improved sanitation and water treatment, and a scaling-up of appropriate environmental regulations.

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PART B

Making It Happen: Deep Dives into Selected Sectors

This part of the book consists of a bottom-up analysis of four sectors (fisheries, ports, marine energy, and marine ICT) to assess the financing needs (from public and private sources), revenue generating potential, and institutional or capacity bottlenecks to be overcome to fulfill the promises of the ocean economy (OE). These chapters include estimates of the merits of investing in the selected sectors, both from the project-level perspective and from the point of view of the economy as a whole. Given the study's time and budget constraints, the analysis does not intend to be comprehensive, but rather illustrative of the opportunities and challenges of expanding traditional OE sectors (e.g., fisheries, ports), as well as emerging ones (marine energy, marine ICT).

The projects examined are those currently under discussion in Mauritius, which in many cases are still far from offering the information necessary to establish their feasibility. Thus, their evaluation is based on very preliminary hypotheses as to their market reach, time profiles, and foreseeable benefits and costs. In an attempt to combine project level and economywide evaluation, and to generate estimates of investment worth consistent across sectors, the projects selected have been analyzed according to a three step procedure.

In the first step, the main project components have been estimated in terms of capital and operational costs, as well as foreseeable revenues and proceeds from market-related activities. Estimates of operating costs include labor, imports, and intermediate local inputs by sector of expenditure, while estimates of construction costs include approximate time scales for construction work and the deployment of the newly acquired productive capacity.

In the second step, these estimates have been used to perform a summary financial analysis of the projects from the point of view of a likely stakeholder (a private party undertaking the project in all or in part with government assistance) and to compute indicators of net present values and benefit-cost ratios for different investment scenarios. For purposes of comparison with the economywide measures of project worth, these project-level measures of economic worth are provided in terms of value added (that is, returns to human and non-human capital used in the project). Because the analysis focuses on value added rather than commercial profitability or total economic benefits of all kinds, further financial and economic evaluation work will be needed before taking a decision about whether individual projects should go ahead.

In the third step, the economic impact of the project is evaluated, using the CGE model. For this purpose, the project is broken down into two separate sets of inputs. In the construction period, the inputs are the components of capital costs by factor (labor and capital) and sector of supply of intermediate capital goods (domestic and imported) used to build the new structures and the productive capacity characterizing the project. In the operational period, the additional capital stock created by the project is credited to the proprietary sectors, whose productivity (in terms of production and value added) is potentially boosted by the increased capacity and the wider substitution possibilities provided by the new capital.

The above inputs allow the model to generate an estimate of the economywide impact of the projects based on estimates of the input-output structure of the Mauritius economy and the simulation of the decentralized behavior of the different economic agents involved. Given the inputs for the construction stage, the model generates a series of effects due to the direct and indirect impact of expenditures through the value chains that are active in the economy. These effects depend on a process of diffusion through the interdependencies across sectors, spurred by linkages at different levels of the value chains (backward and forward multipliers) and by consumption-income linkages.

For the operational period, the dynamic CGE model generates increases in production and all factor components of value added, as well as operational costs, in all sectors directly and indirectly (through backward and forward linkages), driven by the increase in productive capacity arising from the projects.

Because the CGE model reproduces a moving market equilibrium, the economywide effects include simulated price and income levels for factors of production and goods and services. This means that the estimates obtained include price effects, as well as consumer and producer surplus increases, under the hypothesis of optimizing behavior on

the part of firms and consumers. The economywide measures of project worth are not directly comparable with the project-level measures, but they are presented as a complementary set of indicators that may be useful to evaluate project outcomes from the point of view of a “big picture” of the economy.

More specifically, the project-level measures of project worth are intended to provide initial indications of attractiveness for private or public stakeholders, based on present market prices and without accounting for economywide effects or externalities. Unlike project-level measures, the economywide measures aim to address, however imperfectly, the broader question of the social and economic desirability of projects from the point of view of the Mauritius economy and the many stakeholders that may be involved in their implementation and their economic consequences.

Fisheries and Aquaculture and the Ocean Economy

Kieran Kelleher

Key Messages

- An additional investment of US\$330 million over 10 years in fisheries and aquaculture could increase the sector's revenues by US\$380 million per year and generate an additional 3,500 jobs. Bringing the sector up to its true potential will require a combination of reducing overexploitation in some areas and overcoming under-utilization in others.
- In the coastal fisheries, restoring the declining health of the lagoons and reefs is a “no regrets” investment, creating significant sustainable benefits for coastal fisheries, for the tourist industry, and through mitigating coastal erosion.
- In the offshore Banks and deep-water fisheries, catches of high-value fish have been declining, necessitating investment in a modern Banks fishing fleet, a fisheries management regime founded on sound economic principles, and an increased maritime presence in this remote but important area of Mauritius' maritime jurisdiction.
- Aquaculture can expand significantly through farming of invertebrates (like oysters, crabs, or sea cucumbers) and the cage culture of finfish. Expansion will hinge on demonstrated profitability and mitigation of the high risks associated with aquaculture, along with public investment to create a more robust enabling environment for private investment.
- Investments aimed at improving the productivity of existing port and fisheries infrastructure can improve the comparative advantage of Mauritius as a regional seafood hub. Existing regional fleets could increase their use of the port to deliver raw materials for processing and purchasing services.
- A range of cross-cutting measures are needed to backstop sustainable investments, ensure their economic viability and effective social inclusion, and monitor the environmental health of marine and coastal resources. These needed measures include improved governance, investment in human resources, targeted environmental management, and public support for viable private-sector initiatives. Some emerging investment opportunities, such as the development of marine biotechnology and health-care products, are not covered in the analyses here.

Introduction

The fisheries and aquaculture sector are a critical part of the Mauritius economy, representing about 1.5 percent of GDP and employing up to 22,000 people, including in fish processing and services to the fisheries sector.¹ The coastal fisheries also have a vital social dimension (particularly in Rodrigues), not only providing incomes and food security but supporting tourism and livelihoods. The tuna cannery is the single largest employer in Mauritius, and Port Louis is the port of choice for many industrial fleets fishing in the region. Offshore banks and sea-mounts offer untapped fishing potential, while an infant aquaculture is attracting investors.

In recent decades, however, the lagoons, coral reefs, and associated coastal habitat (especially around Mauritius island) have been progressively degraded.² While some of the loss of ecosystem function may be attributed to natural causes and climate change, manmade stresses, particularly overfishing and agricultural and urban pollution, are primary causes. Moreover, coastal and fishing communities are in the front line of climate change, threatened by cyclones, coastal erosion,³ and sea-level rise.

Against this backdrop, what will it take to boost the potential of this sector to contribute to Mauritius' OE and the country's overall development in a sustainable manner? This chapter addresses this question by providing a quantitative basis for exploring various fisheries and aquaculture opportunities, specifically the four areas prioritized by Mauritius: (i) the coastal fisheries and the lagoon environment; (ii) the high-value bottom fisheries on the remote offshore banks, known as the "Banks fisheries"; (iii) aquaculture; and (iv) the Seafood Hub, a complex of port facilities and fish processing and handling in Port Louis. The chapter also explores the linkages between fisheries and other dimensions of the OE, such as marine leisure and tourism, ocean knowledge, the Mauritius port economy, regional cooperation, trade, food security, and adaptation to climate change.

¹ Some employment may be seasonal or part-time, including non-Mauritian employment on fishing vessels and in processing. The employment and GDP estimates are from the Ministry of Energy (MOE) and National Ocean Council (NOC) and may not be consistent with values from Statistics Mauritius because of differences in sector definition.

² There are no definitive assessments of the state of the reefs, lagoons, or coastal fisheries for Mauritius island, but multiple sources attest to different aspects of degradation, and there is broad consensus among stakeholders that urgent action is required to restore these critical ecosystems. See, e.g., <http://www.veynoulagon.com/>.

³ The coral reef and lagoon ecosystems—vital coastal defenses—are eroding through ocean acidification and other stresses.

A key finding is that additional investments of US\$330 million over 10 years could increase the sector's revenues by US\$380 million per year and generate an additional 3,500 jobs. Enabling the fisheries and aquaculture sector to meet its true potential will require reduction in over-exploitation and environmental stresses in the lagoons and coastal fisheries; effective management and development of underused resources in others, such as the Banks fisheries; and an enhanced investment climate for expansion of aquaculture and the Seafood Hub. A range of cross-cutting measures are needed to backstop sustainable investments, ensure their economic viability and effective social inclusion, and monitor the environmental health of marine and coastal resources. These include improved fisheries governance, investment in the human resources for fisheries and in marine environmental information systems, targeted environmental management, adaption of institutions to meet OE challenges, and public support for viable private sector initiatives.

This chapter provides a brief overview of the fisheries and marine environment, presents a summary of the development scenarios, and recommends approaches, including recommendations on complementary cross-cutting investments required to develop and sustain the OE in this sector. Appendix 2 provides supplementary background analysis and further details of the scenarios and their rationale.

State of the Fisheries and Marine Environment

Mauritius' maritime jurisdiction, including the Exclusive Economic Zone (EEZ) and Extended Continental Shelf (ECS),⁴ is over 1,400 times larger than the land area of Mauritius. Currently, the only significant economic activities in this vast area are fishing and maritime transport.

The total value of fisheries production is just over US\$580 million per year. Exports are valued at US\$400 million (about 22 percent of total exports by value), and the sector employs approximately 22,000 people, including in post-harvest activities. Total direct value added is US\$157 million, and the sector contributes an estimated 1.4 to 1.5 percent of GDP.⁵ The tuna post-harvest segment is the most important contributor in value terms. Total annual public expenditure is US\$15 million⁶ and annual receipts from the sale of fishing rights and licenses

⁴ The ECS is shared with Seychelles under a Joint Management Agreement. See also: Prime Minister's Office 2005; and CLCS 2011.

⁵ Values obtained from the NOC and from budget estimates.

⁶ Over 90 percent is for recurrent expenditure and over 80 percent is for salaries and allowances. The allocations are considered to have a historical basis, rather than a strong relationship to performance or tasks.

is just over US\$2 million. Several economic activities attributable to fisheries are not fully reflected in these estimates. These include the sale of port services to the region's tuna fleets; expenditures on maritime surveillance; and expenditures on marine leisure activities, such as diving, which form part of the "tourism GDP." Small-scale fisheries and the associated commerce provide an important source of livelihood and food for many coastal communities, particularly for Rodrigues. The value of Mauritius' marine ecosystems has been estimated at US\$8.6 billion, excluding their role in maintaining genetic diversity (see Appendix 2) (Cesar et al. 2000).

Despite the country's vast maritime jurisdiction, Mauritius' fisheries production is relatively low, for several reasons. The main tuna fishing grounds lie outside⁷ Mauritius' waters; the coastal fisheries are confined to the relatively narrow coastal shelf; and the coral reef and lagoon fisheries are substantially overfished, particularly around Mauritius island. The offshore banks have potential for increased catches, but the distance to these fishing grounds means high production costs. Mauritius' total recorded annual fish production⁸ is just over 16,000 tons, of which almost 10,000 tons are caught by Mauritius-flag tuna purse seiners who land the fish in Seychelles (Table 3.1). With a per capita consumption of 24.3 kilograms, Mauritius imports about 20,000 tons of fish for domestic consumption, including canned fish and bycatch from the tuna fleets.

There has been a progressive degradation of the coastal marine environment, with a loss of about 50 percent of the coral reefs⁹ and increasing coastal erosion despite some recovery of the mangrove areas. The degradation is attributable to a combination of man-made and natural stresses, including overfishing, agricultural runoff, sedimentation from erosion, tourism, and pollution from wastewater and industry. Coral bleaching events, increased ocean temperatures, and ocean

⁷ The distribution of these highly migratory species could change under the influence of climate change.

⁸ Data provided by Albion Fisheries Research Centre (AFRC). Note: These data refer to the *recorded* production.

⁹ Long-term monitoring of coral reefs has been ongoing since the 1990s. Data on the status of coral reefs, water quality and the benthic ecosystem are collected at selected sites and sent to the Global Coral Reef Monitoring Network (SWIO Node). These data show that a gradual decrease in the percentage of live coral cover. However, the time series and coverage are deficient and they are not adequate to attribute the relative impacts of the natural and anthropogenic stresses reducing coral cover. The 50 percent estimate given above is from senior technical officers in the fisheries and environment administrations. Mauritius is at the margin of the more serious coral bleaching events in the SWIO region.

acidification are among the natural stressors. At the same time, the resources of the extensive offshore banks, sea mounts, and deeper ocean appear healthy.

Mauritius has a modest but growing marine science capacity, and monitoring and assessment of the marine resources (other than tuna) remain intermittent. The legislative framework¹⁰ is modern and development and management plans exist for all major fisheries and for aquaculture. However, implementation of management measures and development plans has been less than effective for several reasons: (i) a deficient fisheries information system; (ii) entrenched institutional arrangements with a lack of performance-driven accountability; (iii) development and management plans that often lack the corresponding timetables, budgets, milestones and effective tracking; and (iv) political pressures.

A notable exception is the tuna fishing and processing industry, for which international management measures and export requirements are effectively applied. Measures to manage the Rodrigues lagoon and octopus fishery have also met with success, whereas catch, effort, and other key management indicators for the Mauritius island coastal fisheries are deficient and do not reflect the actual state of the coastal fisheries. The lack of accurate information contributes to weak fisheries management and the decline of the Mauritius island coastal fisheries.

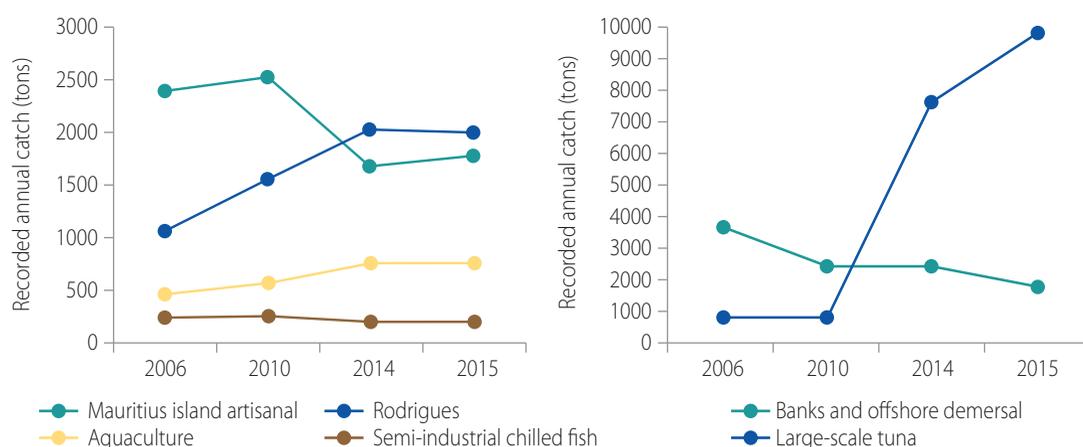
Table 3.1. Fisheries Production in Selected Years, 2006–15

| Fishery | Production in tons | | | |
|---|--------------------|--------|--------|--------|
| | 2006 | 2010 | 2014 | 2015 |
| Mauritius island recorded artisanal catch | 2,400 | 2,533 | 1,663 | 1,778 |
| Recorded semi-industrial chilled fish catch | 251 | 250 | 199 | 207 |
| Rodrigues recorded artisanal catch | 1,067 | 1,555 | 2,024 | 2,000 |
| Aquaculture | 471 | 569 | 753 | 755 |
| Banks and offshore demersal (including St. Brandon) | 3,678 | 2,443 | 2,362 | 1,765 |
| Large-scale tuna ^a | 800 | 800 | 7,595 | 9,774 |
| Total estimated production ^b | 10,673 | 10,160 | 16,610 | 18,294 |

Source: World Bank based on data from AFRC and Indian Ocean Tuna Commission (IOTC) reports, various years.

Note: Mauritius-flag vessels may operate from and land at Seychelles or other tuna ports. In general, Mauritius-flag purse seiners fish and land their catches in Seychelles, while Mauritius-flag longliners (and other Mauritius-based longliners) fish in Mauritian waters, but may fish seasonally in other areas (EEZs and high seas). (a) Details of catches and landings by fleets are available in various Indian Ocean Tuna Commission (IOTC) reports (see Appendix 2 for a graphical illustration of fishing patterns). (b) Total estimated production includes estimates of unrecorded production, such as "amateur fishing". Values in italics are World Bank estimates.

¹⁰ The Fisheries & Marine Resources Act 2007 is complemented by extensive regulations.

Figure 3.1. Trends in the Catch, Fishing Effort, and Catch per Unit Effort in the Banks Fishery, 1990–2015

Source: Table 3.1.

Table 3.2. Sustainability Status and Other Indicators for Selected Priority Fisheries

| Status /Indicators | Coastal | Banks | Aquaculture | Seafood Hub |
|--|------------------------|-----------|------------------|------------------------------|
| State of the fish stocks /marine environment | Overfished | Healthy | Lagoons degraded | Some tuna species overfished |
| Production | Declining ^a | Declining | Increasing | Stable-increasing |
| Employment (numbers) | 11,520 | 202 | 115 | 7,207 |
| Value of production (US\$ million) | 43.71 | 6.75 | 2.87 | 273.35 |
| Operations and maintenance (US\$ million) | 19.3 | 5.74 | 3.90 | n.a. |

Source: World Bank analysis based on data from AFRC and Dept. of Fisheries.

Notes: All values are estimates based on 2014–15 data. The following sections and Appendix 2 provide further details and explanations of these trends. (a) Coastal production is increasing in Rodrigues. n.a. = not available.

Ministry management measures include a seasonal closure of the octopus and large net fisheries, a ban on removal of coral, coral farming to rehabilitate coral reefs, and enhanced monitoring of the coastal ecosystem.

Coastal Fisheries and the Lagoon Ecosystems

The coastal fisheries are largely artisanal, exploited by fishing households either on foot or using un-decked vessels powered by outboard motors, by diesel engines, or by oars (see Appendix 2 for details). The recorded coastal fisheries catch¹¹ is about 3,500 tons, of which over

¹¹ As is typical of reef and lagoon fisheries, the catch comprises multiple species. Reliable detailed species-by-species catch records are not available, since

2,000 tons is from Rodrigues. However, the recorded catches underestimate the real production, since auto-consumption and unrecorded catches may contribute up to an additional 7,000 tons per year. The estimated value of coastal fisheries production is between US\$27 million and US\$44 million a year.¹² The catch comprises a wide variety of lagoon and reef species, important octopus catches in Rodrigues, and catches of tuna and demersal (bottom) fish from outside the fringing reefs. Other than for the octopus fishery there are no stock assessments, and bias in the species-level catch reporting does not permit robust scientific analysis of trends in catches. Catch and effort records for the off-reef fish-aggregating devices (FADs) fishery for tunas, jacks, and pelagic species have not been compiled.

Fisher incomes are stable but remain low, with declining catches offset by reduced fishing effort, rising prices, and social subsidy.¹³ Some fishing takes place outside the lagoons, but the profitability of these operations is fragile and repayment of development bank loans for FAD fishing has not met expectations. The estimated employment¹⁴ in the coastal fisheries is 11,000, including those workers engaged in processing and distribution. Catches from amateur fishers—unregulated non-commercial fishers who fish for home consumption, exchange, or sale—are not recorded. However, Mauritian experts consider that it may even exceed the recorded catch.

Mauritius' lagoon and coral reef ecosystems have been progressively degraded in recent decades, partly due to overfishing. There has been a loss of ecosystem resilience, low and declining coral cover,¹⁵ and increasing erosion¹⁶ and loss of beaches, since almost all fine white sand

landings and sales are highly dispersed. Octopus is one of the most important species, particularly in Rodrigues.

¹² The wide range is attributable to uncertainties regarding catch levels, auto-consumption, and prices.

¹³ The Bad Weather Allowance, which the government would like to gradually phase out.

¹⁴ Author estimates based on registered fishers and estimates of unregistered and the full-time equivalent (FTE) of amateur or weekend fishers. The majority of the catch is sold fresh with minimal processing. Women in many fisher households are involved in processing and marketing.

¹⁵ A JICA report indicates that about half of the coral cover was lost between 1998 and 2010, with the disappearance of seagrass beds in some areas.

¹⁶ Comprehensive estimates of erosion and the cost of erosion are lacking as attention has tended to be focused on specific erosion problems without consideration of an island-level erosion prevention and mitigation strategy. For example, the recommendations of a 2003 (Baird) report appear to have been only partly implemented. A JICA study focused on engineering solutions to erosion at numerous locations and suggested that loss of coral cover attributable to

Table 3.3. Production Values, Rodrigues Artisanal Fisheries, 2006–14

| Fishery | Values in tons | | | |
|------------------------------------|----------------|-------|-------|---------------|
| | 2006 | 2010 | 2014 | Trend 2004–14 |
| Mauritius Island artisanal fishery | 950 | 831 | 609 | -36% |
| Rodrigues Island artisanal fishery | 1,067 | 1,555 | 2,025 | +90% |
| Rodrigues octopus fishery | 266 | 269 | 502 | +89% |

Source: World Bank analysis based on data from AFRC and Rodrigues Statistical Digest (various years).

Note: These are recorded catches, but not all catches are recorded. See Appendix 2 for additional details.

is produced by corals. Although specific estimates for Mauritius are lacking, based on studies from similar countries¹⁷ the contributions of healthy reef and lagoon ecosystems to coastal protection and tourism are considered to far outweigh their contribution to fisheries. Initiatives to reduce fishing effort and to introduce a marine spatial plan (MSP) for sustainable use of the reefs and lagoon have been largely successful in Rodrigues. In Mauritius, efforts to reduce fishing effort¹⁸ and establish marine protected areas may have had a stabilizing influence, but as of 2016 they do not appear to have been sufficient to achieve recovery of fish stocks or of these ecosystems.

While there is an awareness that there will be substantial loss of loss of coral reefs due to warming seas and ocean acidification, the economic consequences of this loss do not appear to be fully appreciated. Because these losses transcend political horizons, mitigating measures are not afforded the policy attention and budgetary resources required to establish a comprehensive reef and lagoon conservation program. Additional details on the coastal fisheries are provided in Appendix 2.

Rodrigues Island is a microcosm of the OE. The island provides several lessons for a blue economy, including its handling of lagoon rehabilitation, octopus fishery management, and alternative livelihoods for fishers

anthropogenic environmental change was a major factor contributing to erosion “[t]he causes of decline seem to be eutrophication in lagoons, inflow of terrestrial sediment into lagoons, fishing activities, marine sports and human impacts.” However, several erosion prevention projects have been considered and some implemented. Measures for mangrove rehabilitation and restrictions on removal of beach sand (for construction) have proved successful. Some hotels replace beach sand regularly. In general, the costs of erosion protection are high and can be unaffordable unless protecting high value assets.

¹⁷ For example, Caribbean countries with important tourism and small-scale fisheries. See Appendix 2.

¹⁸ It is too early to assess the impact of a new octopus regulation (Fisheries and Marine Resources [Fishing of Octopus] Regulations 2016), which is based on the Rodrigues experience.

displaced as a result of fisheries management measures, as well as its development of a “sensitive” tourism model. The island demonstrates the important synergies between sectors—fisheries, tourism, transport, water, energy, horticulture, livestock, and transport to and from markets. The process undertaken in Rodrigues illustrates how social, economic and environmental issues can be balanced through stakeholder dialogue and consensus. However, the social contract achieved in Rodrigues will also require continued monitoring and support to maintain the benefits secured.

The Offshore Banks and Deepwater Bottom Fisheries

Mauritius’ offshore banks and seamounts cover an area about 50 times the land area of Mauritius and are a signature feature of Mauritius’ ocean domain. The largest of the offshore banks, the Saya de Malha Bank, is home to the Indian Ocean’s largest seagrass beds. These beds are a major carbon sink, capturing some US\$17 million worth of carbon annually.¹⁹ The Banks are remote—Nazareth Bank (see Map 3.1) is about the same distance from Port Louis as Rodrigues (over 600 km). For safety and economic reasons, the smaller Banks fishing vessels tend to fish the more southerly banks and seamounts. Fishing is mainly done by handline from smaller iceboats and larger freezer vessels. By reflagging to Comoros to avoid restrictions on carriage of outboard fuel, some dory/mothership operations have continued.

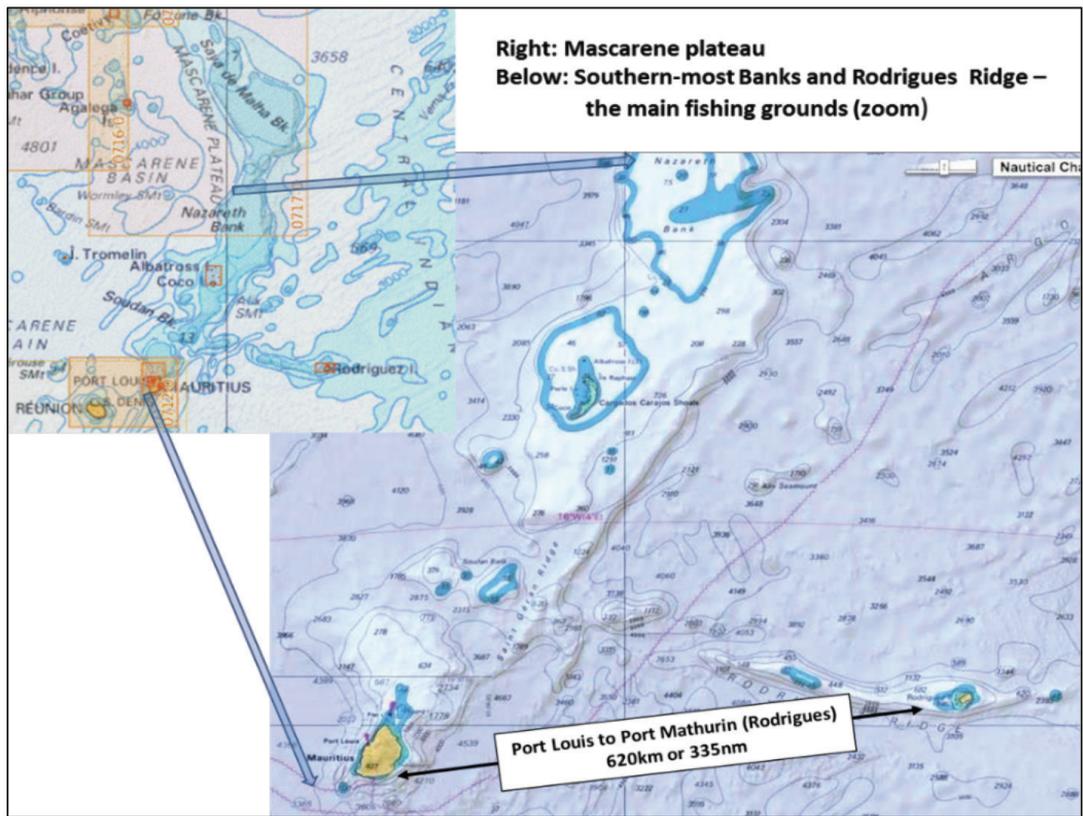
Currently, the demersal or bottom fisheries on the offshore banks and seamounts annually catch about 1,500 tons of high-value emperor, snapper, and grouper worth some US\$6.75 million and employ about 200 people. Catches of these high-value fish resources have been in decline for several reasons, including regulatory changes, shortages of skilled labor, high operating costs, and a decline in catch rates (see Table 3.1 and Appendix 2).

The maximum sustainable biological yield (MSY) has been estimated at 5,367 tons (including the banks and all deep-water demersal) with a potential maximum economic yield (MEY)²⁰ on the order of 3,550 tons, suggesting considerable scope for expansion of these fisheries.

¹⁹ Based on seagrass at 138 gm C per m² covering 80 percent of 40,808 km², a carbon price of US\$7/ton and a 50 percent share of the revenues as per the Treaty. Although a large part of the Saya de Malha lies in the Extended Continental Shelf (ECS), the Parties have rights over the benthic resources (although not to the “mobile” fish resources). The seagrass beds also extend to the Nazareth and other banks (not included in the estimates, however, because the percentage of seagrass cover is not available).

²⁰ The MEY depends not only on healthy fish stocks, but also on the level of fishing effort, the cost of harvesting, and market conditions. The objective of MEY is to maximize profitability rather than production.

Map 3.1. Bathymetry of the Banks with a Focus on the Southern Banks



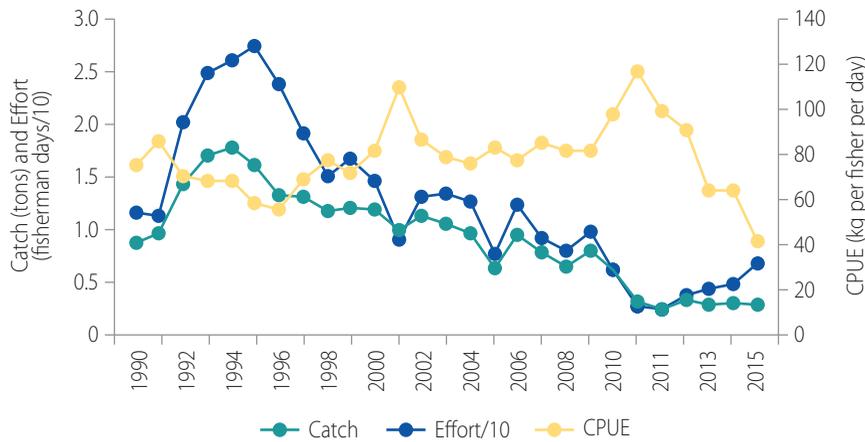
Source: World Bank.

However, while some fishing grounds are located near Mauritius and Rodrigues islands, the more extensive fishing grounds are located over 600 kilometers from the fishing ports. Consequently, risks and costs of production are relatively high and attention to safety at sea is vital, particularly for vessels under 20 meters. Due to stricter application of Merchant Shipping regulations, one fleet segment (dory/mothership)²¹ is obsolete, so new investments in fleet and technology are required for a modern profitable fishery.

There is evidence that catch rates have declined, possibly due to illegal foreign fishing on these remote and rarely patrolled fishing

²¹ These freezer motherships fish for several months at a time, using a fleet of small outboard-powered dories operating from the mothership. Application of safety regulations regarding the carriage of outboard fuel on board the mothership have resulted in suspension of these operations for Mauritius-flag vessels. Shortage of Mauritian crew willing to work in the difficult and high-risk conditions also contributed to the decline and an increase in non-Mauritian fishing crew.

Figure 3.2. Trends in the Catch, Fishing Effort, and Catch per Unit Effort in the Banks Fishery, 1990–2015



Source: World Bank, based on AFRC data.

Note: Fishing effort measured as fisherman days divided by 10. CPUE = catch per unit effort.

grounds (See Appendix 2).²² It is important to note that about half the Mauritius Banks catch is taken from the Saya de Malha Bank, which is part of the ECS shared with Seychelles. This means that neither Mauritius nor Seychelles have exclusive rights over these fisheries, which are managed under the Southern Indian Ocean Fisheries Agreement (SIOFA), in force since June 2012. Although SIOFA has adopted interim management measures,²³ it is still in an early stage of development. Mauritian Banks fishing operations outside the country's EEZ (e.g., on most of the Saya de Malha Bank) will need to be compliant with SIOFA measures.

The key to building a profitable and sustainable fishery involves a combination of new technologies and cooperative export branding and marketing. This needs to be backed by a robust management regime with strict limits on effort and increased surveillance of the fishing grounds to eliminate any unauthorized fishing, as described in the development scenario. In the medium to longer term, a more detailed analysis of the target stocks may be advisable, for example to establish

²² The reasons for the perceived decline are unclear and require further analysis, e.g. the unit of effort (fisherman/day) may not be fully comparable across years given the decline of the dory/mothership operations.

²³ ECS rights pertain only to mineral and sedentary living resources; thus, the *Letherinid*, *Lutjanid* and grouper species targeted by the Banks fishery are excluded and can be exploited *without* authorization from Mauritius or Seychelles (SIOFA 2016, 2017).

if the fishery is targeting single stocks or multiple stocks and if some stocks are shared with Seychelles.

Aquaculture

Farming of invertebrates (such as oysters, crabs, or sea cucumbers) and the cage culture of finfish all have potential. Progress in marine aquaculture development has been slow, and the industry currently employs fewer than 150 people (Appendix 2). Aquaculture has gradually expanded (Table 3.1), effectively due to the production of a single industrial-scale fish farm, Ferme Marine de Mahébourg (FMM).²⁴ FMM produces about 750 tons of red drum, sea bass, and sea bream, of which about 70 percent is exported fresh; most of the balance supplies local hotels. After more than 10 years, FMM expects to become profitable in 2017, when expanded production will deliver economies of scale. Despite public support, little progress has occurred in small-scale production. Less than five tons of freshwater prawn, mangrove crab, and fish are produced by small-scale fish farmers (Appendix 2, Table 6).

However, aquaculture can expand significantly given a favorable business climate and access to medium to long-term finance based on sound business plans.²⁵ The Mauritius Aquaculture Development Plan²⁶ has identified 21 suitable farm sites, including six offshore sites, and has proposed an ambitious long-term production target of 39,000 tons with creation of 5,000 jobs. However, these targets refer essentially to the spatial potential of farm sites, rather than being based on any techno-economic appraisal of specific farm projects. As such, the targets need to be treated with a degree of caution given the economic challenges faced by FMM. Nevertheless, FMM has been a leader, enabling future investors to benefit from an improved aquaculture investment regime. Aquaculture expansion is spatially limited by multiple use of the restricted lagoon areas. This will require some future finfish farms to be located in the more exposed and higher-risk sites²⁷ identified

²⁴ See: <http://www.fmm.mu/>.

²⁵ The Fisheries and Marine Resources (Fish Farming) Regulations 2014 require substantial upgrading. Aqua-farm authorization, environmental and local government approval, and other regulatory clearances need to be more coherent, coordinated, and streamlined. Current work on long-term aqua-farm leases will facilitate securing finance.

²⁶ See BOI and IDEE 2007, a study for implementing the aquaculture master plan.

²⁷ Sites have already been designated under the National Aquaculture Plan, but the designation has not included a process of formal approval by other concerned ministries (for example, the Ministry of Environment).

outside the reefs (see Appendix 2). Aquaculture development will be an important consideration in any MSP exercise.

Several investment proposals are in the pipeline, although in recent years a number of proposals have not materialized, partly due to a challenging investment climate. These challenges include competition for limited space in the lagoons; limited availability of land for shoreside facilities; an onerous approvals processes; and access to finance for an infant industry that has significant perceived risks. Supply of fish seeds and feeds and capacity to combat disease are among the barriers to small-scale entrepreneurs.²⁸ Public policy reforms are required to create a more robust enabling environment with fast-track approvals (such as an environmental impact assessment harmonized across institutions), security of tenure for aquaculture concessions, and facilitated access to sites for shore facilities.

Smallholder outgrower schemes could be envisaged when large-scale farms become viable and can provide essential inputs, expertise, and economies of scale. Although aquaculture competes with tourism and other lagoon and coastal activities, it can be not only compatible but complementary to tourism. For example, pearl culture, giant clam culture, and caged fish can all be attractions for divers, while seaweed culture can contribute to a tourist health and skin-care attraction.²⁹ This is where an MSP can guide the optimum use of lagoon and coastal space and help avoid conflicts.

The Seafood Hub

The complex of port facilities, fish processing, and fleet servicing activities in Port Louis is collectively termed the *Seafood Hub*. Port Louis is a major regional fishing port with almost 1,000 vessel calls per year (Poseidon 2016). Most of these calls are by tuna vessels, including large refrigerated carriers (reefers), which unload tuna supplied (mainly from the Seychelles) to the processing plants. Vessels fishing in the Antarctic fisheries also use Port Louis. Canned and frozen fish products are exported by container or transshipped to reefers. There is a growing trade in fresh tuna exported to markets in Asia and Europe. Although the contribution of fisheries to the revenues of the Mauritius Port

²⁸ Local production of feeds and seeds is contingent on achieving economies of scale to enable local feed mills to manufacture separate lines of fish feeds. Fish feed composition is substantially different from chicken or pig feed, and often several different types are needed for different stages of the fish life cycle. FMM initially imported its fish seed.

²⁹ Tahiti, Fiji, Indonesia, Philippines, and other countries include these and other attractions in their marine tourism programs.

Authority (MPA) are modest, purchases of goods and services by the vessel operators is estimated at over US\$57 million per year. Purchases include bunkering, victualing, vessel repair, crew transfer, and cargo handling.

The Seafood Hub includes two major tuna processors³⁰ (cans, loins, pouches) and several smaller fish processing companies³¹ handling fresh and frozen tuna and other fish both for the export market and for domestic sales (e.g., tuna bycatch). Several fishing companies, engaged in tuna longline and banks fishing, are based in Port Louis, and several ships agents serve Asian (longline) and purse-seine (mainly EU) transshipment, reefer charter, and fishing vessel supply services. MPA's commercial quays, freezer container facility, and storage areas are complemented by privately owned quays and cold stores, a shipyard, and a range of services for vessel and equipment repair and maintenance. Many of these companies have long-standing relationships with foreign tuna operators and fishing vessel construction companies.

Under the MPA master plan, a designated quay area will be provided for fishing vessels and expansion of cold storage, a sheltered anchorage established to relieve pressure on quay space, and an area set aside for a second shipyard (see Chapter 6 for additional details). The Mauritius tuna processing industry, which employs some 3,000 people, imports well over 90 percent of its raw material. The total annual tuna "traffic" is over 140,000 tons, with a steady increase in longline vessel calls since 2008 (Table 3.4). This is because the main fishing grounds for the purse seine fleet, which supply the canneries and loining plants, are outside Mauritius' waters (Appendix Figure 2A.3). Tuna and other highly migratory fish are the South West Indian Ocean's most economically important fisheries resources and are managed through regional arrangements.³² The stocks of skipjack, bigeye, and albacore remain healthy, but stocks of yellowfin (a species of major economic importance to Mauritius) and stocks of some marlin species are overfished.

In the short term, investments to improve the productivity of existing port and fisheries infrastructure can improve the comparative advantage of Mauritius as a regional seafood hub. This can lead to an increase in the number of vessels permanently based in or calling at Port

³⁰ Princes Tuna and Thon des Mascareignes (joint operation). A dedicated company converts processing waste into fish meal.

³¹ Mer des Mascareignes is an example. IBL is a major conglomerate heavily engaged in the sector, while more than 25 companies import or export fish products.

³² Indian Ocean Tuna Commission (IOTC). See <http://www.iotc.org/science/status-summary-species-tuna-and-tuna-species-under-iotc-mandate-well-other-species-impacted-iotc>.

Table 3.4. Total Fish Traffic and Vessel Calls, 2007–14

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|------------------------------|---------|---------|---------|---------|---------|---------|---------|---------|
| Total fish traffic (tons) | 116,983 | 113,466 | 113,526 | 155,774 | 140,928 | 134,763 | 148,297 | 143,410 |
| Total fisheries vessel calls | 746 | 496 | 643 | 708 | 767 | 851 | 993 | 1,067 |

Source: Mauritius Port Authority, Port Operations.

Louis, which generate revenues from port services and improve both the supply of raw material for an expanded processing industry and fish for domestic consumption.

In the medium term, the industrial fisheries can benefit from the proposed public and private investments in port infrastructure and vessel repair services (see Chapter 6 on ports).

Development Scenarios

How much could the fisheries and aquaculture sector contribute to a larger OE and thus a more diversified and stronger national economy? This analysis focuses on the four fisheries and marine environmental activities that the MOE selected³³ for an in-depth assessment: (i) the coastal fisheries and health of the lagoon ecosystems; (ii) the offshore banks fisheries; (iii) aquaculture; and (iv) the Seafood Hub. Scenarios were developed for each activity based on its current status and trends, current investment proposals, and potential for development. This section describes each scenario in terms of its targets, investments, economic, social, and environmental returns, and underlying assumptions. Further details on the scenarios are provided in Appendix 2. The scenarios do not constitute an integrated plan of action for the fisheries sector but, rather, inputs to a model of the OE. The scenarios are essentially separate stand-alone exercises and, while the synergies between them are limited, they jointly contribute to improved fisheries governance, knowledge management, financing of ocean enterprises, and economies of scale in port and other services. The scenarios are based on the best available information on investment costs and returns, but they do not constitute project proposals, which would require specific feasibility studies.

The investments can also catalyze development of the other OE clusters. These include marine science, environmental management, marine IT, and marine finance and insurance, as well as regional cooperation on

³³ Other areas of potential, such as marine biotechnology and production of marine-based medicines or health-care products, have not been assessed.

Box 3.1. Assumptions Underlying the Scenarios

The main external assumptions for the offshore banks fisheries, aquaculture, and Seafood Hub scenarios are as follows:

The Mauritius economy remains relatively stable such that Mauritius remains the regional port of choice for fisheries logistics.

Global supply and demand for fish products remains relatively stable, in particular for tuna.

Global fuel prices remain relatively stable.

There will be no major change in the fish import tariff regime of the EU (that is, ASEAN, or non-ACP producers will not get significant additional tariff quotas).

The main internal assumptions are as follows:

Significant institutional reforms will take place leading to reallocation and more effective use of public resources—including staff and greater synergies between ministries (like MOE)—although it is recognized that there could be significant delays in any public service reforms.

The proposed investments will be profitable, in particular the offshore banks (medium confidence) and aquaculture (low confidence) investments. The recent relatively poor FFM statement of accounts means that the aquaculture scenario is quite optimistic.

Private-sector finance will be available at favorable rates (for example, for aquaculture, where tens of millions are required) (low confidence).

The government will address the issue of private-sector access to finance and risk reduction in an effective manner (medium to low confidence).

Stakeholders (public and private), particularly those in the Seafood Hub, will collaborate effectively to achieve medium/longer-term benefits (medium/high confidence).

fisheries, maritime security, and offshore extractive industries. Further details concerning the basis, rationale, assumptions, and costs and returns for each of the scenarios are provided in Appendix 2.

Scenario 1: Restoring the Health of the Coastal Fisheries and Ecosystems

The coastal fisheries are overexploited³⁴ and the lagoon and coral reef ecosystems upon which they depend are substantially degraded. To an extent, past economic growth in Mauritius has come at the expense of a loss of part of the natural capital represented by the reefs and lagoons. Although not currently quantified, this is reflected by growing concern over loss of beaches and sea walls. Recorded fish catches are slowly declining (on Mauritius Island) and fisher incomes are maintained by a combination of rising fish prices, a gradual reduction in fishing effort,

³⁴ As some of the coastal fisheries in Rodrigues have recovered, the recovery scenario refers primarily to Mauritius island. However, continued support for the successful conservation and management efforts in Rodrigues will be important.

and various government subsidies.³⁵ Efforts to move fishers “off-lagoon” have had mixed success, as some grant-financed vessels have not been viable³⁶ and the blasting of reef passages to access the open sea may have had negative impacts³⁷ on the lagoon ecosystems.

Rationale. Restoring the health of the lagoons and reefs is a “no regrets” investment that will create significant sustainable benefits for coastal fisheries, for the tourist industry, and by mitigating coastal erosion. The initial investments necessary are largely institutional. They require strong political will to drive initiatives that will establish a framework for reduction of environmental stresses³⁸ and optimize the economic and social use of the lagoons, while also sustaining the environmental integrity of the ecosystems.

This task is considerably broader than managing the fisheries. The natural stressors—ocean warming, sea-level rise, ocean acidification, and coral bleaching—cannot be remedied by local actions and are likely to cause irreversible and progressive loss of the reefs and the natural coastal defenses. This makes reduction of the man-made stressors vital. These include overfishing, overuse by tourism, waste-water discharges, agricultural runoff, and other forms of pollution. Overfishing has social, economic, and political dimensions. Solutions are likely to require a social contract with reduction in commercial fishers’ effort offset by opening alternative economic opportunities. Restrictions on “amateur” fishing,³⁹ which account for a significant proportion of the catch, may also be required.

Approach. This scenario represents the first phase of a longer-term process to address these stresses. The proposed activities will build the framework to guide and prioritize future actions. The scenario proposes two institutional investments and several sector investments.

The first investment is to establish a robust and permanent scheme to monitor the state of the coastal environment and the fisheries. The

³⁵ These include the Bad Weather Allowance, grants for vessels, and the persistence of unpaid loans.

³⁶ Discussions with fisher groups and the Mauritius Development Bank.

³⁷ Creation of reef passages may allow flushing of sand required for beach formation and seagrass beds (personal communication with R. Kallee).

³⁸ For example, by reviewing and updating the *EIA Guideline for Proposed Coastal Hotel Projects* (Ministry of Environment 2004). The guidelines refer mainly to the construction phase and could possibly be extended to codes of practice for use of the lagoons by the tourists and operators of sail and dive boats.

³⁹ Fishing by non-commercial fishers for home consumption, exchange, or sale. This is a traditional unregulated activity.

current efforts are sporadic, insufficient, and largely unstructured or, in the case of fisheries, outdated.⁴⁰ The scheme will enable improved attribution of the causes of ecosystem degradation and provide a sound basis for mitigation measures. Existing institutions⁴¹ will establish permanent schemes to monitor the physical and biological state of the reef, lagoon and coastal ecosystems to enable attribution of the environmental degradation to specific stresses and recommendation of remedial actions.

The second institutional investment is to develop an MSP⁴² to optimize the multiple use of the lagoons, coral reefs and other priority areas. This exercise will address not only the physical use of areas, but the administrative and legal frameworks governing their use and approaches to resolve conflicts through dialogue and analysis. It will need to be integrated with broader coastal zone and watershed management and climate change adaptation initiatives. The MSP will establish a framework for sustainable investments and development across sectors, including tourism, aquaculture, coastal transport, and offshore energy. A detailed description of the MSP process is provided in Chapter 7).

Specific fisheries sector investments focus on the reduction of fishing effort, “moving offshore”⁴³ and effective management of selected fisheries, such as the octopus fishery.⁴⁴ Regulation of amateur fishing will be needed following public dialogue on the measures with a view to reduction of fishing effort by amateur fishers. Existing initiatives for reduction of nets⁴⁵ and to move fishers off-lagoon to the FAD or other fisheries will be evaluated and enhanced. The rationale for

⁴⁰ The regional component of the World Bank SWIOFISH project has already initiated work on a Fisheries Information Management System.

⁴¹ E.g., AFRC, Mauritius Oceanography Institute (MOI), University of Mauritius.

⁴² On December 16, 2016, the Cabinet agreed to the elaboration of a marine spatial plan for Mauritius.

⁴³ Government Information Service, “Eight fishermen receive cheques for the purchase of ‘canottes’” (2016). <http://www.govmu.org/English/News/Pages/Eight-fishermen-receive-cheques-for-the-purchase-of-%E2%80%9Ccanottes%E2%80%9D.aspx>.

⁴⁴ Anon. (2014). The fisheries reforms in Rodrigues offer lessons for Mauritius island.

⁴⁵ The buy-back of the lagoon seine nets is expected to be completed. The grant scheme will need to be subject to more rigorous cost/benefit analysis of investments and assistance to small-scale investors in this regard. The grants for fishing vessels will need to be complemented by improved awareness of loan and grant conditions, fisher training or assistance for budgeting, accounting and seasonal planning of loan repayments.

subsidies, such as the Bad Weather Allowance, will need to be reviewed and redirected to more productive ends or recognized purely as a social subsidy and de-linked from fishing effort. These measures will be supplemented by support to communities for creation of non-fisheries economic opportunities, such as marine leisure activities. The detailed design of these schemes is expected to be developed in parallel and through the MSP process, which will aim to balance the interests of the stakeholders and address the political sensitivities of change. The key to this process is the recognition that all stakeholders will need to change behaviors while making every effort to maintain livelihoods dependent on the reefs and lagoons. The outcomes are likely to involve efforts to expand marine protected areas.

The scenario takes note of the ongoing investments in waste water management and efforts to reduce agricultural runoff but does not include additional investments in these areas, since they lie outside the scope of the current exercise. The scientific assessment of the stresses on the coastal marine ecosystems is likely to indicate that significant additional public and private investments will be required, for example in urban waste water treatment, to reduce the use of fertilizers and pesticides in the cane fields or gardens and to reduce sediment loads in the coastal waters by buffering erosion inland. The MSP process is expected to gradually foster a “ridge to reef” approach that would progressively address these stresses and expand marine parks and protected areas through a consultation process.

Costs and returns. The estimated cost of the investments over the initial 10-year period is US\$24 million, and the operating costs average US\$1.7 million per year (Table 3.5). The returns accrue primarily outside the fisheries sector: to tourism and marine leisure, through reduction in the costs of coastal erosion, through reduction in damage caused by cyclones, but also through recovery of selected fisheries and continuity of some jobs in the coastal fisheries.⁴⁶ The estimated annual returns by year 10 are on the order of US\$12 million per year, assuming that actions to reduce the stresses on the ecosystems are undertaken in a timely and comprehensive manner. There will be a net gain of 250 jobs. Employment in lagoon fisheries will be reduced but will be compensated by an increase in jobs in marine leisure, in tourism, in offshore

⁴⁶ With effective management, fisheries for octopus and lobster have high recovery potential. The amateur fishery is likely to require regulation (for example, limited hours at weekends only). Effective regulation of the lagoon fisheries will require strong political will and leadership to address the social challenges involved.

Table 3.5. Coastal Fisheries and Ecosystem Restoration Scenario: Costs, Returns, and Jobs by Year 10

| Restoring marine coastal fisheries and ecosystems | Investment Years 1–10 (US\$ million) | Revenues Year 10 (US\$ million) | Jobs created by Year 10 |
|---|---|--|------------------------------------|
| Baseline: No government investment (business as usual) | | | |
| Restoring marine coastal ecosystems: Fisheries only | n.a. | 43.71 | 11,472 |
| Wastewater and environmental management | n.a. | n.a. | 148 |
| Existing sector development plans (incremental) | | | |
| Restoring marine coastal ecosystems: Fisheries | 1.10 | 0 | 0 |
| Restoring marine coastal ecosystems: Environment (mainly wastewater plans, not necessarily funded) | 224.80 | –8.45 ^a | n.a. |
| Development scenario (incremental results) | | | |
| Restoring marine coastal ecosystems | 23.75 | 12.33 ^b | 250 |

Source:

Note: Coastal fisher assets are estimated at US\$ 9.24 million. (a) Losses are through continued erosion, reduced tourist experiences and fisheries subsidies as the investments (although necessary) will improve only some coastal areas. (b) The revenues assume a timely implementation of effective measures. n.a. = not available

coastal fisheries,⁴⁷ and in environmental and fisheries management, for example jobs linked to marine spatial planning.

It is important to note that the investments do not include actions to reduce wastewater discharge or agricultural runoff, which are major stressors. The investment will, however, enable a quantification of these stresses and inform a program of action to reduce them. It is emphasized that recovery of the lagoon ecosystems is likely to be contingent on strong action to reduce these latter two stressors; because of the current state of knowledge, the costs of these actions are not included in the development scenario.⁴⁸

If the health of the lagoon and reef ecosystems is not restored, the costs to the economy are likely to progressively increase: coastal erosion will increase, including the loss of sand to hotel beaches; cyclone damage will increase; subsidies to stressed fisheries will cause further declines in catches; and the potential for coastal aquaculture will be undermined. In the medium to long-term, these losses are likely to exceed the costs of remedial investments by orders of magnitude.

⁴⁷ Job creation in coastal offshore fisheries depends on the viability of FAD and dropline fisheries around Mauritius island.

⁴⁸ A suitable model for the suite of actions is the Australia/Queensland scheme to protect the Great Barrier Reef, since Northern Queensland has an important sugar cane industry.

Scenario 2: The Banks and Offshore Demersal Fishery

For the purposes of the scenario, all deepwater fisheries, including those on the Saya De Malha Bank,⁴⁹ Nazareth Bank, St. Brandon Banks, around Rodrigues, and on the seamounts and continental slopes around Mauritius are considered as a single fishery—the “Banks” fishery. Recorded production has declined from more than 3,500 tons to 1,500 tons per year, for several reasons, and it is currently well below the estimated MSY. The technology used by the aging fleet of dory/mothership freezer vessels no longer meets maritime safety requirements, and the fleet is being phased out.⁵⁰ The current fleet is dominated by 15-to-25-meter vessels using ice—chill-fish vessels. Vertically integrated companies with chill-fish vessels appear to be cost-effective, while smaller operators without strong market links face challenges. In addition, the presence of foreign fishing vessels is reported, which may contribute to a decline in the catch per unit of effort (CPUE) (see Appendix 2).⁵¹

Approach. The scenario envisages investment in new chill-fish vessels based on commercial assessment of the optimum size and design. The current dropline fishing will be supplemented with passive gears: bottom longlines and traps. This will be done through closely monitored charter arrangements for different vessels operating on a commercial basis but providing the required information on technical performance, costs, and returns. This approach avoids initial commitment of capital to untested harvesting arrangements.

Support for a stakeholder association would be provided. Its tasks would be to help match supply with demand (avoid gluts and ensure

⁴⁹ Note that coastal states do not have exclusive rights over the finfish resources of the Extended Continental Shelf. A large proportion of the Saya de Malha Bank lies in the ECS.

⁵⁰ See Merchant Shipping Act, Merchant Shipping (Bank fishing Dorries) Regulations 2000 GN No. 127 of 2000. The dory/mothership vessels operated under an exemption from the Merchant Shipping safety regulations for several years, and the remaining vessels have reflagged to Comoros to avoid the restrictions.

⁵¹ It should be noted that part of the Banks fishing area lies outside jurisdictional waters for the purposes of fishing non-sedentary species, such as those targeted by the Banks fleet. Consequently, the entire fishery is not subject to enforcement actions by the coastal states.

⁵² The likely target market is for fresh emperor (*Lethrinidae*) and snapper (*Lutjanidae*) by air to Dubai. Stable and regular supply of a sustainably branded product will require collaboration by producers on product standards, orders and prices.

stable supplies); penetrate export markets⁵³ with a sustainable Banks-brand fresh-fish product; and collaborate on safety at sea. Public support will be directed at improving the technology, facilitating access to finance for modern vessels, and training the Mauritian crew.

An individual transferable quota (ITQ) management scheme⁵³ will be established to ensure biological and economic sustainability and, if required, a fishing grounds rotation⁵⁴ scheme will be introduced. Applied scientific research, fisheries monitoring, and expanded maritime surveillance would complement the private sector activities. Studies would be undertaken at St. Brandon and Agalega leading to the establishment of logistics bases for scientific and enforcement activities. This could also lead to an expansion of the small, but exclusive, sport fish fishery for bonefish and jacks. A feasibility study on “blue carbon” sequestration by the Saya de Malha seagrass beds will determine how carbon funds can be accessed to support the conservation of the Banks.

Maintaining a profitable Banks fishery means expanded fisheries surveillance. While a certain level of presence at sea by the National Coast Guard is essential, the area is ideal for deployment of modern cost-effective remote sensing technologies—including buoyed hydrophones and underwater drones⁵⁵ equipped with hydrophones to triangulate noise signals from vessels. This information can be overlaid with an obligatory vessel monitoring system reporting from licensed vessels to help identify any nonreporting vessel activity on the Banks, provide estimates of any illegal fishing, and help plan Coast Guard patrols.

Costs and returns. The estimated investment is US\$27 million, of which about half is private investment, mainly for up to 16 modern fishing vessels. The public operating costs are US\$0.75 million per year. The annual gross returns are estimated to be US\$24 million from the Banks fisheries and a further US\$4.2 million from the blue carbon

⁵³ The Banks fishery appears ideal for such a scheme for several reasons. It is a developing fishery so the quota can be precautionary, quota allocation does not require reduction in vessel numbers or effort (as catches are substantially below the estimated MSY), all landings will be in Port Louis, enabling good control, and any overfishing is likely to affect the economic performance of the fishery long before the fish stocks are threatened, because high catch rates and marketable fish sizes are required to offset the high costs and risk involved in the remote fishing operations.

⁵⁴ This is done in other similar fisheries to avoid depletion of closer grounds while more distant or less-productive fishing grounds remain “under-exploitation.”

⁵⁵ Example only: Wave glider. <https://www.liquid-robotics.com/platform/overview/>.

Table 3.6. The Banks Fisheries Scenario: Costs, Returns, and Jobs by Year 10

| State of Banks fisheries in year 10 | Total investment(US\$ million) | Annual revenues (US\$ million) | Jobs |
|---|--------------------------------|--------------------------------|------|
| Business as usual—no additional investment | n.a. | 6.75 | 202 |
| Existing development plans (incremental) | 9.75 | –2.34* | –70 |
| Additional development scenario (incremental) | | | |
| The Banks: Fisheries | 25.80 | 24.00 | +600 |
| The Banks: Blue carbon potential | 1.65 | 4.19 | 60 |

Source: World Bank analysis.

Note: A decline in revenues is anticipated without ensuring the technical and economic viability of new vessels, developing markets and implementing an effective management regime.

scheme. Without investment, employment is likely to decline gradually. The investments anticipate the maintenance of 200 existing jobs⁵⁶ and an increase of 400 jobs in fishing and post-harvest handling. In the event of a blue carbon initiative, additional jobs at sea and in marine science would be created (Table 3.6). The scenario also contributes to the assertion of Mauritius' maritime control over these isolated resources.

The critical assumption is that the technical and management innovations will create a profitable fishery. Other key assumptions are that the commercial operators will effectively collaborate to supply high-end export markets with a branded product (possibly as a condition of licensing); that an ITQ or similar effort management system will be effectively implemented enforced; and that an effective maritime surveillance presence on the Banks is provided. Thus, the keys to development of a sustainable Banks fishery are financing effective technical innovation on the fishing grounds, limiting the fleet size and fishing effort to maintain profitability, cooperation among the fishers on the fishing grounds and in export marketing, and enhanced monitoring and surveillance.

Scenario 3: Aquaculture Expansion

Approach. The aquaculture scenario builds on the recent issue of concessions and ongoing work to characterize the designated aquaculture sites. The scenario is based on an additional five farms in the inshore and lagoon area and two farms in the offshore area. Some farms will be for invertebrates (such as oysters or sea cucumbers), as the space available for cages within the lagoons is limited. The inshore farms would have approximately the same scale of investment and production as the exist-

⁵⁶ Without investment, many of the existing jobs may progressively be lost.

ing Ferme Marine de Mahebourg (FMM)⁵⁷—that is, FMM is used as a template for the inshore scenario, although it is recognized that some inshore farms could be for invertebrates. The two offshore finfish cage farms have a profile equivalent to that set out in the Growfish⁵⁸ proposal. Small-scale aquaculture is not part of the scenario, although out-grower schemes could be envisaged once the industry is well established.

The scenario provides for public support for aquaculture site baseline studies, facilitating private applied research and innovation, monitoring of diseases, and robust environmental impacts (Ministry of Environment and NDU 2009). Capacity building will need to be integrated with broader human resource development planning. Issues arising in relation to aquaculture legislation and investment fast-tracking will need to take account of the MSP initiative. A progressive aquaculture will require a significantly improved regulatory base, not only in relation to a streamlined inter-ministerial approvals process and long-term site leases, but also for disease control, green certification, and product traceability for exports and for the import of seeds and related biosafety considerations.⁵⁹ The Fisheries Division and the Board of Investment (BOI) have identified a number of aquaculture development activities that can be undertaken. It is advisable that these be undertaken as a partnership with private investors to ensure that the innovations can be rapidly applied at the farm level.

In designing any public support for aquaculture, Mauritius can look to Norway, Vietnam, and Israel for examples. Within the region, Madagascar has useful experience of community-based *beche-de-mer* farming. In addition to a robust legislative and investment framework and investment in human resources, public support is generally focused on governance issues related to seeds, feeds, and disease⁶⁰ and on the innovations required to adapt fish culture systems to the local conditions. Mauritius' aquaculture expansion will remain entirely reliant on private investment, which must be nourished as an infant industry in the medium term until Mauritius achieves economies of scale to allow

⁵⁷ See: <http://www.fmm.mu/>.

⁵⁸ See: <http://www.growfish.biz/index.html>.

⁵⁹ Markets are also increasingly demanding product certification, which may require traceability of feed ingredients, rules on animal welfare (e.g. fish slaughter). Other regulations may be required in relation to impact on biodiversity from escapees or use of fertile invertebrate seed, on GMOs, and on capture of seed from the wild.

⁶⁰ Norway has been particularly active in breeding programs for salmonids and, in combination with applied research on feeds, has cut the feed conversion ratio to 1:1.3 (or less). Growth rates for salmon, tilapia, shrimp, scallops, and other species have improved by orders of magnitude as a result of some programs.

Table 3.7. Aquaculture Scenario: Costs, Returns, and Jobs by Year 10

| State of aquaculture in year 10 | Total investment (US\$ million) | Annual revenues (US\$ million) | Jobs |
|--|---------------------------------|--------------------------------|-------|
| Business as usual | 10.00 | 2.87 | 115 |
| Existing development plans (incremental results) | 6.57 | 14.86 | 250 |
| Additional development scenario (incremental) | 245.00 | 288.80 | 1,450 |

Source: World Bank analysis.

the growth of support services on seeds, feeds, and disease monitoring and control. Until that time, investors and public support will need to share the burden of the support services and investments in feed⁶¹ and seed production or import. Importantly also, Mauritius might want to consider having a robust citizen engagement plan, within an inclusive marine spatial plan, as it starts to expand aquaculture.

Costs and returns. The total investment is US\$245 million over 10 years—based on a unit cost⁶² of US\$17 million for the FMM-type inshore investments (whether for finfish, or invertebrates) and US\$40 million for the offshore investments (including shore facilities). Gross incremental returns are estimated at almost US\$290 million per year, with an increase of about 1,500 in jobs (Table 3.7). Over 90 percent of the production would be exported, and up to half of the inputs would be imported.

The key assumptions are that (i) appropriate financing will be available; (ii) the approval process can be fast-tracked; and (iii) the production systems will be technically and economically sustainable. There is an assumed rate of return of 25 percent—which is at the margin for access to loan finance or risk capital (that is, finance is unlikely to be available unless a high rate of return can be demonstrated).⁶³ Some investors have experienced difficulty in sourcing finance. The financing issue highlights the need for public support and facilitation through secure tenure over

⁶¹ Aquafeeds are significantly different from other animal feeds, since fish require a different balance of nutrients and some ingredients in regular animal feeds may even impede growth. A key ingredient of aquafeeds is fish meal and fish oil, for which there is a limited local supply from the tuna processing industry. In addition, seed fish (fingerlings) may need a different feed composition from growing fish and from those being prepared for market. Feed costs can be in excess of 60 percent of total costs for finfish cage farms, while invertebrates, such as oysters and sea cucumbers, do not require artificial feed.

⁶² These values are drawn from existing investment proposals and may not reflect actual investments. However, a relatively large investment is generally required to achieve economies of scale.

⁶³ Personal communication with IFC.

aquaculture concessions, a fast-track approval process, access to sites for shore facilities, and a favorable investment climate.

Scenario 4. Development of the Seafood Hub

The Seafood Hub scenario includes all the Port Louis activities associated with the industrial fisheries and fish processing. It does not include the expansion of the port fisheries and related infrastructure, which are covered in the port development scenario—notably, additional quay and fish handling space, a protected mooring for (mainly longline) vessels, and prospective private investment in repair (drydock/slipway) facilities (see Chapter 6) (Royal Haskoning DHV 2016). Details of the Seafood Hub infrastructure are not provided here and reference should be made to the relevant sections of the Port Louis port master plan.

Rationale. This scenario focuses largely on: (i) institutional development to increase the use of the existing port facilities to increase sales of services and supply fish to existing processing plants and for domestic consumption; (ii) selected private investments in longline vessels⁶⁴ and in fresh fish handling and cold storage; and (iii) complementary support at the regional level to secure sustainable economic benefits from the tuna fisheries. These activities can be coordinated under a Seafood Hub development plan to include optimizing the efficiency of, and returns from, expanded port services, enabling private investment in fleet, cold storage, fish handling, and vessel repair.

Approach. The institutional investments include the upgrading of the Port State Measures Unit (IT and training) and resolving institutional issues in the Competent Authority (sanitary controls). Restrictions on sale of bycatch will be removed. An upgraded public-private partnership between MPA, ships agents, seafood processors, vessel operators, and other key stakeholders will be tasked with streamlining the logistics of the fisheries activities to improve productivity for all. A dedicated fisheries productivity unit in MPA will provide day-to-day coordination and logistics planning for fishing vessel berthing to maximize use of both public and private quays.⁶⁵ The public-private partnership will engage in discussions with the various foreign fleets operating in

⁶⁴ In 2016 Mauritius operated seven purse seiners and four longliners with a total catch of 9,774 tons. Most of the purse seine fishing took place outside Mauritius waters and landings were mostly in the Seychelles, whereas the longline fleet operates mostly from Mauritius.

⁶⁵ Online advance schedules on vessel arrivals, transshipment, and deliveries to processors will allow all parties to plan and optimize logistics.

the region with a view to establishing a permanent base in Port Louis through a mutually beneficial development of services, improved investment climate, and collaborative commercial framework.

The private investments include current and proposed projects to develop the fresh tuna export industry. These vessels may fish seasonally in regional non-Mauritian waters. The private sector will also expand the cold chain capacity. Regional initiatives, including the Fisheries Improvement Project⁶⁶ and agreements on harmonized minimum terms and conditions of access and MCS, will be progressed, as will engagement with other global initiatives.⁶⁷ Joint actions in support of tariff preferences for Africa-Caribbean-Pacific (ACP) and small-island developing states will be further advanced through dialogue (for example, with the Forum Fisheries Agency (FFA) in the Pacific Islands).⁶⁸ Subject to feasibility studies, an online fish trading hub could be envisaged for both fresh and frozen longline catches. Over time this could be linked to guaranteed space and tariff rates for air and sea containers, giving economies of scale for fresh-fish packing materials. Further analysis of the banking arrangements related to the movement of fish may uncover opportunities for financial services, savings on exchange rates, and regional financial cooperation on tuna trade.

Costs and returns. The scenario envisages investment costs on the order of US\$35 million, mainly for longline vessels, cold storage, and chill fish handling (Table 3.8). The benefits will accrue in several ways: (i) an increase of more than 330 vessel calls per year and the corresponding sale of services; (ii) an increase of up to 25,000 tons of fish landings; and (iii) productivity gains from regional economic cooperation on tuna, including by reducing the risk of tariff preference erosion and ecolabeling of products. Annual sale of additional port and other services are estimated at over US\$16 million, and additional annual landings of fish at

⁶⁶ <http://www.princesgroup.com/news/2016-10-new-fishery-improvement-project/>.

⁶⁷ For example, the Fisheries Industries Transparency Initiative, for which a standard is under development.

⁶⁸ A group of Pacific Islands countries (Nauru Group) operate a joint access regime for purse seine vessels where a limited number of fishing days are sold based on a combination of minimum prices, a bidding/auction scheme and preferential allocation for vessels with economic links to the country, e.g. delivering fish to processing plants, engaging local crew, registered in/paying taxes in the country. Through joint efforts, certain high seas areas between their EEZs have effectively been closed to fishing. The non-FAD skipjack purse seine fishery has also achieved MSC certification giving premium prices to the fish. Coordinated regional efforts can draw on these lessons to increase the value of the region's tuna fisheries.

Table 3.8. Seafood Hub Scenario: Costs, Returns, and Jobs by Year 10

| State of Seafood Hub in year 10 | Total investment over 10 years (US\$ million) | Annual revenues (US\$ million) | Jobs |
|--|---|--------------------------------|-------|
| Business as usual | 800 | 220 | 5,000 |
| Existing private-sector unfinanced development plans (incremental) | 19.50 | 16.35 | 131 |
| Additional development scenario (incremental in relation to the baseline, not the 'Existing plans')* | 34.90 | 51.25 | 869 |

Note: The *Business as usual* values are World Bank estimates of existing capital and revenues. The *Additional development scenario* includes the existing (largely unfinanced) private-sector development plans, since it is not possible to clearly separate these plans within a 10-year scenario. This means that the values presented in this row include the *Existing* investment (e.g. the US\$34.9 million investment includes the US\$19.5 million investment) even though the latter has *not* yet taken place and remains unfinanced as of late 2016.

over US\$30 million in year 10. The estimated incremental gross returns will be over US\$50 million per year, generating more than 800 new jobs. Key assumptions include stability in tuna markets and fuel prices, along with full engagement of the MPA, industry stakeholders, and other actors in making Port Louis the fisheries port of choice in the region.

Summary of the Scenarios

So what do these four sub-sector scenarios add up to for the sector as a whole? Table 3.9 summarizes the scenarios, providing a snapshot of the existing economic characteristics of the scenario targets (baseline). Two types of new investment are included: (i) the planned investments, or those already under way (existing sector development plans); and (ii) the investments and estimated results of the scenarios described above. In addition to the actual (not-discounted) values, the values for investments and revenues discounted at 5 percent are also presented. Further quantitative details of the scenarios are provided in Appendix 1.

The overall results show that private investment constitutes over 85 percent of the total investment, highlighting the need for a robust investment climate, including measures to reduce risk for aquaculture and Banks fishing. Public investment in the Banks fishery includes substantial private sector support for fishing technology development and safety at sea, making up almost 50 percent of the public investment. The coastal fisheries and ecosystem restoration scenario does not provide for private investments. However, the outcome of lagoon health assessments may require hotels or households to invest in improved waste water treatment, or cane farmers to review pest control practices. Aquaculture is seen as essentially private investment with public support provided through existing channels and facilities. And public investment in the Seafood Hub is considered to be catalytic in opening opportunities for increased private investment.

Table 3.9. Investment Costs and Worth of Economy-wide and Project-level Measures for Four Development Scenarios

| | Investment and financing | | | Measures of scenario worth | | | | |
|---|--------------------------|--------|---------|--|--------------------|--------------|---------------------------------------|--------------------|
| | (US\$ million) | | | Economywide measures (US\$ million/jobs) | | | Project level measures (US\$ million) | |
| | Total | Public | Private | NPV | Benefit/cost ratio | Job creation | NPV | Benefit/cost ratio |
| Coastal fisheries and ecosystem restoration | 23.75 | 23.75 | — | 51.89 | 3.54 | 250 | 23.05 | 1.13 |
| Banks fisheries | 27.45 | 14.45 | 13.00 | 59.97 | 3.59 | 860 | 30.09 | 1.77 |
| Aquaculture | 245.00 | 0 | 245.00 | 104.48 | 1.19 | 1,450 | 345.67 | 1.63 |
| Seafood Hub | 34.90 | 3.40 | 31.50 | 81.99 | 3.65 | 1,000 | 12.80 | 1.69 |
| Total | 331.10 | 41.60 | 289.50 | 298.33 | 1.53 | 3,560 | 411.61 | 1.16 |

Source: World Bank analysis.

Note: Job creation is defined as the labor income stream that would support a worker continuously employed for 20 years. NPV = net present value.

Another way to view these results is by looking at the measures of scenario worth at both the economywide and the project level, as calculated by the model. Benefit-cost (B/C) ratios are equivalent to investment present-value multipliers (present value of GDP increases divided by present value of investment). The B/C ratios are larger for the economywide measures, except for aquaculture. This is probably because aquaculture relies on private investment, imports significant factors of production, and does not have a major public good component in the form of infrastructure. However, according to the model, it would lead to considerable job creation. Value added B/C ratios from economy-wide spillover effects are estimated to be especially high for investment in coastal ecosystem and lagoon rehabilitation, which has a high public component. The Banks fishery and Seafood Hub also appear to generate comparatively high economy-wide benefits, probably due to purchase of services and employment creation.

As for production multiplier effects, they are moderate for the entire fishery investment program and concentrated in the private service sector (Table 3.10). The multipliers for the non-service sectors are low, because currently the fisheries do not have an extended value chain relying predominantly on local production, even though development of the scenarios should result in a richer set of domestic suppliers and related linkages.

The scenarios provide a quantitative basis for discussions on policy and investment planning. The actual trajectory of each fishery or scenario is particularly dependent on (i) implementation of policy decisions

Table 3.10. Production Multipliers of Investment in the Fisheries Sector

| Sector | NPV multiplier |
|----------------------------------|----------------|
| Agriculture and animal husbandry | 0.067 |
| Fisheries | 0.057 |
| Minerals | 0.013 |
| Food processing | 0.118 |
| Other manufacturing | 0.273 |
| Services | 1.384 |
| Public Services | 0.351 |
| Total | 2.227 |

Source: World Bank analysis.

Note: NPV = net present value. NPV multiplier = NPV Increase in production/NPV investment.

(coastal ecosystem rehabilitation); (ii) access to affordable finance and technologies (Banks fishery and aquaculture); and (iii) solidarity in stakeholder and regional collaboration (Seafood Hub).

Making It Happen

While the specific activities under each scenario are described above, a range of cross-cutting actions are required to “make it happen.” The relative importance of these measures is indicated in Table 3.11. For example, private sector finance is vital for the Banks fisheries and for aquaculture; public policy and support is fundamental to rehabilitation of the lagoons and the coastal fisheries; while an improved business climate underpins aquaculture investment.

Strengthen Existing Governmental Plans

Mauritius has already set out a vision for the OE (Prime Minister’s Office 2013). For each of the clusters, a detailed strategic plan is required, but much of the groundwork has already been laid. In the case of the fisheries, a fisheries and aquaculture master plan with fishery-by-fishery development and management plans will provide a working framework. Many fishery plans have already been drafted. These plans can be revised and updated through technical and stakeholder consultation, complemented by financing plans and key milestones. Within this planning framework the scenarios can be converted to investment projects following validation, prioritization, and adaption to the changing dynamics of the fisheries.

Table 3.11. Indicative Scale of Cross-Cutting Interventions Required

| Scenario | Public policy | Information systems | Private sector finance | Improved business climate | Human resource development | Public sector reforms |
|---------------------------------|---------------|---------------------|------------------------|---------------------------|----------------------------|-----------------------|
| Coastal fisheries and ecosystem | +++ | +++ | + | | + | ++ |
| Banks fisheries | ++ | ++ | +++ | + | + | + |
| Aquaculture | ++ | + | +++ | +++ | + | ++ |
| Seafood Hub | + | ++ | ++ | ++ | + | + |

Source: World Bank analysis.

Note: The relative importance of each intervention is indicated as follows: +++ indicates very high; ++ indicates high; and + indicates moderate.

When considered in the broader context of the OE, some investments may straddle OE clusters, for example for support to small and medium-size enterprises (SMEs) in applied marine research and in knowledge management or human resource development. Segments of the scenarios may be fast-tracked, such as environmentally sustainable marine leisure, creation of formal tenure instruments for the vacant aquaculture sites, or development of an ITQ scheme for the Banks fisheries.

Improve Implementation of Policies and Plans

Particular attention can be directed to the 2012 analysis by the Director of Audit⁶⁹ indicating a poor performance in the implementation of fisheries sector plans. Some of this poor performance is attributable to a lack of outcome tasking, public service inertia, and neglect of detailed costing of and responsibility for activities and results. This can be addressed through a public expenditure review and associated redirection of human, institutional, and financial resources to time-bound targets and outcomes, a breakup of silos and assignment of responsibilities for outcomes, combined with an improved response to private sector demand for services. Results-based tasking of budgets and staff will ideally involve a substantial reform of the public service, its promotion, bonus payment and staff evaluation processes. Within the public service, outcome-directed tasking of staff and departments linked to budget allocations, staff performance and the planning milestones will mean re-tasking and re-training of some staff. A more structured means of engaging the private sector in these processes will also be of value.

⁶⁹ According to a June 2012 report from the Director of Audit, the plans, which should include, among other things, projects to be undertaken, objectives of the projects, tasks to be performed, people assigned, milestones and deliverables, must be prepared on a short-term basis, medium-term basis, and long-term basis. (Director of Audit 2012).

Develop Human Resources and Knowledge Management

In the public domain, institutional strengthening and human resources development can drive productivity and investment. Specific institutional investments are embedded in the scenarios and focus on broader reforms and investments in policy development, human and institutional capacity, knowledge systems, and access to finance. At a technical level, upgraded and integrated information systems will facilitate economic analyses, tracking of ecosystem health, mapping of coastal ecosystems, and EEZ resources. At a policy level, the institutional architecture for MSP and integrated coastal zone planning will need transparent consultations and institutionalized coordination between stakeholders. A review of legislation will need to resolve overlapping jurisdiction, particularly in the near-shore and foreshore areas. Networking between Mauritius' leading educational institutions and collaborating international centers of excellence will help transfer technologies and skills relevant to the OE (Patil et al. 2016).

Knowledge management requirements include substantial investment in a fisheries information management system (FIMS). This would cover all the value chains described in the above scenarios, with particular attention to the tuna fisheries and Mauritius' international obligations with respect to tuna management. The MSP initiative will require a suite of additional databases and decision tools. These would be populated with oceanographic data, data on water quality, data on coral reef health, and calibration of the stresses on the reefs and lagoons. Information from numerous stakeholders will need to be integrated and selectively shared between research institutes, customs, the coast guard, the MPA, the tourist industry, the fishing associations, and companies and agencies active in the sector.

Encourage More Private Investment

This will require a more pro-active "Doing Business" climate, particularly for infant industries and higher-risk investments. Specific investment guidelines can be built on lessons from Mauritius' past experiences and by drawing on international best practices. Tasks will include, for example, assessment of Mauritius Development Bank (MDB) loans to fishers and analysis of the reasons why previous aquaculture investment proposals failed to advance. In particular, aquaculture ideally requires a one-stop, fast-track approval process, with parallel rather than sequential processing (BOI 2016). This could involve a time-bound "no objections" process once the basic requirements (for example, EIA, stakeholder consultations, and zoning) are met, coupled with measures to grant long-term concessions with secure tenure. Investments will be needed to build skills at all levels, so that new employment opportunities are not simply filled by non-Mauritians.

Financing, particularly for the relatively high-risk Banks and aquaculture scenarios, will require secure long-term concessions to provide “natural capital” and equity to leverage venture finance and secure loans. Tax concessions are already in place. At the SME level, the design of grant finance will need assessment of previous grant-financed investments, realistic cost-benefit analyses; training of fishers in basic financial management; awareness by loan officers of the seasonal nature of fisheries risk and repayment; and advisory support for investors who encounter difficulties. Fisheries administration staff will need to play an active role, not only with regard to resource sustainability but also with regard to the economic viability of the investments.

Make Public Policies and Expenditure More Effective

Outcome and performance-based assessment of recurrent public finance will uncover savings that can be redirected. Similar analysis of the public investment portfolio will identify savings through synergies and scheduling. Dialogue with development partners on the OE investment portfolio will leverage concessional loan and grant finance at both regional and national levels. Policies supporting sustainable private investment will help access impact investment finance to couple economic and financial performance with social and environmental outcomes and risk management.

Making It Last

How can Mauritius maintain a sustainable OE growth trajectory? A renewed commitment to the ocean dimension of “Maurice Isle Durable,” monitoring the performance of the OE, and regional cooperation are among the key actions.

Promote Environmental Sustainability

Sustainability is a core value of the Mauritius Ocean Economy initiative. Environmental and natural resource sustainability are embedded in each of the scenarios and are fundamental principles of responsible fisheries management and aquaculture development. The scientific knowledge to secure environmental sustainability is readily available, nationally, regionally, or through international centers of excellence. Many of the instruments already exist in Mauritius: environmental impact assessments (EIAs) and fisheries management plans. Others, such as MSP and ridge-to-reef environmental plans, will be developed. Benchmarking critical environmental and fisheries indicators will be a cornerstone of a knowledge base for sustainability. A permanent scheme to monitor these indicators, linked to regular national reports on the

state of the marine environment, will build public awareness and drive responses to current and emerging threats. In accordance with best aquaculture practices, strict precautionary carrying capacity limits will need to be established as part of the EIAs for the farm sites.

Mauritius' prominent international role in fisheries—notably in the Indian Ocean Tuna Commission (IOTC), the South West Indian Ocean Fisheries Commission (SWIOFC), and the Indian Ocean Commission (IOC)—will need to be continued and expanded. Similarly, Mauritius will continue to play a leading role in molding environmental actions through the Nairobi Convention and through the African Union, Small-Island Developing States, ACP and other fora.

Strengthen Economic Performance

Weaknesses in tracking the economic performance of the fisheries sector have constrained the current analysis. A more robust fisheries information management system will enable more comprehensive and accurate assessments. Reporting on the economic performance of fleet segments and the post-harvest activities will be part of such efforts. Weakening economic indicators often serve as early warnings as economic overfishing tends to occur in advance of biological overfishing. Maintaining fisheries at an MEY, or at least well above MSY levels, will avoid economic crises and ensuing environmental and social pressures and political demands.

Making it last requires long-term political commitment to restoring the health of the marine coastal ecosystems. Some actions are likely to reduce the traditional economic opportunities of coastal fishing communities. Finding alternatives will require extended community dialogue and support to design and apply a suite of remedies.

Effective regional economic cooperation on tuna⁷⁰, as has been done in the Pacific Islands,⁷¹ offers opportunities to add value to a large proportion of the region's catch, which is currently exported in unprocessed form and competes with the processed products from Mauritius. Preservation of the EU tariff preferences will also be essential to the economic survival of the tuna processing. The private sector will benefit from public commitments to develop the Seafood Hub and related fisheries infrastructure and fast-tracking of selected investments. Smaller businesses will benefit from a review of the performance of the fisheries

⁷⁰ The recent development of a SWIO regional framework agreement on economic cooperation on tuna and development of minimum terms and conditions of access is an important demonstration of this cooperation.

⁷¹ The Pacific Nauru Agreement. See <http://www.pnatuna.com/Documents>.

grant schemes and a technical and financial advice facility⁷² to address difficulties in loan repayments.

Monitor Social Impacts

As with agriculture in middle income countries, as Mauritius moves toward the future, employment in small-scale coastal fisheries will decline. Given finite coastal fisheries resources and increasingly efficient technologies, either the technology or the level of effort must be constrained. The solution is to gradually exert control over all fishing activities (commercial, “amateur” and recreational). The more efficient solution is to restrict commercial fishing to licensed fishers and vessels and establish clear tenure or fishing rights. Tenure can be vested in individuals, cooperatives or associations to buffer potential exclusion of some fishers.

Mauritius has already begun to address some of the social issues in the coastal fisheries by ‘buyout’ schemes for seine net fishing, grants to move fishing offshore, and support for the FADs fishery and small-scale aquaculture. These schemes require monitoring and assessment of performance. Without additional investment in human resource development, expansion of employment in the Banks fishery, in aquaculture, or in the Seafood Hub may result in the import of foreign skilled labor. Close consultation with the private sector can define the skills requirements and design apprenticeship and on-the-job training schemes.

Enhance Resilience to Climate Change

Climate change presents a very real threat to the Mauritius marine ecosystems, the fisheries economy, and coastal livelihoods. All of the four scenarios described here take account of potential climate change impacts. The key is to establish economically viable sustainable fisheries, as these fisheries are more resilience to climate change, while their economic viability enables adaptation, including development of alternative economic opportunities. In particular, the coastal fisheries and ecosystem scenario directly addresses the rebuilding of the reef and lagoon ecosystem health, which provides the natural barriers to erosion and significantly mitigates damage caused by cyclones. Additional damage caused by extreme events resulting from the degradation of these natural barriers has not been estimated in the scenario.

Awareness of the pending loss of the coral reefs is low, and the scale of this threat is significantly underestimated. Natural causes beyond Mauritius’ control—in particular, ocean acidification and sea

⁷² Existing schemes can have a specific focus on fisheries. See: <https://www.smeda.mu/>.

temperature rise—will cause major loss of coral reefs over the next decades. Reducing local stresses (pollution and fishing) will only slow this process, though this might allow time for the corals to adapt.

The resilience of coastal fishing communities to climate change means that the fisheries must be more healthy and resilient, fish stocks need to recover, and fishing effort must be maintained at a level that provides incomes that keep pace with economic expectations. Mauritius will need to remain fully engaged in climate-related initiatives, including in climate finance and emerging opportunities (such as the potential for “blue carbon” credits).

Stay on Track

Reports on the state of the OE, including stakeholder feedback, will be an important instrument in securing broad based political support. Regular assessments of the performance of cluster plans will help identify and address constraints. Dissemination updates on the state of the marine environment will foster dialogue, invite external support, and establish Mauritius as a center of transparency and emerging excellence in marine knowledge.

Recommendations

In summary, Mauritius will need to move from a broad vision for the OE to defined metrics and appraisal of how existing institutional arrangements and public expenditures align with this vision in terms of delivering jobs and growth. Public policy can establish detailed plans with associated feasibility assessments and closely monitor performance. Private sector growth will require an active search for investment finance and new investors with proven technical know-how, coupled with backstopping of the traditional Seafood Hub activities.

A range of cross-cutting measures will be required to backstop sustainable investments, to ensure their economic viability and social inclusion, and to monitor the environmental health of Mauritius’ marine and coastal resources. These measures will include investment in human resources, in governance, and in catalytic public support for private sector initiatives. A first step is to assess the effectiveness of existing public expenditures and policies. Analyses of priorities, synergies and sequencing in the investment portfolio can direct existing public resources more effectively. Retraining and re-tasking of less productive human resources can also deliver public services more efficiently, particularly when reinforced with modern fisheries information management systems.

Despite Mauritius’s favorable Doing Business rating, projects in the sector have been constrained by a difficult investment climate, for

example with respect to aquaculture permits. Offshore fishing and aquaculture are perceived as high-risk ventures requiring substantial capital and lacking conventional security. Large, small, and medium-size investors will benefit from improved access to affordable financing and schemes to reduce risks through more secure tenure.

Enhanced regional cooperation and solidarity will be important to maintain trade preferences, to capture a greater share of the sustainable benefits from the tuna resources, to enforce the tuna management measures, and to maintain maritime security. Marine science and human capacity building can benefit from strengthened regional cooperation and knowledge sharing.

At the national level, Mauritius can build political awareness and support for adaptation and reduce the local stresses of overfishing, agricultural pollution, and urban pollution. At the international level, Mauritius can continue and enhance its efforts to mitigate climate change through regional and global fora.⁷³

Table 3.12 illustrates shorter-term and longer-term recommended actions, by scenario.

Human and Institutional Capital

At the institutional level, increased cooperation and policy coherence can be ensured through MoUs between key actors to jointly implement plans (for example, MOE, Coast Guard, Ministry of Environment, the university, BOI, and private sector associations). The MoUs would set out clear targets and specific commitments on funding, staffing, regulatory, enforcement and other relevant actions. At a higher level, constraints to OE development will benefit from periodic inter-ministerial reviews to improve the effectiveness of the physical planning and investment. The establishment of an investment-focused geographic information system (GIS) for planned public and private projects can enable effective synergies, prioritization, sequencing of investments, EIAs, and assessment of cumulative environmental and spatial stresses in the coastal and marine areas.

Business Promotion

An improved business climate can be facilitated by an OE fisheries business promotion facility, preferably building on existing arrangements and designed through dialogue with Business Mauritius, BOI, banks, and SME support services. The facility could: (i) review business

⁷³ For example: Mauritius Strategy for the Further Implementation of the Programme of Action for the Sustainable Development of SIDS. http://www.un.org/ga/search/view_doc.asp?symbol=A/CONF.207/11&Lang=E.

performance and challenges, including performance of grant-financed fisheries (e.g. FAD fishery grants); (ii) identify financing and risk reduction modalities, delivery of financial services, and fast-tracking of strategic/priority investments; (iii) arrange specific assistance on selected investments, including to SMEs on technical and financial management of loans; (iv) leverage resources potentially available through the Africa Ocean Economy Platform, climate funds, impact investing and other sources; and (v) facilitate means to close skills gaps and replace foreign with Mauritian workers.

Knowledge Platform

A knowledge platform (key ministries, technical institutions and universities) will ideally establish an OE monitoring and evaluation scheme and an economic performance monitoring unit (or regular process) to track OE investments. Key outputs would include: (i) regular reports on the state of the OE, based on the knowledge and monitoring scheme and formal stakeholder consultations (led by MOE and the Prime Minister's office); (ii) raised public awareness of the OE opportunities and threats at all levels, including through the school curriculum, to fortify broad public consensus on development and management of the OE; (iii) enhanced ability to anticipate and respond to internal and external threats on a timely basis; and (iv) progressive improvement of natural capital accounting for oceans (Bureau of Statistics). The platform would contribute to and draw on regional and international organizations (for example, the Indian Ocean Commission (IOC), the United Nations Division of Oceans and Law of the Sea (UNDOLOS), the United National Environment Programme (UNEP) and IOTC).

Table 3.12. Summary Recommendations by Scenario

| | Shorter term (6–18 months) | | Longer term (18–36 months) | |
|--|--|--|--|---|
| | What | Who (lead/associate agencies) | What | Who (lead/associate agencies) |
| SCENARIO 1: COASTAL FISHERIES AND ECOSYSTEM RESTORATION: INVESTMENT | | | | |
| Physical capital | <ol style="list-style-type: none"> 1. Reef/lagoon monitoring facilities 2. Development of off-lagoon fishing (if viable) | MOE/Min. Env. joint lead. M. Tourism associate | <ol style="list-style-type: none"> 1. Comprehensive GIS and knowledge management system for lagoon ecosystems (linked to Marine Spatial Planning initiative) 2. Permanent and substantially expanded monitoring scheme for reef and lagoon health 3. Review of waste water/ agricultural practices impacts. 4. Review of viability of off-lagoon fishing 5. Scheme to support off-lagoon fishing (only if viable) | <ol style="list-style-type: none"> 1. & 2. PM (lead) implementation by MOE and M. Environment with AFRC and MOI. 3. Min. Env. with WWMA/ Min. Agric./local authorities 4. MOE, loan agencies, fishers 5. MOE, Min. Finance, loan agencies |
| Human capital | <ol style="list-style-type: none"> 1. Training of scientists/ coastal planners (local with external advisers, e.g. from Queensland) 2. Dialogue with fishing communities to reduce lagoon fishing effort | <ol style="list-style-type: none"> 1. MOE, AFRC, MOI, university 2. MOE lead | <ol style="list-style-type: none"> 2. Complementary financial and social measures for 'displaced' fishers 3. (Re-)training of fishers; development of alternative livelihoods | <ol style="list-style-type: none"> 1./2. MOE /M. Finance/ development banks 3. Tourist industry |
| Natural capital | Reefs/lagoons/ mangroves/seagrass beds as targets | MOE/Fisheries; Min. Env., local authorities/ NGOs | <ol style="list-style-type: none"> 1. Eliminate net fishing in the lagoons and over coral reefs 2. Significantly reduce 'amateur' fishing effort 3. Implement resource management plans (e.g. octopus) 4. Develop alternative economic opportunities for lagoon fishing households, address any negative social and economic impacts | <ol style="list-style-type: none"> 1. MOE/Fisheries, fishing associations 2. & 3. MOE/Fisheries 4. MOE/Fisheries, Min. Finance, development banks, other ministries |
| SCENARIO 1: COASTAL FISHERIES AND ECOSYSTEM RESTORATION – POLICIES/INSTITUTIONS | | | | |
| Physical capital (mostly 'soft' capital) | State of the lagoons report (annual) Review of legislation related to MSP, including on the respective roles of ministries | MOE/Min. Env. | <ol style="list-style-type: none"> 1. Facilities for MSP (databases) 2. Review of erosion and costs of erosion 3. Review of legislation related to use of agricultural pesticides and fertilizers/ dialogue with cane farmers/ others | <ol style="list-style-type: none"> 1. PM Office /MOE lead¹ with scientific bodies 2. Min. Env. 3. Min. Env. jointly with Min. Agriculture |

(continued on next page)

Table 3.12. Summary Recommendations by Scenario (continued)

| Shorter term (6–18 months) | | Longer term (18–36 months) | |
|--|--|---|--|
| What | Who (lead/associate agencies) | What | Who (lead/associate agencies) |
| Design and financing of MSP | PM Office, MOE M. Finance | Undertake MSP process Develop /apply tourism code of conduct for reef/lagoon use | PM Office/MOE/Min. Environment M. Tourism and T. Association |
| Human capital | <ol style="list-style-type: none"> High-level commitment to restore the environmental health of the coastal ecosystems Policy commitment on lagoon rehabilitation Lagoon rehabilitation plan/strategy/finance | <ol style="list-style-type: none"> Implement lagoon rehabilitation plan: wastewater, agricultural runoff, MSP, reduction of fishing effort Develop regulatory measures to reduce fishing pressure (including ‘amateur’ fishing) Improve awareness by hotels and tourists of lagoon /reef health | <ol style="list-style-type: none"> Inter-ministerial task force (Chair PM, or MOE) with tasks allocated to line ministries, e.g. engagement of the ministry responsible for public utilities (waste water) MOE-Fisheries Ministry responsible for tourism |
| Stakeholder consultations with: fishers, hotels, fish farmers, women’s/youth groups, teachers | MOE/local authorities, with fisher associations, other stakeholders | 1. Permanent stakeholder consultation mechanism to improve/maintain lagoon health | 1. MOE, Chair independent (e.g. NGO) |
| Develop a Fisheries Master Plan and consolidate, revise, and update available fisheries management plans | MOE, fisheries | <ol style="list-style-type: none"> Review and reallocate MOE fisheries budgets and staff to implement the master plan; include milestones, budgets and resource allocations Set output-based targets and budgets for the subsidiary institutions (AFRC, FITEC, MOI, others) Introduce performance-based staff appraisal; review sector skills requirements; reassign staff to ensure performance | MOE-Fisheries |
| Comprehensive fisheries information mgt. system (FIMS) | MOE-Fisheries | Implementation of FIMS (also see Seafood Hub) Ensure linkages to coastal and MSP GIS, lagoon health monitoring | MOE-Fisheries (with AFRC, PSMU and CA) |
| Review overlap of shore-based activities of the FPS and CG | MOE, CG with Public Service Commission | Re-task the Fisheries Protection Service and ensure complementarity with Coast Guard tasks | MOE, CG with Public Service Commission |

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Table 3.12. Summary Recommendations by Scenario (continued)

| | Shorter term (6–18 months) | | Longer term (18–36 months) | |
|---|--|---|---|---|
| | What | Who (lead/associate agencies) | What | Who (lead/associate agencies) |
| Natural capital | <ol style="list-style-type: none"> 1. Establish targets for lagoon health 2. Expand MPAs and create new MPAs | <ol style="list-style-type: none"> 1. Min. Env. 2. Min. Env. in cooperation with tourist industry | <ol style="list-style-type: none"> 1. Enhanced and permanent monitoring of lagoon health 2. Significantly expand the existing marine protected areas (MPAs) and create additional MPAs as a matter of urgency. | <ol style="list-style-type: none"> 1. Min. Env. (implementation by AFRC, MOI); enforcement by local authorities; NGO oversight 2. Min. Env. (lead) in cooperation with other stakeholders |
| SCENARIO 2: BANKS FISHERY – INVESTMENT | | | | |
| Physical capital | <p>Fishing vessels, new fishing technologies</p> <p>Access to finance</p> | <p>Investors in discussion with domestic and external sources of finance</p> | <p>Fishing vessels, new fishing technologies</p> <p>Access to finance</p> <p>Update the coastal and Banks catch and effort system with links to national statistics</p> <p>Provide database software, equipment and staff training (see FIMS)</p> | <p>Investors in discussion with domestic and external sources of finance</p> |
| Human capital | <p>Formation of Banks fishing association</p> | <p>Industry operators with MOE</p> | <p>Co-management measures or active formalized industry dialogue</p> <p>Export branding and market studies</p> <p>Implement economic management plan for fishery</p> | <p>Industry/MOE-Fisheries</p> <p>Industry with assistance from BOI and others; CG</p> |
| Natural capital | <p>Develop ITQ or similar effort management plan</p> <p>Increased surveillance (MCS)</p> | <p>MOE-Fisheries</p> <p>Coast Guard</p> | <p>Fishing effort management system/plan</p> <p>ITQ system or similar with possible rotation of fishing grounds</p> <p>Adequate surveillance patrols</p> | <p>MOE, Fisheries; monitoring by AFRC</p> <p>CG</p> |
| SCENARIO 2: BANKS FISHERY – POLICIES/INSTITUTIONS TO ENCOURAGE INVESTMENTS | | | | |
| Physical capital | <p>Finance</p> | <p>MOE, Fisheries and Min. Finance</p> <p>Coast Guard (budget/operations plan)</p> | <p>Concessional finance based on sound feasibility and adequate equity capital</p> <p>Examine feasibility of logistics hub at St. Brandon (MCS, safety)</p> | <p>MOE, Min. Finance, commercial banks, investors; lead by investors and MOE-Fisheries</p> |
| Human capital | <p>Detailed feasibility studies with commercial fishing trials using new technologies</p> | <p>MOE with AFRC</p> <p>monitoring of catch and economic returns</p> | <p>Training in new technologies</p> <p>Training for implementing management plan</p> | <p>Upgraded FISIC</p> |

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Table 3.12. Summary Recommendations by Scenario (continued)

| | Shorter term (6–18 months) | | Longer term (18–36 months) | |
|--|--|--|---|---|
| | What | Who (lead/associate agencies) | What | Who (lead/associate agencies) |
| Natural capital | New/revised policy on Banks fisheries | MOE and Min. Finance in consultation with industry | Comprehensive fisheries management plan Monitoring of catch, CPUE and economic returns | MOE with stakeholder consultation and Min. Finance AFRC with enhanced economic analysis capability |
| SCENARIO 3: AQUACULTURE – INVESTMENT | | | | |
| Physical capital | Fish farm (including invertebrates) proposals and fast-tracked approval process. | Investors/MOE lead BOI engagement | Investment in farms as per individual private sector proposals Facilitation of SMEs through clustering, advisory and financial services Characterization of aquaculture sites | Investors, equity financiers, commercial banks (working capital) |
| Human capital | Mauritian technicians, fishery biologists, experts in fish processing and marketing, aquaculture engineering | MOE with university and industry | Specific to type of farm Dialogue with universities to design specific training | Universities responding to investors demand; AFRC/ MOI for specific trials/ studies |
| Natural capital | MSP initiation | MOE and/or PM Office | EIAs and monitoring of water quality, disease | Farm operators, Min. Env., MOE (AFRC) |
| SCENARIO 3: AQUACULTURE – POLICIES/INSTITUTIONS TO ENCOURAGE INVESTMENT | | | | |
| Physical capital | MSP with specific allocation of areas for aquaculture. Improved investment climate, tenure arrangements, access to shore sites, fiscal and other measures to mitigate risk | MOE and/or PM Office; Min. Finance with MOE | Farm investment Facilities and schemes for monitoring of disease, water quality and farm management practices | Investors, equity financiers, commercial banks (working capital) MOE |
| Human capital | Scholarship opportunities (domestic and overseas) | Universities with finance from Min. Education | Possible outgrower farmer schemes | MOE, SME agencies, development banks, MOE |
| Natural capital | Streamlined EIA process | MOE lead, BOI, Business Mauritius, and Min. Env. | Fast-track approvals process with effective EIA and EIA monitoring | MOE with Min. Env. and local authorities |
| SCENARIO 4: SEAFOOD HUB – INVESTMENT | | | | |
| Physical capital | Fishing vessels, some fish handling and cold storage | S. Hub industry (private sector) and MPA | Fishing vessels, some fish handling and cold storage; Infrastructure development including expanded vessel repair facilities (see Port chapter) | Industry investment projects MPA investment projects |

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Table 3.12. Summary Recommendations by Scenario (continued)

| | Shorter term (6–18 months) | | Longer term (18–36 months) | |
|--|---|---|---|--|
| | What | Who (lead/associate agencies) | What | Who (lead/associate agencies) |
| Human capital: Improve the productivity of the Seafood Hub | <ol style="list-style-type: none"> 1. Seafood Hub association dialogue to maximize use of quays and other facilities 2. Seafood Hub logistics unit in MPA to optimize vessel logistics to increase efficiency in day-to-day operations 3. Structured dialogue with foreign fleets on use of Port Louis 4. Improved FIMS | <ol style="list-style-type: none"> 1. MOE/MEXA/MPA, ships agents, banks, airlines customs, and others as necessary 2. In MEXA or MPA 3. MOE lead 4. MOE with PSMU and CA and AFRC | <ol style="list-style-type: none"> 1. Consolidate the Port State Measures data system (import, export, traceability and links to the Competent Authority records) 2. Structure a formal permanent dialogue with foreign tuna fleets to increase visits/landings, basing of vessels, improve logistics 3. Liberalize bycatch sales arrangements 4. Complement and inform priority infrastructure investments (e.g. new vessel repair facilities) 5. Align training and HR development with business needs | As short term |
| Natural capital | Compliance with IOTC requirements | MOE-Fisheries | Operationalize linkages with IOTC tuna data system (vessels, catches) and with national statistics | PSM unit and AFRC in particular |
| SCENARIO 4: SEAFOOD HUB – POLICIES/INSTITUTIONS TO ENCOURAGE INVESTMENT | | | | |
| Physical capital | Fiscal measures (continue/enhance) | M. Finance with MOE in dialogue with industry | As short term | |
| Human capital | Regional and other dialogues on EU tariffs | MOE, Min. Foreign Affairs., industry associations | <ol style="list-style-type: none"> 1. Conclude a regional agreement on regional economic cooperation on tuna and implement protocols on minimum terms and conditions of access, on MCS and on joint positions in the IOTC and other fora. 2. Work with region on fisheries tariff preference protection (EU market) | MOE with SWIOFC, IOC, IOTC PM Office and Min. Foreign Affairs on regional agreements Min. Commerce on trade issues |
| Natural capital | Implementation of regional tuna arrangements (MTC, MCS, FIPs) | MOE and industry | As short-term | MOE and IOTC |

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Table 3.12. Summary Recommendations by Scenario (continued)

| | | Shorter term (6–18 months) | | Longer term (18–36 months) | |
|--|---|---|--|---|---|
| | | What | Who (lead/associate agencies) | What | Who (lead/associate agencies) |
| CROSS-CUTTING ACTIONS – INVESTMENT | | | | | |
| Human capital | Ensure coherency between key actors through formal arrangements | PM, MOE | | Establish MoUs between key actors to jointly implement plans: e.g., MOE, Coast Guard, Min. Env., university, BOl, private sector associations MoUs to have with clear targets and specific commitments on funding, staffing, regulatory, enforcement and other relevant actions | MOE, PM Office Multiple actors |
| | Design an OE/fisheries business promotion facility | MOE/MF/Business Mauritius/banks | | <ol style="list-style-type: none"> 1. Review business performance and challenges, including performance of grant-financed fisheries (e.g. FAD fishery grants) 2. Identify financing and risk reduction modalities, delivery and impact monitoring, including fast-tracking of strategic/priority investments. 3. Provide specific assistance on selected investments, including to SMEs on technical and financial management of loans 4. Leverage resources potentially available through Africa Ocean Economy Platform, climate funds, impact investing and other sources. 5. Facilitate means to close skills gaps and replace foreign with Mauritian workers | MOE, MF, Business Mauritius, banks, business advisory services, training institutions |
| Natural capital | | | | Progressively improve natural capital accounting for oceans | Bureau of Statistics |
| CROSS-CUTTING ACTIONS – POLICIES/INSTITUTIONS | | | | | |
| Human capital | <ol style="list-style-type: none"> 1. Establish an OE monitoring and evaluation scheme | <ol style="list-style-type: none"> 1. MOE 2. Min. Finance/ Statistics | | <ol style="list-style-type: none"> 1. Produce regular “State of the OE” reports, based on a comprehensive knowledge and monitoring system (MOE) and formal stakeholder consultations (MOE/PM office). | MOE |

(continued on next page)

Table 3.12. Summary Recommendations by Scenario (continued)

| | Shorter term (6–18 months) | | Longer term (18–36 months) | |
|--------------------------|---|-------------------------------------|---|---|
| | What | Who (lead/associate agencies) | What | Who (lead/associate agencies) |
| Human capital (cont.) | 2. Establish an economic performance monitoring unit (or regular process) to track OE investments | | 3. Raise public awareness of the OE opportunities and threats at all levels, including through the school curriculum to fortify broad public consensus on development and management of the OE 4. Enable continuous assessment of OE economic performance to anticipate and respond to internal and external threats on a timely basis | |
| | Improve the effectiveness of the physical planning and investment processes | Inter-ministerial | Establish an “investment geographic information system” to enable effective synergies, prioritization, sequencing of investments, EIAs and assessment of cumulative environmental and spatial stresses in the coastal and marine areas | Inter-ministerial |
| | Continue and expand regional ‘blue economy’ initiatives | | Continue and expand regional initiatives on climate change | |
| | Establish a Mauritius OE knowledge excellence network (or alternative institutional forum) | MOE | 1. Consultations to determine the scope and nature of the network 2. Implementation plan complete with financing and regional and international knowledge and human resource development components | MOE IOC, other regional and international organizations (UNDOLOS, IOC, UNEP, IOTC) |
| Natural capital | Undertake a valuation of natural capital | MOE, Statistics | Link the assessment of the physical health of the natural assets (reefs, lagoons, fisheries, beaches) to an economic valuation; changes in the imputed values would be reflected in the “State of the OE” reports. | MOE, Statistics |

Note: AFRC = Albion Fisheries Research Centre; BOI = Board of Investment; CPUE = catch per unit of effort; FADs = fish-aggregating devices; FIMS = fisheries information management systems; FIPs = Fisheries Improvement Programmes; IOTC = Indian Ocean Tuna Commission; ITQ = individual transferable quota; MPA = Mauritius Port Authority; Min. Agric = Ministry of Agriculture; Min. Env. = Ministry of Environment; Min. Finance = Ministry of Finance; Min. Foreign Affairs = Ministry of Foreign Affairs; MPA = marine protected area; MSP = marine spatial plan; PM = Prime Minister; PSMU = Port State Measures Unit; SWIOFC = South West Indian Ocean Fisheries Commission; IOC = International Oceanographic Commission; WMA = Wastewater Management Authority.

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Information, Communications, and Technology in the Ocean Economy

Tim Kelly

Key Messages

- The information, communications, and technology (ICT) sector now contributes 5.6 percent of national GDP, just under 10 percent of which is related in some way to the ocean economy (OE).
- ICT could play a much bigger role in transforming the Mauritian economy, but for that to happen there needs to be a well-thought-out strategy of stepped-up investments and progressive policy reforms.
- A capital investment of an additional US\$150 million over a 10-year period could generate a benefit-cost ratio of 2.1 at the project level, with the ratio increasing to 3.6 when the full range of economywide effects is considered. Plus, an estimated 3,500 jobs would be created.
- A top priority is boosting investment in submarine cables while rethinking their geopolitical orientations—that is, whether the focus should be regional (the current case) or global in ambition.
- Mauritius also needs to invest more in its domestic backbone network (including domestic fiber-optic capacity and the building of an Internet Exchange Point) to ensure greater connectivity—and explore new areas like hosting floating and underwater data centers.
- However, new investments must be backed by policy reforms, led by the ICT regulatory agency, to improve the sector's competitiveness—ranging from privatizing the government's majority share in Mauritius Telecom to encouraging measures (like local loop unbundling) to deliver high-speed internet services at an affordable price.

Introduction

As Mauritius looks for ways to transition from being a middle-income to a high-income country, the information and communications technology (ICT) sector and the OE stand out as two of the best hopes for future economic growth:

In 2000, just before the arrival of the first submarine fiber-optic cable, Mauritius identified itself as a “cyber island” (International Telecommunication Union, 2004), and the ICT sector is now recognized as one of the pillars of the economy, after sugar, tourism, textiles, and financial services. In the 2016–17 budget speech, “moving towards a fully-fledged digital society” was recognized as one of the country’s 10 key strategies for a new era of development. ICT contributed some 5.6 percent of national GDP in 2014, and the sector accounts for around 15,000 jobs, or 4 to 5 percent of the total workforce (Statistics Mauritius 2016).

In its *Roadmap of the Ocean Economy* (Mauritius 2013), the government developed a plan to significantly increase the size of the OE, which in 2012 contributed about 10.8 percent of GDP. This contribution comes mainly from three sectors: coastal tourism and leisure, sea-port activities, and seafood-related activities. The *Roadmap* identified seven clusters as the focus for this expansion. Marine ICT contributes directly to the marine services cluster, and ICT contributes indirectly to all seven clusters.

Thus, the interface between ICT and OE activities is critical for Mauritius’ economic trajectory. The big question is exactly how, and by how much, this sector can better contribute to diversification and competitiveness. This chapter tackles that question by exploring how ICTs play a growing part in the marine economy and then setting out the scope for an economic analysis of the potential of ICTs in the OE. It finds that the ICT sector holds great potential for reinvigorating the Mauritian economy and facilitating sustainable development. But to make that happen, there will need to be stepped-up investment (in submarine cables and the domestic backbone network) and greater exploration of new areas (like hosting floating and underwater data centers), accompanied by policy reforms that encourage greater competition and address the needs of end users.

It should be borne in mind that this chapter does not discuss the ICT sector as a whole in Mauritius, only those aspects that are part of the OE. For example, although mobile communications are the biggest component of the ICT sector, they are only discussed here insofar as they are part of the OE (for instance, used by tourists on ocean liners).

Linkages Between ICT and the Ocean Economy

In what ways can the ICT sector be considered a part of the OE? Certainly, the *adoption of ICT in other OE activities* can boost competitiveness, whether through its adoption in industrial processes, such as GPS tracking of fishing boats, or in services, such as ocean monitoring, control and surveillance, “smart” port services, and ship registration. However, in terms of contribution to GDP per capita, this is tiny by comparison to the major drivers. Instead, ICT drives the OE in three main ways, all based on investing in infrastructure directly in the ICT sector and using Mauritius’ island location to generate revenue and future growth (Table 4.1).

The primary linkage is through the *global network of undersea cables*, which provide the “first mile” of the internet to a majority of the world’s population. Since the first undersea telegraph cables were laid in the mid-1800s, the global network has expanded to cover virtually every coastal nation, with constantly increasing capacity. Mauritius was an early beneficiary when the Cable and Wireless Trans Indian Ocean cable reached Mauritius Island (from Durban) and Rodrigues Island (from Zanzibar) in 1901. The first fiber-optic cable (SAFE) arrived in 2002, and a second landing came in 2009 (LION), although these cables are now limited by capacity and competitive constraints. Two further cables are planned, and Mauritius is open to further investment, but there is perhaps a need for greater ambition.

A second potentially important linkage comes from the use of *off-shore data centers*. Several companies already have data centers on oceangoing ships, such as the Google Barges,¹ and now Microsoft has gone a step further by experimenting in Project Natick² with an under-sea data center, working at a depth of 30 meters in trials. The logic is to reduce costs for space rental and cooling, both of which make up a significant part of the budget for a data center. Mauritius, with its abundance of cold, deep water close to shore, is an obvious candidate to host such floating and underwater datacenters.

Thirdly, *cellular mobile services*, which constitute the largest segment of the ICT sector worldwide, can be extended offshore to provide services to mariners, mainly leisure users but also coastal fisheries. Mauritius’s success in being one of the first countries in Africa to complete the digital switchover from analogue TV broadcasting has released a large swathe of valuable spectrum (below 1 GHz), much of which is

¹ https://en.wikipedia.org/wiki/Google_barges.

² <http://natick.research.microsoft.com/>.

Table 4.1. How ICT Contributes to, Links with, and Offers Advantages for the Ocean Economy

| ICT/OE activity | Relative significance and contribution | ICT links to the OE | Mauritius's comparative advantage |
|---|---|---|---|
| ICT adoption in OE services and processes: OE as a user of digital technologies | Small but growing downstream contribution: OE activities, especially tourism, are becoming increasingly information-intensive | There is a wide range of ICT activities used in the OE economy (Table 4.3), from online booking and payment of hotel stays to use of GPS navigation by mariners and Radio Frequency Identification (RFID)/barcode tracking of catches by fisheries. | Mauritius has been an early adopter of more advanced technology, including launch of 3G mobile services in 2007 and 4G services in 2012, well ahead of most other African countries. As a result, the technological sophistication of OE activities in Mauritius is ahead of the game in Africa. |
| Submarine fiber optic cables: Currently two cables, with at least two more planned | Very high contribution: Submarine cables provide virtually all Mauritius's internet connectivity (satellite used for backup only) | Submarine cables deliver high-speed internet connectivity via coastal landing stations located in the south (Baie Jacotet) and north (Terre Rouge) of the island. In 2016, Mauritius had an estimated 543,000 internet users, representing 42.5 percent of the population. | Mauritius sits midway between Africa and Asia, and is thus in a good position to provide a landing point and traffic hub. Mauritius's pleasant location means it often hosts meetings of cable consortia, and tax incentives play an important factor in cable consortia like SEACOM and Liquid Telecom having local offices. |
| Floating and undersea data centers: Project still at experimental stage | Potentially a modest contribution: an emerging business opportunity | The costs of energy (especially for cooling) and land rental play important roles in locating data centers. Data centers could usefully be located on offshore barges, or in undersea locations to take advantage of cold deep ocean water. Possible tie-in with the use of wave and wind power for energy. | Mauritius is surrounded by relatively cold water and is somewhat protected from cyclones and earthquakes. In addition, as a stable regime with sound policies on encryption, data protection, and cybersecurity, it could provide a hub for low-cost offshore data storage. |
| Offshore mobile cellular coverage: Extending range | Potentially a modest contribution: extension of existing business model | Mauritius already has a high cover of mobile subscribers, with 1.76 million subscribers at the start of 2016, or 140 percent penetration. Extending service offshore would be particularly useful for casual or leisure mariners, as well as for fisheries operating in coastal waters. This could also supplement existing maritime safety services. | Mauritius completed the digital switchover in mid-2015, and the analogue switch-off releases valuable spectrum, below 1 GHz, that could provide extensive offshore coverage from shore-based antennae. TV White Spaces spectrum could also be used. The lack of neighboring countries gives Mauritius more freedom in spectrum management than is afforded to most African nations. |

Source: World Bank.

earmarked for mobile cellular use. The future allocation of this spectrum, which is particularly useful for offshore services because of its long range and low attenuation, could generate significant income, especially if allocated using market mechanisms (such as auctions).

ICT Applications in the Ocean Economy

Although the ICT sector is relatively important to Mauritius in its own right, its major significance lies in its role in enabling innovative applications and productivity in the rest of the economy. In the context of this book, there are a number of different ways in which the major segments of the OE—principally tourism and leisure, port services, and seafood and fisheries—are becoming more intensive in their ICT use, which may be seen as a downstream use. This is particularly relevant for developing the OE’s dynamic computable general equilibrium (CGE) model.

These downstream ICT applications can be split into two types of innovation activities: (i) ICT adoption in industrial processes (such as GPS tracking of fishing boats and use of internet for hotel booking); and (ii) ICT adoption in services (such as ocean monitoring, control, and surveillance; “smart” port services; ship registration; and internet services in hotel rooms). As shown in Table 4.2, specific technologies may be involved—for example, digital services, analytics and big data,³ apps, content and mobility, cloud services, financial technology (fintech),⁴ and the so-called Internet of Things (IoT).⁵ This will require short-term investment (the construction period), but it should produce a medium- and longer-term impact, with these technologies gradually substituting for the traditional technologies, facilitating OE expansion, and increasing the overall productivity of the economic system. Over time, all of these activities are likely to become more information-intensive, thereby displacing labor (for example, self-steering boats, which are a logical extension of self-driving cars).

Submarine Cables Serving Mauritius

The 2016 *World Development Report*,⁶ demonstrates how digital technologies underlie the competitiveness of modern economies, with ICTs being significant not only as an important sector in their own right but also as an important factor in productivity growth in the rest of the economy. The analysis in the report shows the benefits of having a coastline for access to fiber-optic submarine cables. For Africa, the average price per megabit per second (Mbit/s) of bandwidth per month is more than US\$200 cheaper in coastal countries than in landlocked

³ <http://www.investmauritius.com/investment-opportunities/big-data-analytics.aspx>.

⁴ <http://www.investmauritius.com/investment-opportunities/financial-technology.aspx>.

⁵ [http://www.investmauritius.com/investment-opportunities/internet-of-things-\(iot\).aspx](http://www.investmauritius.com/investment-opportunities/internet-of-things-(iot).aspx).

⁶ <http://www.worldbank.org/en/publication/wdr2016>.

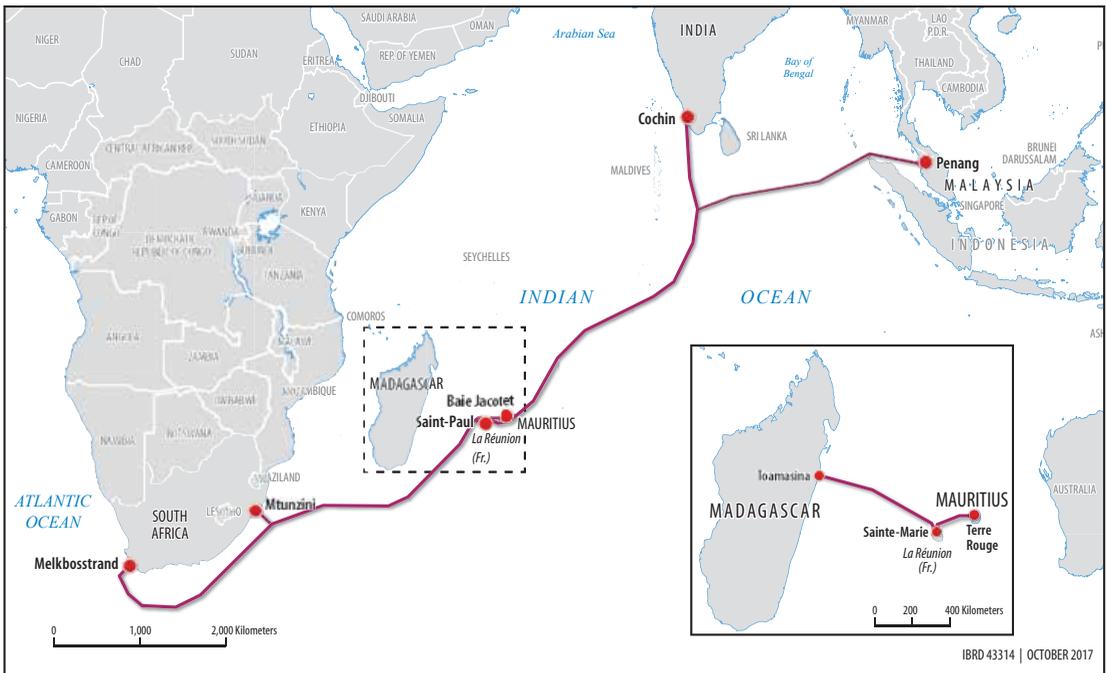
Table 4.2. Marine ICT Activities: Examples in Downstream Applications

| Activities | Possible Sectors/Services Involved |
|--|---|
| Information and communication | Telecommunications, banking, financial services and insurance, IT application development and maintenance support. Business process outsourcing, both nonvoice and voice |
| Off-shore wind, tidal, and wave energy | Telecommunications, banking, financial services and insurance, financial technology (FinTech), Internet of Things (IoT) |
| Offshore extraction of oil and gas in deep-sea and other extreme locations | Telecommunications, banking, financial services and insurance, FinTech, IoT |
| Sea-bed mining for metals and minerals | Digital Services, FinTech, IoT |
| Marine aquaculture | Banking, financial services and insurance, IT application development and maintenance support |
| Marine biotechnology | Analytics and big data, mobile applications, content and mobility, cloud services. |
| Ocean-related tourism and leisure activities | Banking, financial services and insurance, IT application development and maintenance support, business process outsourcing (both nonvoice and voice) |
| Ocean monitoring, control, and surveillance | Telecommunications, banking, financial services and insurance, IT application development and maintenance support, business process outsourcing (both nonvoice and voice), FinTech, analytics and big data, apps, content and mobility, cloud services |
| Port services | Telecommunications, banking, financial services and insurance, IT application development and maintenance support, business process outsourcing (both nonvoice and voice), FinTech, analytics and big data, apps, content and mobility, cloud services |
| Ship registration, monitoring, and control | Analytics and big data, apps, content and mobility, cloud services. Development of a full-fledged open ship registry should help with the ripple effect of ICT in the wider marine economy. |
| Development of marine apps | Mobile and internet applications aimed specifically at marine users. Mauritius could potentially host a thematic mobile application lab aimed at developing a center of excellence in the marine ICT field—as in Tanzania, which has a “flying labs” tech hub for drone apps. Marine apps could be developed for various type of usage, including navigation, shipping, early warnings, or ports. |
| Use of mobile communications on ocean cruise liners | Facilitated by extending mobile coverage to coastal areas, and enhancing coverage in ports. |
| Marine sensor networks | Using existing marine furniture (such as meteorological stations and buoys) to support a network of sensors that could be used, for instance, for early warning of the arrival of tsunamis. |
| Integrated Ocean Database | The MOI is proposing to establish an integrated ocean database to allow for detailed analysis to support decision making. The ocean database for Mauritius and the Indian Ocean region would manage a large amount of ocean data and would facilitate assessment of living and non-living resources in maritime areas. |
| Ocean Meteorology | The setting up of a Regional Ocean Modelling System should improve regional ocean climate forecasting, as well as general weather forecasting. |

Source: World Bank, drawing upon Mauritius (2013).

Note: Similar ICT services would also apply to tourism and leisure.

Map 4.1. Mauritius' Existing Submarine Cables

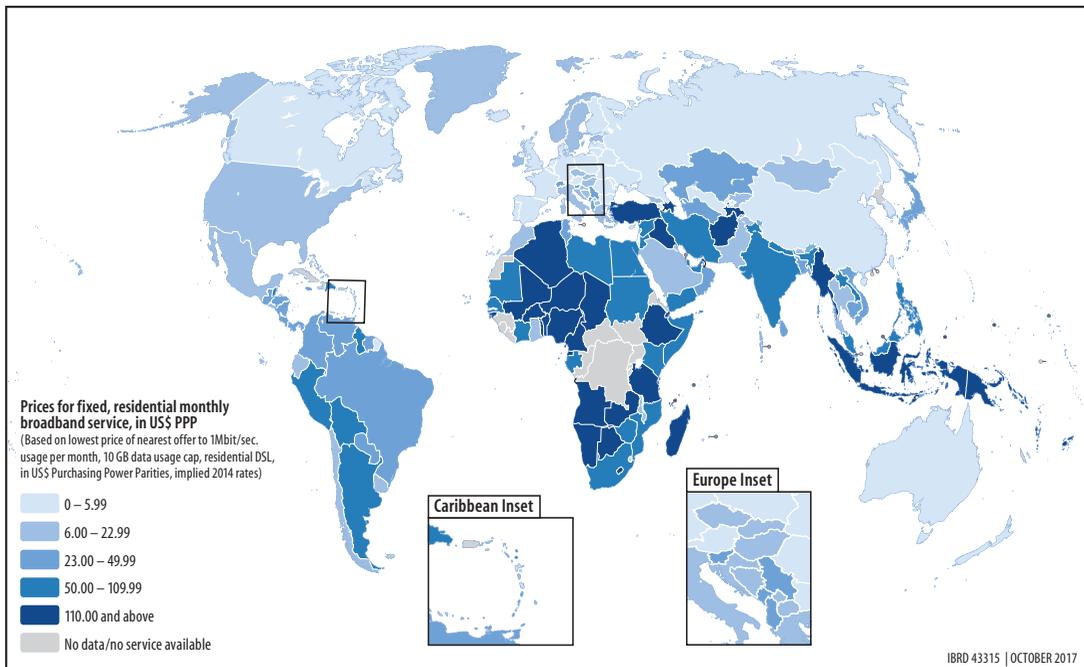


Source: TeleGeography.

countries. Mauritius is currently served by two undersea cables: the South Africa-Far East (or SAFE) cable and the Lower Indian Ocean Network (LION-1) cable (Map 4.1), and it hosts many meetings of international cable consortia, notably Seacom and Liquid Telecom. But the existing cables suffer from drawbacks and constraints, hampering Mauritius's ability to fulfill its true potential either as an international connectivity hub for the southern Indian Ocean or as an exporter of ICT-based services, such as in business process outsourcing (BPO).

SAFE cable. This was one of the first fiber-optic networks to serve Africa when it was launched in April 2002. It joins South Africa with the SAT-3 cable, of the same vintage, that links to West Africa and Europe. It is a "club cable"—that is, owned by a consortium of some 30 telecom operators, of which Mauritius Telecom, is one—but it is not an "open access" cable, in the sense that capacity can only be sold through its members, which restricts scope for price competition. Furthermore, it represents the technology of its day, carrying only two "lit" (that is, usable) fiber pairs with a maximum capacity of 440 Gbit/s. It cannot easily be upgraded, and it is approaching the end of its expected lifespan. By contrast, a modern cable, like AEC (in service since January

Map 4.2. Internet Service Cost: Prices for Residential Broadband Service, per Mbit/s per Month, mid-2015, in US\$ PPPs



Source: TeleGeography.

2016) has a capacity of 78,000 Gbit/s, or almost 180 times greater. It is believed that the available capacity on SAFE is close to exhaustion. SAFE makes landfall in Mauritius at Baie Jacotet and also has landings in South Africa (2), Reunion, South India, and Malaysia.

LION-1 cable. This is a more recent cable (in service since November 2009) with a much greater potential capacity, 1,280 Gbit/s, although as of mid-2016, only 20 Gbit/s (1.6 percent) was actually lit. It is effectively a proprietary owners cable, belonging to Orange (formerly France Telecom), though the ownership is formally divided with its subsidiaries, Telecom Mauritius and Orange Madagascar. LION-1 connects to the LION-2 cable, from a branching unit off the coast of Madagascar, and from there to Mayotte and Nairobi, where it links with four other cables. The LION-1 cable makes landfall in Terre Rouge, in the north of the island. Thus, the only connection between the SAFE and LION-1 cables is via Telecom Mauritius's domestic network, enabling this telecom to maintain its stranglehold over prices.

Furthermore, even though Emtel (Mauritius's second operator) has purchased capacity on LION-1, the terms of its license prevent it from

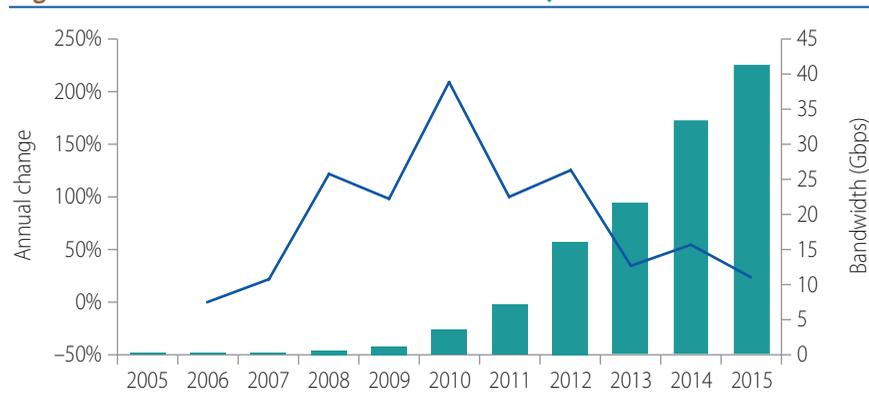
increasing that capacity. Thus, although EMTEL was interested in purchasing capacity on the World Bank-financed FLY/LION-3, which would have given it a direct link via Mayotte to the Eastern Africa Submarine Cable System (EASSy) in Moroni, it decided not to do so because it would have been unable to upgrade its capacity on LION-1 and LION-2. Thus LION-1 is not a true open-access cable and brings very little price competition to Mauritius.

As for internet bandwidth, Mauritius ranks third in Sub-Saharan Africa (after Ghana and Malawi) for having the lowest prices (Map 4.2). However, its US\$26.09 per Mbit/s monthly price is still much higher than international competitors for OE activities, especially when expressed in terms of purchasing power parities (US\$46.77). By contrast, economies such as Hong Kong (a shipping and port competitor) offer rates as low as US\$1.06 per Mbit/s per month and Bahamas (a tourism competitor) offer rates of US\$3.92—while even Vietnam (a fisheries and seafood competitor) is able to offer rates at around US\$26.06 per month, or just over half the price of Mauritius. Although wholesale prices have come down since the liberalization of open access to international landing stations in Mauritius in 2013 (Kelly, Minges and Donovan 2013), other constraints to competition are preventing further price reductions (notably, the monopolistic practices of Orange).

Mauritius' lit international bandwidth has grown at a reasonable rate, from around 7 Gbit/s in 2011 to more than 40 Gbit/s in 2015 (Figure 4.1). But the rate of growth is slowing, from a peak of over 200 percent in 2010 to around 25 percent in 2015. Of course, a reduction in the rate of growth is to be expected as the base grows in scale, but the precipitous slowdown in the rate of price reductions in the case of Mauritius suggests that capacity is constrained.

One way to “test” the hypothesis of constrained growth is through benchmarking with other countries, especially those that may be considered direct competitors, in the region and in the BPO market. Table 4.3 shows how Mauritius compares with Kenya, India, and South Africa. At first view, the picture looks bright for Mauritius, as its 41 Gbit/s of lit international bandwidth gives it the highest level of bandwidth per capita in the list—three times higher than South Africa, six times higher than Kenya, and more than 10 times higher than India. However, its average speeds (as measured by user experience) are *lower* than in Kenya or South Africa, and only barely higher than in India.

By dividing each country's average speed by its bandwidth per person (and dividing by 1,000) it is possible to get an aggregate measure of competitive efficiency, or the country's ability to convert additional international bandwidth into higher user speeds and therefore improved user experience. This exercise shows that Mauritius' competitive efficiency

Figure 4.1. Usable International Bandwidth, 2005–15

Source: TeleGeography.

index, at just 0.17, is the lowest in the country group. What then is going on? There are a number of possible explanations, but the most likely one is that consumers in Mauritius are choosing broadband packages with lower speeds than in the other countries, either because the prices are too high or because higher speeds are simply not available.

The liberalization of the market for international bandwidth in 2013 has proved beneficial for the Mauritius market in terms of price competition. It allowed owners of spare capacity on the SAFE cable, notably Belgacom, to market bandwidth to those mobile operators and internet service providers (ISPs) in Mauritius that are not aligned with Orange. Plus, the price of a gigabit (Gb) per month of mobile data, which was US\$20.82 in October 2011, had dropped to US\$9.97 by mid-2015 (or US\$17.88 in purchasing power parity terms). But the liberalization had no effect on the LION cable, since that is monopolized by Orange, and the beneficial effects were somewhat mitigated by the lack of scope for expansion on SAFE, along with its high initial construction costs.

Table 4.3. Internet Bandwidth, Average Speed, and Competitive Efficiency in Mauritius and Selected Comparator Countries

| Country | Population | Int'l Bandwidth (Gbit/s) | Bandwidth per population (kbit/s) | Average speed (Mbit/s) | "Competitive Efficiency" index |
|--------------|---------------|--------------------------|-----------------------------------|------------------------|--------------------------------|
| Mauritius | 1,249,151 | 41.3 | 33.08 | 5.6 | 0.17 |
| Kenya | 45,545,980 | 228.3 | 5.01 | 7.3 | 1.46 |
| India | 1,267,401,849 | 3,014.3 | 2.38 | 3.5 | 1.47 |
| South Africa | 53,139,528 | 512.5 | 9.65 | 6.5 | 0.67 |

Source: World Bank analysis, based on data from TeleGeography, Akamai, and World Bank.

Offshore Data Storage

A second potentially significant area of overlap between the ICT sector and the OE comes with the development of Mauritius as a hub for offshore data storage. Its geographical position, midway between Asia and Africa, as well as its neutral status and favorable regime for data protection, means that it is in a good position to do this. Mauritius has already been successful in developing its BPO capabilities, facilitated by ICT (ICT/BPO) through investments in infrastructure, intelligence, and innovation. With some 700 ICT/BPO-based enterprises, the country appears to offer the promise of becoming one of the richest technology ecosystems in Africa that thrives on innovation and collaboration across sectors.⁷ The move into offering commercial offshore data storage is a logical extension of this.

Of particular interest is the emergence of deep ocean water applications (DOWAs) that have particular relevance for data storage. The first of these proposes the use of floating data centers, which both generate renewable electricity (from wave and wind power) and provide cooling by drawing on deep ocean water. Google has applied for a patent for this technology and has reportedly experimented with tethered barges on the West Coast of the United States. The second goes one step

⁷ According to the Mauritius Board of Investment, global players such as Accenture, Ceridian, Huawei, Orange Business Services, and Infosys, amongst others, have established their operations in Mauritius. The sector has developed distinctive strengths in Telecoms, BFSI, IT application development, as well as maintenance support. Business opportunities exist in the following segments, among others: BPO voice—call centers; BPO nonvoice—back office; payroll, finance, and accounting outsourcing; legal process outsourcing; information technology outsourcing; software development; mobile apps development; web development; e-commerce; multimedia; IT services—data centers; disaster recovery (for data center resilience); training and consultancy for data centers; digital content for e-commerce and e-payment; digital content production; applications for e-learning and online training systems; animation; and mobile games.

further by putting the data underwater, where it is less vulnerable to intrusion and has easier access to cold water for cooling. Microsoft has successfully piloted the use of underwater data storage in a self-contained module that carried out data processing and storage functions at a depth of around 30 meters off the coast of Seattle.

For the ICT sector, the development of “green data centers” is something of a holy grail, to offset the industry’s “bad boy” image as a contributor to global warming rather than a solution. Already ICT contributes around 3 percent of global greenhouse gas emissions, due to electricity consumption, and this is projected to get worse as the world shifts toward ever more powerful broadband networks and always-on devices (Adolph and Kelly 2008). Data centers are a particularly egregious contributor to global warming. In the United States, they consume the energy output equivalent to 35 coal-burning power stations, with usage split more or less evenly between running the computers and cooling them down. As networks become faster and more reliable, the actual location of data becomes largely irrelevant, and already data center owners have been gravitating toward low-cost renewable energy locations (such as next to hydro-power plants) or in cool locations (such as Iceland).

Modern data centers require minimal, if any, human intervention, so the next logical step is to move them to the oceans. This has the added advantage that space rental can be effectively free. But the biggest advantage of all could be that putting data under the ocean takes it away from prying eyes, whether it be industrial espionage or more likely from government surveillance. In the same way that pirate radio stations in the 1960s, like Radio Caroline, took to the high seas to evade legal jurisdiction, some data owners may also prefer to take their data offshore to avoid possible future exposure to lawsuits. Examples include blockchain technologies, like bitcoin, which currently operate in a legal gray zone in many countries, or content delivery services, like *The Pirate’s Bay*, which may lead to allegations of intellectual property infringement. Beyond that, and for services that have hitherto been fully legal—such as the harvesting of personal data and purchasing habits from social media and eCommerce sites—there may be an incentive to seek out legal regimes that are more liberal on privacy and data protection. Thus, to misquote Jules Verne, “20,000 Terrabytes under the sea” is not such a far-fetched vision.

Offshore Cellular Radio

A third type of infrastructure investment that Mauritius should consider would be extending cellular services to cover coastal waters. Already, radio antennae that serve inland areas close to the coast overlap

with maritime zones, which is particularly useful for docks and ports. But until now, there has not been a deliberate attempt to extend coverage further, largely due to insufficient demand and a lack of alternative technologies (such as ship-to-shore HF radio, or satellite) for most commercial ships for their communication needs. But these technologies are expensive and do not necessarily provide the high capacity bandwidth to support data. Rather, they are optimized for safety-of-life and navigation services that use minimal bandwidth. However, modern oceangoing ships (like cruise liners) are increasingly data-intensive, and there is considerable scope for extending land-based technologies (like mobile phones and tablets) for use at sea.

With the release of digital dividends spectrum (below 1 GHz), there is scope for a concerted effort to provide coverage up to a range of about 50 miles from shore. This would encompass the needs of most leisure-based maritime users, as well as cruise liners and big game fishing boats. These are exactly the sort of users that Mauritius is trying to attract through its OE program, specifically the marine-based tourism and leisure cluster. Although there is no viable market yet for offshore internet and entertainment services, it behooves Mauritius to plan ahead if it wishes to grow this segment of the market. Furthermore, in addition to commercial use, offshore cellular mobile can be used to assure safety-of-life services to “amateur” marine tourists (such as sea kayakers, sea-karters, wind and kite surfers, and big game anglers). Licenses for big game anglers were projected to increase from 76 in 2013 to 120 in 2015.

The most likely users of offshore cellular mobile services are passengers on cruise liners. With the planned construction of a cruise liner terminal, and the medium term target of 50,000 passengers per year, the potential market for offshore cellular services could become highly profitable—especially given a likely increase in passengers from the Far East who might be reluctant to travel without guaranteed access to high speed internet.

Three Development Scenarios: Description

In line with the general approach adopted for other OE sectors in the book, we envision three possible scenarios—business as usual, conservative, and optimistic—for use in modelling the CGE model for Mauritius. The two key factors that distinguish these scenarios are:

- The degree of investment in first-mile technologies, particularly submarine cables, and the geopolitical orientation of the cables (regional or global); and

Table 4.4. Descriptive Analysis of ICT Developments Under Three Alternative Scenarios

| Scenario | 1. Submarine Cable capacity | 2. Offshore data storage | 3. Offshore cellular mobile | 4. Marine ICT applications |
|----------------------------|---|--|---|--|
| Business-as-usual scenario | Effectively no change (beyond incremental increase in capacity) in the current level of international bandwidth for Mauritius, which is provided by the SAFE and LION-1 cables. | No attempt to develop a local market for offshore data storage. | No attempt to extend cellular coverage for offshore usage. | Slow incremental increase in ICT use, with price reductions exceeding adoption so that ICT as a percentage of GDP falls below its current level of 5.6 percent. |
| Conservative scenario | Mauritius completes “third” undersea cable to Rodrigues, and regional MeTISS cable within five to ten years, generating a modest increase in capacity. Commitment to allow the Central Electricity Board (CEB) to enter domestic market fulfilled. | Some trials carried out for floating data centers but no serious commercial exploitation or sustained attempt to build a regional data center business. | Encouraging existing operators to extend mobile coverage and to offer roaming services for cruise liner passengers. | Coordinated attempt to increase the information intensity of marine activities, combined with increase in capacity, keeps ICT as percent of GDP at around current level. |
| Optimistic scenario | Mauritius initiates selection process for a “BRICS” style cable, with an accelerated procedure to galvanize funding. Policy reforms to back up the “full fledged digital” strategy include completing the sale of government assets in Mauritius Telecom and CEB telecom arm; unbundling the local loop; and enforcing open access on a backbone network. | Active policy for establishing Mauritius as a global leader in deep ocean water applications for “green” data storage. Backed up by policy reforms to ensure Mauritius’ data protection, cybersecurity, and privacy regulations are business friendly. Marketing campaign to sell cloud computing and data hosting services in African market. | Auctioning of spectrum for offshore use, to encourage innovative applications and new market entry. Early allocation process for 5G spectrum and use of TV white spaces spectrum. | Strong commitment to making Mauritius a global leader in marine ICT, backed up by policy measures to require full automation of processes in ports, shipping, and tourist businesses. Accelerated expansion of capacity, together with very low prices, spur demand so that ICT as percent GDP rises toward 10 percent (equivalent to Ireland or Estonia). |

Source: World Bank.

- The level of commitment to policy reform in areas such as privatization, open access, local loop unbundling, and spectrum policies.

Given that these strategies and policies will affect the economy as a whole (terrestrial and marine), the lead indicator being proposed to monitor this change is “ICT as a percentage of GDP.” The current government plans, as stated in the budget speech and reflected in the *conservative scenario* that follows, are likely to sustain this indicator at around its current level. ICT currently contributes around 5.6 percent of total GDP, of which up to 10 percent is directly related to the OE. But failure to implement these plans in a timely manner would see

Table 4.5. ICT Investment Assumptions Under Three Alternative Scenarios

| Optimistic scenario | | | | | |
|---|--|--|--|--|--|
| Investment typology 1 | Investment typology 2 | Investment typology 3 | Conservative scenario | Counterfactual scenario (business-as-usual) | Specifications and units of measure |
| <i>Submarine Fiber Optic Technology:</i> Based around laying fiber-optic cables on the sea bed between coastal landing stations and expanding current use of “club” cables to embrace open access cables. | <i>Mobile cellular technology in coastal waters:</i> Based around the extension of terrestrial mobile cellular service to coastal waters, with a range of several dozen km, to serve users in fishing, tourism, aquaculture, etc. Use of “digital dividends” spectrum (below 1 GHz). | <i>ICT enabling tools for OE users:</i> Based around technologies such as GPS (global positioning system) tracking and RFID (radio frequency identification) monitoring, safety of life services, navigation, etc. | Some limited expansion of submarine cables within region, with existing model (club cables). Use of spectrum only above 1 GHz. Limited commercial investment in additional ICT enabling tools. | Use of existing submarine fiber-optic cable only (laid between 2000 and 2010). No additional efforts to provide additional cellular coverage of coastal waters. No additional efforts to promote ICT enabling tools. | US\$ Impacts upon: 1. terrestrial users of bandwidth such as government, businesses, and consumers; and 2. OE users such as ships, aquafarms, and hotels. |

Source: World Bank.

the indicator fall, as under the *business-as-usual scenario*. On the other hand, under an *optimistic scenario*, a sustained commitment to invest in new cables, leveraging primarily private-sector funds with a modicum of public sector seed money, together with progressive policy reforms, could see the indicator rise, toward 10 percent—around the kind of levels enjoyed by Estonia and Ireland—and perhaps even as high as the 16 percent achieved by Israel. Tables 4.4 and 4.5 lay out a comparative analysis of the advantages and likely outcomes for major ICT developments under these three alternative scenarios, as well as the investment assumptions required under each.

Development Scenarios: A Computable General Equilibrium Analysis

Focusing on the optimistic scenario, as Table 4.7 shows, the key results of the computable general equilibrium (CGE) analysis indicate a much higher impact of the ICT investment in terms of economywide effects than for project-specific returns (a benefit/cost ratio of almost 3.6 instead of 2). This is due to several reasons:

- The ICT projects all include public good components in the form of infrastructure that can be shared by virtually all sectors and economic agents (e.g., the submarine cables);

Table 4.6. ICT Technology Under Three Alternative Scenarios

| Optimistic Scenario | | | | | |
|---|---|--|--------------------------------------|---|---|
| Technology 1: Submarine cables | Technology 2: Cellular technology in coastal waters | Technology 3: ICT enabling tools | Technologies in Alternative Scenario | Technologies in Counterfactual Scenario (business-as-usual) | Units and Other Specifications |
| Data compression; Frequency Division multiplexing | WiMAX, Dynamic spectrum allocation | GPS (Global Positioning System); RFID (Radio Frequency Identification) | Same as for Optimistic scenario | Same as for Optimistic scenario | US\$ Key factors include cost of data (per GB) and speed (in Mbit/s) |

Source: World Bank.

Table 4.7. Economy-wide Impacts of ICT Investment (Optimistic Scenario)

| | Economywide worth | | | | | Project-level worth | | | |
|--|-------------------------------------|--|------------------------------|--------------------------|-----------|---------------------------|------------------------------|----------------------------|-------------|
| | PV value added model (US\$ million) | Total investment cost and incremental O/M (US\$ million) | PV cost model (US\$ million) | NPV model (US\$ million) | B/C model | Job creation ^a | PV Va Project (US\$ million) | NPV Project (US\$ million) | B/C Project |
| Optimistic scenario | 939 | 302 | 259 | 637 | 3.62 | 3,478 | 479 | 91 | 1.84 |
| Low elasticity of supply of skilled labor ^b | 537 | 302 | 259 | 278 | 2.07 | 2,243 | | | |

Source: World Bank simulations.

Note: Results of the simulation are still preliminary, but they do show that the economywide impact of the investment becomes closer to the project-specific impact, if the model simulations are run under the hypothesis of skilled labor shortages—which can also be interpreted as equivalent to investment costs in human capital not explicitly considered in the ICT projects. (a) Job creation is defined as the number of labor income streams that would support a worker for 20 years. (b) The simulation of this scenario is based on the hypothesis that the elasticity of supply of workers with more than secondary and with tertiary education are, respectively, 1 percent and 0.1 percent in the short term, so that either an important increase in the education budget will have to be undertaken or a substantial amount of skilled labor will have to be imported (or both).

- The construction activities activate several other sectors through their linkages with the rest of the economy; and
- The telecommunications sector, the ultimate destination of the investment, has multiple important linkages with most service activities, especially financial services and tourism.

As for production multipliers, Table 4.8 shows that the increase in the present value of production (at 5 percent discount rate) in response to a unit increase in the present value of ICT investment is especially large for “other services”—that is, services (like telecommunication) that are unrelated to the OE. The very high multiplier of these services depends on the multiple connections of the activities in the construction period (construction services are included in the “other services”

Table 4.8. NPV Production Multipliers Under the “Business as Usual” Scenario, by Sector

| Sector | NPV Multiplier |
|------------------------|----------------|
| Primary | 0.25 |
| Food | 0.33 |
| Manufacturing | 0.61 |
| Ocean related services | 0.49 |
| Telecommunication | 0.60 |
| Other Services | 4.24 |
| Total | 6.52 |

Source: World Bank.

category) and on the telecommunications’ rich set of links with all services in the investment operational period.

Making It Happen

It has been seven years since the last cable investment in Mauritius, which is an eternity in the fast-moving ICT world, although two other cables have been in the planning stages for many years and recently were endorsed in the 2016–17 budget speech.

“Rodrigues” cable

This “third” cable, in which the African Development Bank and the European Investment Bank were at one time interested in investing,⁸ is now expected to cover its costs from the Universal service fund—largely funded from a tax on incoming international calls and revenue from international mobile roaming. A market-sounding call for expressions of interest was issued by the government in November 2015 for a “third international gateway” to link Mauritius Island with Rodrigues,⁹ a dependency of 40,000 people around 600 kilometers to the east of Mauritius Island. In the 2016–17 budget speech (para 146), it was announced that Mauritius Telecom will undertake the project. The government commitment will take the form of a guaranteed purchase of bandwidth by the Rodrigues Regional Assembly over a 10-year

⁸ See: <http://business.mega.mu/2013/05/07/internet-europe-wants-finance-cable-rodrigues/>.

⁹ See: [https://www.kuwait-fund.org/documents/11433/66693/Third+Submarine+Cable+-+Expression+of+Interest+\(EOI\).pdf/80325a22-66a1-4408-af73-6320fee28e8a](https://www.kuwait-fund.org/documents/11433/66693/Third+Submarine+Cable+-+Expression+of+Interest+(EOI).pdf/80325a22-66a1-4408-af73-6320fee28e8a).

indefeasible right of use. However, the fact that, in the same budget speech, the government announced an upgrade in satellite capacity from 200 to 500 Mbit/s by 2018 (para 286) suggests that it does not expect the cable to be completed soon.

Why the delay? One reason is that Mauritius Telecom apparently wants to extend the cable from Rodrigues to link with a branching unit on the SEACOM cable, off the coast of East Africa. This may make sense commercially, because it would provide Mauritius Telecom (and Rodrigues) with redundancy and an alternative international exit. But looking at a map, one sees that Rodrigues and the SEACOM cable are in completely different directions. Furthermore, the distance from Rodrigues to the SEACOM branching unit would more than double the length (and therefore the cost) of the cable. Mauritius Telecom says it is seeking other partners to cofinance the cable. This may be an attempt by the telecom to kill the Rodrigues cable project (by slowing it down or making it too expensive), or else the telecom may be using the guaranteed government subsidy plus Universal Service Funds to cross-subsidize a cable from the Mauritian mainland to SEACOM that it was planning to do anyway.

Regional MeTISS Cable

The MeTISS (Melting Pot Indianoceanic Submarine System) cable, which was proposed by the Indian Ocean Commission (IOC), is likely to stretch from Mauritius Island to Reunion and Madagascar, and then onwards to South Africa. So far, the consortium of companies that have signed up include Emtel, the second Mauritian mobile operator; Telma, the incumbent operator from Madagascar; Altice and Canal + Telecom (from Reunion); and ISPs Blueline (Madagascar) and Zeop (Reunion). The main issue is the absence of Mauritius Telecom and any other Orange partners. This seems to have been a deliberate policy on behalf of the consultant hired by IOC to avoid domination of the consortium by Orange. The IOC claims to have secured some funding from the EU and African Development Bank, and states that the cable will cost around 75 million euros and should be completed by 2018. However, details such as the shares among the different members, or where MeTISS will interface with other cables in the region (and where it would land in South Africa), are hazy.

A More Ambitious Cable Expansion Program

Both the Rodrigues and the MeTISS cable are limited in their ambition, and both might be described as “socially driven” and regional rather than “commercially driven” and global cables. Specifically, they propose to link relatively small populations together, none of which are major

sources of internet content. For construction, both are drawing upon subsidized sources of funding—in the case of Rodrigues, the Universal Service Fund, and in the case of MeTISS, the EU 11th European Development Funds (FED) program. But there is no guarantee of covering their operations and maintenance costs. In the event of multiple cable cuts, which are quite common in the region, it is uncertain that the owners would be willing to cover the cost of repairs. In the case of Rodrigues, the local population is unlikely to benefit unless there is a parallel investment in local terrestrial infrastructure.

A further reason for skepticism is that both projects have been on the books in one form or another for several years. An initial study for the Rodrigues cable was carried out in 2012, and a feasibility study was done in 2015, while the origins of IOC's plans for MeTISS lie in SEGAcOm, a proposal for a regional network that dates from 2009. Given that neither cable currently has either an identified cable constructor or a construction and maintenance agreement signed between operators, it is unlikely that either will proceed quickly. As a general rule of thumb, there are at least five cables on paper for each fiber-optic cable constructed. Furthermore, such "paper cables" damage the viability of cables with real funding behind them, such as the World Bank financed FLY-LION3, because they create a climate of uncertainty and doubt.

Nevertheless, the most serious problem with the two proposed cables is that they lack ambition. Neither cable is likely to have a significant impact on reducing prices or stimulating economic growth, and both are unlikely to significantly improve the level of quality of service. A more ambitious cable project would need to meet a number of criteria:

A new cable needs to look further east (to Asia), and north (to the Gulf and Europe), not solely within the Indian Ocean region. That is "where the data is"—in the sense of sources of content, both local generated (especially in India, where Bollywood films are very popular), and cached (from the United States). Asia is also where future growth, especially tourism, will come from, given its large population mass.

A new cable needs to break away from the control of a single proprietary player (Orange) or a club of network operators (SAFE) and instead be an open-access cable, from which any company can purchase capacity. In that sense, a cable funded by investors that do not have a direct stake in the market, or by content owners (such as Google or Facebook), would be ideal.

A new cable would need to be self-sustaining and not funded by one-time donor funds that cannot sustain the risks of future cable cuts. Again, this would favor an eastward-looking investment cable, based on a sound business plan, rather than a socially driven regional cable.

Since the liberalization of the landing station market in Mauritius, the country is officially open for business and would welcome the arrival of cable proposals, irrespective of their source. There are a number of potentially interesting cable plans that look westwards and northwards. Following are three of them.

Australia West Express (AWE) cable. This would link Perth in Western Australia with Djibouti, and from there onwards to Europe.¹⁰ AWE could elicit interest from the U.S. military and may land in Diego Garcia. Even if AWE does not land directly in Mauritius, if a branching unit could be added, then a spur from a future Rodrigues cable could be of commercial interest.

BRICS cable. This is a potentially more interesting cable that would link the BRICS nations (Brazil, Russia, India, China and South Africa), which are industrial powerhouses. The projected route would see it pass through (or at least very near) Mauritius, making it a logical replacement (or upgrade) for SAFE (Map 4.3). The initiative for the BRICS cable came after the Edward Snowden affair, when it was revealed that U.S. state intelligence was listening in to all traffic that passed through U.S. territory. Brazil, for instance, has initiated cable links directly to Europe and Africa to bypass the United States.¹¹ But even without this motivation, the BRICS cable makes a lot of commercial sense and fits well with the desire of the BRICS nations for closer economic and political integration. It is planned to be 34,000 kilometers in length, with 12 terrabits per second (Tbit/s) capacity (that is, 300 times greater than SAFE) and would interconnect with the SEACOM, EASSy, WACS, and SAFE cables, among others. It would make an ideal funding vehicle for entities like the newly established Asian Infrastructure Bank. Because of Mauritius' midway position and its neutral status among the BRICS economies, it would be in an ideal position to make this happen.

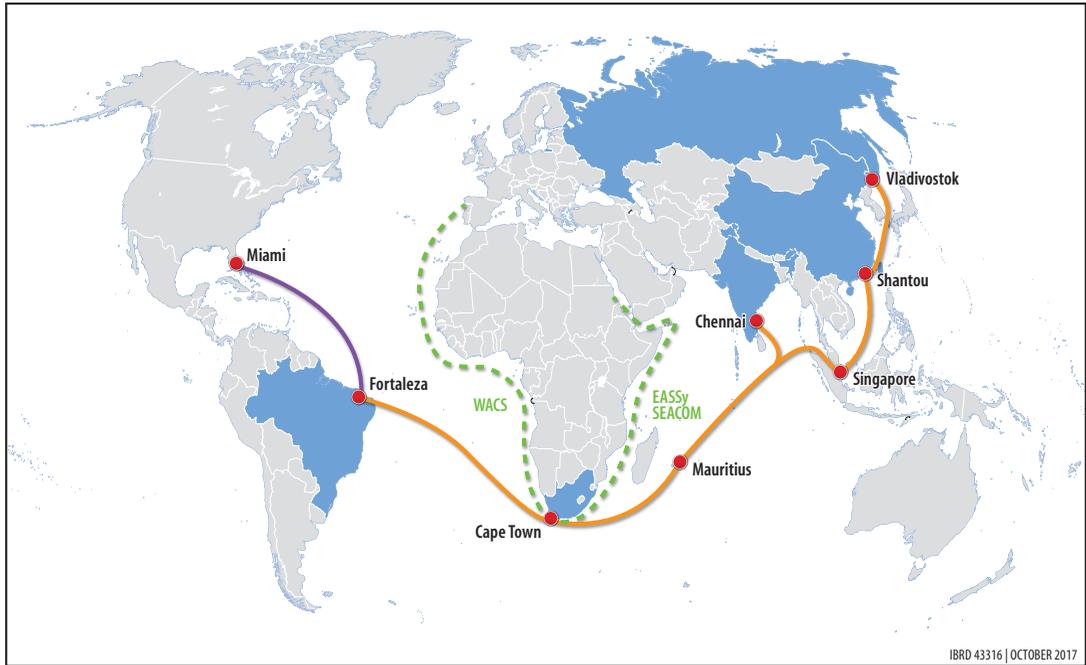
Mauritius IOC cable.¹² A Mauritius IOC cable has been proposed by a SEACOM spinoff, which suggests a new cable from Mauritius to India. What distinguishes this proposal is that it would be an open access "carriers' carrier" cable, not a "club" cable, in which owners are also users. This holds the prospect of lower prices and more competition.

¹⁰ See: <http://australiawestexpress.net/>.

¹¹ See: <https://jsis.washington.edu/news/reactions-u-s-cybersecurity-policy-bric-undersea-cable/>.

¹² See: <http://allafrica.com/stories/201701300423.html>.

Map 4.3. Route of Proposed BRICS Cable



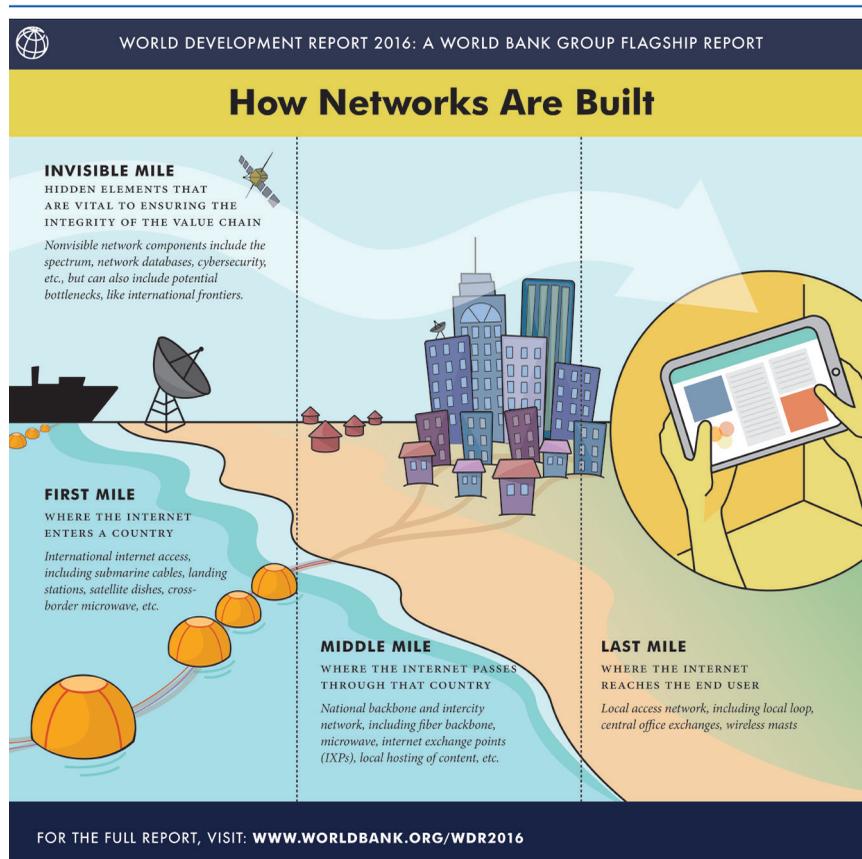
Source: TeleGeography.

Greater Domestic Connectivity

A significant increase in Mauritius's international submarine fiber-optic capacity is fully justified and fits well with the future plans for the OE. But it only makes sense if twinned with parallel investment in Mauritius's domestic backbone network, so that the advantages in terms of cheaper and faster international bandwidth actually reach the customer. To do this would require both fresh investment and policy reform. It is useful to consider the OE aspect of the investment as equivalent to the first mile in a chain for which policy reforms are required at each stage (Figure 4.2). While this book focuses on the first-mile investments in increased submarine capacity that are needed to achieve true digital dividends (World Bank 2016), it is also necessary for Mauritius to address policy reforms in the "middle mile," where the internet passes through the country, in the "last mile," which delivers the internet directly to end users, and in the "invisible mile," which addresses policy bottlenecks in the less visible parts of the network, such as the spectrum of cybersecurity.

As a general-purpose technology, ICT can enhance the productivity of many sectors, and especially some of those related to fostering and expanding the scope for OE innovation. But being a general-purpose

Figure 4.2. Visible and Invisible Segments of the Internet's Digital Network



Source: World Bank, adapted from World Development Report 2016.

technology also means ICT's diffusion through existing and new final and intermediate products may require costly infrastructural changes, such as laying new submarine cables. This is because new forms of productive capacity will have to be created in terms of physical, human, and social capital. At the middle-mile level, policy initiatives that would help in converting first mile investments into last-mile gains would include a series of investments, policy changes, and other actions, described next.

Increasing the Level of Investment in Domestic Fiber-Optic Capacity

Plans are afoot to increase investment in domestic fiber-optic capacity, as reflected in the budget speech commitment to accelerate the deployment of fiber-to-the-home technology to reach every town and village by December 2017 (Mauritius 2016, para 146 iii). Significantly, the budget speech makes a commitment that this should be done spe-

cifically by Mauritius Telecom, to the neglect of other market players, such as Bharat Telecom, Emtel, or the Central Electricity Board (CEB), suggesting a lack of neutrality in the government's position.

Encouraging the Usage of Alternative Infrastructure

The issue here is the proposed market entry of the CEB, a state-owned electricity generation and distribution entity. CEB already possesses a fiber-optic network running alongside its electricity distribution network, which it uses for its own network management purposes. The government has committed (again in the 2016–17 budget speech), to spending an additional MUR 200 million to extend the CEB network to ISPs (Mauritius 2016, para 146 iv). It should be relatively simple to sell spare capacity on this network to the commercial market, most likely to wholesale bandwidth providers competing against Mauritius Telecom (such as Emtel or Bharat Telecom), as well as to ISPs. This would make a second route available for interconnection between the cable landing stations for SAFE and the future Rodrigues cable (Baie Jacotet) and LION (Terre Rouge), currently monopolized by Mauritius Telecom. The technology to make use of the network for electricity generation, known as Optical Fibre Ground Wire, is now being used by some electricity distributors in Africa to enter the telecom market (such as Eskom in Malawi, in partnership with Huawei, an equipment manufacturer).

Enforcing Open Access Rules for Backbone Capacity

For the moment, when competing telecom infrastructure providers wish to make use of Mauritius Telecom's network, they must purchase it at the same retail price as any other customer. That means that to compete effectively with Mauritius Telecom, they are obliged to construct their own parallel infrastructures, which is both costly and time consuming. The government should consider enforcing open-access rules on Mauritius Telecom's network to allow competitors to purchase capacity (in the form of leased lines that can be connected at one or both ends, or IRUs) from Mauritius Telecom at retail rates. This will allow competitive infrastructure providers to make a rational build-or-buy decision. The same principles could be applied to the CEB network, given that both the CEB and Mauritius Telecom networks were constructed with a high degree of state involvement.

Empowering the Internet Exchange Point (IXP)

This would be an important step toward ensuring competition in the middle mile, and reducing costs, particularly for second-tier operators, as it would facilitate local peering and exchange of traffic. Mauritius has had an Internet exchange point (IXP) for a number of years, but there

is scope for formalizing the management structure of the IXP to ensure that no single operator becomes dominant.

Privatizing the Remaining Government Shareholding in Mauritius Telecom

There have been recent moves to reduce the government's shareholding from 60 percent to closer to 50 percent, while still retaining a controlling share. Retaining a significant government shareholding in Mauritius Telecom is both unnecessary and market-distorting. Emtel has complained, with some justification, that the government favors Mauritius Telecom in its award of contracts and in its regulatory decisions. The budget speech statements on FTTH and the Rodrigues cable, which specifically mention the Mauritius Telecom role, tend to confirm this. Even if the government is not ready to reduce its shareholding in Mauritius Telecom, it should announce its policy and perhaps a timetable for review to provide greater certainty to the private sector.

Investing in Data Storage

Mauritius is particularly well positioned to benefit from DOWA technologies, and DOWA is identified as one of seven clusters in the government's *Roadmap of the Ocean Economy*. The sea around Mauritius falls to a temperature of around 5 C at a depth of 1,000 meters, although it is not necessary to go so deep to derive benefits. Potential DOWA applications include aquaculture, thalassotherapy, and manufacture of pharmaceuticals, but it is the use of deep ocean water for cooling that is of most interest here. Mauritius has licensed two zones for DOWA applications, around Port-Louis where there is a pilot program for urban cooling, and around Mahebourg, close to the airport, where it is planned to develop cooling applications for data centers. Indeed, Mauritius has the capacity to become a market leader in this field.

Developing Marine Apps

Mauritius could potentially host a thematic mobile application lab aimed at developing a center of excellence in the marine ICT field. As a similar example, Tanzania has developed a "flying labs" tech hub for drone apps. Marine apps could be developed for various types of usage including navigation, shipping, early warnings, or ports.

Making It Last

The next step is to tackle the *last mile and the invisible mile*. For Mauritius, like most low- and middle-income countries, the primary network for reaching the customer is the mobile network. The country

is fortunate to have a competitive mobile sector, with market share divided between Mauritius Telecom (just over 50 percent), Emtel (around 35 percent), and MTML (which has risen recently to 15 percent). All three mobile carriers now offer 4G LTE services, as well as older 2G and 3G coverage. But there is scope for encouraging further last-mile competition, for instance by pursuing the following approaches.

Encouraging Market Entry by Mobile Virtual Network Operators

Mobile virtual network operators resell mobile capacity and add value by targeting specific services (such as mobile money) or market segments (such as maritime users). Encouraging them may require a more flexible approach to spectrum management, such as by allowing secondary spectrum trading and resale.

Facilitating the Use of Alternative Technologies

Recently, a raft of new technologies have become available that may be particularly appropriate for thinly populated rural areas or Mauritius's outer islands. These include WiMAX, broadband wireless access, line-of-sight technologies, nanosats (very small satellites in near-earth orbit), balloons (such as Google's Project Loon), and drones. Facebook, for instance, is experimenting with the use of solar-powered drones that can stay aloft for months at a time and provide wide area coverage of high-capacity internet service. ICTA, the Mauritius ICT regulatory agency, should take a proactive approach to licensing the use of alternative last-mile technologies.

Encouraging Local Loop Unbundling (LLU)

Ultimately, to deliver high speed internet services at an affordable price direct to end users may require a fixed line rather than a mobile network. The preferred approach to ensuring last-mile broadband connectivity in most of the world is through LLU. This obliges the incumbent to offer capacity to competitors at a wholesale price, by renting them the use of the copper that links the customer to the local exchange at a price which is below retail prices. As part of such deals, the incumbent operator must publish a reference interconnect offer, which is available to other licensed operators. LLU would bring greater price competition into the local-access market and is a long overdue policy step.

Addressing the Demand Side of the Local Access Market

The 2016–17 budget speech includes a number of measures to address the demand side of the local access market, including a commitment to create an additional 250 public WiFi hotspots to bring the total to 600 (Mauritius 2016, para 144) and to promote greater digital literacy (para 145)—for example, by distributing tablets to students in grades 1 and 2.

Finally, Mauritius must also remove bottlenecks in the invisible mile, which may be delaying the development of a more level competitive playing field.

Liberalizing Spectrum Management

Spectrum management could be liberalized through systematic use of market mechanisms (such as auctions) for spectrum assignment. The facilitation of spectrum trading and resale would help to promote innovative new uses of spectrum, especially in niche segments, such as marine ICT.

Allocating Digital Dividend Spectrum

An early engagement in allocation of the “digital dividend” spectrum, released through the analogue TV switchoff, would be welcome, as would an early start to the allocation process for the 5G mobile spectrum. This would provide more certainty for investors. It is expected that 5G spectrum would be particularly appropriate for IoT applications, which could include many technologies relevant to the OE, such as 15-sensor networks for environmental monitoring or telemetry networks for offshore meteorological networks.

Protecting Data and Users

There is a growing need for the development of regulations regarding data protection, cybersecurity, privacy, legal intercept, and the use of big data. These are particularly relevant if Mauritius wishes to position itself as a hub for offshore data storage. If Mauritius wants to position itself as a global leader in this area, it must first become a global leader in the enabling environment for cybersecurity, data protection, and the use of big data.

Recommendations

In terms of policy, recommendations focus on reforms to infrastructure policy and to data privacy, protection, and cybersecurity (Table 4.9). Mauritius should position itself as a best-practice country in terms of telecom policy, and this needs attention to issues such as alternative infrastructures, unbundling the local loop, and paying more attention to cybersecurity.

In terms of investment, the Government of Mauritius may need to play a more active role in shaping future undersea cable initiatives. Although the investment may come from the private sector, more ambitious programs are needed than those currently on the table. Similarly, for DOWA applications to data centers, the government can play a demonstration role, perhaps as an anchor tenant.

Finally, for capacity building, there is scope for creating a more focused kind of tech hub to explore the potential for marine ICT applications.

Table 4.9. Summary of main policy recommendations

| What | How | Who (lead agency) | When (short term: 6–18 months or medium term 18–36 months) |
|--|--|---|---|
| A. Policies | | | |
| A1. Infrastructure policy reforms | Encourage use of alternative infrastructures (such as CEB), unbundling the local loop, empowering the IXP, and enforcing open access rules. | ICTA | Short- to medium- term |
| A2. Reforms to data privacy, data protection, and cybersecurity guidelines | If Mauritius aspires to be a natural home for offshore decentralized data storage, it must become a best practice leader in policies for data privacy and protection and for cybersecurity. | ICTA | Short- to medium- term |
| B. Investment | | | |
| B1. A more ambitious program for construction of undersea fiber optic cables | Although Mauritius has plans for two regional cables, a more ambitious cable looking eastwards (to Asia) and north (to Europe and the Gulf) is required to generate future growth potential. Furthermore, it should ideally be an open access cable, not a “club” or consortium cable like the existing ones that serve the island. | Private sector should take the lead, with encouragement from ICTA and the Board of Investment. | Short-term planning for longer term investment and pay-off |
| B2. Develop pilot program for use of DOWA for data storage | Mauritius is particularly well positioned to benefit from DOWA technologies given cold sea temperatures offshore. The potential use of deep ocean water for cooling is of particular relevance for data storage where it can be used for cooling data centers, either submerged or floating. Mauritius has the capacity to become a market leader in this field. | Ministry of Ocean Economy, which has licensed a site close to the airport for DOWA pilot programs | Long-term |
| C. Capacity Building | | | |
| C1. Mauritius as a center of excellence for marine ICT applications | Develop a thematic tech hub, similar to the “flying labs” for drone technology in Dar es Salaam, that would position Mauritius as the global leader for the development of apps for marine ICT. | Ministry of Ocean Economy and Ministry of ICT | Medium- to long-term |

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Energy and the Ocean Economy

Mark Howells and Thomas Alfstad

Key Messages

- The potential for ocean-renewable energy technology (O-RET) deployment is increasingly improving as an option for Mauritius to generate more renewable and clean energy.
- Seizing that potential may reduce the country's dependence on fossil fuels (especially coal) and lower its greenhouse gas (GHG) emissions—with potential import reductions of 3 to 19 percent and GHG emissions reductions of 3 to 18 percent through O-RET deployment.
- Key potential exists for deep ocean water applications (DOWA)—notably, for air conditioning and cooling in Port Louis—underscoring the need for plans to be audited, and supporting policy (including pricing arrangements) to be investigated and put in place.
- Offshore wind energy shows potential provided there is appropriate concessional finance (such as carbon financing), which would likely only need to be modest, unlike wave energy, which would require higher levels of supporting finance. Mauritius could be a demonstration site for both, attracting external co-financing from developers and others.
- For large deployment of O-RET to happen, there will need to be a combination of clear longer-term vision, human capacity development, standards, comprehensive tariffs, and targeted opportunities to attract private investment and realize the sector's potential.

Introduction

Affordable access to essential services underpins development. Energy fuels almost all such services, with electricity supplying most of those needed for a modern economy. The “energy-system” harnesses resources and transforms them into energy carriers that are used in appliances and machinery to provide those services. This energy system may impact and interact with the economy, the environment (including other physical resource or commodity systems), and society, and the effects of this impact and interaction should be sustainably managed for current and future generations (Howells and Roehrl 2012).

As Mauritius looks for ways to encourage the use of renewable and clean energy to reduce the country’s dependence on fossil fuels and decrease greenhouse gas (GHG) emissions, ocean-renewable energy technology (O-RET) is being explored as a possible alternative. The country has a total area of close to 2 million square kilometers of Exclusive Economic Zone (EEZ) and is geographically well positioned to harness ocean energy, in the form of offshore wind, ocean wave, ocean current, ocean thermal, and ocean saline energy. Currently, the Mauritian energy sector is carbon-intensive and dominated by imported fuel. The power sector fuel input is split between 20 percent renewable bagasse, 26 percent oil, and 54 percent coal. Just over 5 percent of generation is from hydro, and small quantities of electricity are generated by wind and waste (CEB 2014; World Bank 2015). Although coal is imported, it is the lowest cost option for further expansion of the power system (OECD 2015). However, coal is GHG-intensive.

Other potential expansion of the system is split into conventional land-based and new ocean-based options. Recent national analysis indicates that the renewable options—which include bagasse, wind, solar, and hydro power, but not yet O-RET—might contribute as much as 35 percent by 2030 (Dhununjoy and Ramparsad 2015; Soonarane 2016). Wind and solar are expected to play an increasingly important role, but they are intermittent and will require that other power plants balance the system, that the grid be strengthened, and that market rules change. Globally, the use of offshore wind power is growing—with one recent study noting that in 2015 the European Union (EU) represented 14 percent of the world’s total wind power installations, up 4 percent from the previous year; by 2020, the EU’s present capacity is expected to grow threefold (Khoodaruth et al. 2017).

How much of a role can O-RET play in supplying energy in Mauritius? At this point, the newly launched Mauritius Renewable Energy Agency (MARENA) is actively coordinating and promoting investment to harness the potential of O-RET. The government is deploying measuring devices to assess wave potential (TET, n.d.), and it

is funding photovoltaic solar farm deployment, net-metering, and subsidies for photovoltaic under green energy schemes (Mauritius 2017).

This chapter explores the possibilities, beginning with a review of technology options, followed by quantitative modeling to determine the optimal investment strategy and production mix of various technologies and fuels needed to satisfy electricity demand, while simultaneously accounting for capacity shortfalls from the decommissioning of existing power plants. To ensure that the scenarios are internally consistent and that basic techno-economic constraints are obeyed, a medium- to long-term systems model is employed. The model is developed from a Climate-, Land-, Energy- and Water (CLEW) model of the island (UNDESA 2016) that was generated by the Open Source Energy Modelling System (OSeMOSYS) (Howells et al. 2011).

Our results show that currently DOWA holds the greatest economic potential, already being explored for air conditioning in Port Louis. Next offshore wind shows extensive potential with appropriate concessional finance (such as carbon financing), which would likely only need to be modest, thanks to rapid cost and performance improvement, unlike wave energy, which would require higher levels of supporting finance. Thus, it would make sense for Mauritius to position itself as an excellent location for pilot demonstration projects for offshore wind and wave technologies, which could later be scaled up, as these would attract external cofinancing from developers and others.

Snapshot of Technology Options

What are the new power plant options? Our development scenarios focus on fossil fuels and land- and ocean-based renewable energy.¹

Fossil Fuel Options

The three fossil fuel options for power generation in Mauritius are coal, oil, and liquified natural gas (LNG). Coal-fired generation takes

¹ Basic data used were taken from the most recent national planning documents, including the National Integrated Energy Plan (CEB 2014) and recent power sector analysis (World Bank 2015). Other data were taken from UNDESA (2016), and all technology cost and performance data were updated with recent International Energy Agency data (OECD 2015). Long-term oil and coal outlooks were taken from the World Bank commodity price outlooks (World Bank 2015). Wind and wave performance data were taken from Duke (2016). Figures for DOWA, due to this technology's nature, were taken from Mauritian developer estimates (Personal communication with SOTRAVIC CEO Emmanuel Andre, 2016).

the form of super-critical steam power plants. They are the cheapest option available to the island. Coal would be purchased at international prices. Oil-fired-generation, which provides low-capital-cost generating capacity, has relatively expensive running costs; its low-cost capacity can be useful when a generating reserve that is not expected to run at high load factors is required. LNG power generation, which is more expensive than coal though less expensive than oil, would require building a re-gasification terminal to import LNG to the island.

Land-based Renewable Energy Options

The land-based renewable energy options include wind, solar photovoltaic, and bagasse. Wind currently provides 9 megawatts (MW) and has untapped potential, although it is limited by technical potentials and acceptability constraints. Solar photovoltaic currently exists in both rooftop and solar-farm configurations on the island, including a recently completed 15 MW solar farm (CEB 2014).

Note that future bagasse based generation is limited (Welsch et al. 2014), due to the stagnation of sugarcane growing. Similarly, most potential hydro power sites have been exhausted, and thus their expansion is not considered.

O-RET Options

Deep ocean water applications (DOWA). This is cost-competitive, but the focus of the current application is limited to buildings with central chiller systems located close to deep water. A pilot in Port Louis is being considered that might reduce electricity demand by 2 to 4 percent. The process involves extracting deep cold ocean water and using it to chill water that in turn cools air in modified central air-chillers. Note however, that access to a cold seawater stream has multiple potential uses, such as for cooling surface ICT data-centers, improving the efficiency of industrial freezing, aquaculture (like abalone farming), thalasso, bottling, and others. These non-air-conditioning uses may increase the revenue and provide a space for new product development. It is assumed that with dynamic expansion, as much as 4 percent² of demand may be

² This is an expert judgment, based on an assessment that at least 15 percent of the island's commercial and industrial energy is used for cooling (AFD 2012) and assuming that as much as 30 percent might be captured by DOWA. The percentage cooling is likely to rise with increased air-conditioning and processing requirements. Clearly however, deeper analysis would need to be done concerning the potential spatial evolution of cooling demand. For example, if low-cost district cooling were available, it would likely attract activities with high cooling requirements.

reduced by taking advantage of DOWA. Options not included in this analysis but that may hold future potential include deep-water pumped storage (Economist 2016).

Offshore wind energy. At present, offshore wind energy production is not cost-competitive compared with producing electricity from coal or even land-based wind turbines, although the latter are restricted by limited siting space. But it could become competitive if costs were to drop or the mitigated emissions were to be subsidized through a carbon-credit market. One possible technology is fixed turbines, which are cheaper (per kW) than turbines based on floating platforms but require shallow water, such as exists in and around the lagoon. If this technology were adopted, careful marine spatial planning (MSP) would be required to trade off social, environmental, and economic deployment. (This will be important to ensure the overlap of environmentally, socially and techno-economically³ optimal sites.) The other possible technology is floating turbines, which can be situated further from land; their drawback is that they are expensive and their technology is still immature (Martin n.d.).

Wave energy. The potential for wave energy appears high, although it is not economic at present. However, it has several advantages. One is that the electricity that this technology provides is not as intermittent as wind energy.⁴ Another is that while the technology is immature, its costs are declining and they are subject to aggressive learning. Wave energy could become economical if paired with carbon-credit finance. Some companies are developing pilot sites internationally, and Mauritius may be an excellent site for a highly subsidized pilot (CWE 2016).

Other. Not analyzed in the model scenarios, but worth noting, are two other technologies. One of these is the role of LNG and oil for bun-

³ For example, Port Luis and (offshore) its surrounding are protected from the southeast trade winds by the Moka Mountain range and, according recent studies, wind turbine for power generation is not recommended in this part of the country.

⁴ The consistency of wave energy is a result of the ability of waves to travel long distances with little loss of energy. This means that many sites for wave farms will be receiving significant swell waves created by winds out to sea, even when there is little or no local wind. This extra persistence of swell waves gives wave energy a significant advantage over wind energy. Wave energy is also more forecastable than wind energy, allowing for easier integration into power grids. Typically, wave sizes can be accurately forecast three to five days in advance (McArthur and Brekken 2010).

kering⁵ and the associated *combined-cycle gas turbine* (CCGT) power plant. CCGT, which would initially use light oil, is more efficient than coal and has lower carbon emissions; but if oil prices rise, so will electricity prices, and once the LNG is introduced, this type of power plant will be run continuously, introducing inflexibility into the power system and possibly crowding-out other lower-carbon renewable energy investments.⁶ A second technology is the use of *algae-based biofuel*. This appears to hold potential, but recent estimates indicate important uncertainties associated with its economic potential (IRENA 2016a). A third technology is electricity generation from *ocean thermal energy conversion* (OTEC), a technology that is still in its infancy and expensive, and for which existing demonstration projects are small.⁷ Finally, a fourth technology is the *desalination of ocean water*: this is becoming increasingly important as a *use* of electricity that can be switched on and off to match the intermittency of intermittent renewable energy technology (RET), including O-RET, and demand for it is increasing.

Economics of Future Options

To understand the economics of future investment, it is helpful to begin with the cost picture for an average power plant, as shown in Table 5.1. In general, RET, including O-RET, is characterized by higher capital costs. However, since it relies on free renewable resources, its “fuel” costs are low, although running costs associated with maintenance are relatively high. The next step is to use these costs to calculate the levelized cost of electricity (LCOE) generation for O-RET and competing fossil

⁵ Note that LNG for power generation only and the use of CCGTs are modelled (see the section on “Fossil Fuel Options” considered); however, they are not modelled as part of, and together with, a large integrated LNG bunkering package and associated infrastructure. Further details on bunkering are addressed in Chapter 6, which covers ports.

⁶ This is not to say that gas-fired power plants cannot be operated flexibly to accommodate intermittent renewables. It is rather that the CCGT, as part of a larger package, is likely to be used as a “baseload anchor” customer consuming sizable and predictable flows of gas. This would translate to sufficient and sizable financing flows, which would likely be needed to make the bunkering package viable.

⁷ By 2016, the largest was a 0.1 MW plant in Honolulu, which was built at a reported cost of more than \$5 million, about 50 percent higher than the current cost of wave energy (Vyawahare 2015). At this point, leading organizations like the International Energy Agency (OECD 2015) do not yet include current or projected costs of OTEC power generation in their reference-cost-projection publications, but costs may fall quickly as deployment increases. China is building a 10 MW OTEC machine on Hainan island, and the associated scale and learning may lead to significant cost decreases (Power Technology n.d.). A watching brief should be kept on the technology and its potential in Mauritian waters.

Table 5.1. New Power Plant Aggregate Cost and Performance Data

| | Capital (USD/kW) | Installed capacity (MW) | O&M Fixed (USD/ kW) | Fuel cost 2015 (USD/GJ) | 2030 (USD/GJ) | Fuel type |
|-------------------|---------------------|-------------------------------|---------------------------|-------------------------------|------------------|--------------|
| Steam (coal) | 2,100 | 219 | 40 | 2.7 | 3.0 | coal |
| Steam (bagasse) | | | | | | bagasse |
| CCGT | 1,000 | | 93 | 6.6 | 9.5 | Gas |
| GT/IC | 500 | 365 | 40 | 8.2 ^a | 12.4 | oil |
| Hydro | 3000 | 58 | 20 | | | |
| Land-fill gas | 747 | 3 | 420 | | | |
| Solar | 2000 | 15 | 289 | | | |
| Wind, onshore | 2,500 | 9 | 409 | | | |
| Wind, offshore | 3,700 | 0 | 473 | | | |
| Wave | 7,000 | 0 | 473 | | | |
| DOWA ^b | 2,500 ^c | 0 | 360 | | | |

Source: Capital cost values are based on recent global averages taken from OECD (2015) supplemented with local estimates for DOWA (Personal communication with SOTRAVIC CEO Emmanuel Andre, 2016). Natural gas price forecasts are taken from World Bank (2016) commodity price forecasts. Oil and coal price forecasts are taken from UNDESA (2016).

Notes: (a) Assuming a mix of heavy and light fuel oil. (b) We represent DOWA cooling as a “virtual power plant” (Saboori, Mohammadi, and Taghe 2011)—not an uncommon method to compare measures that reduce energy demand with those that supply energy (if one unit of energy is displaced by DOWA cooling, it comes at a cost; by representing this as DOWA cooling supplying “virtual energy” at the same cost, it can be compared with a power plant that would otherwise supply that energy if DOWA cooling were absent). (c) Note that this is an equivalence value estimated with and by SOTRAVIC (Personal communication with SOTRAVIC CEO Emmanuel Andre, 2016). UNDESA and WBG coal price forecasts are comparable; for 2025, UNDESA (2016) assumes a landed coal price of \$75/ton, minus 25 percent landing costs, which gives a market price of \$60/ton, as per the World Bank (2016) forecast for the same year, while UNDESA oil price projections are lower. For 2025, UNDESA (2016) projects a crude price of \$63/bbl, while World Bank (2016) assumes \$82/bbl. CCGT = combined cycle gas turbine; GT/IC = gas turbine and internal combustion plants; MW = megawatts; USD/kW = US dollars/kilowatt; USD/GJ = US dollars/gigajoule.

fuel generations option, which will give us a sense of under what conditions investment in O-RET is competitive against other power plants.

LCOE data at current costs are indicated in Table 5.2.

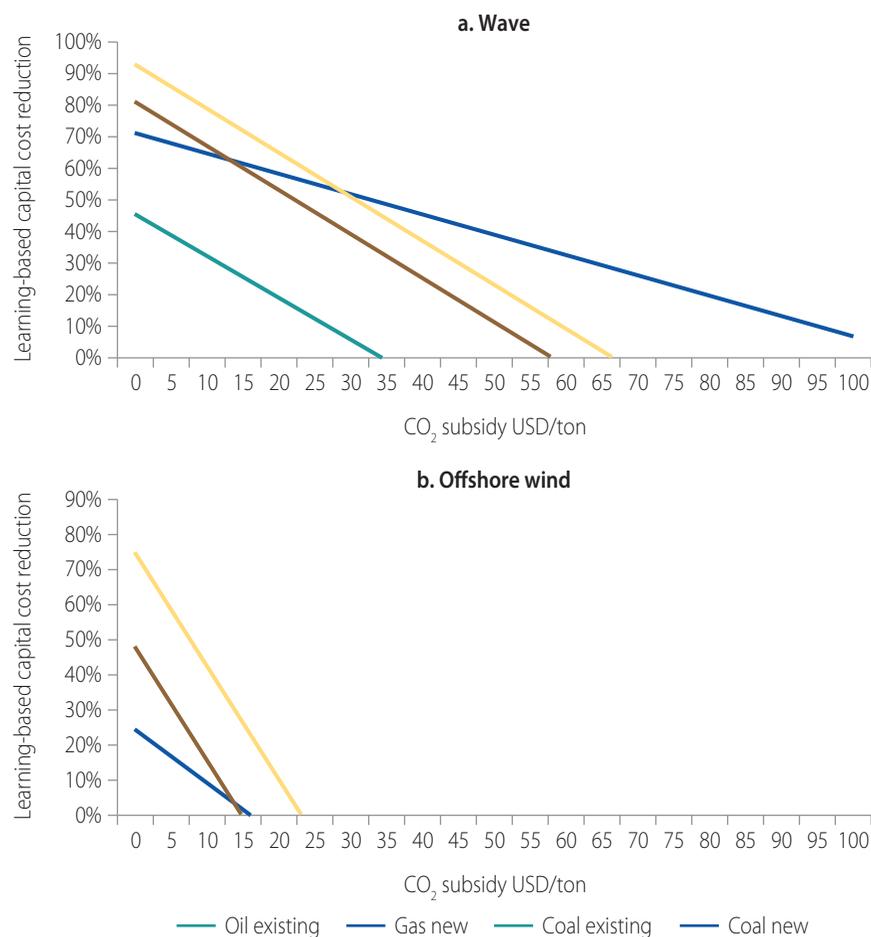
Table 5.2. Levelized Cost of Electricity (LCOE) Generation from New Power Plant Options

| LCOE | c/KWh | Load factor | LCOE | c/KWh | Load factor |
|-----------|-------|-------------|------------|-------|-------------|
| Oil new | 16 | 80% | Wave | 29 | 40% |
| Gas new | 8 | 80% | Ocean wind | 17 | 50% |
| Coal new | 7 | 80% | DOWA* | 7 | 90% |
| Land wind | 23 | 30% | | | |
| PV | 16 | 30% | | | |

Source: World Bank, based on the data from table 5.1

Note: LCOE is measured in c per kWh. It is the cost at which each kWh of electricity produced should be set in order to re-coupe the entire cost of the power plant investment. Load factor is the ratio of average to maximum production possible. Note that some renewable energy technologies (RET) often have lower load factors as the availability of their source (sun and wind) varies.

Figure 5.1. Change in Cost of Wave and Offshore-Wind Energy Capacity, Based on CO₂ Subsidy Isoquants



Source: World Bank calculations based on CEB (2014), Duke (2016), Howells et al (2011), IRENA (2016a, 2016b), OECD (2015), OffshoreWind.biz (n.d.), Vyawahare (2015), and World Bank (2016).

Note: Any point above or to the right of the red line indicates the technology learning or CO₂ subsidy needed to make the investment attractive if the alternative is running an existing oil fired power plant. Offshore wind competes with existing oil with no subsidy at current costs (thus there is no red line in panel b). Above or to the right of the black line indicates when the investment is preferred to running existing coal fired power plants. Thus, if the investment is above or to the right of the blue or black lines, the wave or offshore wind energy it will be cheaper than energy obtained by building and operating new gas (LNG)- or coal-fired power plants.

An excellent way to visualize these trade-offs is with an *isoquant*—a curve that shows the various combinations of different inputs that can be used to produce any given output. In this case, as shown in Figure 5.1, the two inputs are: (i) O-RET cost reductions, which come about as the performance of the technology improves; and (ii) a CO₂ subsidy for the emissions that the O-RET displaces. A number of lines are drawn to reflect the fact that the costs of O-RET and the amount of CO₂ displaced differ depending on the type of power plant (existing oil,

new gas, existing coal, or new coal). At any point on the line, the cost of generating electricity from the O-RET is the same as the cost for the power plant the line represents.⁸ We set the capital cost reduction and CO₂ subsidy such that the LCOE of the O-RET is equal to the LCOE of its alternative. In addition, capital costs are expected to decrease as the technologies are relatively immature. For example, from 2009 to 2014, with the increased use of global deployment technologies such as photovoltaic, capital costs fell more than 50 percent (IRENA 2016b).

In this isoquant, we assume that as new O-RET is deployed, it will either displace existing fossil-based generation or reduce investment in new fossil-based generation,⁹ as well as reducing emissions over its life. In a market with an emissions subsidy, the higher the subsidy the more competitive O-RET becomes. (Note that Mauritius currently receives carbon credits under the Clean Development Mechanism (CDM) for landfill gas renewable energy.) Similarly, competitiveness increases as the capital cost of O-RET falls due to learning. If the capital cost reduction or CO₂ subsidy is higher than any point on that line, the O-RET has a lower LCOE, indicating it may be competitive.

DOWA options (not shown in the figure) are cost-competitive against all existing and new options in the Mauritian power system. But offshore wind and (moreso) wave are not competitive compared to LNG or coal-fired generation without a combination of technology learning and CO₂ subsidy. If the technology costs were to be reduced by half, then compared with coal the CO₂ subsidies required would be US\$30/ton for wave energy and less than US\$15/ton for offshore wind.

Offshore wind is competitive, by contrast, with oil-fired generation, a finding that has important implications for the island of Rodrigues Island, which is smaller than the main island of Mauritius and is currently powered primarily by oil (Box 5.1) (CEB 2014). That said, much depends on the geology where the wind turbines are placed. If the water is shallow, they can be fixed to the sea-bed; if it is deep, they should be placed on floating platforms, which will not damage corals, although this can be significantly more expensive.

Development Scenarios

What would the impacts of potential O-RET penetration in the Mauritian system look like? To answer this, we developed simple scenarios. These include a baseline, existing sector development plans (EDP) and additional

⁸ The isoquant is a straight line because the inputs are perfect substitutes.

⁹ Note that in the subsequent OSeMOSYS modelling, the cost optimal penetration of O-RET displaces coal and small quantities of oil (see Figure 5.2).

Box 5.1. Rodrigues: Well-suited for O-RET Demonstration Projects

The Island of Rodrigues is in a special situation, as it depends on oil for generation (unlike the main island, which depends on coal, which is cheaper), with about 12.7 MW of capacity, of which 1.3MW is wind—and new capacity is required in 2018 (CEB 2014). Further, oil prices are volatile, resulting in relatively high prices of electricity. And the island itself, prized for its natural beauty, is developing, which puts a premium on not blighting its limited land surface. Yet land-based renewable energy technologies such as wind and solar require large areas to produce the equivalent electricity of one of the island's current power plants.

The two factors, volatile oil prices and limited land availability, suggest that O-RET may have an important role to place in its future power generation—especially for wind. And as Figure 5.1 shows, wave energy may even become economical with technology learning and carbon financing. Further, the costs involved in managing the existing internal combustion engines on the island—to handle O-RET intermittency—may not be significant.

Thus, Rodrigues might be very well suited to attract demonstration O-RET projects—a good reason to undertake a detailed integrated energy plan for the island, mirroring aspects of the larger island.

development options (ADO), using the cost-optimizing energy models, OSeMOSYS. Unlike the framing of this report as a whole, here we do not consider a “doubling” of the ocean energy economy (O₂), because O-RET is yet to be deployed. (Depending on the scenarios, it is not unlikely that as much as 5 to 15 percent of the capital costs might be public contributions in the form of an equity share of the investment. And given the large security and GHG mitigation gains, there is the potential that the O-RET might gain access to various concessionary finance streams.)

OSeMOSYS is a dynamic, bottom-up, multiyear energy-system model that applies linear optimization techniques. It determines the optimal investment strategy and production mix of technologies and fuels required to satisfy an exogenously defined electricity demand, on the one hand, and the capacity shortfall from the decommissioning of existing power plants, on the other. This is done while simultaneously satisfying constraints imposed by the analyst. In this application, constraints include minimum levels of O-RET penetration. Technical, economic, and environmental implications associated with the identified least-cost energy systems are extracted from the model results. Like other optimization models, OSeMOSYS assumes a perfect market with perfect competition and foresight (Taliotis et al. 2016).

Baseline Scenario

In the baseline scenario, no new (land- or ocean-based) RET investments are made. This provides insight into the cheapest development path for the island and the CO₂ emissions that might be displaced by alternative development paths. Note that we develop a “reference” scenario, which includes a high level of land-based renewable energy technologies: 8 percent wind, 17 percent bagasse, and 4 percent photovoltaic by 2025.

Existing Sector Development Plans (ESDP)

Building on the baseline and adding a reference level¹⁰ of land-based RET, limited generation is supplied by limited quantities of O-RET. These are consistent with pilot projects for which demonstration funds might be secured. Offshore wind is expected to generate 2 percent and wave 1 percent of national needs. Meanwhile, DOWA cost comparatively displaces 1 percent of electricity demand by 2025.

Additional Development Options (ADO)

Assuming that Mauritius takes advantage of various mechanisms and technological advances, and much higher levels of O-RET and DOWA are deployed between 2025 and 2030: by 2030, offshore wind then reaches 19 percent of generation and wave reaches 8 percent. Meanwhile, DOWA displaces higher demand (4 percent) by increasing the efficiency of commercial and industrial cooling demand.

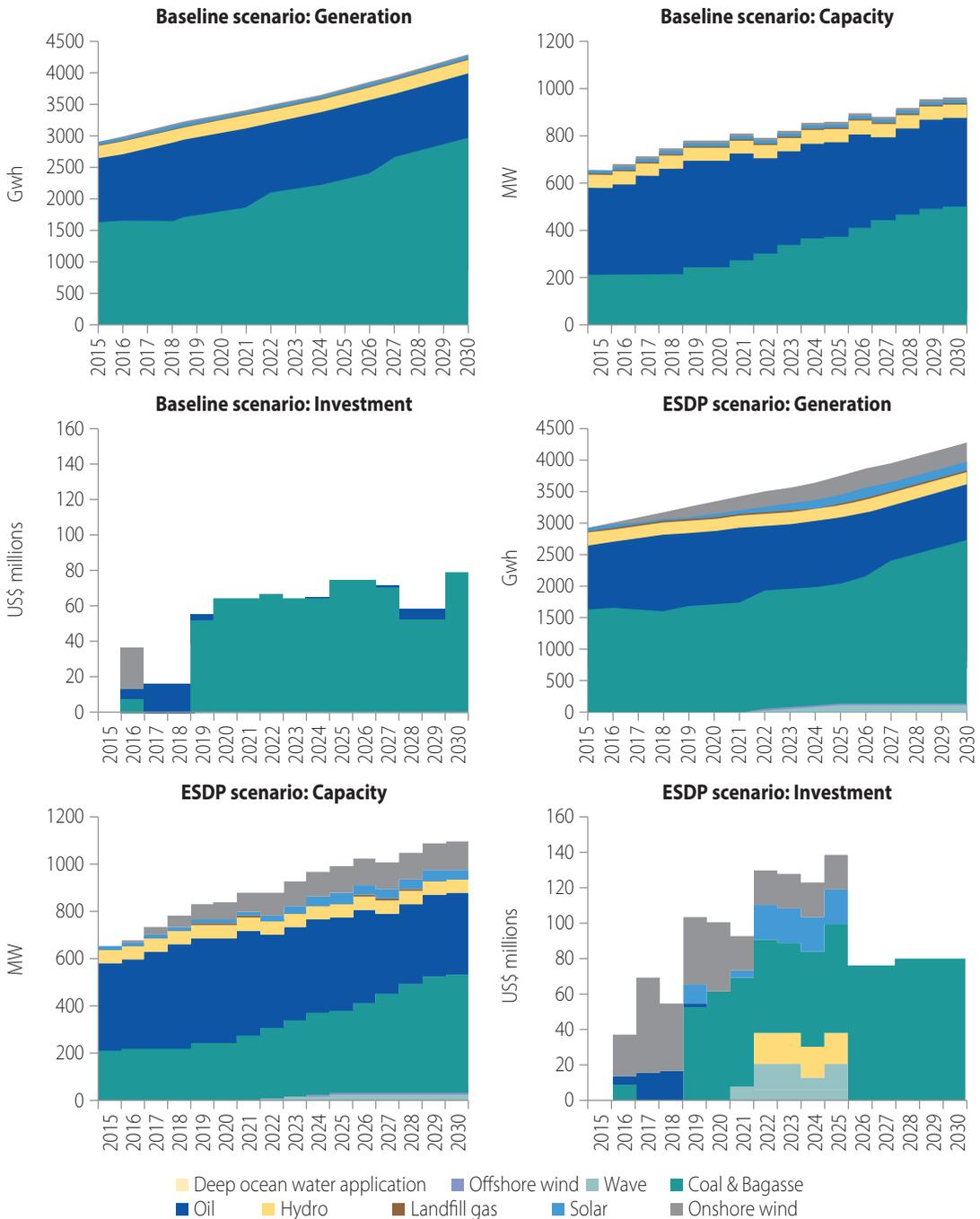
The results show that if we move from the baseline to the additional development option (ADO) scenarios, increasing quantities of RET enter the solution (Figure 5.2). Under the ESDP scenario, this would include 132 MW of land- and 35 MW of ocean-based RET by 2025 (the O-RET investment includes 9 MW-equivalent of DOWA, 16 MW of wind, and 10 MW of wave). In the ADO scenario, this increases to 13 MW-equivalent of DOWA, 58 MW of wind, and 10 MW of wave.

The net results are an increase in energy-sector investment of 14 percent for the ESDP scenario over the baseline, and a 66 percent for the more ambitious ADO scenario over the baseline. Note that the disproportionate increase in investment in the ADO scenario is due to the high investment cost of offshore wind and wave. The total cost of the system is reduced with the introduction of DOWA. Note also that in the case of DOWA, it is already competitive with its fossil fuel alternatives at the costs provided and assumed. Further, it is expected that wave and off-shore wind costs will drop over time. This implies that lower carbon-credit values would be required to make these investments viable, depending on the timing of that investment.¹¹

¹⁰ The latest available indications of existing RET sector development plans are taken from Dhununjoy and Ramparsad (2015) and Soonarane (2016). They contain no O-RET, but give clear land-based RET targets. These are used to define a “reference level” deployment of land-based RET.

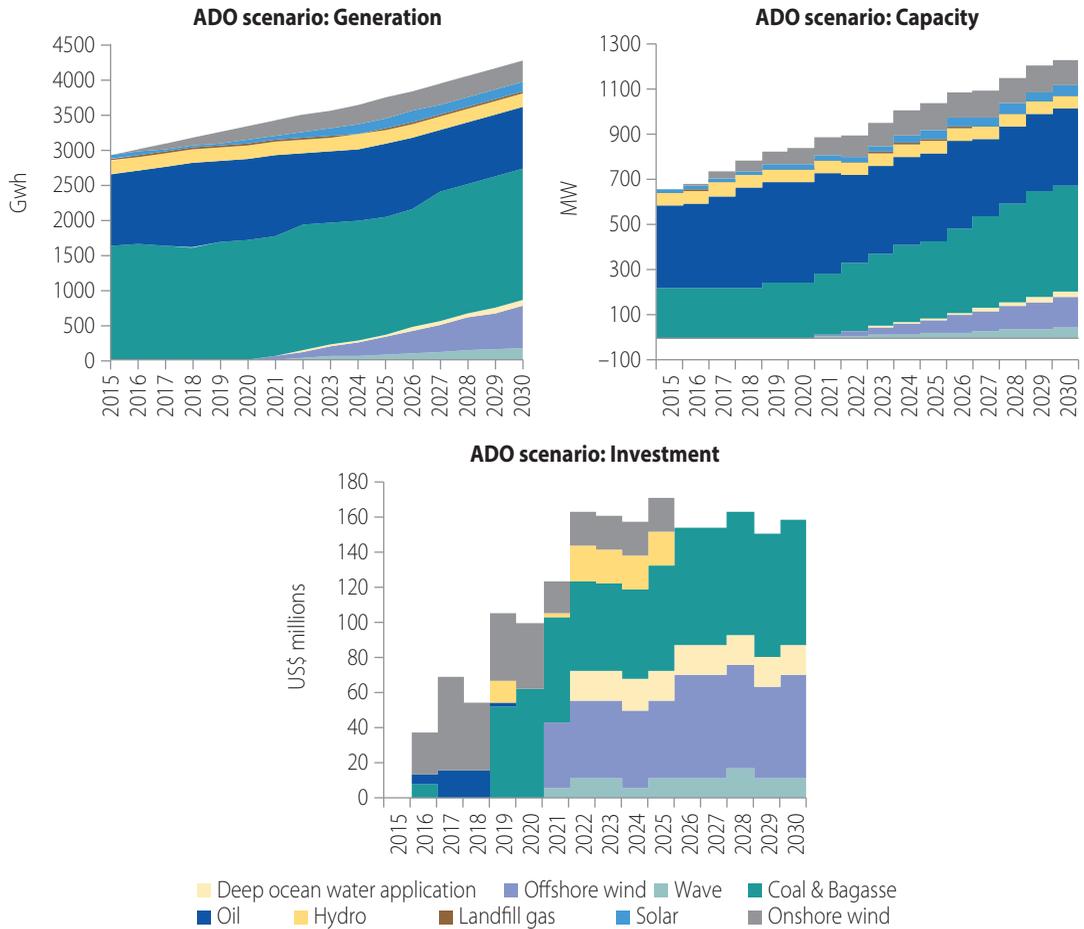
¹¹ It should be noted that this analysis takes a limited set of scenarios and constraints to investigate. Were a broader set of questions to be examined, such as how to improve environmental performance generally, there may be notable system changes. While they might not change the dynamic associated with the introduction of O-RET, they might change other investment. For example, the introduction

Figure 5.2. Projected Power Generation, Power Capacity, and Investment for Ocean-based Renewable Energy Technology Under Baseline and Two Development Scenarios, 2015–30



(continued on next page)

Figure 5.2. Projected Power Generation, Power Capacity, and Investment for Ocean-based Renewable Energy Technology Under Baseline and Two Development Scenarios, 2015–30 (continued)



Source: World Bank calculations based on AFD (2012), CEB (2014), Duke (2016), Howells et al (2011), IRENA (2016a, 2016b), Mauritius and IRENA (2015), OECD (2015), OffshoreWind.biz. (n.d.), Saboori, Mohammadi, and Taghe (2011), Vyawahare (2015), and World Bank (2015, 2016), as well as Personal communication with SOTRATIC CEO Emmanuel Andre, 2016.

Note: All blue entries at the bottom of the graphics are for ocean-based renewable energy technology O-RET. Green, brown, and yellow at the top of each figure indicate land-based renewable energy technologies. Black and red, indicate, respectively, coal and oil generation, capacity, and investments.

In terms of system dynamics, not only is there an increase in RET capacity, there is also an increase in the overall capacity of the ADO over the baseline of 20 percent. This is because variable RET generally has a lower load factor and requires capacity reserves to maintain a stable system. The wind is not always blowing, nor the sun always shining, so standby generation—or power storage—is needed. However, that

of natural gas could help increase system flexibility and simultaneously improve environmental performance were it to replace oil or coal. Environmental improvement would include lower sulphur dioxide, particulate, and GHG emissions.

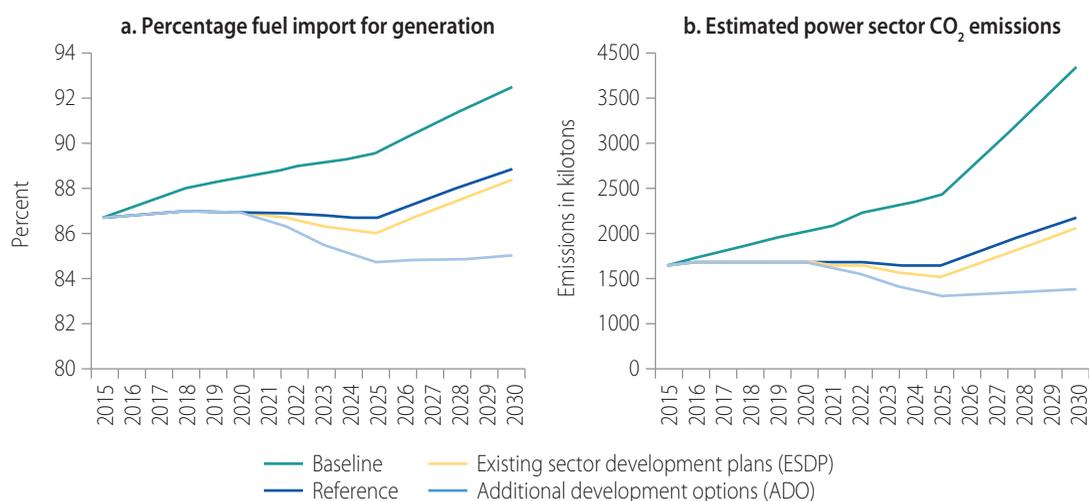
dynamic is marginally reduced when moving to ocean-based solutions, because offshore wind and wave have higher load factors than onshore wind or solar. For DOWA, fossil-fuel-comparable load-factors and contribution to the capacity reserve margin are thought to be feasible, because the supply of cold water is constant.

Implications for Cost, Revenue, Jobs, Imports, and Emissions

The results show that as O-RET penetration rises, there is an increase in cost, revenue, and jobs—a function of greater intensities associated with construction and maintenance. For revenues, this will be reflected in a higher tariff or in external concessionary (such as carbon) finance streams. That in turn means more carbon (or other concessionary) finance streams are essentially required to make sure the investments do not raise either the tariff or the tax. The actual revenue increase comes to a 20 percent internal rate of return on the 20 percent private share of the investment (Mauritius 2013).

How about import levels and CO₂ emissions? Reductions over the least-cost baseline are significant. In the ESDP and ADO scenarios, there are 32 percent and 51 percent less imports, respectively, in 2030, and there are 38 percent and 58 percent lower GHG emissions for the same year. O-RET accounts for 3 percent of the total reductions in imports and emissions under the ESDP scenario and 18–19 percent of these reductions under ADO. As Figure 5.3. shows, imports in

Figure 5.3. Projected Fuel Importation and CO₂ Emissions for the Power Sector, by Year, 2015–30



Source: World Bank calculations based on AFD (2012), CEB (2014), Duke (2016), Howells et al (2011), IRENA (2016), Mauritius and IRENA (2015), OECD (2015), OffshoreWind.biz. (n.d.), Saboori, Mohammadi, and Taghe (2011), Vyawahare (2015), and World Bank (2015, 2016), as well as personal communication with SOTRATIC CEO Emmanuel Andre, 2016.

and GHG levels from the power sector are significantly reduced with the increasing introduction of land-based RET, shown as the difference between the reference and the baseline scenarios. There is also a further reduction as small quantities of O-RET enter the solution in the ESDP scenario. Further land-based RET expansion is assumed to be limited by space constraints, while O-RET is not. Thus, large reductions in imports and emissions in the ADO scenario are due to extensive O-RET deployment. However, with the exception of DOWA, this is at a cost—although a commensurate carbon reduction credit (or other concessionary finance) may turn all these into economic options.

Economywide Impacts

The results of this analysis mirror and extend recent reporting by the International Renewable Energy Agency and the government of Mauritius (Mauritius 2015). Intermediate results were reviewed with stakeholders during several workshops with national experts during August 2016. Note that costs used are based on international values, calibrated with available updates for the Mauritian context. In the case of DOWA, these are taken directly from the developer. Thus, it is important to revise, review, and update these figures as the sector and available new information develop.

What are the economywide impacts and present worth of the energy sector? Both the ESDP and ADO scenarios posited for investment in ocean energy (wave, wind and DOWA) suggest large economywide effects from both renewable ocean energy and the deep water application for cooling. In both cases, the benefit-cost ratio (which can be interpreted as an investment present value (PV) multiplier) in terms of value added (PV) is above 2—and in the case of the more conservative ESDP scenario, it is close to 3 (Table 5.3). But while the more optimistic ADO scenario shows a lower benefit-cost ratio, it appears much more effective at job creation. Almost 10 times as many jobs are created under the

Table 5.3. Cost, Financing, and Economywide Worth of Two OE Scenarios (present values at 5% discount rate)

| Development scenario | Total investment cost (US\$ millions) | | Financing | | | Economywide measures of worth | | |
|----------------------|---------------------------------------|---------------|---------------|----------------|----------|---------------------------------|------|---------------------------|
| | Total cost | Present value | Public sector | Private sector | Combined | NPV value added (US\$ millions) | B/C | Jobs created ^a |
| ESDP | 152 | 127 | — | — | 152.0 | 239 | 2.88 | 476 |
| ADO | 619.5 | 463.9 | — | — | 619.5 | 666.2 | 2.44 | 5,472 |

Source: World Bank analysis.

Note: a. Each job created is defined as the production of a labor income stream that would support a worker for 20 years. BC stands for benefit-cost ratio. ESDP = existing sector development plans; ADO = additional development options.

Table 5.4. Production Multipliers for Two OE Scenarios (present value of production increase/present value of investment)

| | ESDP scenario | ADO scenario |
|----------|---------------|--------------|
| Primary | 0.254 | 0.113 |
| Industry | 1.574 | 0.678 |
| Services | 4.669 | 2.212 |
| Total | 6.243 | 3.003 |

Source: World Bank analysis.

ADO scenario as are created under the ESDP scenario, even though the former is only five times larger in its investment costs. This is due in part to the prevalence of the higher-labor-intensity sectors (wind and wave) and in part to the fact that the optimistic ADO scenario is more intensive in construction work. On the other hand, thanks to the higher proportion of machinery and construction as components of its capital costs, the conservative ESDP scenario appears to display much higher production multipliers (Table 5.4).

What are the policy implications? Given that introducing O-RET would reduce imports, GHG emissions, and meet RET targets, Mauritius should consider making O-RET a part of its sector development strategies. At present this is not the case. O-RET is absent from prominent national energy, RET, development, and GHG mitigation policy documents. Further, DOWA and related applications have the potential to employ Mauritians and spur innovation and related entrepreneurial activity.

Making It Happen

In recent years, Mauritius has been moving quickly to revitalize its energy sector in a way that emphasizes renewables (Box 5.2). Previously, the legal and institutional framework governing the energy sector was characterized by regulatory deficiencies—notably the fact that the Central Electricity Board (CEB), the dominant power supplier (accounting for close to 40 percent of electricity generation) and sole grid operator, also acted as the sector regulator (GCF 2016). In September 2016, an independent regulator, the Utility Regulatory Authority (URA), was operationalized. Also in 2016, the government launched the Mauritius Renewable Energy Agency (MARENA), which is charged with coordinating and promoting investment in renewables, in particular for independent renewable-energy power producers (GCF 2016). These steps are in keeping both with the framework of Mauritius' Long-Term Energy Strategy 2009–2025 and with growing

Box 5.2. A Snapshot of Government Efforts to Support Renewable Energy

A renewable energy agency

Under the Ministry of Energy (MOE), the Mauritius Renewable Energy Agency (MARENA) is synthesizing analyses to inform national renewable energy technologies targets, grid integration, and the role of the ocean. To assist integration, a document setting up norms and standards for the importation, installation, maintenance, and recycling of RET devices has been drafted.

Promotion of renewables

Recent efforts include funding photovoltaic farm deployment (such as a 15 MW facility in 2014), net-metering, and deploying subsidies for photovoltaic under green energy schemes (Mauritius 2017). Seed funding for wave-based mini-grid generation (including securing USD 0.6 million from Australia) has been attracted. Green Climate Fund support for the operationalization of MARENA and improving the readiness of the electricity grid to receive greater quantities of distributed renewable energy generation have also been secured (GCF, n.d.)

Bilateral wave energy collaboration

Collaboration with Australia on wave energy development is expected to yield an actionable wave sector development roadmap. For wind, a call for an expression of interest in a 10–20 MW offshore farm is being drafted. Given growth potential in wind, wave, and DOWA, an ocean technology incubator has been identified as a facility to be jointly developed with the Central Electricity Board (CEB).

A regional wave database

The Mauritius Oceanography Institute (MOI) has developed a referential wave database for the entire Indian Ocean Commission (IOC) region. It has collaboratively deployed wave observation buoys and undertaken extensive satellite-based assessments. Being situated in a location with limited coral barrier, it intends to demonstrate wave potential with a small, low-cost pilot plant during 2017. It has also been the recipient of requests for information on water temperature profiles by potential ocean thermal energy conversion (OTEC) project developers.

concerns over the projected increases in power that will be necessary in the near future (implying considerably more fossil fuel imports).

First: As Mauritius weighs how to make O-RET a reality, a key initial step is to develop clear techno-economic models of the sector's development.

Clear techno-economic models are essential for decision makers—especially in the Ministry of Energy and Public Utilities, MARENA, and other subsidiary bodies. From a technical perspective, these models enable analysts to compare different system configurations without incurring the up-front cost of actually building them, helping to mitigate uncertainty. From a practical perspective, they facilitate the design of systems in a way that accounts for local resources, demands, and constraints that are placed upon real-life electricity systems. This ensures that generation meets demand in the most cost-effective way and that

Box 5.3. Extending the OSeMOSYS Analysis in Mauritius

The OSeMOSYS model employed in this report could be extended to cover a wide array of initiatives and investment, going far beyond our indicative assessment of selected O-RET technology deployment scenarios. Such an analysis could include a thorough investigation of the entire island's energy supply and demand and its long-term evolution—taking into account large-scale centralized as well as decentralized bottom-up investment and development. It could also involve an extensive examination of issues like the role of distributed generation, electrification of transport, technology learning (including OTEC and storage), integration of intermittency, energy efficiency, and GHG mitigation potential.

This tool is especially important because it can account for the entirety of the energy system and its techno-economic development, thereby providing a way to develop consistent policy scenarios that would move through the domains of the energy sector, OE, environment, and economic development. It also is a good fit for the dynamic energy sector, which requires a highly adoptable and adaptable tool. Its availability would help Mauritius take advantage of changes in the sector, mitigate shocks, and rapidly assess the costs and benefits of concessional and cooperative opportunities. Such shocks might include technology changes, oil price hikes, carbon finance, and pilot project development.

public utilities and governmental institutions can structure tariffs to minimize consumer electricity bills. It also ensures that scenarios of future energy system developments are internally consistent. Such scenarios can serve as effective communication tools for nonpartisan political commitment—helping to garner and mobilize private-sector support and to solicit agreement and feedback from society at large. A key tool in this regard would be the OSeMOSYS model, which we have used in this report (Box 5.3).¹²

Second: The modelling process, from data collection to the investment scenarios that result, needs to be coordinated among sectors.

While we focus on the OE, the analysis is within the domain of the energy sector, and more specifically, the power sector. Further, the implications affect policy related to GHG emissions, balance of trade, industrial development, import security, and others. Each of these sectors has planning processes, yet they may not be coordinated. Thus an inter-sectoral process is required.

Third: During this process, the options assessed need to be mapped to the opportunities they present.

For example, DOWA provides significant and varied development prospects. Building a district cooling system and innovative uses of the

¹² Note that an international network of analysts, training material, and open data for OSeMOSYS is accessible via www.osemosys.org.

derived cold water stream offers integrated development opportunities that may involve: research and development (R&D), small and medium-size enterprise (SME) business development, and skills development. The selling of cold water will involve the establishment of a new energy services company and related business model, for which pricing mechanisms must be determined. GHG emissions will be reduced as fossil fuel fired electricity generation will be displaced. And, because cold water supply is not variable, not only will the electrical energy requirement be reduced, but so too will “capacity” requirements. For each of these there are a number of potential revenue streams—varying from domestic to international assistance (including carbon markets)—which will need to be coordinated to maximize the returns and potential of this effort.

Fourth: After the mapping and cost-benefit assessments, applications will need to be submitted for financial support.

One possibility is promoting a national development agenda. For example, feed-in tariffs for RET generation might be used to reduce fuel imports and improve energy security. Other support may be internationally sought. For example, for all the O-RET considered, there appears to be strong potential to apply for carbon finance and signal a national intention to do so. That would mean Mauritius urgently considering the inclusion of O-RET as a conditional contribution within broader NDC communications at COPs and within national Low Emissions Development strategies (LEDs) and Nationally Appropriate Mitigation Actions (NAMAs)—which is not currently happening. Specific applications for climate-related funds should be investigated, such as the Clean Development Mechanism (CDM),¹³ NAMA facility, and the Green Climate Fund. Further, given the vacuum of applications to date, early (well-informed) movers in the Paris agreement may make significant gains.

The reality is that without carbon (or other) finance, offshore wind and wave are not yet economical. However, the technologies are relatively immature, and several developers not only seek demonstration pilot sites but could also partially fund the demonstration projects. Mauritius and its ocean provide an attractive location in terms of resource and high skills levels, as well as being a potential “lighthouse” example for small-island developing states. As noted earlier, MARENA has taken early strides securing such seed funding.

¹³ Note that both large and small-scale CDM methodologies for the introduction of renewable electricity generation to displace fossil fuel exist. These might be easily extended to include off-shore wind and wave generation. However, methodologies are yet to be developed for DOWA.

Fifth: There is a need to revisit electricity market policy and structure.

As both ocean- and land-based variable renewable electricity generation increases, so too do stresses—and opportunities. These stresses, caused by fluctuations and inflexibility in power production, require so-called ancillary services, which quickly absorb (or curtail) power surges and provide reserves to fill shortfalls. Thus, appropriate levels of ancillary service¹⁴ supply present a technical as well as an economic challenge. But they also offer an opportunity, as surges provide large quantities of cheap power, which might be absorbed by a process (such as desalinating water) that does not require tight scheduling (Howells et al. 2013).

To meet these challenges, at a technical level long-term energy planning requires grid-stability assessments—and related work is planned to be funded (GCF 2016). Further insights gained will need to be transformed into appropriate market rules. Market structures need to be adapted to explicitly recognize and economically reward the role of ancillary service provision. It is advisable for Mauritius to develop partnerships with other islands that are undergoing similar transformations, such as Hawaii and Cyprus.

Sixth: Preliminary supporting policies need to be strengthened or put in place to facilitate the potential introduction of O-RET.

Preliminary supporting policies are needed, such as assessing ease of application and the rules defining financial risk mitigation in the sector. A special assessment of the role of RET feed-in (or other supporting) tariffs and their levels with respect to extending them to O-RET installations will be needed. Precedents are likely to provide useful insight, such as work done in Europe (OffshoreWind.biz. n. d.) or new offshore RET support schemes being developed in China (4c Offshore 2016). Supporting activities should include the extending of environmental impact assessments (EIAs), specifically incorporating MSP into O-RET development. For ocean cooling, standards will need to be developed, as will performance indicators and integrated development plans. For

¹⁴ Ancillary services can be defined as “those services required to ensure that the interconnected electric system is operated in a manner that provides a satisfactory level of service with acceptable levels of voltage and frequency.” For example, “Operating Reserves” (defined as primary, secondary, and tertiary) are used to maintain system reliability when there is an unexpected imbalance between supply and demand due to various system conditions or contingencies. Operating Reserves can be provided from unloaded capacity at a generation facility or from a curtailable load that can be dispatched on short notice to maintain system reliability. The reserves can be contracted and paid for (adapted from AESO n.d.).

example, new infrastructure will be built, and its construction through busy parts of Port Louis will require careful scheduling.

Seventh: There will need to be human capacity building in affected arms of the national government (and its parastatals), supported by appropriate higher education activities.

This could involve expanding energy systems and policy analysis at the national university. In particular, this becomes trans-disciplinary. For example, it affects all the STEM disciplines—science, technology, engineering, and mathematics. Energy planning involves applied mathematics and engineering, and developing new solutions requires the intersection of science and engineering. An example would be exploiting DOWA joint centers of excellence to incubate and facilitate innovation. Another example would be contracting delivery of specific training courses, either in-country or in the form of study trips, such as fellowships and scientific visits. Participating agencies could include the World Bank Group, United Nations, International Renewable Energy Agency, International Atomic Energy Agency, and the German Development Agency (GIZ).

The bottom line is that there will need to be a combination of clear, longer-term vision, human capacity development, standards, comprehensive tariffs, and targeted opportunities to attract private investment and realize the sector's potential. The development of a master plan informed, in parallel, by the preceding steps is needed at two levels: First at a national level and focusing on the energy sector directly with the Ministry of Energy and Public Utilities; and second, subsections of that master plan should be owned by the relevant bodies under the ministry. In the case of RET and O-RET, these might logically lie within the remit of MARENA.

In the short term, a pragmatic master plan might involve a limited set of pilot demonstration projects that could later be scaled up. Those chosen should show positive benefit-cost ratios, or strongly positive potential longer-term benefits. At this point, it appears that a DOWA air-conditioning and cooling application in Port Louis might be actively pursued. Offshore wind and wave pilots should be considered on a case-by-case basis, following negotiations with suppliers and a full assessment of the integration, supplementary revenues, and in-kind contributions associated with setting up demonstration projects.

The key to making O-RET last in Mauritius will be to ensure that lessons learned from the pilot projects are absorbed and translated into policy that facilitates sustainable and appropriate institutional support—along with the co-creation of an enabling environment. This means that the pilot demonstration plants should be designed with the

end in sight, on the one hand, and the understanding that the situation is dynamic, on the other.

With this in mind, monitoring and verification of the policy process efficacy is suggested. Thus, at the institutional level, monitoring and verification of the effectiveness of the following should be actively designed and reported: (i) integrated energy modelling; (ii) inter-sector coordination; (iii) electricity market rules; (iv) opportunity and incentive identification (such as for concessionary finance for GHG mitigation); (v) supplementary policies (such as standards, EIA, and MSP); (vi) human capacity development; and (vii) centers of excellence performance.

For the pilot studies, there will need to be monitoring and verification of the performance of the DOWA, wind, and wave applications—which should be undertaken in terms of technical energy, finance, economic, and environmental performance. The monitoring and verification would be required through the project life-cycle, from planning to de-commissioning. For example, for DOWA, it will be important to report associated indirect effects, such as reduction in electricity demand and emissions from systemwide power plants.

There will also need to be a situational analysis in the form of regular updates of modelling and policy assessment, especially for movement in key drivers. For example, fossil fuel prices, the level of carbon financing, and the cost of immature technologies will likely be subject to change, which will impact the economic performance of O-RET and its expansion.

As for adapting to a changing climate, DOWA cooling can play an important role. It is expected that heating demand, cooling demand, the level of rainfall, and other things that directly affect the energy system will change with the climate. DOWA cooling (and potentially schedulable pumping and water storage) will provide important resilience to the system in the face of climate change.

Recommendations

In summary, we offer the following recommendations, which are also summarized in Table 5.5.

Energy Planning

Energy planning needs to be developed to include the analytical ability to assess the various aspects of a transition to increased deployment of both ocean- and land-based and RET options, which is not currently being done. Strong local capacity exists within the CEB, but not elsewhere. This expertise (in the CEB, but also elsewhere) is crucial, as new deployment of RET will require existing power plants to change both their operating regimes and financial models. This effort needs to go

hand in hand with strengthening the power grid and reforming the market to ensure the sector's economic sustainability. The model developed for our scenarios may serve as a useful starting point.

Inter-sector Panel Coordination

This should be undertaken at two levels. The first, a higher-level coordination team, should focus on harmonization between cross-sector policy. The second, a planning group, should inform the activity of integrated energy planning and develop annual reports for key stakeholders.

Gap and Opportunity Analysis

This should be undertaken for external (and national) funds associated with developing O-RET—ranging from GHG mitigation and technology transfer to business development and demonstration funds.

Finance Applications

A general analysis of potential grants, concessional finance, and related support available from international finance institutions and funds should be made. Selected applications can immediately be developed for the CDM,¹⁵ NAMA facility, and Green Climate Fund. O-RET should be included as conditional NDCs—assuming appropriate GHG co-funding and technology learning levels are being achieved.

Ancillary Service Requirements

This involves grid stability and the future electricity market structure vis-a-vis stability and investment transparency, and may go hand-in-hand with targeted partnerships with islands in similar circumstances. This should inform broader energy planning activities. In particular, it would increase options available for system expansion, including the role of flexible gas, storage, and demand-side management.

Supporting Policies

These include EIAs and MSPs, which need to be extended to include O-RET projects.

Human Capacity Building

This effort should be undertaken at the government level, with appropriate curricula developed and implemented at the national university.

¹⁵ Note that this may be non-trivial. New methodologies for applications may need to be made. For example, no DOWA applications for CDM funds have yet been successful.

Table 5.5. Summary of Recommendations

| Shorter term (6–18 months) | | Longer term (18–36 months) | |
|---|---|---|---|
| What | Who (lead and associate agencies) | What | Who (lead and associate agencies) |
| Investment | | | |
| Development of DOWA demonstration project | MARENA, MoEPU, CEB, MoFED, EEMO, URA, MoESDDBM, BOI | Establishment of regional DOWA hub / center of excellence | MoEHR, MoBEC, UOM |
| | | Development of wind and wave demonstration projects | MARENA, MoEPU, MoFED |
| Continued development of the MOI small-scale wave converter | MOI with MARENA, MoEPU, CEB, MoFED, EEMO, URA, MoESDDBM | | |
| Human capacity building efforts in government and academia | MoEPU, CEB, MARENA, EEMO, URA, UoM, MoEHR, MoESDDBM | Development of national teaching curriculum for young professionals | MoEPU, CEB, MARENA, EEMO, URA, MoESDDBM MoEHR, UoM |
| Policies/ institutions to encourage investment | | | |
| Integrated energy planning process and inter-sector coordination panel | MoEPU, CEB, MARENA, EEMO, URA, MoFED, MoESDDBM, UoM | <i>(Continuation of LHS)</i> | MoEPU, CEB, MARENA, EEMO, URA, MoFED, MoESDDBM, UoM |
| Grid stability and ancillary service analysis | MoEPU, CEB, MARENA, URA. | <i>(Continuation of LHS)</i> | MoEPU, CEB, MARENA, URA. |
| Co-funding gap and opportunity analysis, including an assessment of concessional finance and IMIs | MARENA | <i>(Continuation of LHS)</i> | MARENA |
| Development of CDM, NAMA, GDF applications, and revised NC | MoESDDBM, MoEPU, MARENA, EEMO, URA, MoFED | <i>(Continuation of LHS)</i> | MoESDDBM, MoEPU, MARENA, EEMO, URA, MoFED |
| Audit of proposed Port Louis DOWA project | URA, MARENA, MoFED, EEMO | | |
| Audits of proposed O-RET wind and wave demonstration project, including MSP assessment | URA, MARENA, MoFED, MoESDDBM | | |
| Extension and implementation of EIA and MSP techniques to include O-RET expansion | MoESDDBM, MARENA | | |
| Targeted energy sector partnerships with related islands | | <i>(Continuation of LHS)</i> | |
| Development of detailed integrated energy plan for Rodrigues | MoEPU, CEB, MARENA, EEMO, URA, MoFED, MoESDDBM, UoM | | |

(continued on next page)

Table 5.5. Summary of Recommendations (continued)

| Shorter term (6–18 months) | | Longer term (18–36 months) | |
|---|-----------------------------------|---|-----------------------------------|
| What | Who (lead and associate agencies) | What | Who (lead and associate agencies) |
| Assessment of potential power market designs for high-penetration RET | | Development and implementation of redesigned market model | |
| Feasibility study of DOWA center of excellence, R&D, and innovation hub | MoEHR, MoBEC, UoM | | |
| Development of policy process and facility level M&V | MoEPU, MARENA, EEMO, URA | Assessment and revision of the M&V | MoEPU, MARENA, EEMO, URA |

Note: CDM = Clean Development Facility; CEB = Central Electricity Board; DOWA = deep water ocean applications; EEMO = Energy Efficiency Management Office; GDF = Global Development Facility; LHS = Left Hand Side; M&V = monitoring and verification; MARENA = Mauritius Renewable Energy Agency; MoBEC = Ministry of Business, Enterprise and Cooperatives; MoEHR = Ministry of Education & Human Resources; MoEPU = Ministry of Energy and Public Utilities; MoESDDBM = Ministry of Environment, Sustainable Development, Disaster and Beach Management; MoFED = Ministry of Finance and Economic Development; MSP = Marine Spatial Planning; NAMA = Nationally Appropriate Mitigation Actions; NC = National Communication; ; O-RET stands for ocean-based renewable energy technology; UoM = University of Mauritius; URA = Utility Regulatory Authority.

Potential Pilots

These demonstration projects should be rapidly audited and, where economical, carefully implemented, verified by monitored performance. These include the Port Luis DOWA scheme, the Mauritius Research Council (MRC) wave energy converter, and others that might pave the way for commercial-scale activities.

Monitoring and verification (M&V). These processes should be put in place to assess the effectiveness of related policy and processes associated with implementing O-RET to ensure an enabling environment.

Centers of excellence. These should be established for R&D, business development, and exploitation of the technology in the region—especially for DOWA.

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Ports and the Ocean Economy

Sheila Ferrell

Key Messages

- Mauritius Port Authority (MPA) has made a good start to implementing the policies set out in the 2016 Port Master Plan and has the potential for further expansion to serve third-party customers outside of Mauritius.
- Mauritius already acts as a container transshipment hub, but it needs to forge stronger and more permanent links with leading container-shipping lines and identify other types of cargo for which it could become an important trading intermediary, particularly petroleum products.
- With appropriate investments in logistics and the development of a new Special Economic Zone (SEZ), it could also act as a regional distribution center for the Western Indian Ocean, as well as meeting the needs of the domestic economy. There is also scope to provide more services to passing ships (such as bunkers, stores, repairs, inspections, crew changes, security, and search and rescue).
- There are several large projects under discussion at the moment—including a new breakwater and Island Container Terminal near Fort George, and a petroleum products complex at Albion—that could transform the role of the port and substantially increase its earnings from nondomestic trade. However, these projects need to be further evaluated before deciding to go ahead.
- Container and oil transshipment are internationally mobile and will be looking for attractive investment packages as well as suitable port facilities. There will be an increased need for proactive marketing of Mauritius as an investment destination, which in turn will require a strengthening of MPA's commercial functions and a higher level of inter-ministerial coordination than has been normal in the past. This will allow Mauritius to build on its existing reputation as a stable and attractive place in which to do business.

Introduction

Strategically located at the crossroads of Asian and African sea routes, Port Louis, the main seaport of Mauritius, handles 99 percent of the country's external trade and has become an important hub for the transshipment of containers moving between other countries. It accounts for around 2 percent of the country's gross output, 1.6 percent of GDP, and around 9,000 jobs.

The size of the sector is recorded in the National Accounts, where ports form the main component of the subsector, "Services Allied to Transport." This includes activities carried out by the Mauritius Ports Authority (MPA), the Cargo Handling Corporation Ltd (CHCL), port and airport services, and storage and warehousing. For the purposes of this exercise, the ports sector has been taken to include private terminal operators like Mauritius Coal Terminal and Lafarge Cement, the two local shipyards, and a wide range of port-related services such as freight forwarding, bunkering, and crew transfers.

Over the past two decades, major investments have transformed Port Louis into an efficient, modern seaport. The government is now planning to reposition it as a regional trade hub, with the focus on transshipment of petroleum products as well as containers, seafood processing, bunkering, and cruise activities. This is intended to bring in substantial additional income from outside of Mauritius, as well as serving the needs of an expanding domestic economy.

The key question for Mauritius is how it can increase the port sector's contribution to the OE in a sustainable and economically desirable manner. This chapter examines the port's current investment plans and uses CGE modeling to evaluate their impact on the Mauritius economy as a whole.

Our findings show that the projects currently under way should more than pay for themselves and will have an even larger positive impact on the economy once multiplier effects are taken into account. Some of the longer-term projects in the Port Master Plan—such as the Island Container Terminal, which includes a large breakwater, and an oil jetty development at Fort William or Albion—are more difficult to justify financially and will require substantial private sector investment to achieve positive public-sector returns. Nevertheless, these projects have a positive impact on the economy as a whole and are worth developing further.

Whether or not they go ahead will depend on the creation of a more favorable environment for private investment and the implementation of a series of measures to "make it happen." Because the longer-term investments are larger and more complex than those being undertaken

now, a more proactive approach to project development will be required, with more involvement of government bodies outside of the port, such as the Ministry of Finance and Economic Development (MoFED), Ministry of Ocean Economy, Marine Resources, Fisheries and Shipping (hereafter Ministry of Ocean Economy) and the Board of Investment.

A Profile of Mauritius' Ports

Responsibility for the provision of port infrastructure and services rests primarily with two state-owned organizations: MPA, which is the main body responsible for port planning, infrastructure investment, pilotage and towage, and port administration; and the CHCL, which is responsible for cargo handling, mainly of containers. Some private companies own or lease their own dedicated facilities within the port, and provide their own handling services for specific bulk cargoes such as wheat, petroleum products, cement, and fish.

In 2015, MPA and CHCL had revenues of US\$34.2 million (MUR 1,230 million) and \$59.6 million (MUR 2,144 million), respectively. Together they employed around 1,800 people and generated around 0.8 percent of GDP. Private companies providing port services account for a further 0.8 percent of GDP. However, direct contributions to GDP underestimate the role of the port in supporting the remainder of the economy. Although air freight is important for high-value goods, requiring just-in-time delivery, the port handles around 99 percent by volume of Mauritius trade and has strong linkages to many other parts of the economy.

Frequent, competitively priced shipping services to multiple destinations are an important plus point in attracting footloose foreign investment and have allowed Mauritius to expand and diversify its economy by seeking export opportunities overseas. Exports of goods and services make up about 49 percent of the country's GDP, much higher than in neighboring African countries (Table 6.1). As a small, open economy, Mauritius also depends on imports of raw materials and intermediate goods to sustain its exports. In 2015 imports of goods and services accounted for 59 percent of GDP.

As for port traffic (in and out), it reached 8.4 million tons in 2016. This was slightly below the record throughput achieved in 2012 due to upgrading work at the container terminal, which required MPA to request shipping lines to reduce their transshipment volumes and use smaller vessels while the work was in progress (Figure 6.1).

Around 60 percent of the throughput is domestic trade. The rest comes from external trade between third countries made up of

Table 6.1. Exports of Goods & Services as a Percent of GDP, Mauritius and Neighboring Countries, 2015

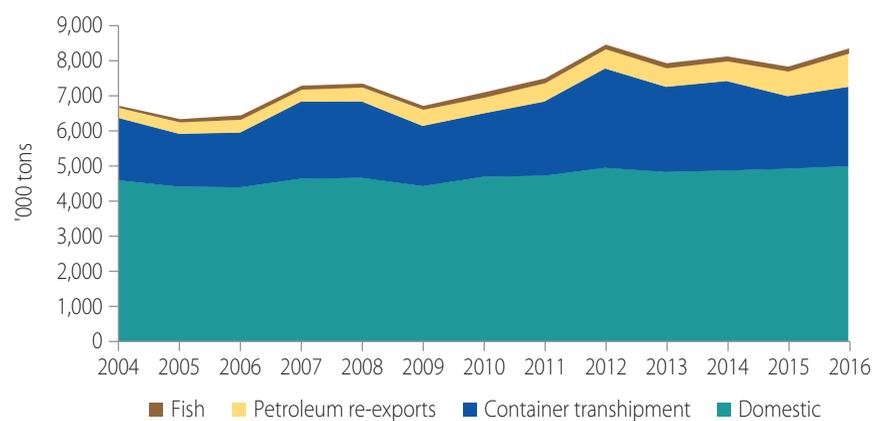
| Country | Exports (percent of GDP) |
|--------------|--------------------------|
| Mauritius | 49 |
| Madagascar | 34 |
| South Africa | 31 |
| Mozambique | 32 |
| Tanzania | 22 |
| Kenya | 16 |

Source: World Bank, World Development Indicators, 2015.

container transshipment (27 percent), re-exported petroleum products such as bunkers and liquified petroleum gas (LPG) (12 percent), and fish (2 percent). Domestic trade has remained fairly static at 4.5–5.0 million tons per year, with external trade accounting for almost all of the growth in port traffic. This has given Mauritius a better level of connectivity with the outside world than might otherwise have been the case, as well as generating additional income and jobs. Port traffic is dominated by containers (52 percent), but there are also sizeable movements of dry and liquid bulk cargo (22 percent and 24 percent respectively), and smaller movements of general cargo and fish (Figure 6.2).

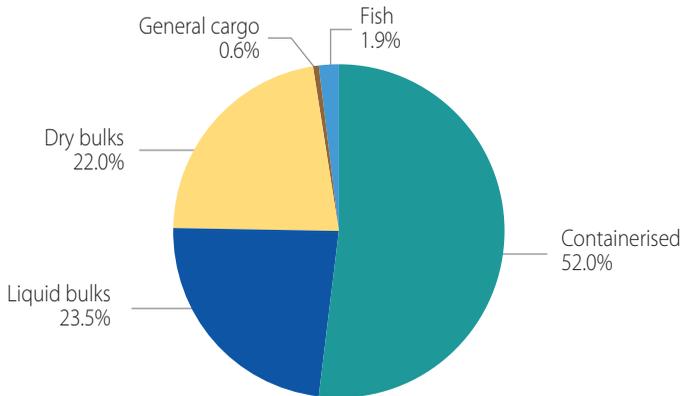
Container Traffic

For an economy of its size, Mauritius has a large number of long-distance container services. It has capitalized on its location at the crossroads of

Figure 6.1. Tonnage of Container Transshipment, 2004–16

Source: Mauritius Port Authority.

Note: Transshipment containers have been counted twice (in + out).

Figure 6.2. Composition of Port Traffic, 2016

Source: Mauritius Port Authority.

Indian Ocean trade to develop as a transshipment hub—handling both relay traffic, switching between long-distance routes, and hub-and-spoke traffic for other Indian Ocean islands. Unfortunately, it has not been able to develop a “regional carrier” role for Mauritius Shipping Corporation (the national shipping line), in part because of the difficulty of serving low-density Indian Ocean routes profitably. The high cost, low frequency, and lack of control over regional shipping services are obstacles to becoming a regional distribution center.

Container transshipment in Mauritius only began in 2003, but by 2012 it had grown to make up more than half of all the boxes moving across the quay (Figure 6.3). It has fallen since then, largely as a result

Figure 6.3. Domestic and Transshipment Container Traffic, 1999–2016

Source: Mauritius Port Authority.

of the container terminal expansion works. It is expected to resume its upward growth path once these have been completed in October 2017.

Transshipment traffic is very mobile, and the global container industry is now undergoing a major restructuring, as a result of overcapacity, mergers and acquisitions, and tumbling freight rates. As networks are redesigned, Mauritius must keep in touch with the main players to ensure that it retains or improves on its present position. Further reductions in port charges should be avoided if these would result in operating subsidies, and the container lines' co-operation sought in identifying mutually beneficial ways of improving productivity, expanding traffic, and increasing the number of destinations served.

Liquid Bulk

Petroleum products (96 percent of total liquid bulk cargo) are imported for both domestic consumption and resale. Over the last 10 years, re-exports of ships' bunkers have grown by over 90 percent as incentives have been introduced to attract both passing trade and ships already calling at the port. Ships' bunkers have increased from 17 percent to 23 percent of petroleum imports, with the prospect of a further increase once the product range is expanded. In 2014, Petredec, a global LPG company, set up a storage and distribution center in Mauritius for transshipment of imported LPG to other Indian Ocean countries, driven by similar economic pressures to container transshipment. Exports in 2016 were greater than 90,000 tons and are expected to increase further.

The question now is whether this model, which is particularly suitable for LPG, can be rolled out to other types of petroleum product. There is a widespread shortage of storage capacity in the region that prevents countries from taking advantage of low oil prices, and there is a growing international demand for storage from traders speculating in the oil futures market. Since this study began, Mauritius has received several enquiries from private investors interested in oil transshipment, but further work is required to bring the projects to financial closure.

The project currently receiving most attention is for an oil transshipment facility at Albion that is being jointly sponsored by the Indian Oil Company, Mangalore Refinery, and the Indian Government. It comprises a common user jetty to be funded by an Indian government grant, and a privately funded tank farm to be built in two phases.

Other projects put forward for the Albion area that are less well-developed include a floating oil refinery proposal from Near Shore Resources, the reservation of a site for the storage and regasification of liquefied natural gas (LNG) for power station use, the reservation of land for additional power plants to be built over the next 50 years, and a site for a private-sector solar power farm.

Table 6.2. Investment Scenarios Used for CGE Modeling (US\$ million)

| Project | CAPEX (US\$ million) | | |
|---|----------------------|----------------|--------------|
| | Public sector | Private sector | Total |
| Conservative scenario | | | |
| MCT gate complex | 22 | — | 22 |
| Second oil jetty at Fort George | — | 100 | 100 |
| Island container terminal | | | |
| breakwater, dredging & land reclamation | 373 | — | 373 |
| first container berth | | 242 | 242 |
| Cruise terminal | 18 | — | 18 |
| Caudan marina | — | 4 | 4 |
| Albion jetty + phase 1 tank farm | 170 | 160 | 330 |
| Total | 583 | 506 | 1,089 |
| Optimistic scenario | | | |
| Albion Phase 2 tank farm | — | 101 | 101 |
| Reconstruction of Quay 1 | 27 | 9 | 36 |
| GRNW marina | — | 12 | 12 |
| Fort William fishing harbour | 29 | — | 29 |
| Third ship repair yard | — | 65 | 65 |
| Total | 56 | 187 | 243 |
| Grand total | 639 | 693 | 1,332 |

Source: Royal Haskoning DHV, Port Louis Masterplan (July 2016), plus additional information from MPA.

Note: The redevelopment of Quays D-E for fish landing and processing has been included in the Fisheries sector.

Within the domestic market, half of all petroleum imports are used for transport, and a quarter of imports are used for power generation. The remainder is used for manufacturing, household, and commercial purposes. Oil currently accounts for around 30 percent of power generation, and this proportion may fall if the share of renewables is increased as planned from 20 percent to 35 percent by 2025. Offshore wind and wave energy, another component of the OE, are substitutes for oil, and will free up space at the existing oil jetty for re-exports of petroleum products should this market develop in future. There is also a proposal for the next power station to be dual-fired, using either gas oil or LNG; the choice will depend on comparative prices and the speed with which the supporting infrastructure for LNG imports can be built. The decision is still to be taken, but an LNG import facility designed to handle large ships would give Mauritius “first mover” advantage in developing LNG bunkering and regional LNG transshipment activities.

Dry Bulk

Coal is the other main power station fuel, accounting around 40 percent of power generation and over 800,000 tons per year of imports in 2016 (45 percent of all dry bulk imports). It is cheap but dirty, and was originally introduced because of its ability to complement seasonal supplies of bagasse as a power station fuel. Imports are likely to remain at around their current level because of the capital sunk into existing power stations. They could increase significantly after 2025 if the government were to adopt a “least cost” strategy for power generation, but this seems unlikely for sustainability and risk-reduction reasons.

Other dry bulk imports include cement (605,000 tons in 2016) and grains (295,000 tons in 2016). If better regional shipping services were available, imports of this type could be used to manufacture value-added goods (such as building materials and bakery products) for re-export to neighboring countries, resulting in more imports and exports.

Seafood

The development of Mauritius as a seafood hub has been one of the government’s big success stories, generating an estimated 6,500 jobs in the fish processing sector. Tuna constitutes around 96 percent of the total export value of fish and fish products from Mauritius (around US\$400 million per year), with most of the raw tuna imported from the Seychelles. There are around 40 importers and exporters in a market dominated by Princes Tuna and Thon de Mascareignes.

A Chinese company expressed interest some time ago in developing a third major fish unloading and processing facility in the port, but the strength of this interest has not been tested. Purse seiner operations—the main form of fishing in the Indian Ocean—are beginning to approach sustainability limits, which will restrict the size of the future market for tuna-processing. However, there is likely to be demand for smaller-scale facilities to support the long-line fishing fleet, which could increase port throughput of fish by 15 percent by 2025.

Cruise Passengers

The Indian Ocean cruise industry is still in its infancy, partly because of piracy incidents in the waters to the north of Madagascar and partly because of the difficulty of putting together attractive itineraries when so few of the region’s ports have proper facilities to receive large cruise ships. There are still fewer than 30 cruise ship calls each year. Nevertheless, it has been estimated by one of the cruise line agents in Mauritius that cruise passengers inject around US\$15 million per year into the economy, including Air Mauritius air fares, airport taxes, and local expenditures; they also improve the country’s image as a

luxury tourism destination. Cruise passengers now exceed the number of people arriving on the mixed passenger-cargo services operated by Mauritius Shipping Corporation to Rodrigues and Réunion, who are increasingly diverting to air transport.

Shipbuilding and Repair

Mauritius has two shipyards—Taylor Smith and Chantier Naval de l’Ocean Indien (CNOI)—which repair small ships (such as fishing vessels, yachts, port craft, and small naval patrol vessels), and CNOI also builds these types of ships. Together, the two yards have a turnover of US\$35–40 million per year (equivalent to 40 percent of the revenues of MPA and CHCL, the two state-owned port companies) and employ around 450 full-time and 200 casual workers. Imports make up around 20 percent of the value of their output.

Other Port Services

Although CHCL undertakes most of the cargo handling work in the port, some of the bulk importers (such as cement, petroleum products, fish and wheat) handle their own cargo, particularly onshore. Private-sector support services (such as ship agency, chandlery, ship and cargo inspection, crew changes, and security) further increase the value-added and employment generated by the port, although by exactly how much is still unknown.

Development Scenarios

What is the potential of the port sector to contribute to the OE and Mauritius’ overall economic development?

The projects that have been identified by MPA as possibly being undertaken within the next 10 years are shown in Table 6.2. They have been derived from the Port Master Plan, which was completed by the Dutch engineering firm Royal Haskoning DHV in July 2016 and updated to take into account new projects initiated since then, such as the Albion oil jetty. They do not include the Riche Terre SEZ, which has been treated as a general industrial development project even though it is located close to the port and would generate significant quantities of imports and exports.

The projects have been grouped into two scenarios—*conservative* and *optimistic*—for the purposes of CGE modeling. The conservative scenario includes the projects actively under discussion now, while the optimistic scenario comprises additional projects that might be undertaken if additional funding were available, and/or a suitable project sponsor could be found. The majority of the projects in both scenarios still

require economic and financial evaluation before taking the decision to go ahead.

Both scenarios assume that all the short-term investments currently at the planning stage—totaling US\$520 million—will go ahead. These include: (i) routine investment undertaken by MPA (port infrastructure) and CHCL (port services) in asset replacement, and small-scale improvements for performance improvement, safety and security, and administrative or social reasons (US\$183 million); (ii) larger investments to which MPA and CHCL are contractually committed—the most important being the expansion of the Mauritius Container Terminal (MCT) container terminal (for a combined total of US\$306 million between 2015–20); and (iii) expected capital outlays of private port service providers—this is mainly routine expenditures on asset replacement, but also includes the current expansion plans of the two ship repair yards (US\$31 million).

Conservative Scenario

In the Conservative Scenario, a new gate complex is proposed for Mauritius Container Terminal to increase security, reduce truck turnaround times and documentation costs, and improve terminal performance by moving ancillary facilities like scanners and customs inspection areas away from the main container stacks. It is not expected to generate any additional revenue, but would improve service standards for the port's domestic containers. The project would be funded by MPA as an extension to the ongoing container terminal expansion program.

The second oil jetty at Fort George is intended to serve LPG vessels and bunker barges loading oil for transfer to the offshore anchorage. This will overcome capacity constraints at the existing oil jetty, which the Port Master Plan expects to reach full capacity working in 2023. The jetty and the associated tank farms would most probably be funded by private investors. The additional revenues generated for the jetty users are difficult to quantify, but have been included in the analysis on the basis of the “local content” component of private-sector earnings from bunkering and LPG storage at other ports.

The island container terminal is a large and complex project with two main components:

- A large breakwater (US\$373 million, including associated dredging and reclamation costs), which would protect the existing container terminal and oil jetty against the effects of climate change and help to retain the container transshipment traffic using the existing container terminal. This would almost certainly have to be funded by the government, although grants may be available from one or more Climate Change Funds;

- A 460-meter container berth with a capacity of approximately 650,000 meters p.a. The quay wall, superstructure, and equipment costs of US\$242 million are assumed to be paid by a private-sector partner, most probably a shipping line or large international terminal operator

The breakwater would be largely non-revenue-earning, apart from the increase in port dues and marine services revenues generated by the additional transshipment traffic. The revenues arising from the container berth will depend on the choice of private operator, which could be either an international terminal operator like PSA Corp or DP World or a major container shipping line. If it were to be an independent third-party operator it would probably have to match MPA and CHCL's charges at the existing container terminal, which for transshipment traffic are very low.

Container transshipment is a mobile and highly competitive business in which Mauritius is to a large extent a price taker rather than a price maker, making it difficult to justify capital expenditure on the island berth for additional transshipment traffic alone. A third-party operator could create a commercially viable business at existing tariffs, but only by taking higher-value domestic container traffic away from the existing terminal operator, which would not necessarily be economically beneficial for Mauritius.

If the new container terminal were to be operated by a shipping line, it is possible that the benefits it obtains from transshipment in Mauritius might be higher than the current prices charged by MPA and CHCL—that is, there may be an element of consumer surplus that the government could capture in the form of concession fees.

Global transshipment networks are complex even for a single shipping line, and the situation has been further complicated by recent major changes to the three main shipping line alliances. At the time of writing these were the 2M Alliance (Maersk and Mediterranean Shipping Company), the OCEAN Alliance (CMA CGM, Evergreen and Cosco), and THE Alliance (NYK, MOL, K Line, Yang Ming and Hapag Lloyd). Maersk and Mediterranean Shipping Company already transship cargo in Mauritius, but CMA CGM has recently moved its transshipment operations to a new hub in Réunion.

In the light of the findings of the techno-economic study being implemented by the MPA, a decision on the possible funding of the breakwater construction by government could be considered. The Island Terminal Project was included in the 2009 Port Master Plan Study prepared by engineering consultants Halcrow and has been further examined by the consultants Royal Haskoning DHV in the 2016 Port Master Plan Study. It is now the subject of further studies.

The cruise terminal is a public-sector project serving a small but already well-established market. Cruise ships already call at Mauritius using the existing quays to berth, but are likely to do so in increased numbers if high-quality facilities are provided. The impact of the terminal on MPA's finances is likely to be small and will depend on the rents that can be obtained for commercial floor space within the terminal building. The main economic impact will be local expenditures by cruise ship passengers, crews, and cruise ship agents, which are estimated by MPA to be around US\$15 million per year at present.

The Caudan breakwater is a small investment required partly for flood protection purposes that would also provide an area of sheltered water suitable for marina development close to the city center. Although the marina could generate revenues for both MPA and the private operator, these have been considered too small to be included in the CGE modeling work.

The Albion oil transshipment terminal was considered in the 1996 Port Master Plan but could not be implemented because of the high cost of the infrastructure, especially the jetty, and the absence of willing promoters. The 2016 Port Master Plan reached the same conclusion, namely that the site should be earmarked for future large-scale energy projects, and shortly afterwards new sponsors materialized.

The project comprises a jetty for very large tankers (US\$171 million), which is to be funded by a grant from the Indian government, and the phased development of a tank farm by Mangalore Refinery and Petrochemicals Limited and the Indian Oil Company for the storage and re-export of petroleum products. At the time of writing, Phase 1 of the tank farm was expected to cost US\$160 million and to have a maximum throughput of 3.23 million tons of petroleum products per year, while Phase 2 was expected to cost US\$101 million, increasing the total maximum throughput of the complex to 9.56 million tons per year.

These are very large throughputs compared with Mauritius' 2016 oil traffic: 1.42 million tons of imports, of which 0.44 million tons were re-exported. They also represent relatively large shares of the target markets for petroleum products, which stretch from Djibouti to South Africa (10–15 percent in Phase 1, rising to 25 percent in Phase 2).

No information is currently available about the expected revenues and operating costs of the transshipment operation, although we understand from MPA that the proposal submitted by the project sponsors expected it to have an NPV of US\$63.3 million over a 15-year period at a 10 percent discount rate. This information, combined with assumed future prices for petroleum products based on a crude oil price of US\$70 per barrel, has allowed us to “back-estimate” the likely cash

flow as an input to the CGE model. Construction is assumed to begin in 2017, with Phase 1 of the project becoming operational in 2020.

Optimistic Scenario

Phase 2 of the Albion oil transshipment project has been included in the optimistic scenario, as its funding is conditional on the commercial viability of Phase 1.

The reconstruction of Quay 1, a dry bulk berth used mainly for the handling of coal, has been included in the optimistic scenario because of uncertainty over future levels of coal imports, which are closely linked to the Central Electricity Board's power generation strategy and the role of renewable energy and/or LNG. There is little financial incentive for MPA to undertake this project, because its main benefits—labor cost savings due to terminal automation and the ability to use larger ships fully-laden—accrue to the Mauritius Coal Terminal, which appears unwilling to undertake the associated private-sector investments at the present time.

The Grand River North-West marina has been under discussion for some time, but suffers from the small scale of existing marina facilities in Mauritius, their association with resort developments, and possible objections from local residents. The commercial viability of a new marina at Grand River North-West is still unknown, as no private sector operators have yet come forward.

The Fort William fishing harbor is a non-revenue-earning project intended to remove non-operational fishing vessels from Trou Fanfaron in the city center, where they hold back the full development of the waterfront for tourism and commercial purposes, and are said to be the cause of various social problems. Until a redevelopment plan for the Trou Fanfaron area has been agreed, the economic and financial impacts of the project will be relatively small, resulting in some flexibility in timing.

The third ship repair yard is a project that is still at the concept stage, and the market it would serve has not yet been clearly identified. A request for Expressions of Interest is expected to be issued in 2017, and the project will then be developed further on the basis of the most attractive response(s). For modeling purposes it has been assumed that the new yard would serve regional niche markets, such as port craft, off-shore support vessels, and large fishing boats, and that its cost and revenue structure would be broadly similar to that of Chantier Naval de l'Océan Indien (CNOI).

CGE Modelling Results

CGE modelling has been used to calculate the net worth of the investments proposed in the conservative and optimistic scenarios, firstly by

Table 6.3. Investment Cost, Project-level Worth, and Economywide Worth of Port Development Scenarios

| Development scenario | Investment costs (US\$ million) | | | Project-level measures of project worth | | | Economywide worth | | |
|-------------------------|---------------------------------|----------------|-------|---|------------------|---------------------------------|-------------------|---------------------------------|--------------|
| | Public sector | Private sector | Total | PV ^b | NPV ^c | Benefit/cost ratio ^d | NPV ^c | Benefit/cost ratio ^d | Jobs created |
| Conservative | 587 | 496 | 1,083 | 842 | 142 | 1.17 | 495 | 1.59 | 1,440 |
| Optimistic ^a | 56 | 187 | 243 | 188 | 408 | 3.52 | 75 | 1.44 | 230 |

Note: (a) Incremental investments undertaken in addition to the conservative scenario. (b) Investment costs 2017–27, discounted to present values (PV) at 5 percent. (c) Annual increases in value-added 2017–40 discounted to PV at 5 percent, minus PV of investment cost. (d) Annual increases in value-added 2017–40 discounted to PV at 5 percent, divided by PV of investment costs. PV = present value; NPV = net present value.

looking at the value-added associated with the projects included in each scenario, and secondly by including in the analysis the indirect economywide benefits caused by multiplier effects.

The model results shown in Table 6.3 have been based on a 10-year investment program (2017–27) and an evaluation period that extends to 2040. This allows for the fact that port installations rarely begin working at full capacity immediately; in some cases, it may take many years for port traffic growth to absorb the large and indivisible increments of port capacity provided by particular projects.

Conservative Scenario

The project-level benefit-cost ratio for the conservative scenario is relatively low (1.17) because of the existence of non-revenue-earning investments (such as the island breakwater) that are required to protect existing traffic, as well as enabling private-sector investments to go ahead. However, it increases to 1.59 when economywide linkages are taken into account, generating over 1,400 permanent new jobs, plus an estimated 4,000 full-time equivalent jobs during the 10-year construction period.

Optimistic Scenario

The project-level benefit-cost ratio for the Optimistic Scenario is relatively high (3.52) because of the smaller amount of investment required and the fact that the local value-added component of the main project (a third shipyard) should be quite high compared with the main projects in the conservative scenario, which generate smaller potential operating surpluses. The economywide benefit-cost ratio for the optimistic scenario is slightly lower than for the conservative scenario at 1.44.

The number of permanent jobs created by the optimistic scenario appears low when compared with independent bottom-up estimates of around 600 jobs, and may be an under-estimate. In addition, around

1,000 full-time-equivalent jobs are expected to be generated during the construction phase.

Sensitivities

All these results need to be treated with care, as many of the projects are still at an early stage in their development. Their capital costs, revenues, and operating costs will inevitably change as more information becomes available and the projects are adapted to meet the needs of particular private-sector sponsors.

The timing of individual projects in relation to the growth in demand, and the amounts of additional cargo that the project sponsors are able to bring with them, will also have an effect on the commercial viability and wider economic impacts of individual projects. This is because there are large indivisibilities in port investments (such as the island breakwater/container berth and the Albion oil jetty) whose capacity may take some years to fill up.

The structure of the public-private partnerships underlying many of the projects, as well as the way in which costs and benefits are divided between the public and private sectors, will also affect their worth, particularly when the project benefits accrue mainly to companies outside Mauritius, such as container shipping lines and international oil traders. Attention must be paid to securing appropriate risk/reward ratios for all parties.

Because the analysis in Table 6.3 is focused on value-added rather than profits, it should not be construed as implying that all the private sector investments listed in each scenario will automatically find sponsors. In some cases, a great deal of work may be required to put together investment packages that are attractive to the private sector while generating enough benefits for Mauritius to justify associated public-sector investments.

Finally, there is the issue of risk. The OE is moving toward a new phase in which Mauritius will be competing on the global stage for port projects that could equally well be located in other countries. Due to government budgetary constraints, for these projects Mauritius will also become increasingly dependent on private finance. Risk allocation is therefore likely to become increasingly important in the structuring of new projects, while uncertainty about their timing will require more a flexible approach to port planning. The institutional changes needed to achieve this are described in the next section.

Making It Happen

The scale and nature of the new port projects arising from the OE make it desirable for MPA to acquire the new skills that will allow it to strengthen and expand its commercial functions.

The number of additional staff required in MPA is likely to be fairly small, with the emphasis placed on obtaining the right people rather than the actual numbers. We envisage the creation of a small Commercial Division within the port, headed at the second- or third-tier management level by someone with business development experience from a rapidly-growing port outside Mauritius. The head of the Commercial Division would be supported by four or five local staff, mainly graduates with a business background who would be trained on the job, perhaps making use of a training scheme at another larger port.

The investment program set out in Table 6.2 is large in relation to the public-sector resources available for gross fixed capital formation in Mauritius. Thus, “making it happen” revolves around three main issues: (i) how to prioritize investment expenditures; (ii) how to increase the private sector’s share of investment expenditures, particularly from overseas; and (iii) how to ensure that public-sector investments represent good value for money. Expansion of its commercial functions will enable MPA to address all three issues more effectively and involve a variety of measures.

Helping Existing Customers to Grow

The port’s existing customer base is one of its largest assets, and helping customers to expand is a low risk way of contributing to OE objectives.

Understanding customer requirements is fundamental, and one way of achieving this is to use customer relationship management tools to build up an information database on each of the port’s main users, focusing on the economics of their supply chains and the new business opportunities and threats to existing businesses that result. Opportunities for helping customers to grow can be discussed at annual “liaison” meetings, with the outcomes passed on to other relevant government departments at routine inter-ministerial meetings set up to monitor the progress of the OE.

Some port-related activities, such as shipping, ship building and repairing, and ship agency work would benefit from an expansion of government training schemes. The Mauritius Maritime Training Academy, for example, produces hotel staff for cruise vessels rather than engineers and deck officers for cargo ships. With the possible exception of welding, training courses are not available for the specialist skills needed in a shipyard, so workers have to be trained in-house without any form of subsidy or tax relief. And because Mauritius is a small country, there are relatively few courses providing the skills needed to conduct international trade, such as freight forwarding, insurance, ship brokering, or customs clearance.

Because basic educational standards in Mauritius are lower than in many competing Asian countries, particularly for technical subjects,

there is a catch-up component to in-house training costs, which the government might consider contributing to, especially as normal labor turnover spreads the general benefits of this training to other industries.

There is also the question of whether public-sector procurement policies should give preference to local suppliers. Shipyards in Mauritius do not receive preferential treatment in the placing orders for new vessels by organizations like the MPA and the Fisheries Division of the Ministry of Ocean Economy, even though this is common practice in other parts of the world (for example, France, India, South Korea, and China).

Automatic inclusion of local yards on tender lists, allowing them to match the best offers obtained through competitive tendering or even accepting small price margins above the best bid, would help to keep this work in Mauritius. This implies a move away from the free market principles that have characterized past economic policies, but it might be justified for a limited period if it boosts the OE.

Finding New Customers

MPA has recently appointed its first marketing officer, who with a limited budget still needs to develop a proactive marketing strategy that will increase awareness of Mauritius amongst overseas companies not using the port at the moment. This is likely to involve a mixture of desk research, carefully targeted publicity material, and international travel, focused on the cargo types and port-related services for which Mauritius has the greatest comparative advantage. In practice, there is likely to be some overlap between promoting the use of existing facilities and attracting private investment in new ones.

Attracting Private Investment

There is a global trend toward increased private investment in ports, and Mauritius is not alone in having a number of projects on the drawing board that are suitable for public-private partnerships. However, these need to be more widely publicized, while following guidelines for attracting private investment that range from considering new projects from the point of view of investors to conducting value-for-money assessments for any public investments needed to support the project (Box 6.1).

More desk research is needed to improve MPA's understanding of new activities like ship repairing and international oil trading. Regular contacts need to be maintained with companies interested in investing in Mauritius and customized business cases need to be prepared to demonstrate the advantages of Mauritius as an investment location. Because of the need to offer a package of investment incentives, later-stage marketing should be undertaken jointly with the Board of Investment and other relevant government bodies.

Box 6.1. Guidelines for Attracting Private Investment

- Be vigilant, always on the look-out for new opportunities.
- Be aware of, and develop contacts with, the main players in each separate market.
- Understand the economics of the different businesses—the client base, cost structure, pricing policies, attitudes towards risk, and upstream and downstream linkages to other activities.
- Consider new projects from the point of view of investors—what’s in it for them.
- Analyze the advantages and disadvantages of Mauritius from the investor’s perspective, and compare with those of competing locations.
- Think widely about the potential costs and benefits of each project for Mauritius, including job creation, local value-added, backward and forward linkages, and government tax revenues.
- Allow for “leakages” of potential income overseas through imports and repatriation of profits.
- Consider ways in which the attractiveness of Mauritius can be improved through associated public investments, fiscal incentives, regulatory changes, labor training, “start-up” assistance, and other government policies designed to create a favorable business environment.
- Conduct value-for-money assessments for any public investments needed to support the project, ensuring that these are justified by the project’s contribution to economic growth.
- Be flexible but realistic when negotiating deals—the objective is to arrive at a win-win situation for each party.

At the same time, there is a need to take into account the impact of new projects on existing businesses in Mauritius. In some cases, these may be positive; for example, if the proposed new deepwater oil jetty at Albion can be accessed by other oil companies, it would allow them to use larger ships. In other cases, the impact may be negative; for example, if the third shipyard were to compete in exactly the same niche markets as the two existing shipyards, it could steal their business. Every project therefore needs to be considered from as wide a perspective as possible, considering Mauritius as a whole.

A better understanding of potential investors’ businesses will help Mauritius to obtain the best possible deals in terms of public-private equity contributions, profit sharing, and the allocation of risk. The frequency of contacts with potential partners should be raised as each project progresses, and professional advice should be sought for large public-private partnerships such as the Island Container Terminal.

Port-related Investments

Because the port is so central to the success of the OE, there may be a need for MPA to become involved in projects being developed by other public-sector organizations when these increase the demand for port facilities, or MPA can offer incentives that improve the project’s chances of success.

Table 6.4. Potential Economic Impacts of a New Special Economic Zone at Riche Terre

| | Time scale (years) | Site area (acres) | Investment (US\$ million) | Revenues (US\$ million p.a.) | Local value- added (US\$ million p.a.) | Permanent jobs |
|------------------|-------------------------------|------------------------------|--------------------------------------|---|---|---------------------------|
| Phase 1 | 5–10 | 130 | 100–250 | 50–100 | 20–40 | 1,500–3,000 |
| Full development | 15–25 | 325 | 300–600 | 125–250 | 50–100 | 4,000–8,000 |

Source: BDO, Review of the DP World Proposal for the Riche Terre Special Economic Zone (RTSEZ).

One such project is the Terre Rouge SEZ close to the port, which would strengthen the position of Mauritius as a regional transshipment and distribution hub (Table 6.4). The economic impact of the SEZ will depend on how it is developed (labor-intensive manufacturing or capital-intensive distribution activities), and whether it is built using foreign direct investment or local capital. The range of potential outcomes is large. However, “best estimates” made during the evaluation of a recent DP World proposal suggest the scale of economic impacts listed in Table 6.4.

Various models are available for the development of an SEZ, but the majority of the investment usually comes from the private sector, with public sector investment in land, infrastructure, common services and an initial stock of buildings kept to a minimum by “revolving fund” financing.

Project Evaluation

The Port Master Plan takes a broad look at future investment needs, encompassing most foreseeable projects, but does not attempt to prioritize investments. The larger projects listed in Table 6.2 now need to be properly evaluated, resulting in more detailed plans for the projects that are suitable for implementation within the next 10 years.

Although large projects are normally evaluated by MPA as a condition for obtaining external finance, whether from commercial banks or international financial institutions, this is often done at a relatively late stage. Less use is made of economic evaluation techniques for projects that are to be funded from MPA or CHCL’s own resources.

It would be useful to look at the economywide benefits received in exchange for the public sector component of any large investment, including such items as roads that lie outside of the port boundaries. Rotterdam is one of the world’s leading ports in this respect. Since September 2012, it has been working closely with the Municipality of Rotterdam, the Province of South-Holland, the Dutch national government, and key port users to implement an action plan set out in its Port Vision 2030. Some of the planning and evaluation techniques it uses for individual projects are equally applicable in Mauritius, particularly

those involving multi-organization approaches to marketing, project implementation, and financing.

Because economic evaluations can be time-consuming and expensive, we suggest a phased approach in which the quality of the input increases as the project moves toward financial close:

- At the concept review stage, the main need is to understand why the project is being undertaken and what its principle costs and benefits will be. This is similar to the economic evaluation work that was undertaken in the Port Master Plan, where rough estimates were usually sufficient to decide whether or not individual projects were worth developing further.
- At the project review stage, the costs and benefits are normally derived from a “live” project for which pre-tender designs and cost estimates are available, customers or partners have been identified, traffic projections have been based on their specific requirements, and an outline financing plan has been put in place. For small- and medium-size projects, this may be the end of the economic evaluation work.
- For large projects such as the Island Container Terminal, a final review should be undertaken prior to any commitment of public funds. This would typically involve financial modeling and due-diligence work similar to that undertaken by banks and private equity funds, together with an economic impact assessment looking at the project’s implications for other parts of the economy.

At the concept stage, efforts should be made to investigate and discuss all available options before finalizing project specifications. Key port users, along with a strengthened and more active Port Users Council, may have a role to play in this process. In South Africa, for example, Port Consultative Committees actively review Transnet’s investment plans for each port and hold open workshops to discuss the plans with Transnet National Ports Authority. These committees are also consulted regularly by the Ports Regulator and the Department of Transport about what needs to be done to improve port performance.

All port-related projects requiring significant public investments should be subject to financial and economic evaluation. The financial evaluation should calculate the project’s financial internal rate of return and net present value by looking solely at the public-sector component of the capital expenditure, and comparing this on a discounted cash flow basis with net changes in public sector revenues and operating costs arising specifically from the project. These would normally be calculated on a time series basis by comparison with a “do nothing” situation in which the project did not take place.

The economic (or value-for-money) evaluation is much broader and compares the government's contribution to capital costs with the discounted increase in value-added for the Mauritius economy as a whole—taking into account multiplier effects and any increase in consumer surplus caused by reductions in the delivered prices of imports. The methodology, which is a modified form of cost benefit analysis, will vary from project to project.

The economic impact of all major OE projects should be reviewed at the government level before deciding whether or not to go ahead with them, using an approach that is as standardized as possible between sectors and consistent with OE policies as a whole.

Financial Planning

MPA and CHCL already produce five-year, rolling capital expenditure plans as part of their normal budgeting processes. However, the scale and complexity of some future projects increases the need for a better understanding of international financing options for large infrastructure projects, along with the capacity to model and track financial transactions between the different stakeholders. This would allow more use to be made of project-specific government grants, subordinated loans, and revenue or profit sharing deals with private sector partners, while keeping MPA's exposure to financial risks within acceptable limits.

Tariff Reviews

As well as using foreign direct investment to increase the leverage of public-sector investments in the port, attention needs to be paid to the way in which the resulting “economic rent” is split between Mauritius and its overseas partners. This requires tariff structures and public-private partnership concession agreements to be designed to keep as many of the project benefits as possible in Mauritius.

Some ports now use a supply-chain approach to tariff setting, looking at the amount of economic rent they can capture before risking loss of cargo to the next most competitive port. This is quite common in parts of the world where tariffs are unregulated and inter-port competition is strong—for example, China, the United Arab Emirates, and northwest Europe (Antwerp, Rotterdam, and Hamburg). It is less usual in countries like Mauritius, where the port has a natural monopoly, and in countries where port tariffs are externally regulated.

Looking at the supply chains of individual customers is easiest for the bulk trades and other commodities, like steel and timber, where the number of customers is small and their supply chains are well-defined. It is more difficult for container traffic, where the number of consignees is large and their characteristics are more diverse. However, the high

level of consolidation that has taken place in container shipping over the last two years may make it worthwhile to look again at the networks of the three main alliances—with a view to identifying the routes offering the best opportunities for transshipment in Mauritius and the tariff rates at which transshipment in Mauritius becomes more attractive than transshipment at alternative hub ports. This would strengthen MPA's position in negotiations with its most important customers and could lead to some increase in transshipment tariffs.

Lease Negotiations

Another issue is the allocation of port land away from the waterfront, including the new areas of reclaimed land becoming available at the entrance to the harbor at Fort George (4 hectares) and Fort William (35 hectares).

New leases should include clauses that make it easier to move the lessee—with appropriate compensation—to another location should the land be required for other purposes. We understand, for example, that the expansion of the CNOI shipyard is being delayed by the difficulty of moving Mauritius Coal Terminal to a site near Quay 1. Temporary leases on concessionary terms could also be used to avoid having land standing idle until suitable long-term tenants can be found.

Port Statistics

The process of making better use of existing assets starts with better information about how they are used at present. The integration of MPA and CHCL's operational and financial statistics into a single Port Management Information System (PMIS) might lead to the development of better diagnostic tools that could be used to identify areas in the port where there is still scope for performance improvement, such as the under-used Bulk Sugar Terminal.

MPA, CHCL, and Mauritius Cargo Community Services Ltd (MACCS) are already developing a port community information system that extends to importers, exporters, Mauritius Revenue Authority, and various other transport service providers. Smart IT applications would allow large numbers of transactions to be analyzed quickly, deepening MPA's understanding of its customer base. Mauritius is still some way behind world leaders like Rotterdam and Singapore in this area, so additional budgetary resources may be needed to enable it to catch up.

Performance Auditing

Improving the operational performance of CHCL has for many years been one of the main challenges facing the port, as it is reducing the

productivity of existing assets below the level that could be achieved by a private operator. For example, average crane productivity in 2016 was only 19.9 moves per hour compared with a median value in Northern Europe of 27.5 moves per hour, while the actual time worked per day—after allowance for shift changes, meal breaks, etc.—was only 19 hours rather than the norm of 22 hours per day at efficient ports elsewhere.

In the past, the government has considered introducing a strategic partner into CHCL's shareholding structure, but has always backed away. We recognize that this is a very sensitive political decision, but note that continued protection of CHCL will probably reduce the attractiveness of the island container terminal to private investors and could limit the operational cash flow available for financing it as a public sector investment.

The Port Master Plan looked closely at ways of improving cargo handling operations, but its scope did not extend as far as the organizational structure and cost base of the port. Continuous monitoring and evaluation of their own performance as businesses is now a common feature of many leading ports, forming a natural part of the business planning cycle. It would therefore be useful to supplement Port Louis's physical performance indicators with detailed financial performance indicators derived from MPA and CHCL's management accounts. This would allow the port's overall performance—physical and financial—to be reviewed at the level of individual installations or cargo types.

Making It Last

How should the port sector respond to climate change and what should it do to prevent it?

Responses to Climate Change

As sea levels rise and extreme weather events become more common, more attention will need to be paid to protecting the port against the consequences of climate change. This can be done in several different ways:

- Monitoring weather conditions (now done automatically) and correlating them with the physical and financial consequences of extreme events. Consequences such as flooding and structural failures need to be recorded and mapped, and estimates made of the costs of the damage. Linking this information together will make the consequences of climate change easier to predict.

- Extending the analysis beyond the ports to consider not only damage caused by rain, winds, and sea conditions, but also the run-off regime of rivers flowing into the port area from the mountains behind it. These rivers pass through increasingly impermeable urban areas, where improvements to drainage could reduce damage risks to the port.
- Ensuring that insurance policies cover extreme weather events and provide adequate compensation for damage.
- Regularly reviewing and testing emergency response procedures, and actions that can be taken before the arrival of extreme weather events to minimize the damage caused (for example, by moving containers to less exposed locations and tying down mobile equipment).
- Designing all future investments to withstand the effects of climate change. Here, it would be useful to develop expected and worst-case scenarios for each part of the island, based on the climate change modeling work already carried out by the World Bank.
- Investing in breakwater protection and other measures that would mitigate the effects of climate change. This is a very expensive response that needs to be carefully evaluated. The costs of building a breakwater to protect the MCT container terminal, for example, are currently estimated at US\$280–370 million. A feasibility study for the breakwater, funded by the African Development Bank, is expected to begin shortly. The outputs of the World Bank’s climate change modeling work for Mauritius—possibly expanded—should provide an important input into this study.

Measures to Reduce Climate Change

Ports can contribute to climate change mitigation in two ways: through their own behavior and through their influence on the behavior of shipping lines. Green port policies are now becoming widespread. In the context of Mauritius, those related to climate change (rather than other forms of sustainability) include:

- Better monitoring of energy consumption within the port through metering, plus introduction of energy-saving devices like LED lighting and switches linked to movement sensors. Electricity rather than diesel should be used for powering equipment where possible, and efforts should be made to reduce engine use when equipment is on standby, for example for tugs and pilot launches.
 - Increased use of renewable energy within the port.
 - Photovoltaic panels can be added to warehouse roofs and even installed independently as solar farms on areas of unused land. Because they are easily dismantled, they

can be re-used at other locations when the unused land is redeveloped for port use.

- MPA should not act alone in increasing its use of renewable energy, but should take the lead in promoting its use within the whole port community, sponsoring a communitywide plan that will allow renewable energy to be generated and distributed at a lower cost.
- Provision of cheap and accessible shore power supplies to encourage ships to reduce engine use in port.
- Regulation of activities at the Petroleum Hub to ensure, among other things: (i) use of double bottom tanks with leak detection systems; (ii) vapor recovery systems to prevent vapor leaking into the atmosphere during cargo handling operations (including truck loading); and (iii) regular updating and testing of the emergency response plan for oil spills.
- Relocation of the open coal storage yard to a site closer to the berth, from which coal can be moved by a covered conveyor system rather than trucks. Consideration should be given to enclosing the coal storage area to prevent coal dust escaping to the atmosphere, as well as more conventional dust suppression measures.
- Control of effluents from the shipyards, fish processing factories, and other port-related industries.
- Identification of the best areas for ship-to-ship transfers at sea (including bunkering) that will minimize the incidence and impact of spills and airborne dust.

Many green ports have opted for pricing policies as a means of encouraging shipping companies to use more environmentally friendly vessels. The World Ports Climate Initiative has developed an environmental shipping index that scores ships' environmental performance based on common pollutants linked to climate change (such as nitrogen oxide and carbon dioxide). Concessionary tariffs can then be offered to ships whose score is above a pre-determined level.

Summary of Recommendations

A summary of our main recommendations is shown in Table 6.5.

Table 6.5. Recommendations

| Objective | Short term (6–18 months) | Longer term (18–36 months) |
|------------------|---|--|
| Making it happen | Strengthen MPA commercial functions (capacity building) | Proceed with Albion if externally funded with beneficial terms and conditions |
| | Investigate training needs of port service providers | Develop and evaluate other major projects (breakwater/Island Container Terminal, third shipyard) |
| | Consider changes to government procurement rules for ship building and repairs | Arrange breakwater funding (assuming this goes ahead) |
| | Develop marketing strategy | Seek private finance for Island Container Terminal |
| | Introduce new procedures for project evaluation (possibly involving other ministries) | Develop Riche Terre SEZ |
| | Include economic impact assessments in next tariff review | Implement other parts of modified Port Master Plan |
| Making it last | Improve port statistics and develop Port Community IT system | |
| | Ensure that breakwater feasibility study allows for climate change | Set up system for monitoring climate change impacts |
| | Prepare Green Port plan | Design future investments to withstand climate change |

PART C

Making it Last

This part of the book asks what needs to happen to ensure the longer-term sustainability of the ocean economy (OE). Any OE expansion would also entail the need to cope with environmental threats coming from a combination of anthropogenic influences and the effects of climate change. Damage to the local biotopes is already significant from climate change, and water pollution is already significantly damaging for coral reefs, lagoons habitats, and biodiversity. Coastal erosion and higher vulnerability to weather extreme events is also rising. A more active use of the OE requires technical and institutional mechanisms to reconcile, across sectors and time, competing claims over ocean and coastal resources.

This is the reason why at the end of 2016 Mauritius embarked on the process of developing a marine spatial plan (MSP). The book outlines options that could be considered in the next stages of the MSP preparation. The analysis is based on a review of international MSP experiences and takes into account Mauritius-specific issues and challenges in terms of the current legislative framework and the sources of environmental pressure to be mitigated.

Another key aspect of longer term sustainability of the OE is climate change. The final chapter of the book reviews those climate risks that are known and those that are less well known. It illustrates how the CGE model developed by the study team for Mauritius could be used to quantify the socio-economic risks (notably, in terms of growth and jobs) of climate change, focusing on a particular class of climate shocks, namely tropical cyclones. This can help in assessing the merits of investing in preventive adaptation measures.

Options for Adopting Marine Spatial Planning

Joanna Smith

Key Messages

- The Prime Minister's Office announced on December 29, 2016, the intention to develop a marine spatial plan (MSP) for the Exclusive Economic Zone (EEZ) of the Republic of Mauritius to address increasing demand for marine space in particular fisheries and in aquaculture, tourism, and leisure.¹ The purpose of this chapter is to support the development of MSP in Mauritius for multiple ecological and socio-economic objectives, including preparing a summary of environmental issues that could be addressed through coastal and marine spatial planning, sharing several international examples, lessons learned, and providing examples of MSP models for consideration.
- Globally, 22 nations or states have completed, approved, and/or implemented their own marine spatial plans, and planning is underway in at least 20 more. The approved plans range from policy documents through to regulatory plans. Mauritius can review and examine other MSP processes in formulating aspects of its own MSP including governance frameworks, stakeholder engagement processes, and zoning frameworks.
- As identified by the government, marine spatial planning is an excellent strategy to advance the ocean economy (OE) and address climate change impacts in Mauritius. Key components of an MSP will include: clear objectives, stakeholder participation, and defining the geographic boundary of the plan. Following best practices guidelines and an ecosystem-based approach, MSP in Mauritius could address spatial conflicts between uses, improve integration of government agencies for decision making, and prioritize key strategies to restore the marine ecosystem. Internationally, we have learned that there are tangible benefits to multi-objective, integrated MSPs over single-sector management plans, including reduced permitting times, increased coordination between government agencies, and stakeholder buy-in for new marine protected areas.
- Best practices for MSP suggest that implementation plans, including new regulations, financing, timing, and governance structures are built into the planning outputs from day one.

(continued on next page)

¹ <http://www.govmu.org/English/News/Pages/Marine-Spatial-Plan-to-be-elaborated-for-the-Exclusive-Economic-Zone-of-Mauritius.aspx>.

Key Messages *(continued)*

- Two example models for a planning process are relevant to Mauritius' needs:
 - *Example Model 1:* First, develop a high-level strategic framework for decision-making and management of marine economic sectors (see Table 7.1). Then, implement and monitor the strategic plan for five years, revise and adapt where necessary. During this period, compile spatial data and develop planning tools for zoning. Finally, develop a spatial plan with zones and management plans.
 - *Example Model 2:* Develop a decision-making framework and comprehensive zoning design simultaneously or sequentially, but without a period of adaptation prior to implementing the complete marine spatial plan.

Introduction

As Mauritius begins the process of marine spatial planning (MSP), how will it strike a balance between economic development, addressing climate change, and protecting the environment? So far, this book has looked at what a doubling of the OE could mean for Mauritius as a whole, and has assessed the potential expansion of four specific sub-sectors of the OE: energy, fisheries and aquaculture, ports, and information communications technologies. A recurrent finding in previous chapters is that expansion of the OE needs to be accompanied by improved management of the coastal and marine environment and by reduction in pressure on key natural resources such as the lagoon. This chapter starts by reviewing how MSP is being used around the world. After summarizing global best practices, it provides examples for Mauritius to consider for developing its own MSP.

In September 2016, at the UN African Ministerial Conference on Ocean Economy and Climate Change, which was held in Mauritius, MSP was highlighted as a key component of developing a sustainable OE for nations in the Western Indian Ocean. A few months later, in December 2016, the Cabinet of Mauritius agreed to the elaboration of a Marine Spatial Plan for the Exclusive Economic Zone of Mauritius, in view of the increasing demand for marine space.² Issues related to the UN Sustainable Development Goals, coastal zone management, cross-sectoral needs for jetties, embarkation/disembarkation, and marinas, as well as allocating space for offshore wind farms, aquaculture, deep ocean water application (DOWA), and others all require immediate attention and planning. Mauritius has launched “expressions of

² <http://www.govmu.org/English/News/Pages/Marine-Spatial-Plan-to-be-elaborated-for-the-Exclusive-Economic-Zone-of-Mauritius.aspx>.

Box 7.1. Definitions of Marine Spatial Planning (MSP)

MSP is a “public process of analysing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that are usually specified through a political process” (Ehler and Douvère 2009).

IOC-UNESCO defines MSP as “a practical way to create and establish a more rational organization of the use of marine space and the interactions between its uses, to balance demands for development with the need to protect marine ecosystems, and to achieve social and economic objectives in an open participatory and planned way.” (Ehler and Douvère 2009).

interest” for exploration surveys in four regions of the Mauritius EEZ, and all would be subject to some MSP.³

Marine spatial planning would accompany Mauritius’ GDP growth strategies while simultaneously protecting the environment and improving the sustainability of its key sub-sectors: energy, fisheries and aquaculture, ports, and information communication technologies.

Overview of Marine Spatial Planning

The main concept of MSP is that it is a public process to allocate space for multiple objectives, typically for economic activities and environmental conservation. Principles or characteristics associated with marine spatial planning include an ecosystem-based approach that is area-based, integrated, adaptive, strategic, and participatory (Ehler and Douvère 2009). Planning is undertaken using a variety of spatial and nonspatial tools at various geographical scales including data catalogues, compatible use matrix, and tradeoff analyses that evaluate alternate scenarios for the future.

Importantly, an MSP process is *participatory* and includes robust stakeholder engagement and participation to have the best available information and buy-in for the completed plan. A *government mandate* is an important starting point for MSP; a recent review of 16 marine plans around the world found that all the plans that have been implemented to date have a high-level government mandate and the authority to implement spatial planning vested in existing institutions (Collie et al. 2012). Additionally, these processes are *iterative and adaptive*, including

³ Deep-dive on Marine Spatial Planning, workshop sponsored by the World Bank and Mauritius Oceanographic Institute, Mauritius, September 8, 2017.

during implementation, so the planning tools that are developed to support the process must similarly be flexible, adaptive, and easily updated as new information or approaches are employed. Finally, the concept is *multi-sectoral*, involving all sectors that will be affected by the planning. Global best practices show the need to carefully think through implementation plans during the planning process so that there is no loss of momentum from the planning phase and implementation can begin as soon as a plan is approved.

Marine spatial planning was formally introduced as a concept about 10 years ago, in 2006, and since then 13 countries have approved plans covering about seven percent of the surface area of the exclusive economic zones (EEZs) of the world. The Intergovernmental Oceanographic Commission (IOC) – UNESCO estimates that by 2025, 40 countries will have approved plans, possibly covering over 30 percent of the world’s EEZs. The planning area for Mauritius is among the largest in the world, and it will join a short list of small island developing states that are undertaking MSP.

Why was marine spatial planning introduced as a concept in 2006? Initially, the intention was to develop marine protected areas in a transparent way, involving stakeholders from the sectors that would be affected by, or benefit from, the MPAs (e.g., Australia’s Great Barrier Reef). Then, as MSP grew, the rationale expanded to address rapid growth in the marine economic sectors, shifting consumer demand for more food, energy, and trade, and an increasingly larger proportion of goods and services coming from the marine environment as space and resources became more limited on land. MSP takes its origins from, and integrates the concepts of, ecosystem-based management and environmental impact assessments. In fact, professionals that are involved in these other fields can find the terminology confusing because the concepts are quite interchangeable.

Generally speaking, there are two ways to approach an MSP: by developing a strategic framework or by developing a comprehensive spatial plan. Whether one or both are completed will depend on whether it is considered a “marine spatial plan”; if a *non-spatial* strategic plan is completed, IOC-UNESCO generally will not consider this to be an MSP (e.g., Canada’s plan for the Pacific North Coast Integrated Management Area, PNCIMA). Strategic plans are a high-level output from a planning process that identifies key strategies for managing the ocean, and typically they develop decision-making frameworks (Table 7.1). Strategic plans are usually not spatial, do not involve analyses of spatial data, may or may not have full stakeholder participation, and usually are policy documents rather than regulatory plans. A strategic plan may only take a few years to complete; it can be an important

Table 7.1. Characteristics of Strategic versus Comprehensive Zoning Marine Spatial Plans

| Typology | Description |
|---------------------------|--|
| Strategic Plan | <ul style="list-style-type: none"> • Develops a strategic framework for making decisions • Identifies priority strategies • Usually is not spatial; may be the first phase of a marine spatial plan • Identifies available information and key data gaps • May include an integrated management plan • Has stakeholder input that may or may not involve all sectors • Typically takes 2 to 4 years to develop • Often serves as policy guidance, not regulatory • <i>Examples:</i> Canada (PNCIMA); Malta |
| Comprehensive Zoning Plan | <ul style="list-style-type: none"> • Develops a spatial zoning design for existing and future activities and uses; multi-sectoral • Employs spatial analyses including integrated stakeholder layers, tradeoff analysis, and MPA network design • Includes a management plan identifying allowable activities, restrictions, and prohibitions • Relies on robust stakeholder engagement and participation • Typically takes 4 to 10 years to develop • Is enforceable through legislation and regulations • <i>Examples:</i> Norway; The Netherlands; Canada (MaPP); Belgium (v2) |

Source: The Nature Conservancy.

first phase of MSP if the time is also used to develop a spatial database and organize stakeholder engagement for spatial planning.

In contrast, comprehensive zoning designs are highly detailed plans involving spatial analyses to allocate space for uses and activities. Comprehensive zoning plans should also include (but have not always included) spatially explicit management considerations for implementing and managing activities within the zones, and they involve all key stakeholders. Data gathering, analyses, zoning and a participatory process can be time-consuming, so zoning plans typically take several more years to complete than strategic plans.

According to IOC-UNESCO's website (updated as of March 2017), 11 countries have completed marine spatial plans (for a total of 16 plans), 11 countries have approved plans (for a total of 13 plans), four countries have implemented their marine spatial plans (for a total of 5 plans), and two countries have completed a five-year review (Table 7.2.)—totaling almost 40 plans, globally. In addition, 12 countries have MSP underway and another 21 countries have either indicated that they will have marine plans by 2021, or the planning directives suggest that they will have by 2021, including Mauritius. The European Union (EU) issued a Directive for MSP in July 2014 that all EU countries must complete an MSP by 2021. There are an additional 9 countries with interest, proposals, pilots or pre-planning activities. All told, these efforts involve 61 countries and 87 different plans.

There are huge ranges in the size of the planning areas for completed MSP processes, in how long the process lasts, and in the legal status for

Table 7.2. Nations With Marine Spatial Plans, Completed or Under Development, as of 2016

| Status | Nation or State |
|--|--|
| Implemented and 5-year review | The Netherlands; Norway; Belgium |
| Implemented | Australia; Canada; Germany; United States (2) |
| Approved | Belize; Canada (2); China; Philippines; United Arab Emirates; United Kingdom; United States; Vietnam |
| Completed | Antigua and Barbuda; Cambodia, Canada (4); Fiji; Latvia; Mexico; New Zealand; St Kitts and Nevis; South Africa; United Kingdom; United States (3) |
| Development now under way | Angola; Iceland; Indonesia; Mexico; Montserrat (UK); Namibia; Puerto Rico (USA); Seychelles; Thailand; Vietnam; United Kingdom (3); United States (4) |
| Will have by 2021 | Bulgaria, Colombia; Croatia; Cyprus; Denmark; Estonia; Finland; France; Greece, Ireland; Italy; Lithuania; Malta; Mauritius; Poland; Portugal; Romania; Slovenia; United Kingdom |
| Interested, proposed, in pre-planning, pilot, or uncertain | Australia; Costa Rica; Dominica; Grenada; Israel; Madagascar; Mauritania; Netherlands; Russia |

Source: IOC-UNESCO website; The Nature Conservancy.

implementation (Table 7.3). It can be expected that an MSP process can take up to six years, depending on how much pre-planning work is done and when a government determines it has started MSP. The

Table 7.3. Sizes, Legal Status, and Completion Times for Selected Marine Spatial Plans, 2003–16

| Year | Country | Name of Plan | Size of planning area (km ²) | Legal status | Time to complete |
|------|-----------------|---|--|--------------|------------------|
| 2003 | Belgium | North Sea | 3,600 | Advisory | 3 years |
| 2006 | Norway | Barents Sea – Lofoten | | Advisory | |
| 2009 | Norway | Norwegian Sea and North Sea | 1,200,000 | Advisory | 4 years |
| 2005 | The Netherlands | Spatial Planning Policy Document | 58,000 | Advisory | 2 years |
| 2009 | The Netherlands | Policy Document of the North Sea | 58,000 | Advisory | 2 years |
| 2010 | The Netherlands | National Water Plan 2010 | 58,000 | Advisory | 1 year |
| 2014 | Belgium | New Belgian Marine Spatial Plan | 3,600 | Legislative | |
| 2015 | Canada | Marine Plan Partnership for the North Pacific Coast (MaPP) | 103,000 | Advisory | 4 years |
| 2015 | The Netherlands | National Water Plan 2016–2021; North Sea Policy Document | 58,000 | Advisory | |
| 2016 | Belize | Belize Integrated Coastal Zone Management Plan 2016 | TBC | Legislative | 6 years |
| 2016 | New Zealand | Sea Change – Tai Timu Tai Pari (Hauraki Gulf Marine Spatial Plan) | 12,000 | Legislative | 3 years |

Source: IOC-UNESCO, individual plans, The Nature Conservancy.

planning area tends to be a specific region or area, a territorial sea, or an exclusive economic zone (EEZ). Once marine plans are completed and approved, they may be implemented as advisory or regulatory. If plans are advisory, it typically means that the plan contains information that will inform, or provide advice, during decision-making. For example, in Canada, the Marine Planning Partnership (MaPP) is an advisory plan and is consulted, for example, to inform decisions for permits and tenures in the marine environment.

In contrast, the Belgium MSP is a regulatory plan, and so is the Belize Integrated Coastal Zone Management Plan. Regulatory plans have more teeth when it comes to implementation; instead of a “should follow” approach to future decisions they issue “must follow” directives. However, not all governments will have the existing legislative instruments to make a plan regulatory, so if new regulations are needed, this should be built into the MSP timeline. Notwithstanding the strengths of a regulatory plan, if an advisory plan is well written, with good support and buy-in from both government and stakeholders, it can be very effective.

It can be difficult to identify when a planning process actually begins because there is a lot of preparatory work that goes into the initial steps and this period may or may not be counted as “planning” years. For example, for a marine planning process in Canada’s Pacific Ocean, planning discussions started in the mid-2000s with information gathering and identifying of needs, authority, and funding. During this time, a marine conservation analysis group also began the process of compiling best available data and identifying high-priority marine conservation areas using Marxan.⁴ This analysis took more than six years, with more than 100 expert scientists, stakeholders and reviewers (2006–13), and it created a spatial data catalog that is still maintained to support decisions and other planning processes. The marine planning process occurred between 2011 and 2015, leaving the impression that it “only” took four years.

Given that there are nearly 40 completed marine spatial plans, it is helpful to think about what can be learned from these processes, in particular what worked well. It is more difficult to characterize specifically what did not work well in a particular planning process, because such information is rarely published; however, we address it in the summary of Global Best Practices and “lessons learned,” below. The following

⁴ British Columbia Marine Conservation Analysis, available at <http://bcmca.ca> (accessed January 12, 2017).

descriptions illustrate the processes used for the types of questions or issues that may also need to be addressed in Mauritius.

Belgium – Master Plan for the North Sea

Belgium was among the first countries to implement an operational, multi-use MSP that covered its territorial sea and EEZ—its sea constitutes about 10 percent of the country's territory. The first plan was advisory and addressed the main drivers: offshore wind and EU requirements for protecting natural areas (Natura 2000 sites). The country then developed a master plan to allocate space for specific maritime uses, implemented starting in 2003, and then created a new MSP in 2014 to lay out principles, goals, objectives, and a long-term vision. This new plan is legally binding and will be reviewed every six years. This approach may work well for Mauritius if improvements are needed in how decisions are made before a spatial plan can be developed. The approach builds an MSP in two phases, where the first plan is an advisory decision-making framework and the updated plan is spatial.

Norway – Barents Sea – Lofoten Area and Norwegian Sea and North Sea Area

The Barents Sea—Lofoten marine plan was first announced in 2001–02 and was completed in 2006. It clarifies the overall framework and encourages closer coordination and clear priorities for managing Norway's sea areas. These priorities increase predictability and facilitate coexistence among industries that are based on the use of the sea areas and their natural resources. The purpose of the management plan was to provide a framework for the sustainable use of these natural resources and goods and maintain some structure, functioning, productivity, and diversity of the areas' ecosystems. The first update, made in 2011, includes new knowledge, including mapping of the seabed, seabird populations, and geology of the area. Also updated was information on ecosystems, ecological goods and services, and key resources for value creation, trends in impacts, pressures, and environmental risk. The Norwegian and North Sea Area marine plan was developed to establish the overall political and strategic framework and guidelines for management across economic sectors, including fishing. An integrated ecosystem-based management plan was developed from 2007 to 2009, modeled after the Barents Sea plan. It covers 1.2 million square kilometers and is aimed at both creating value for the Norwegian economy and maintaining nature conservation.

Future development was included, such as offshore wind energy. The plan lays out management measures for the petroleum, fishing, and marine transport industries as well as conservation. In 2013, Charles Ehler felt

that the top three plans in the world were those in Norway, Belgium, and the Netherlands;⁵ at that time, there were very few comprehensive plans completed. The Norway plans are particularly helpful to examine, because they have not only been implemented but also recently completed their five-year review. The approach in Norway has been to develop area plans, rather than an EEZ plan. This may be a helpful approach for Mauritius if the planning areas are unique or distinct enough to warrant separate plans (e.g., for Mauritius and Rodrigues islands).

The Netherlands – National Marine Spatial Planning

The marine planning in the Netherlands has been under way since the initial efforts in 2005 to prevent fragmentation of marine space and promote efficient use. A new MSP was introduced in 2009 in response to the increasing interest in new activities in the North Sea—notably, developing offshore wind farms in a manner that would not interrupt the busy navigation routes. There was also a growing demand for establishing a framework for governmental coordination of these developments. The Netherlands is a great example of a plan that focused on planning for a specific future development of one activity (offshore wind) and minimizing impact on another current activity (shipping). The Netherlands planning process was not comprehensive, and it did not engage with all possible stakeholders, so in the context of Mauritius it may be a type of plan that would be helpful for the deep, offshore waters, where the main interests are deep-sea mining (future activity) and fishing (current activity).

Canada – Marine Plan Partnership for the North Pacific Coast (MaPP)

This is a comprehensive marine plan for zoning in the Province of British Columbia, covering about 103,000 square kilometers. One of the significant aspects of this plan is the co-led partnership between the provincial government and 17 First Nations governments, the first such planning process in Canada. MaPP developed three zone types and identified more than 14,000 square kilometers of proposed new protected areas. A cultural and economic development zone type was created—known as a Special Management Zone—that identified important spatial locations for First Nations culture, aquaculture development, renewable energy development, and new or emerging tourism opportunities. This MaPP planning process may be useful for Mauritius to examine because of strong similarities with the North Pacific Coast: both are large geograph-

⁵ Based on a personal communication with Charles (Bud) Ehler, Senior Consultant, Marine Spatial Planning, Intergovernmental Oceanographic Commission, UNESCO.

ical areas, there is more than one distinct region for the plan, governance occurs at both a national and a regional level, there is a need for regional consistency and regional flexibility in terms of planning objectives and outputs, and there are simultaneous planning processes or efforts underway. The MaPP study area contains far fewer people than Mauritius, so the process design elements, for example stakeholder engagement, would need to be carefully reviewed and not just replicated.

Belize – Integrated Coastal Zone Management

This integrated coastal zone management plan in Central America relies heavily on ecosystem-services modeling and creates multiple scenarios for development along the coast of Belize and offshore. It is driven by severe threats from population growth, construction, and overfishing, and is legislative in nature. The coast of Belize is home to the world's second longest unbroken reef system, the Belize Barrier Reef, which contains a rich diversity of species, including three atolls and extensive mangrove forests. The Belize plan is a great example of a plan that has integrated coastal and offshore objectives and used an ecosystem-service approach to create scenarios and evaluate tradeoffs. The plan is legislated, and an implementation plan is currently being developed.

Global Best Practices

The IOC-UNESCO, the Nature Conservancy, the Environmental Law Institute, and others agree that to be effective, an MSP must be

- Ecosystem-based
- Integrated
- Place- or area-based
- Adaptive
- Strategic and anticipatory, and
- Participatory.

These six principles are inseparable. These underlying principles also align with the concept of ecosystem-based management, an integrated approach that considers cumulative impacts of all activities to maintain (or restore) ecosystem resilience. When conducted using global best practices, MSP recognizes the interconnections between ecosystem structure and function and seeks to integrate ecological, social, economic and governance (or institutional) perspectives.

What are some of the global best practices for MSP? There are several good resources that answer this, notably Beck et al. (2009) and Collie et al. (2012), as well as the consistent approaches found among

plans that have reached implementation. The latter include: (i) identifying the planning area; (ii) identifying a clear spatial boundary; (iii) choosing the geographic scale and resolution of planning that is achievable with available resources; (iv) performing data collection and management; (v) formulating clear objectives; (vi) devising interactive decision support systems; (vii) having a clear government mandate; and (viii) responding to obvious drivers and needs with clear timelines and sufficient resources. However, because most MSPs are still fairly young, with implementation still in the early stages for all but three plans, we could say that these are not so much “best” as “good” practices, because the best practices have not yet been fully identified or tested.

To this list, we could also now add: (i) developing implementation plans during the planning process; and (ii) identifying implementation funding, governance structures, staff capacity, and priorities as early as possible to ensure there is no break in momentum from plan to implementation. The first plans that were completed did not have strong implementation strategies; most plans have taken several years before implementation; and some approved plans have still not been implemented. In contrast, some current planning processes have used innovative financing mechanisms, like debt swaps, to create long-term funding mechanisms for implementation and even to help support some of the planning (e.g., Seychelles). There is a market for impact investors who are looking for opportunities to leverage financial support in return for “green” outcomes.

In addition to the good practices listed above, we can identify some lessons learned from adopting these practices on-the-ground and speak to the challenges that some of the MSP principles create so as to allow Mauritius to learn from these experiences (Smith, unpublished). These are described next.

Decision-making and Governance

Transparent decision-making is critical and requires a strong governance framework. Create a governance framework at the beginning of the MSP and ensure that there is representation from government and stakeholders at all levels of the framework, from executive or ministerial committees to technical working groups. The approvals process for MSP outputs and finalizing a MSP will likely be developed near the end of the process and should be discussed as soon as possible. Governance frameworks may need to be adapted, revised, or updated so they should be reviewed no less than annually and revised to reflect any gaps or issues with representation. Clear communication and transparent decision-making goals are key for developing trust and for changing the status quo of “top down” decision-making that lacks input from affected economic and social sectors.

Spatial Data

Most geographies do not have enough information to make science-based decisions for all possible activities however this should not hold up the process. Rather than develop data inventories for all possible uses or issues, clearly define the scope for the MSP and decide what data are required from that list. Also, there typically are data gaps for human uses or sectoral spatial information that can be overcome using participatory mapping and optimization models; generally in all MSP processes there is an ongoing need to develop or identify spatially-explicit data for socio-economic uses. To that end, building a flexible spatial data framework in a GIS that is adaptive to changes in the MSP Spatial Data Catalogue is an important element of a planning process; data layers will be added throughout the entire process. All spatial data will need to be viewed and reviewed by stakeholders, especially sectoral uses but also data on biodiversity for species and habitats. Some marine planning processes use a decision-support tools (DSTs) such as an online data layer viewer and planning tool to share spatial information with process participants and engage them in interactive sketching and analyses (like SeaSketch). DST's that do not require internet connections include Adobe GeoPDF, a product that can be formulated to hold more than 50 data layers and have participatory map in using plugins. Spatial data can also be viewed using an online and/or printed MSP atlas, a relatively modestly priced planning tool that can bring a process to life.

Resolution of the Planning Outputs

Choosing at what resolution the data need to be identified is a critical decision, and it should be made such that it matches or aligns with both the planning objectives and the availability of spatial data. For example, an EEZ-wide MSP does not usually require high-resolution data if the zones or planning units are going to be thousands of square kilometers large. If, however, the MSP is for a much smaller area and the zones are expected to be similarly small (tens of square kilometers), then coarse-scale data will not be adequate to support evidence-based decisions (Box 7.1).

Timelines

There is never enough time. Timelines or workplan milestones are always a challenge and are often too ambitious given the amount of uncertainty in a planning process, but without timelines and deadlines things will not get done. Output development during a rapid timeline can be overcome by limiting the number of planning objectives, increasing staff, increasing the number of consultancies, and creating realistic milestones (with the understanding that they might change). An MSP

is, by nature, a political process, so other factors, such as elections, can affect timelines, and a planning process must adapt and keep moving forward as best as possible. Sometimes, a planning process cannot move forward publicly while stakeholder consultations are still underway; however, there is usually much to be done behind the scenes, so to speak, that does not need extensive stakeholder review (e.g., compile new data, write methodology text).

Integration and Synergies

As in other MSP processes around the world, Mauritius will have simultaneous and parallel initiatives or projects in their marine waters that need to be integrated, aligned with, and synergized with the objectives of the MSP process to avoid redundancy, or legal issues related to authority and jurisdiction. It is important to identify all of these projects early on and dedicate staff time to tracking and integrating them with all relevant initiatives. During stakeholder meetings, dedicate an agenda item to ask for updates and information on new activities or initiatives to understand objectives, outputs, and timelines.

Land-sea Linkages

Depending on the nature of the activities and the environmental damage or issues in a planning area, an MSP should include both coastal and marine areas to explicitly make the connection between land and sea for planning. At the very least, any new marine protected areas should consider the adjacency of terrestrial protected areas to enhance the level of protection for both areas.

Stakeholder Engagement

Stakeholder engagement is an essential MSP “best practice.” The difficulty of the engagement can vary—from easy to achieve to complex to achieve—depending on the geography and existing organization of stakeholders in associations or committees. Stakeholder support funding can assist with engagement before, during, and after meetings to provide input on planning outputs. A stakeholder engagement framework needs to be transparent, flexible, and adaptive to stakeholders’ needs; it is important to monitor and evaluate stakeholder engagement on a regular basis and encourage stakeholders to comment on and contribute to the structure of the governance framework.

Staff Capacity and Training

The challenge of having enough staff (and consultants) to undertake all aspects of an MSP can be immense, and it is likely to remain so. It must be managed with respect to timelines and outputs, yet nearly

every process suffers from being understaffed. Building local capacity is important, as is having access to training, mentors, advisors, and experts.

Keep Moving Forward

Planning processes can face many obstacles to moving forward, ranging from minor barriers that can be overcome with innovation and creativity (e.g., lack of spatial data for a particular sector) to significant political barriers that cause a process to come to a temporary halt (e.g., elections). Regardless of the obstacles, it is important to keep moving forward and making progress. Also, there may be instances where certain sectors choose to withdraw or temporarily not participate because of governance or decision-making issues and progress must still be made in other areas.

Key Marine Environmental Issues in Mauritius

A key step in preparing for an MSP is to identify and understand the issues, opportunities, and trends in both the environmental and economic sectors. The other chapters in this book provide a summary of the key economic sectors in relation to the OE in Mauritius. What follows here is a brief summary of the condition of, and threats to, key habitat or ecosystem types in relation to human uses and activities in Mauritius. It is crucial to get agreement from government and stakeholders on the list of environmental issues, and decide what is inside and what is outside the scope of an MSP process—this list is not meant to provide that scope. It may be necessary to place limitations on the scope of the planning relative to the list of issues that are identified by stakeholders to align with resources available and the timeline of the MSP. It is perhaps helpful to realize that rarely can all issues be addressed or resolved in the first version of a marine plan and that it is advisable to regularly review and update a marine plan. What is important is to identify, prioritize, and include those issues of greatest urgency where recommendations are likely to be actionable—realistic deliverables are key to retaining momentum in a planning process and carrying it through implementation.

In order to ensure an efficient and sustainable management of marine uses and activities in Mauritius, scientific information is needed, such as biophysical characteristics, carrying capacity, and ecosystem service values. Maritime surveillance can provide authorities with a picture of what is happening at sea with respect to pressure on marine resources and improve monitoring and enforcement.

In Mauritius, the main environmental problems for corals, fish, lagoons, mangrove, and seagrass are associated with human activities,

Table 7.4. Key Anthropogenic and Climate-Change Stressors in Mauritius, by Habitat and Ecosystem

| Key stressors | Key habitats and ecosystems | | | | | |
|-----------------------------------|-----------------------------|----------------------|-------------------------|------------------|----------|----------|
| | Coastal shoreline | Coral reef ecosystem | Fish – reef and coastal | Lagoon ecosystem | Mangrove | Seagrass |
| Agricultural run-off | | x | x | x | | x |
| Climate change: sea level rise | x | | | x | x | |
| Climate change: ocean temperature | | x | x | | | |
| Coastal development | x | | x | | x | x |
| Fishing pressure | | x | x | x | | x |
| Oil spills | x | x | x | x | x | x |
| Plastic pollution | x | x | x | x | | |
| Sedimentation and Siltation | | x | x | x | | x |
| Wastewater pollution | | x | x | x | | x |

Source: The Nature Conservancy; references cited below.

in some cases multiple human activities (Table 7.4). The key anthropogenic stressors are agricultural run-off, fisheries pressure and overfishing, wastewater pollution, sedimentation of nearshore habitats, loss of mangroves⁶ and seagrass, destruction of coral reefs, and erosion from coastal development. Two significant climate change related issues are sea level rise and warm ocean temperatures. Water pollution is caused mainly by sewage and agricultural chemicals entering the coastal ecosystem. Plastic pollution is caused by garbage entering the ocean, including microplastics, and is a threat to fish, seabirds, whales, turtles and nearly all marine life.

Anthropogenic (human-made) stressors can harm a variety of biota and ecosystem services. Similarly, a single biota or ecosystem service may experience cumulative effects from multiple anthropogenic stressors. Table 7.4 illustrates some of the key linkages between stressors and biota/ecosystem services in Mauritius—although the matrix may not account for all the potential downstream effects of each stressor and the indirect effects to other ecosystem components, species, or habitats.

Coral Reefs

Healthy coral reefs are hotspots of biodiversity (Bellwood and Hughes 2001) and are also economically important, especially to the tour-

⁶ There has been a historical loss of mangroves, although restoration efforts are now increasing their area.

ism and fisheries sectors (Naim, Pascale, and Mangar 2000; Spalding, Ravillious, and Green 2001). Anthropogenic stressors include increased sea surface temperatures due to climate change, water quality degradation, destructive fishing practices, and sedimentation. On a global scale, climate change is considered a major threat to coral reef habitats (Hoegh-Guldberg 1999). In 1998, reefs in the Western Indian Ocean (WIO) experienced a widespread bleaching event associated with elevated sea surface temperatures (Turner 1999; Turner et al. 2000). While the impacts on Mauritian reefs were not as severe as on other WIO reefs, mild bleaching events were nevertheless widespread (Moothien-Pillay, Terashima, and Kawasaki 2002; Turner and Klaus 2005). As coral bleaching events continue to occur in the region, concerns about bleaching due to climate stress remain (Ramessur 2013).

In Mauritius, the primary stressors on coral reef ecosystems are thought to originate with more localized pollution sources (sewage, industrial effluence and agricultural run-off), which lead to eutrophication and sedimentation (Baird 2013). Coral die-offs have been observed in lagoons containing high nutrient loads (Ramessur 2002), and in 2012 live coral declines of 10–30 percent in coastal lagoons were attributed to deterioration in water quality from industrial wastes (Ramessur 2013). These stressors can also have a combined effect. For example, one study concludes that the combination of eutrophication from sewage outfall and overfishing could further degrade Mauritius reefs by promoting overpopulation of grazing urchins (Thomassin et al., 1998). Other destructive fishing methods (including large net fishing and basket traps) can also physically damage corals, as can activities associated with tourism (including reef walking, boating, and snorkeling) (Turner and Klaus 2005; Ramessur 2002).

Fisheries

Fisheries are a pillar of the Mauritian OE—with production valued at over US\$580 million per year, and the sector employing about 20,000 people (Kelleher 2016). Healthy fisheries are also associated with enhanced revenue from tourism (Sobhee 2006), and artisanal fishing in lagoons and reefs matters both culturally and as a source of food security to some coastal communities. In Mauritius, artisanal fisheries are becoming increasingly overfished and will likely exceed, or have already exceeded, sustainable catch levels (Turner and Klaus 2005; Kelleher 2016). Although limited data make it difficult to assess the overall status of the fisheries (Van der Elst et al. 2005), a key concern is overfishing, particularly of coral reef fisheries (Turner et al. 2000; Boistal et al. 2011). Fortunately, measures are in place to encourage artisanal fishers to fish outside of the lagoon using fish aggregation

devices (Ramessur 2002), and expanding aquaculture activities is being promoted as a more sustainable complement to exploiting wild fisheries (Ramessur 2002; Kelleher 2016).

While fishing practices can impact ecosystems, the health of ecosystems can, in return, affect the health of fisheries. One recent study found that coral reef fisheries in Mauritius had relatively low vulnerability to stress from climate change, yet climate stress on coral reef ecosystems was a concern (Cinner et al. 2011). Degradation of water quality in fish habitats (like lagoons and coral reefs) can also be expected to harm fisheries overall.

Lagoons

As lagoons provide a habitat for coral reefs, water quality and ecosystem dynamics in Mauritian lagoons constitute important environmental issues. Increasing development in the coastal zone has resulted in more sewage discharge into lagoons, resulting in an overall degradation of water quality. One study in the early 2000s noted an algal invasion resulting from eutrophication in the Blue Bay lagoon (Ramessur 2002), and another study noted algal blooms that indicated excess nutrients in the Péréybere, Grand Bay, and Palmar lagoons (Baird 2013). Another major stressor on coral reef ecosystems is poor water quality, which can come from polluted lagoons—and agriculture is believed to be the primary source of dissolved phosphate in lagoons via leaching from groundwater. Heavy metal contamination has been documented in lagoons, and hot spots of sediment, seawater, and biotic contamination were found in locations associated with untreated sewage and/or industrial effluent (Daby 2006). Submarine groundwater discharge is another possible source. (JICA 2013; Ramessur 2013).

The shoreline of the Flic en Flac lagoon is a popular public beach. A study of this lagoon's physical, chemical, and biological characteristics for 1999–2000 notes relatively stable water quality parameters, including safe levels of coliform indicators (Chineah et al. 2002), but this and similar studies highlight the value of continuing to monitor water quality at popular tourist sites. There is also a potential for sea level rise to indirectly impact ecosystem dynamics in coastal lagoons by introducing non-native species from other parts of the lagoon-reef complex, although the severity and the nature of that threat is not easily predicted (Baird 2013).

Oil spills are another concern in the lagoons. In 2016, the motor vessel *Benita* sank off the coast of Le Bouchon, in the southeast of Mauritius. The spill was immediately put under control in order to prevent the oil from reaching the Blue Bay Marine Park, a protected area and Ramsar convention site; however, the oil spill did reach the coast

of Brocus Island, near Le Bouchon, and caused environmental damage. Development in the port area plus an increase in vessel traffic entering the territorial sea are concerns for future oil spills and the risks to the fragile ecosystems in the lagoons and throughout Mauritius.

Mangroves

Mangroves are important coastal ecosystems in Mauritius because they offer a buffer against coastal erosion and wave action, protect lagoons from the effects of sedimentation, and provide habitats for ecologically and economically important wildlife (Mauritius 1991; Appadoo 2003). The major threat to mangroves is habitat loss due to development for residential, industrial, commercial, and agricultural purposes—and studies show that Mauritius experienced a loss of 30 percent of its mangroves between 1987 and 1994 (Mauritius 1991; Ramessur 2002; Appadoo 2003; Mamoun, Nigel, and Rughooputh 2013). Many mangroves are located in close proximity to highly developed areas and face continuing threats from the prospect of their continued expansion (Hammond et al. 2015). Although mangrove coverage continues to decline, a mangrove restoration program has been instituted, and as of 2010 nearly 23 hectares had been restored (Mauritius 2010).

Coastal Shoreline

Many areas of the coastline have experienced high levels of erosion due to natural events such as cyclones (Ramessur 2002). Development of coastal areas can further exacerbate coastal erosion, which can decrease protection from, and resilience to, sea level rise. In addition, the loss of mangrove habitats can leave coastal communities vulnerable to the impacts of coastal erosion and damage from waves. Sea level rise can lead to increased storm run-up and wave action, which can damage coastal areas. For example, heavy rainfall and subsequent flash flooding attributed to climate change have both been increasing in recent years, particularly in the Port-Louis area (Ramessur 2013). Although coastal protection projects have been implemented in a number of locations, existing shoreline protections are likely to be inadequate in preventing increasing rates of erosion throughout the island, which in turn is expected to harm infrastructure, ecosystems, and by extension, tourism (Ramessur 2002).

Seagrasses

Loss of seagrasses can harm fisheries and contribute to coastal erosion (Fonseca 1989; Gullstrom et al. 2002). Eutrophication, sedimentation, bottom trawls, and other seafloor activities can also damage seagrass beds (Kemp et al. 1983; Tomasko, Dawes, and Hall 1996; McGlathery 2001; Gullstrom et al. 2002; Ramessur 2002). In the West Indian Ocean,

increasing coastal populations and overexploitation of resources are putting seagrass populations at risk. (Gullstrom et al. 2002). Historically, sand mining in coastal lagoons has contributed to the degradation of seagrasses; however, after sand mining was banned in Mauritius in 2001, some recuperation of seagrasses has been observed (Mauritius 2010).

Data for Environmental Issues

All of the aforementioned environmental issues require associated data in order to evaluate condition, threats, and status for a planning process in Mauritius. In any MSP process, there are data and knowledge gaps and processes that tend to be characterized as “data poor” or “data rich” according to status of available data and its quality. While it is doubtful that any MSP process has all the data necessary for making every decision, this does not and should not prevent a process from moving forward. Sometimes data can be created, and at other times questions may need to be modified or addressed later, when the missing data become available. If data are not available and a decision is necessary, then proxy data or other information may help to inform the decision, or a decision can be made with a notation on what basis it rests for the sake of full transparency. Given the list of environmental issues in Mauritius noted above and elsewhere in this book, an assessment of data needs and an inventory of available data will reveal the data gaps and provide important perspectives on what is possible to address now and what will need to be addressed in the future.

For example, an up-to-date map of coral reef cover will be needed to address coastal protection and restoration objectives and priorities, including in relation to coastal protection and coral reef restoration. In Mauritius, the most recent survey of coral reef cover was done in 2012–13, conducted by the Japan International Cooperation Agency (JICA) in support of the Ministry of Environment, Sustainable Development, Disaster and Beach Management (MoESDDBM) for a project related to capacity development on coastal protection and rehabilitation in Mauritius (JICA 2015). This and all other datasets will need to be examined and evaluated for their application to address MSP objectives.

In summary, an inventory of available ecological and socioeconomic data will reveal what can and cannot be addressed during a planning process, and strategies developed to gather or create new data for future revisions.

Existing Marine Protected Areas

One aspect of understanding the state of the environment is to inventory existing marine protected areas and have a clear understanding of

the current level of protections afforded to the marine environment in Mauritius as well as international commitments. The Republic of Mauritius is committed to the 2030 UN Sustainable Development Goals, which call for 10 percent marine protection by 2030; currently marine protected areas comprise less than 1 percent of the country's EEZ. Mauritius ranks third in the world for the number of endangered species (2001), and according to the International Union for the Conservation of Nature (IUCN) and the United Nations Environment Programme's World Conservation Monitoring Centre (UNEP-WCMC), only 50 square kilometers of marine waters are covered by marine protected areas (MPAs), constituting less than 1 percent of Mauritius's total marine area (note that this area does not include marine reserves or the marine protected area in Rodrigues).⁷ There are 31 areas with marine protection in Mauritius, and each area falls into one of seven categories: marine parks, fishing reserves, marine reserves, marine protected areas, turtle reserves, and nature reserves (Appendix 5). It will be necessary to evaluate both the categories and the level of protection during the MSP process and decide if these categories or designations suffice, or if new categories should be considered, potentially through zoning.

Review of Administrative Instruments in Relation to Marine Spatial Planning

In view of making MSP a reality in Mauritius, six governmental and nongovernmental institutions are taking the first steps toward developing a marine spatial plan. It is important to understand the strengths of these institutions, and what activities are currently taking place. A workplan with timelines and outputs will also be needed to articulate the roles and responsibilities of the different institutions so as to support MSP within the context of Mauritius. The six institutions and their roles to date are described next—as the MSP progresses, the roles of these institutions may change.

Prime Minister's Office

In December 2016, Cabinet approved the elaboration of an MSP in the EEZ of Mauritius. At the level of the Prime Minister's Office, research is currently being undertaken with regard to MSP to ensure smooth management and implementation of the plan.

⁷ Unless less otherwise cited, information on marine reserves in this chapter is derived from IUCN and UNEP-WCMC (2017) and/or the MPA Atlas (Marine Conservation Institute 2017).

Ministry of Environment, Sustainable Development and Disaster and Beach Management

In the year 2000, an Integrated Coastal Zone Management (ICZM) Division was created under the aegis of the Ministry of Environment, Sustainable Development and Disaster and Beach Management in order to “maintain a high quality coastal environment and conserve coastal and marine biodiversity.” With the development of MSP in Mauritius and its outer islands, the ICZM Division will have the responsibility of ensuring that the plan’s implementation is sustainable, as well as engaging with other organizations to continue the preservation of marine biodiversity.

Ministry of Ocean Economy, Marine Resources, Fisheries and Shipping

This particular ministry will have a crucial role to play in the implementation of MSP in Mauritius. Being the parent ministry for the development of the OE, its major task will be to strike the right balance between ensuring economic growth and social development of the people on the one hand and ascertaining the sustainable use of aquatic resources on the other.

Mauritius Oceanography Institute (MOI)

The MOI is responsible for collecting, coordinateing, storing and disseminating information related to oceanography. Furthermore, it can help policymakers to make laws that can be tailor-made to protect the marine biodiversity of Mauritius and its outer islands. Referring to its mandate, the MOI would host the database framework to provide a centralized information system for MSP. The MOI serves as the technical arm of the Ministry of Ocean Economy, Marine Resources, Fisheries and Shipping. The mission of MOI is identified in a Strategic Plan 2016–2020 and further reinforced under the Budget Speech 2016–2017 and through the Sub-Committee on Agro-Economy, Ocean Economy, Tourism and Financial Services, under the Task Force on Economy. To support the MSP, MOI will develop a database of ocean parameters for aquaculture sites and a geographic information system (GIS). There are volumes of published, scientific studies of the marine environment in Mauritius, as well as many ongoing ocean studies in the region including studies of fish population genetics. The University of Mauritius (UoM) and the MOI will both play key roles in identifying the relevant information from those studies and developing new information and analyses necessary for an MSP.

National Ocean Council (NOC)

In 2015, the National Ocean Council was created with a mandate to coordinate the activities of the different stakeholders in development of

the OE. The NOC's mandate is to assess the provision of modern logistics, infrastructure and services for the development of the maritime and shipping industry and formulate a new action plan for the shipping industry.

University of Mauritius (UoM)

The UoM has received the mandate from the government to handle the training and education aspect of the OE concept. In line with this, in 2014 a Faculty of Ocean Studies was created at UoM to provide both postgraduate and undergraduate courses to students. Furthermore, research in the fields of marine and ocean science, ocean engineering, and maritime trade and finance is also being done by the academics in order to contribute to the development of the OE. In addition to the courses designed for students, workshops as well as conferences are being organized to inform the general public about the activities conducted in relation to the development of the OE.

Legal Issues and Recommendations

In addition to the capacity found at the above institutions, there are no fewer than 25 Acts or frameworks in Mauritius that are relevant to MSP. As is detailed in Appendix 6, in Mauritius there exists an extensive list of legal instruments that can be used for the implementation of MSP. Despite the presence of these laws, some gaps in policy do exist and are discussed below, with recommendations for the MSP.

The first gap that can be underlined is linked to the formulation of MSP in the existing laws. None of the acts listed in Appendix 6 gives a precise definition of marine spatial planning or elaborates on the concept. Despite the fact that there is the Integrated Coastal Zone Management Framework and other laws that embodies the *spirit* of MSP, none of the existing legislation in Mauritius actually serves as a unique legal tool to frame MSP. *It is recommended that, since the planning process is starting for the implementation of MSP in Mauritius, a legal framework be developed to outline the structure and legal implications involved in MSP.*

A second gap can be linked to conflict resolution. Although MSP aims at avoiding conflict among its users, there is always the risk of conflict arising. For the time being, not much has been stated about how conflicts are to be resolved among the various stakeholders. *It is recommended that a conflict resolution mechanism be developed to provide for an effective and efficient way of resolving conflict among the various users of the sea. It is being proposed that either (i) an Arbitration Tribunal should be established to provide for arbitration services as a way to solve disputes among the parties, or else (ii) parties should have recourse to the existing*

Environment and Land Use Appeal Tribunal, which would receive the mandate to settle disputes.

Thirdly, an observation that one may consider as a gap in policy relates to the status and definitions of Marine Protected Areas in Mauritian law. The Fisheries and Marine Resources Act 2007, at Section 4, provides for the types of area that can be classified as Marine Protected Areas. However, the intrinsic elements that a particular area is required to possess to be classified as a Marine Protected Area are not defined in this Act. For example, Section 4 states that the relevant minister can declare any area in a maritime zone—including the seabed underlying such zones—any land associated with the maritime zones, or any wetland to be a Marine Protected Area. Along with these, the minister may also designate a Marine Protected Area to be a Fishing Reserve; a Marine Park; or a Marine Reserve. What is being underlined here is the lack of information about what *features* in these above-mentioned areas justify their designation as a Marine Protected Area. *It is recommended that the law be reviewed to be more explicit about what characteristics a particular area requires to have the status of a Marine Protected Area. The advantage of doing so in the context of MSP will be that it will help the users to spot an area fulfilling the characteristics provided by the law and avoid using it for commercial purposes. Furthermore, with explicit features stated in the law, there will be more transparency as to the places that need to be protected as MPAs and areas that fall outside the definition can be used for other purposes. By having clearly defined MPAs and measures taken to conserve them, this will allow Mauritius to achieve the 10% coastal and marine areas to be protected as requested by the 2020 Aichi Biodiversity targets.*

Examples of Models for Marine Spatial Planning for Mauritius

The process of proposing models for MSP in Mauritius involved a number of steps after summarizing the aforementioned information about global MSP and lessons learned, environmental issues in Mauritius, legal instruments, and so forth. At a minimum, we need to understand what the enabling conditions are; what the drivers are; what the proposed objectives or needs are; what sectors are involved; what is the appropriate geographic scale to address the drivers and meet the objectives; and what is achievable given the timelines and resources.

Prior to proposing a model, a high-level review and analysis of enabling conditions in Mauritius was undertaken for this book. The Nature Conservancy's Global Oceans Team has developed a checklist to assist with this exercise, and based on the mission to Mauritius in September 2016, an initial assessment was completed (Table 7.5). The purpose of the checklist was to gain situational awareness for MSP

Table 7.5. High-level Summary of Enabling Conditions for an MSP in Mauritius, Assessed September 2016 and March 2017

| Criteria | Summary |
|--------------------------------------|--|
| Driver | Government and stakeholders say that planning is needed to plan for marine uses and avoid conflicts. The benefits to the OE can be translated through the sustainable development of sectors such as aquaculture, fisheries, tourism, ocean energy and biotechnology. ^a For these and other activities in the lagoons, issues that need to be addressed include overlapping and conflicting activities, as well as deep-sea mineral exploration, coastal beach erosion, and reducing the negative impacts of waste water and agricultural run-off to lagoons. Clear messages about objectives are needed, along with discussions on how one process would handle all these issues. ^b |
| Government authority | The Prime Minister's Office has the authority for marine spatial planning under the Maritime Zones Act, and MoESDDBM has authority to manage the "coastal zone" and +1 kilometer inland/offshore—both agencies are interested in MSP, and MoESDDBM in particular is interested in an integrated coastal zone management plan. |
| Government champion | At the National Ocean Council Workshop in September 2016, there was a lot of support for marine spatial planning—with likely champions being the Prime Minister's Office and MoESDDBM. Now, with the declaration of the MSP in December 2016, it will be decided who will lead the MSP in Mauritius. |
| Financial Resources | Funding for marine spatial planning is essential, but it is unclear where financing will come from for the MSP process and what the total amount needed in Mauritius will be. Innovative financing mechanisms like debt swaps and the creation of conservation funds can support implementation of MSP, and in some cases even the planning process itself. |
| Local staff capacity | The Prime Minister's Office and MoESDDBM have staff that either do planning or engage in other activities that support planning. Some ministries already have planning staff for land-use plans (including experience with GIS). In fall 2016, the Prime Minister's Office was hiring four new staff to advance an MSP (data portal, GIS database, and ocean observatory). The Prime Minister's Office has recent experience with spatial planning, siting a Deep Ocean Water Application near Port Louis. |
| Spatial data | There will be much data to evaluate in Mauritius and determine if it is at the scale needed for the MSP. The Prime Minister's Office will begin to compile data layers and build an ocean observatory and data portal. Mapping of the coral reefs is not up-to-date and will need to be a priority for MSP in the coastal zone; the last mapping was in 1996. MOI, UoM, and Mauritius Fisheries Institute are good sources of spatial data outside the ministries. The Prime Minister's Office is committed to developing an Ocean Observatory Database to begin collecting or collating data for the marine environment. In February 2017, the Department of Continental Shelf, and Maritime Zones Administration have initiated the development of a Geographical Information System and data catalogue to undertake the MSP. Stakeholders and strategic partners have begun the work of identifying relevant spatial layers to contribute to this system. |
| Scientific information and knowledge | There are volumes of published, scientific studies for the marine environment in Mauritius, and many on-going studies in the ocean including fish population genetics. The UoM and the MOI will play key roles in identifying and developing information and analyses necessary for a MSP. The MOI is responsible "to collect, coordinate, store, and disseminate information related to oceanography." MoESDDBM will be an important source of information related to climate change and coastal habitats. |
| Legal instruments | There are several acts that authorize marine activities; the Maritime Zones Act is a key piece of legislation for the authority to plan. An in-depth analysis of the legal instruments would normally be undertaken during a marine planning process once the outputs of a plan are decided to understand what is needed to implement an MSP (including new policy and laws). |
| Stakeholders consultations | Local stakeholders appear to be enthusiastic about participation and have recently attended a Coordinating Committee workshop. Some of the sectors are organized with associations, and it is unclear in terms of the number of staff and resources available for participating in a multi-year MSP process. |

Source: MSP Deep Dive Workshop; The Nature Conservancy.

Note: GIS = geographic information systems; MOI = Mauritius Oceanographic Institute; MoESDDBM = Ministry of Environment, Sustainable Development, Disaster and Beach Management; UoM = University of Mauritius.

^a Prime Minister's Office, Republic of Mauritius (March 2017).

^b MSP workshop, Mauritius Oceanographic Institute (September 2016).

(prior to the announcement by the government in December 2016) and identify possible gaps that may pose a challenge for an MSP process. This checklist helps to inform the type of MSP in Mauritius that could be undertaken immediately. For example, hypothetically, if it were learned that there were no spatial data at this time, the recommendation would be to focus on non-spatial tasks first, while the spatial data inventory was being developed.

In Mauritius, there are clear drivers for MSP such as siting for aquaculture, resolving spatial conflicts between fisheries, tourism and other activities in the lagoons, and addressing pollution and coastal erosion. There is a government authority for MSP and there is at least one government champion. While it is unclear what financial resources are available to undertake MSP, there appear to be staff resources in several ministries and a great interest in starting MSP. The availability of spatial data is being examined by the Prime Ministers' Office with support from the MOI, and there appears to be a robust scientific community with many published and ongoing marine studies. There are several relevant legal instruments, although this will need to be looked at much more closely during the MSP process itself. Finally, there was a positive reception for MSP from stakeholders who participated in an "MSP deep dive" held at MOI in September 2016. A proper assessment of capacity, resources and internal coordination will be needed before a framework for stakeholder engagement could be developed.

The environmental drivers that MoESDDBM has identified are: coastal protection, controlling beach erosion, climate change impacts, and controlling pollution of the marine environment (from wastewater and agricultural runoff). The economic drivers identified by the Prime Minister's Office include renewable energy, non-renewable resources (such as deep-sea minerals), and fisheries. The social drivers identified by the stakeholders include capacity building, collaboration, communication, participation, and dialogue (see Appendix 4).

Following the identification of the drivers, it is necessary to understand the objective(s) for MSP. On December 29, 2016, the government announced that it is preparing an MSP for the EEZ:

The main purpose of marine spatial planning is to identify the utilization of marine space for different sea uses in accordance with national policies and legislation, while taking into consideration the preservation, protection and improvement of marine environment, including resilience to climate change impacts. Furthermore, the Plan will also contribute to the effective management of marine activities and the sustainable use of marine and coastal resources through the creation of

a framework for consistent, transparent, sustainable and evidence-based decision-making. The elaboration of the Marine Spatial Plan is in line with the implementation of the 2030 UN Agenda for Sustainable Development and the Sustainable Development Goals.⁸

The government is proposing an ecosystem-based approach, looking to integrate coastal economic activities, dynamic coastal processes, climate/water cycles, living resources, preservation of ecosystem services, and non-living resources (Radal and Runghen 2016).

The proposed MSP would cover an area of about 2.3 million square kilometers, according to a Cabinet decision on May 27, 2016.

With a large EEZ, a decision will be needed about the scale of the MSP. What does an MSP's geographic boundary entail? It is typically understood to be from the high tide (or high water) mark to offshore waters. The offshore boundary is decided by the planning authority and could range from hundreds of meters to the entire 200 nautical mile EEZ. For Mauritius, the Prime Minister's Office has indicated that MSP will be for the EEZ. Typically, there is some overlap between the EEZ and the marine sectors in the country's territorial sea, yet there are several sectors that occur only in one of these geographies (Box 7.2). Thus, stakeholder participation needs to be tailored to the sectors that will benefit from or be impacted by the planning. The spatial scale of the use, economic or financial investments, and potential environmental impacts may be different between the coastal industries and the offshore industries, and this should be a consideration in planning with respect to how to engage the stakeholders and how often.

As for the Integrated Coastal Zone Management area (ICZM), it is usually defined as management of adjacent lands and waters, typically from one kilometer inland to one kilometer offshore. The integrated component of an ICZM means that it is for multiple sectors and that government agencies are integrated on decisions regarding objectives, strategies, management plans, budgets, staffing, implementation, monitoring, and enforcement.

Examples of MSP Models

Two examples of MSP models for Mauritius are presented, based on the review of information above, and discussions with government and stakeholders in Mauritius. Both models assume an ecosystem-based

⁸ <http://www.govmu.org/English/News/Pages/Marine-Spatial-Plan-to-be-elaborated-for-the-Exclusive-Economic-Zone-of-Mauritius.aspx>.

Box 7.2. MSP-Relevant Sectors: Territorial Sea and Exclusive Economic Zone**Sectors for an MSP in the Territorial Sea** (12 nautical miles):

- Aquaculture
- Artisanal fishing
- Commercial fishing, domestic (semi-industrial)
- Conservation and biodiversity protection (marine protected areas)
- Deep ocean water application (dowa)
- Dive charters
- Marine charters
- Offshore renewable energy
- Public recreation
- Sand and aggregate mining
- Sport fishing
- Sustenance fishing, and
- Tourism.

Sectors for an MSP for entire Exclusive Economic Zone (200 nautical miles):

- Commercial fishing (domestic)
- Commercial fishing (international, industrial)
- Deep-sea mining
- Marine charters (deep sea)
- Non-renewable resources
- Offshore renewable energy
- Petroleum exploration and development
- Public recreation, and
- Sport fishing (deep sea).

approach to the plan, using global best practices, incorporating lessons learned from other geographies, planning for multiple objectives including climate change adaptation, and that the planning area includes both the coastal and offshore marine environments. Given the December 2016 announcement to undertake MSP, these examples are provided based on analysis of MSP processes from 2006-present, with associated advantages and disadvantages.

Example 1: First, develop a high-level strategic framework for decision-making and management of marine economic sectors (see Table 7.1). The framework will guide development and future marine investments, identify the highest priorities in terms of environmental issues to address in Mauritius, and identify future developments likely to create spatial conflicts with existing uses. Implement and monitor the strategic plan for five years, revise and adapt where necessary, and then develop a

spatial plan with zones and management considerations. During the five-year monitoring period, spatial data are gathered, systematic conservation planning and other analyses are undertaken to identify high priority conservation areas, stakeholder engagement is organized and funded, and governance structures are developed. This would be similar to the approach that Norway used to develop a comprehensive MSP. It has the advantage of ensuring that the decision-making framework is robust, tested, and adapted based on government and stakeholder feedback before spatial planning begins. It also has the advantage that more spatial data are likely to be available in the second phase in order to make decisions. It has the disadvantage that allocation of space for new activities might not occur for up to 10 years and the urgency of MSP may be lost.

Example 2: Develop a decision-making framework and comprehensive zoning design simultaneously or sequentially, but without a period of adaptation prior to implementing the complete MSP. This approach has the advantage of planning for future activities within the next five to six years, planning for increased marine protection to meet the UN Convention of Biological Diversity goal (10 percent by 2020), immediately starting to address climate change impacts, generating momentum with stakeholders without any disruptions, and completing the whole plan before undertaking monitoring and a five-year review. It has the disadvantage that spatial data may not be available for all decisions and it may exceed resources available in the short-term (i.e., need more time for fundraising).

Making it Happen

Marine spatial planning has begun in Mauritius, with the first Coordinating Committee meeting in February 2017 to apprise stakeholders of the government's decision. A questionnaire survey was prepared and given to stakeholders to begin the process of identifying maritime space usage. The questionnaire requested stakeholders to identify priority use areas within the EEZ and Territorial Sea that need to be included in the planning. Also, it was proposed at that time to establish technical committees for each of the major sectors for the zoning and management plan creation.

Sequence of Steps

Once an overall approach is decided (see example models, above), the steps for MSP are fairly straightforward, although there are varying viewpoints on this as well. A 2009 report from the Environmental Law Institute prepared an excellent summary of the ideal stages of MSP, featuring steps from the Massachusetts Ocean Action Plan (Gopnik 2008)

Table 7.6. Two Step-by-Step Guidelines to the Preparation of a Marine Spatial Plan

| Massachusetts Ocean Action Plan | MSP Guidebook (IOC-UNESCO) |
|---|---|
| 1. Setting high-level policy goals | 1. Identifying need and establishing authority |
| 2. Issuing guidance documents for planners | 2. Obtaining financial support |
| 3. Conducting spatial assessments of the ecosystem and human uses | 3. Organizing the process through pre-planning |
| 4. Engaging stakeholders | 4. Organizing stakeholder participation |
| 5. Creating plans based on scenario analyses and negotiation | 5. Defining and analyzing existing conditions |
| 6. Drawing detailed maps with assignments of zones | 6. Defining and analyzing future conditions |
| 7. Issuing regulations | 7. Preparing and approving the spatial management plan |
| 8. Monitoring and enforcement | 8. Implementing and enforcing the spatial management plan |
| 9. Evaluation and adaptation | 9. Monitoring and evaluating performance |
| | 10. Adapting the marine spatial management process |

Source: Gopnik (2008); Ehler and Douvère (2009).

and steps from the oft-cited IOC-UNESCO *MSP Guidebook* (Ehler and Douvère 2009). The major difference between these two approaches is that the Massachusetts Ocean Action Plan specifically calls for scenario analysis and tradeoffs (or negotiation), whereas the *MSP Guidebook* does not. A comparison of the two approaches is laid out in Table 7.6. What may not be obvious from the table is that planning is iterative and will necessarily seem like it is going backwards in order to go forward. For example, new data must be integrated into the spatial data catalogue and developing updated spatial products, like maps and models.

The timeframe for completing MSP will vary depending on the specific objectives of the planning, but in general it could be expected to take from seven to 10 years from preplanning to “approved and regulated.” In Mauritius, there are numerous environmental issues, and several of the anthropogenic stressors are interconnected. Solving some of these issues may take time, and so may developing an integrated decision-making framework and the conflict resolution mechanism being requested by stakeholders.

MSP can be thought of as occurring in phases:

- Pre-planning: Identify need, authority, financial support, and spatial boundary: 1–2 years.
- Phase 1: MSP as a framework for decision-making: 2–3 years.
- Phase 2: MSP as a zoning design and approved legislation: 3–5 years.

A sample workplan for Example MSP Model 2 can be found in Appendix 4.

Climate Change Adaptation

In terms of climate change adaptation, what are the key areas where adaptation will be needed? Recent analysis suggests five areas for

Mauritius and other small island developing states:⁹ (i) reef resilience network and MPA network design criteria (ecological, social, economic); (ii) coral reef restoration; (iii) coastal resilience; (iv) ecosystem services; and (v) climate change adaptation measures.¹⁰

Specifically, this will entail making sure that the MSP does the following:

- Identifies priority areas for conservation and climate change adaptation;
- Identifies key species and habitats resilient to climate change, or with high genetic diversity;
- Identifies unique habitat types and the range of variation;
- Identifies threats and pressures;
- Identifies stressors and drivers;
- Maps coral reef cover (past, present, percent change, condition); and
- Maps mangrove cover (past, present, percent change, condition).

One of the key ways to adapt to climate change in the marine environment is to ensure functional resilience for marine biodiversity and ecological communities, as well as create a well-designed marine protected area network to ensure appropriate levels of protection for marine resources.¹¹ In designing an MPA network for climate change adaptation, the ecological criteria that have been developed and tested for the last decade or more are suitable: (i) connectivity; (ii) size and spacing; (iii) redundancy and replication; (iv) unique or rare species and habitat types; (v) spawning aggregations, breeding areas, and foraging areas; and (vi) representative habitats.

Challenges for MSP in Mauritius

In developing an MSP process in Mauritius, at least five challenges or considerations should be examined and considered while the concept is being implemented: (i) defining the role of each institution; (ii) MSP in the outer islands; (iii) coordination with Rodrigues; (iv) Joint Management Area with Seychelles on the Mascarene Plateau; and (v) international pelagic resources. These are next discussed in turn.

⁹ http://environment.govmu.org/English/Climate_Change/Pages/Climate-Change.aspx.

¹⁰ Based on a World Bank global analysis (2010) and MoESDDBM.

¹¹ Not all marine ecosystems require the highest levels of protection as described by the IUCN (such as IUCN's Category 1a: No-take marine reserve). The level of protection should ideally be assigned based on the condition of the ecosystem (or component), global status (e.g., IUCN Red List), vulnerability to disturbance, and risk factors.

Defining institutional roles. As previously mentioned, the first challenge is to clearly define the role of each institution in implementing and managing the MSP concept. This can be seen as an opportunity to improve efficiencies, identify overlaps or gaps, and improve working relationships amongst the institutions. Currently, the Prime Minister's Office has the authority to oversee MSP in Mauritius under the Maritime Zones Act and is also the driver for renewable energy, non-renewable resources and fisheries. The MoESDDBM is responsible for the protection of coastal and marine environment under the concept. However, the role and responsibilities of the Ministry of Ocean Economy, Marine Resources, Fisheries and Shipping also has to be clearly identified. This latter ministry has a key role to play in the implementation of MSP, since a successful implementation of the plan will lead to the successful development of the OE strategies. Therefore, it is important that the duties of the Ministry of Ocean Economy, Marine Resources, Fisheries and Shipping be clearly outlined with regards to MSP for Mauritius. Formulating clear roles for each institution is an important opportunity to improve collaboration and coordination among agencies that are responsible for the coastal and marine environment.

MSP in the outer islands. Another challenge to Mauritius is the implementation of MSP in the maritime zones generated by the Chagos Archipelago (including Diego Garcia) and the Island of Tromelin which form part of the territory of Mauritius under the Constitution of Mauritius and over which other nations claim sovereignty. The Government of Mauritius has reiterated that the Chagos Archipelago and Tromelin have always formed, and continue to form, an integral part of the territory of Mauritius, and that Mauritius does not recognize the so-called "British Indian Ocean Territory"^{12,13}

Coordination with Rodrigues. Since 2007, Rodrigues has taken steps to protect its marine ecosystem through the creation of four marine reserves (no-take zones) in the north of the island. These reserves were identified through the participatory process of local communities and non-governmental organizations. Furthermore, in 2009, the South East Marine Protected Area (SEMPA) was created. The SEMPA is a multi-use marine protected area that, like the marine reserves, involved the

¹² Constitution of the Republic of Mauritius (Section 111, Ch XI) <http://mauritiusassembly.govmu.org/English/constitution/Pages/constitution2016.pdf>

¹³ Communique from Government of Mauritius [http://mdr.govmu.org/English/Documents/Communique%20%20%2017%20\(Visits%20to%20Chagos%20Archipelago\).pdf](http://mdr.govmu.org/English/Documents/Communique%20%20%2017%20(Visits%20to%20Chagos%20Archipelago).pdf)

participatory process of local communities in its creation. It has to be underlined that the SEMPA covers 43 square kilometers and is currently the largest MPA for the Republic of Mauritius.

The creation of the marine reserves and the SEMPA can be linked to the use of a systematic conservation planning tool in Rodrigues. This tool allows for the use of a scientific approach to choose areas for protection, and it allowed Rodrigues to establish its four marine reserves, which cover approximately 24.3 square kilometers and amount to 10 percent of its lagoon. As for the SEMPA, part of it is used for protection and conservation of marine ecosystem and the rest is used for commercial and recreational activities.

Since Rodrigues is autonomous from the Republic of Mauritius, it has devised its own regulations to best serve its interests. Therefore, by using the systematic conservation planning, Rodrigues was able to adopt a framework that allowed it to scientifically and strategically devised its marine reserves and the SEMPA. Rodrigues' way of managing its sea is a good example that Mauritius should follow. In Mauritius, with the implementation of MSP, the island shall be able to designate further marine reserves and protected areas and the activities to be carried out therein.

Seychelles-Mauritius Joint Management Area (JMA) on the Mascarene Plateau. There is interest in Seychelles in pursuing a discussion with Mauritius for a political and strategic framework for decision-making and management of the JMA. This framework would focus on the seabed resources, as per the jurisdiction of the JMA. This can easily be framed as an opportunity for enhanced environmental management and economic development for both countries, although there will be challenges because examples of transboundary MSPs are hard to find. This joint management area would ideally be a separate planning process from either the Mauritius or Seychelles MSP, because it has quite specific objectives, the planning boundary is legally distinct, and implementation would probably require different legal instruments from those needed for the national MSPs. However, it would be an advantage to proceed with this joint project simultaneously or in parallel with the national MSP processes, because of crucial information that may influence the location of zones adjacent to the JMA and allowable activities within the national EEZs.

Pelagic resources and international rules. Finally, some pelagic marine resources are managed jointly with international bodies, for example tuna and the Indian Ocean Tuna Commission. These resources require careful consideration in any MSP process, because additional stakeholders may need to be involved in discussions about objectives, con-

ervation targets, zone locations, and allowable uses. For example, a joint regional model could be advantageous with Seychelles and other countries in the Western Indian Ocean for managing tuna populations and Fish Aggregating Devices. To address the recent declaration that yellowfin tuna is overfished, there is already a regional effort underway by the IOTC.

Merits of a Proposed MSP in Mauritius

Strong international evidence of the benefits of an MSP is still limited, and more will be more forthcoming once there are a greater number of implemented plans that have been through a five-year review. MSP is still at an early stage. However, anticipated benefits have been articulated by Ehler (2008) and Gopnik (2008) and have been estimated in more recent government documents. (such as the EU 2011). The benefits of MSP can be grouped into three categories: (i) benefits of the planning process; (ii) economic and social gains; and (iii) environmental improvements (Gopnik 2008). In Mauritius, the Prime Minister's Office has proposed three key benefits of marine spatial planning: sustainable use of space, enlarged economic space, and avoiding conflicting use of space, the latter largely falling under the "economic and social gains" benefits. The benefits described below are connected to global best practices and lessons learned described earlier in this chapter.

Social benefits from planning. There are numerous social benefits to MSP that have lasting impacts for implementation and other processes that involve similar participants (e.g., Marine Protected Area Networks, Geographic Spill Response Plans). Benefits include identifying a vision for future uses of the ocean, and objectives for management—as noted by Badal and Runghen (2016), one of the outputs from an MSP in Mauritius is a vision statement. MSP is an improvement over sector-by-sector management because it involves multiple sectors or interests, and participants in a planning process can articulate a shared vision and create sophisticated economic and environmental scenarios. The benefit of scenario building was seen in the Belgium North Sea waters plan, when the process forced participants to acknowledge the consequences of otherwise unquestioned choices and assumptions (Gopnik 2008). Other social benefits include bringing all stakeholders to the table and providing a transparent, structured mechanism to identify and address conflicts, create or review data layers, and develop a common base of understanding.

Economic benefits and social gains. Arguably, these are the benefits that are of greatest interest to investors. The EU (2011) describes direct economic effects in terms of certainty and predictability, including reduced

transaction costs, lower administrative costs, lower legal costs, and an enhanced investment climate. MSP lowers the transaction costs through improved coordination efficiency and effectiveness for governmental procedures. MSP processes create comprehensive spatial data catalogues that undergo extensive quality assurance/quality control by GIS experts. These databases contain spatially explicit information such as current uses and activities, spatial model outputs for conservation priorities, ecosystem service values, habitat classification systems, oceanographic data, and more. An important legacy of MSP processes is the GIS spatial data catalogue for use in implementation and future decision making. If these databases are publicly available, for example data relevant to offshore wind permit applications (wind speed, depth, substrate), then all companies will have access to the same information and data are not being collected on a case-by-case basis, eliminating redundancy and inefficient spending. In addition, regulatory and compliance costs for government should be lower under MSP because there is buy-in for the zoning and management directions, there is improved information exchange between agencies and marine sectors, and a more predictable setting to make regulatory and business decisions (Gopnik 2008).

Benefits to the environment. Finally, MSP benefits the environment. An integrated MSP includes environmental protection goals that are discussed alongside economic and social development goals. MSP is an improvement over MPA network design processes because the discussion includes not only how best to allocate space for the protection goal or target, but also how to allocate the *remainder* of the space, thus improving ocean management for 100 percent of the planning area. Also, MSP processes are more and more concerned with climate change adaptation, especially for small island developing states, which have serious concerns over sea level rise, cyclone frequency, and warming ocean temperatures threaten the OE and expose weaknesses in coastal infrastructure and defense.

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Addressing the Challenge of Climate Change

Kenneth M. Strzepek, James E. Neumann, Kerry Emanuel, Lucio Scandizzo, and Jacqueline Willwerth

Key Messages

- Climate change is likely to endanger much of the development potential of Mauritius' ocean economy (OE). Important climate related stressors threatening the OE include sea-level rise (including increases in coastal erosion), tropical storm intensification (including storm surges and changes in wave dynamics), intensified rainfall patterns, increased temperatures, and ocean acidification (which can affect fishery resources).
- The Government of Mauritius has taken important steps already to interpret the relevant climate science for the island and the South West Indian Ocean region; in many cases it has translated this knowledge to understanding key physical effects of importance, such as the impact of ocean acidification and sea temperature changes on fisheries resources. In a few cases it has quantified and monetized these impacts; for example, Mauritius' Second National Communication states that over the last decade, 18,500 square meters of beach have eroded in Mauritius, land with a rental value of MUR 1.2 million).
- Analysis of the latest climate change scenarios shows that localized precipitation projections through the year 2050 are highly variable and could range from a decline of more than 25 percent to an increase of more than 25 percent, compared to historical rainfall. The variability is the result of uncertainties in global efforts to mitigate carbon emissions and in climate science. This stressor may be critically important to Mauritius, as more intense rainfall could greatly exacerbate inland flood risks.
- Based on detailed, Mauritius-specific storm simulation modeling conducted for this book, climate change could also substantially increase both the rainfall and the wind speed and landfall patterns associated with tropical cyclones. As a result, we estimate that total tropical cyclone damage (from wind, storm surge, and inland flooding) in the worst case climate scenario could increase by approximately a factor of two.
- Virtually all storms would be stronger with climate change, and the frequency overall would also increase. An important result from this analysis is that the once- in-100-year storm, with climate change, could be characterized by peak wind speeds 30 km/hour higher than the historical baseline. For reference, Cyclone Hollanda,

(continued on next page)

Key Messages *(continued)*

which struck Mauritius in 1994, was roughly a once-in-100-year storm—climate change would make that storm much more damaging.

- As a deep-dive illustration of just one effect of climate change, and based on an application of the CGE model described in Chapter 2, the economic effects of this change in cyclone strikes on Mauritius are demonstrated to reduce the cumulative GDP (in present value terms) by more than 10 percent by the end of a 40-year simulation period, relative to a scenario that simulates historical storm occurrence. In addition, if a single 100-year return-period storm of the sort anticipated with climate change were to occur in the next 10 years, the effect would be to cause GDP to shrink for a time, and to reduce GDP growth rates by approximately 2 percentage points for at least the following five years.
- The CGE simulations also show that while expected losses under climate change are larger than the historic baseline at the mean, a potentially more significant change will be seen in the risk of large-scale losses. For example, under current climate conditions, a large storm causing a loss of 7.5 percent GDP has a 10 percent probability of occurring; under climate change, this probability increases to 30 percent.
- Mauritius has already taken steps to address climate change vulnerability, both at the policy level (e.g. the 2012 National Climate Change Adaptation Policy Framework) and at a more operational level, through the 2016 guideline for coastal setback, formulated in anticipation of sea-level-rise-risks to coastal assets. More can be done for better understanding, and mitigating, the increased risks that climate change may pose to the entire OE (and in fact to the economy as a whole). To mitigate the resulting social and economic impacts, there is a need to consider both structural responses (such as a review of building codes to assess resilience to stronger cyclones) and disaster risk financing options (such as the sovereign insurance scheme developed by Africa Risk Capacity or the World Bank's Catastrophe Deferred Drawdown Option (CAT-DDO)).

Climate Change and the Ocean Economy: A Framework for Assessing Threats and Responses

The Government of Mauritius has prioritized the development of a strong OE as a near-term and long-term economic strategy for the country. The sectors of the OE have been supported by numerous government programs, legislation, and investment (Mauritius 2013). The potential impacts of climate change must be considered in planning decisions to ensure that this investment is protected into the future. Table 8.1 lists the clusters of the OE and the climate change shocks and stressors discussed in this chapter.

The Systematic Analysis of Climate-Resilient Development

The wide range of vulnerabilities to climate change for an OE, coupled with the magnitude of the possible loss associated with natural hazards amplified by climate change, suggests that the use of suitable models

Table 8.1. Potential and Demonstrated Risks to Ocean Economy Clusters of Climate Change Shocks and Stressors

| OE Clusters | Climate Change Shocks and Stressors | | | | |
|--|-------------------------------------|--------------|-------------------|-----------------------------|--------------------|
| | Sea level rise | Storm surges | Tropical cyclones | Non-tropical cyclone floods | Other ^a |
| 1. Seabed Exploration for Hydrocarbon & Minerals | | | + | | + |
| 2. Fishing, Seafood Processing and Aquaculture | | | ++ | | ++ |
| 3. Deep Ocean Water Applications (DOWA) | | | | | + |
| 4. Marine Services: | | | | | |
| a. Marine Tourism and Leisure | ++ | ++ | ++ | ++ | ++ |
| b. Marine ICT | | | + | | |
| c. Marine Finance | | + | + | + | |
| d. Marine Biotechnology | | | | | + |
| e. Ship Registration | | | + | | |
| 5. Seaport-related Activities | ++ | ++ | ++ | + | |
| 6. Marine Renewable Energies | | | + | | |
| 7. Ocean Knowledge | + | | | | + |

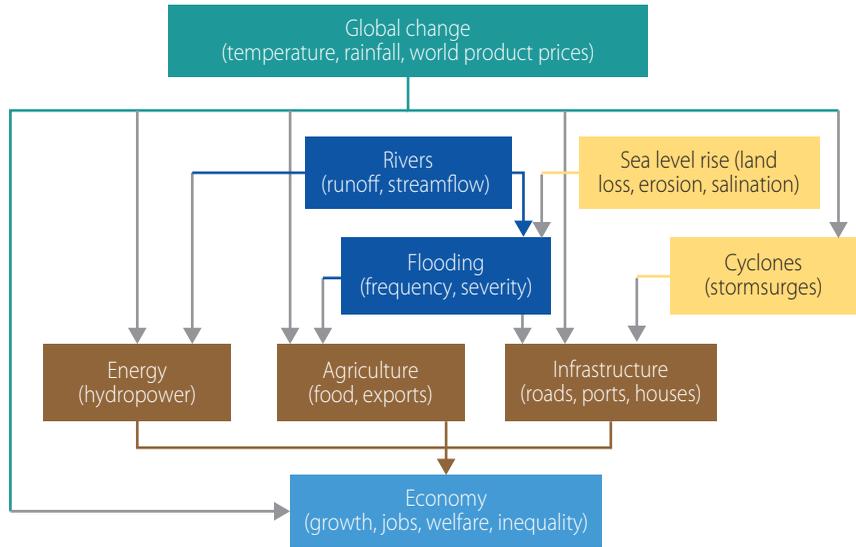
Source: Author Analysis based on literature review in text

Note: + indicates potential for risk; ++ indicates demonstrated risk. (a) Other Shocks and Stressors include ocean acidification, and ocean and air temperature change.

should be explored and tested to better characterize and quantify the risks outlined in Table 8.1. Fortunately, there has been significant effort in recent years to quantify these risks, which has fueled recent activity to develop, refine, and apply suitable models (see for example, Cervigni et al., 2015).

To assist policy makers in evaluating the potential economic impacts of climate change and identify specific regional and sector vulnerabilities, the United Nations University—World Institute for Development Economic Research (UNU-WIDER), in collaboration with external partners, has progressively developed an analytical framework known as Systematic Analysis of Climate Resilient Development (SACReD), which integrates comprehensive biophysical and economic analysis. The climate impacts and adaptations component of the SACReD framework is illustrated in Figure 8.1.

The framework begins with climate change scenarios for a particular country. Climate change manifests itself as changes in projected levels for temperature, precipitation, barometric pressure, humidity, and other weather outcomes. However, with this information alone, it is difficult to assess the potential impacts of climate change on many variables of interest such as economic growth, development prospects, and the material well-being of the population. As such, the SACReD framework traces the

Figure 8.1. Systematic Analysis for Climate Resilient Development (SACReD) Framework

Source: United Nations University—World Institute for Development Economic Research (UNU-WIDER).

implications of changes in a broad range of climate outcomes through a series of important impact channels—including the production of hydropower, agricultural yield, water supply/demand balance, and costs of maintaining and repairing damaged infrastructure and other installed capital.

These climate change impacts then serve as inputs into an economywide model of the country in question. The economywide models employed respect macroeconomic identities, meaning that all futures are economically coherent and account for multiple simultaneous impacts. For example, higher levels of rainfall may be favorable for hydropower generation, water supply, and agricultural production, but unfavorable for road infrastructure due to washouts or widespread flooding—both effects are accounted for in the framework.

The critical element of this framework that is missing in many country applications is linking the climate science and physical impacts of climate change to the function and productivity of the economy. In Mauritius as in other countries, many aspects of the economy use environmental resources (water, agriculture, beaches) as key factors of production, and climate change affects those factors of production, often though not always in negative ways. Nonetheless, this type of analysis is becoming more common. For example, variants of the SACReD framework outlined above have been applied to Ethiopia (Robinson, Strzepek, and Cervigni 2013), Ghana (Arndt, Asante, and Thurlow 2015a), Malawi (Arndt, Pauw, and Thurlow 2014), Mozambique (Arndt et al 2011a), Tanzania (Arndt et al

2011b), Vietnam (Arndt, Tarp, and Thurlow 2015b), Zambia (Schlosser and Strzepek 2013), and South Africa (Cullis et al. 2015).

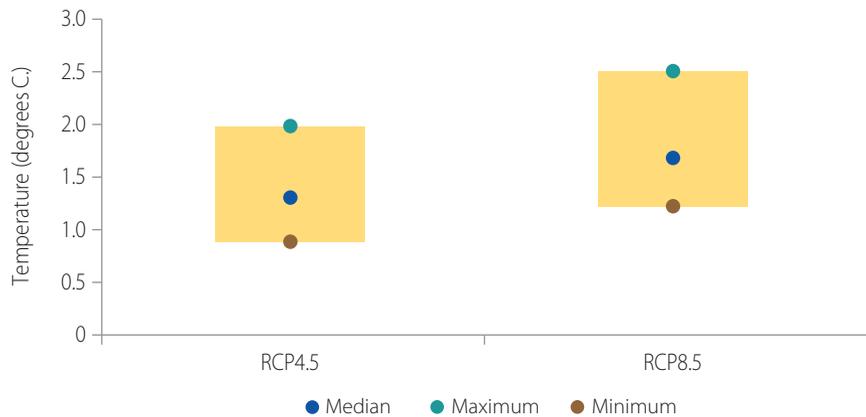
In the sections below, we review existing work by and for Mauritius that characterizes and quantifies climate risks, mainly in physical terms but in some cases (e.g., coastal erosion) with some sense of primary economic stress as well, such as land area lost to erosion, now and in the future, and the value of that lost land to the landowners. What has not yet been done for Mauritius, to our knowledge, is assessing how climate change puts at risk the factors of production, and how those risks translate to loss of economic productivity, typically measured as GDP. To demonstrate this concept, this chapter traces one aspect of the SACReD framework, the impact of climate change on tropical cyclone frequency and intensity, and how the damage to critical OE capital assets of more frequent and/or severe storms will affect the Mauritius economy.¹

Climate Variability and Change in Mauritius

As a small island nation, Mauritius has the potential to be particularly vulnerable to climate change impacts (Nurse et al. 2014). Mauritius has seen a trend of increasing average temperatures of about 0.15 degrees centigrade over the last century (MOESD 2012). According to the Mauritius Meteorological Services, annual rainfall decreased over the last century. Total annual rainfall has decreased about 8 percent in the past 10 years compared to the 1950s on the main island and, to a lesser and more variable extent, on the outer islands (MMS n.d.). Climate projections for the West Indian Ocean region under a low emissions scenario future (RCP4.5), based on averages from 42 Coupled Model Intercomparison Project Phase 5 (CMIP5) models, show an increase in annual average temperature of about 1.4 degrees centigrade by the end of the century compared to the average for 1986–2005 (median value; 25 to 75th percentile: 1.2 to 1.8 degrees).

Over the same time period precipitation is projected to increase by 2 percent (median value; 25 to 75th percentile range is 0 to 5 percent), and sea level is projected to rise by 0.5–0.6 meters, a significant issue for small island nations in particular (Nurse et al. 2014). The Government of Mauritius is aware of these projections and has used them to inform

¹ It should be noted that cyclones do have the potential to impact the Mauritius OE through other impact channels identified in the SACReD framework as well. For example, tropical cyclones very often bring with them high precipitation events, which have caused severe flooding in Mauritius in the past. Although not shown in Figure 8.1, the “deep dive” demonstration analysis considers the damage associated with both tropical storm related wind and flooding.

Figure 8.2. Projected Average Daily Maximum Temperature Increase by 2050 Compared to Historic Baseline

Source: World Bank calculations based on IPCC AR5 CMIP5 data archive for Mauritius area (see http://www.ipcc-data.org/sim/gcm_monthly/AR5/), as described in detail in Cervigni et al. (2015).

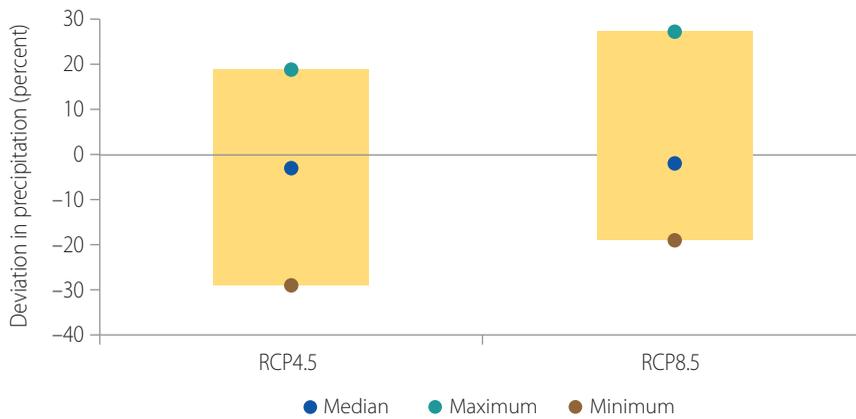
Note: The figure shows the range of changes in temperature projected by the UN IPCC in 2050 relative to historic temperatures over the last 20 years, for two global greenhouse gas emissions scenarios: RCP 4.5 on the left is a more moderate emissions pathway, and RCP 8.5 is a higher emissions pathway. The edges of the box show the maximum and minimum projections, and the green triangle shows the median projection.

various climate change adaptation and mitigation planning documents (e.g. MOESD 2012; MAIFS et al. 2012; Mauritius 2012). More recent information suggests that the potential for higher levels of sea-level rise, perhaps one meter or more by the end of the century, is associated with dynamic ice-sheet melting in Greenland and Antarctica (Vermeer and Rahmstorf 2009), or more rapid break-up of land-based ice sheets in Antarctica (DeConto and Pollard 2016).

Figure 8.2 shows the projected change in maximum daily temperature specifically for Mauritius by mid-century based on a suite of 21 General Circulation Models (GCMs). The median changes in maximum daily temperature under RCP4.5 (a high greenhouse gas mitigation effort scenario) and RCP8.5 (a low greenhouse gas mitigation effort scenario) are 1.3 and 1.7 degrees centigrade, respectively. The high-end estimate under RCP8.5 shows changes in temperature of 2.5 degrees centigrade. Changes in minimum daily temperature follow similar trends. These patterns are consistent with the projections for the West Indian Ocean.

Projections of precipitation outcomes in Mauritius under climate change show significantly more variability. Under both the low-emission scenario and the high-emission scenario, the median estimate of annual precipitation is projected to decrease by about 2 percent compared to the historic baseline; however, the high- and low-end estimates for the two emission scenarios show a large amount of variability. Under both RCPs, projections range from large increases to large decreases in precipitation compared to

Figure 8.3. Projected Deviation in Precipitation, 2050 Compared to Historic Baseline



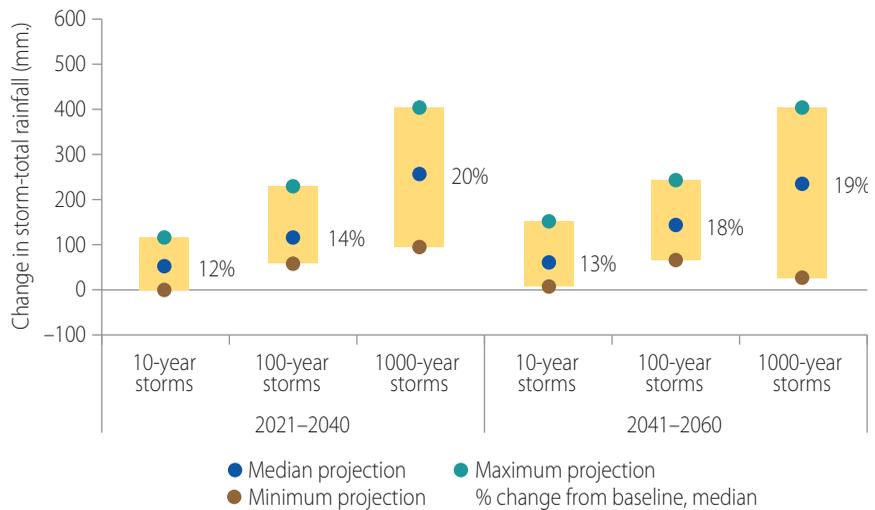
Source: World Bank calculations based on IPCC AR5 CMIP5 data archive for Mauritius area (see http://www.ipcc-data.org/sim/gcm_monthly/AR5/), as described in detail in Cervigni et al. (2015).

Note: The figure shows the range of changes in annual precipitation projected by the UN IPCC in 2050 relative to historic precipitation over the last 20 years, for two global greenhouse gas emissions scenarios: RCP 4.5 on the left is a more moderate emissions pathway, and RCP 8.5 is a higher emissions pathway. The edges of the box show the maximum and minimum projections, and the green triangle shows the median projection.

the baseline. Changes of this magnitude in either direction could cause serious impacts in Mauritius, as indicated in the column of Table 8.1 labeled “non-tropical cyclone floods,” including impacts on a wide range of capital assets inland from the coast and so technically not components of the OE. Variability in precipitation projections of this magnitude also complicates efforts to adapt and modify water resource supply systems in response to these changes, owing to the projection uncertainty.

While the models do not always agree on the direction of change in total annual precipitation, there is a general consensus that precipitation events will be more extreme, with both higher intensity storms likely to occur more often than in the current climate, and the possibility of lower or higher annual precipitation. High-intensity storms increase inland flooding, storm surge risks, and the risk of wind damage. Tropical cyclones, storms with peak wind speeds over 70 km/hour, can be particularly damaging. Figure 8.4 shows the change in storm total rainfall for tropical cyclones for two future eras, standardized by historical climate rainfall for each of three storm-return periods (10-year, 100-year, and 1000-year; see Box 8.1). These results were modeled by the WindRiskTech CHIPS model.² In the near-future era (2021

² The CHIPS model projects tropical storm activity and intensity for five GCMs and two RCPs. A more detailed discussion of the model can be found in the technical appendix.

Figure 8.4. Projected Change in Storm Total Rainfall Relative to Historic Baseline in Two Future Eras Under RCP8.5

Source: World Bank calculations based on IPCC AR5 CMIP5 data archive for Mauritius area (see http://www.ipcc-data.org/sim/gcm_monthly/AR5/), as described in detail in Cervigni et al. (2015).

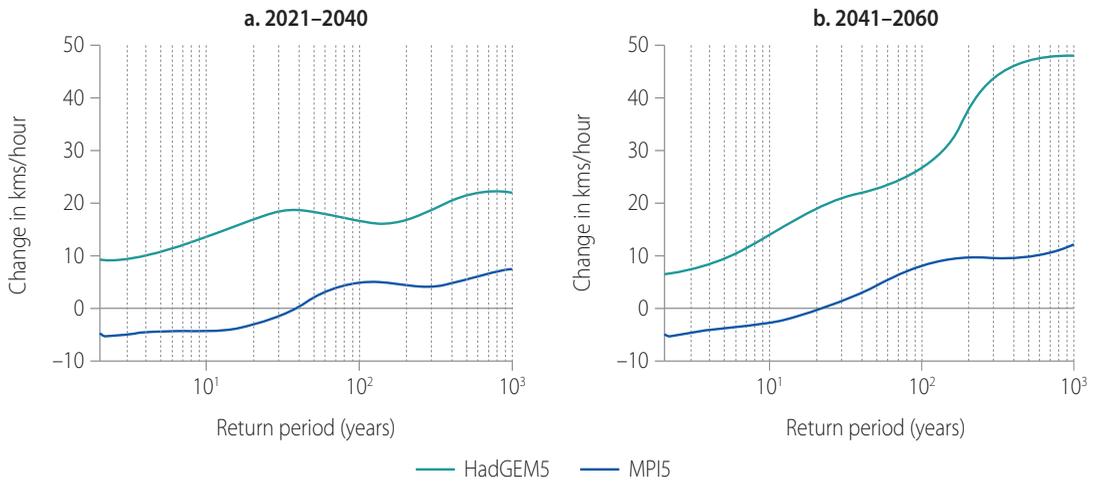
Note: The figure shows the range of changes in rainfall associated with specific magnitudes of storms under future climate conditions, using six climate models whose results are published by the UN IPCC, relative to rainfall for the comparable storm in the historic record. The results are presented for one global greenhouse gas emissions scenario, RCP 8.5, which is a higher emissions pathway. The edges of the box show the maximum and minimum projections, and the green triangle shows the median projection—the median is also called out to the right of the box.

to 2040), a typical 10-year storm will produce 12 percent more rainfall than the historical 10-year storm. As storm intensity increases, so does the change in projected rainfall. A 1000-year storm is projected to produce 20 percent more rain than the historic baseline. These patterns are very similar in the mid-century (2041 to 2060) era.

Box 8.1. Tropical Cyclone Return Periods

Storms are often categorized by the probability at which a storm of equal or greater magnitude is expected to occur, meaning the magnitude of a storm that is expected to occur once every 10 years is classified as a “10-year storm” and if expected to occur once every 100 years as a “100-year storm.” These expected rates, or return periods, are based on probabilities and do not signify that these frequencies will happen with certainty. In other words, a 100-year storm is a storm event that occurs with 1 percent probability each year; a 10-year storm is a storm event that occurs with 10 percent probability each year. It is possible that a 10-year storm could occur twice in one year. It is also possible, although unlikely, that two 100-year storms could occur in one year or that zero 10-year storms could occur in 50 years.

Figure 8.5. High- and Low-end Estimates of the Change in Wind Speed for 100-Year Tropical Cyclones, by Return Periods



Source: World Bank analysis using CHIPS cyclone activity projection framework.

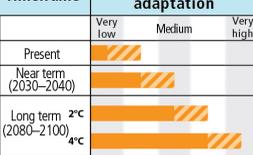
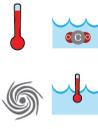
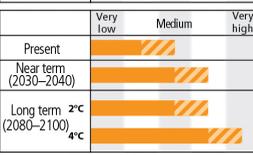
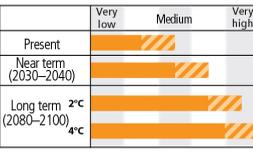
Note: The HadGEM5 model is the high-end climate projection model, while the MPI5 model is the low-end model; see text for further explanation.

Tropical cyclone wind speeds are a primary driver of storm damage—these wind speeds are also projected to increase under future climates. Figure 8.5 shows the high- and low-end estimates of the change in wind speed (by return periods, e.g., the 100-year storm) for tropical cyclones in Mauritius. The results are presented for two future eras (as modeled by the WindRiskTech CHIPS model). Both the high- and low-end future climate projections show an increase in wind speeds for high-intensity storms, on the right of the graph. These high intensity storms are the ones that cause the most significant property damage. The low-end climate model (or GCM, in this case the MPI5 model) shows a slight decrease in the more frequent storms. The deep dive analysis described below makes use of the storm wind intensity and frequency projections from the two climate models depicted in Figure 8.5: the HadGEM5 and MPI climate models. These two models represent high and low impacts of climate change.

Climate Change Impacts: Current Understanding and Key Knowledge Gaps

For Mauritius, where the OE is slated to contribute greatly to the economic development of the country, climate change impacts to coastal regions could significantly slow economic growth if proper adaptation measures are not implemented. As a small island nation, Mauritius is already more economically vulnerable than the average nation, and

Table 8.2. Selected Key Climate Change Risks and Small Islands' Prospects for Adapting to Them, Present Day, Near Term, and Long Term

| Climate-related drivers of impacts | | | | | | | | Level of risk & potential for adaptation |
|---|---|--|---|--|---|---|---|--|
|  Warming trend |  Extreme temperature |  Drying trend |  Extreme precipitation |  Damaging cyclone |  Sea level |  Ocean acidification |  Sea surface temperature |  <p>Potential for additional adaptation to reduce risk</p> <p>Risk level with high adaptation Risk level with current adaptation</p> |
| Key risk | Adaptation issues & prospects | | | Climatic drivers | | Timeframe | Risk & potential for adaptation | |
| Loss of livelihoods, coastal settlements, infrastructure, ecosystem services, and economic stability (<i>high confidence</i>) [29.6, 29.8, Figure 29-4] | <ul style="list-style-type: none"> Significant potential exists for adaptation in islands, but additional external resources and technologies will enhance response. Maintenance and enhancement of ecosystem functions and services and of water and food security Efficacy of traditional community coping strategies is expected to be substantially reduced in the future. | | |  | | Present Near term (2030–2040) Long term 2°C (2080–2100) 4°C |  | |
| Decline and possible loss of coral reef ecosystems in small islands through thermal stress (<i>high confidence</i>) [29.3.1.2] | Limited coral reef adaptation responses; however, minimizing the negative impact of anthropogenic stresses (ie: water quality change, destructive fishing practices) may increase resilience. | | |  | | Present Near term (2030–2040) Long term 2°C (2080–2100) 4°C |  | |
| The interaction of rising global mean sea level in the 21st century with high-water-level events will threaten low-lying coastal areas (<i>high confidence</i>) [29.4, Table 29-1; WGI AR5 13.5, Table 13.5] | <ul style="list-style-type: none"> High ratio of coastal area to land mass will make adaptation a significant financial and resource challenge for islands. Adaptation options include maintenance and restoration of coastal landforms and ecosystems, improved management of soils and freshwater resources, and appropriate building codes and settlement patterns. | | |  | | Present Near term (2030–2040) Long term 2°C (2080–2100) 4°C |  | |

Source: IPCC Fifth Assessment Report (Nurse et al. 2014).

because of its size any extreme weather event that hits the country often leads to a large proportion of damage (Anthoff, Nicholls, and Tol 2010). Table 8.2 shows the key impacts of climate change specific to small island nations from the United Nations' IPCC Fifth Assessment Report.

Several of the OE clusters are predicted to see large impacts of climate change with high confidence, while impacts on other sectors require more research (Nurse et al. 2014). Generally speaking, there is a lack of data on the impacts of climate change on small island nations due to the precise scale of modeling required to understand the localized effects. This is particularly true for Mauritius, where there are relatively large differences in elevation across the island (up to more than 800 meters above sea level). Areas with large differences in elevation show much greater variability in outcomes from changes in rainfall (owing to orographic effects on clouds and precipitation), flooding (owing to steeper terrain and concentration of rainfall into runoff channels), and even heat stress (owing to temperature elevation gradients).

Fisheries, seafood processing, and aquaculture are important components of the current economy and are planned to remain significant under future economic plans. Seafood fishing and processing contributed about 1.4 percent of GDP from 2012 to 2014 (see Chapter 1), and fisheries products make up about 22 percent of total exports by value

(see Chapter 3 for more details on the fisheries sector). Climate change threats to this growing sector include:

- **Coral bleaching leading to reduced fisheries production:** Healthy coral is vital to healthy fisheries, particularly in the Western Indian Ocean. Coral bleaching due to rising ocean temperatures and acidification has negative impacts on fishery production (Hoegh-Guldberg et al. 2014; Hoegh-Guldberg et al. 2007). Coral calcification rates could decrease by up to 30 percent by 2050 due to increases in carbon dioxide levels, and by 2100 live corals could be reduced by 80 to 100 percent if temperature for the Mauritius region rises 3.28 degrees (Mauritius 2010). Loss of mangroves, a critical habitat for many commercially important species, due to sea level rise is also a concern for fisheries production (Mauritius 2012). The government has worked with several NGOs to combat mangrove loss through replanting efforts (MAIFS et al. 2012).
- **Ocean acidification affecting mollusk shell formation:** Ocean acidification can impede mollusk shell formation (De Silva and Soto 2009) which could impact oyster and oyster pearl culture, industries shown to have high economic potential in Mauritius (RoM 2013).
- **Severe weather, erosion, and storm surge infrastructure damage:** These threats damage coastal infrastructure, particularly aquaculture infrastructure, leading to escapes (including potentially invasive species) and loss of productivity (De Silva and Soto 2009).
- **Changing ocean temperatures and species distribution:** Changing ocean temperatures can alter currents and fish migration patterns, changing the availability of species across space (Nurse et al. 2014). Changing temperatures can also introduce new species to the area, which may disrupt existing catch allocation arrangements (Mauritius 2010).

The fishing industry in Mauritius has already seen declines in productivity, making further reductions due to climate change even more damaging. As seen in Chapter 3, fisheries production, excluding large-scale tuna production, has declined by 17 percent since 2006. Total fisheries production has increased over the same period due to large increases (a twelve-fold growth since 2006) in large-scale tuna production; however tuna migratory patterns often shift and are vulnerable to changing ocean temperatures. Any impacts to fisheries and aquaculture will be passed on to the seafood processing industry, since the processing plants rely on steady production from the fisheries for their supplies.

The threats of climate change on seaport related activities are also well studied. The value of Mauritius' seaport ranks high due to local

port logistics and infrastructure, and cruise port amenities make it a likely cluster to see continued growth in the future (Mauritius 2013). Threats to these activities include damage to port infrastructure, change in navigability of access channels, interruptions in business activities and movements (World Bank 2016). More frequent extreme weather events may disrupt complex supply chains, while sediment from coastal erosion may increase dredging costs (UNCTAD 2008). Integrated investment, planning, and operation will be necessary for ports to adapt (Becker et al. 2013). There may be opportunities for the marine finance industry to benefit from involvement in these adaptation projects.

Chapter 6 discusses the most important responses to climate change necessary to protect investments in port infrastructure, including monitoring weather conditions and correlating conditions with consequences of extreme events; expanding analyses to include the hazard of inland flooding; ensuring adequate insurance coverage is in place; reviewing and testing emergency response procedures; incorporating climate change resiliency in investment planning; and investing in breakwater protection and other mitigating measures.

Coastal tourism is another important seaport related activity—in 2012 it was 6.5 percent of total GDP (Mauritius 2013). In addition to the threat of infrastructure damage from flooding, winds, and coastal erosion, the tourism sector may also be impacted by water shortages exacerbated by rising temperatures and more variable rainfall (Mauritius 2012). Altered seasonality could impact the tourism industry through the effects of heat stress on tourists, increased cooling costs, changes in wildlife populations, and infectious diseases (MAIFS et al. 2012). Beach erosion is also a concern for the tourism industry. Mauritius' Second National Communication states that over the last decade, 18,500 square meters of beach have eroded in Mauritius. That land has a rental value of MUR 1.2 million (Mauritius 2010). The Government of Mauritius has taken actions to reduce the impacts to the tourism sector, including implementing a mandatory setback from the high water mark to protect against the threats of coastal erosion and storm surge (Ministry of Housing and Lands 2004; Mauritius 2016).

Other sectors of the economy, while potentially vulnerable to climate change, do not have the historical evidence of impacts and research support of the above sectors. For example, while the most significant ocean warming has been observed at surface levels, deep ocean waters (700 to 2,000 meters) are also experiencing similar, yet less significant changes (Hoegh-Guldberg et al. 2014). The impact of climate change on deep-sea environments is difficult to observe because of access issues and lack of long-term data (Smith, Jr. et al., 2009).

The Government of Mauritius has already taken important steps to protect the OE from climate change impacts. The Disaster Risk Reduction Strategic Framework and Action Plan (MOESD 2012), the National Climate Change Adaptation Policy Framework for the Republic of Mauritius (Mauritius 2012) and the Intended Nationally Determined Contribution for the Republic of Mauritius (Mauritius 2015) lay out a path forward for Mauritius to both minimize risk with appropriate adaptation measures and mitigate climate change through sustainable practices. These documents stress the importance of understanding where the primary areas of risk are located and of minimizing vulnerable infrastructure in these risk-prone areas among other risk-minimizing plans.

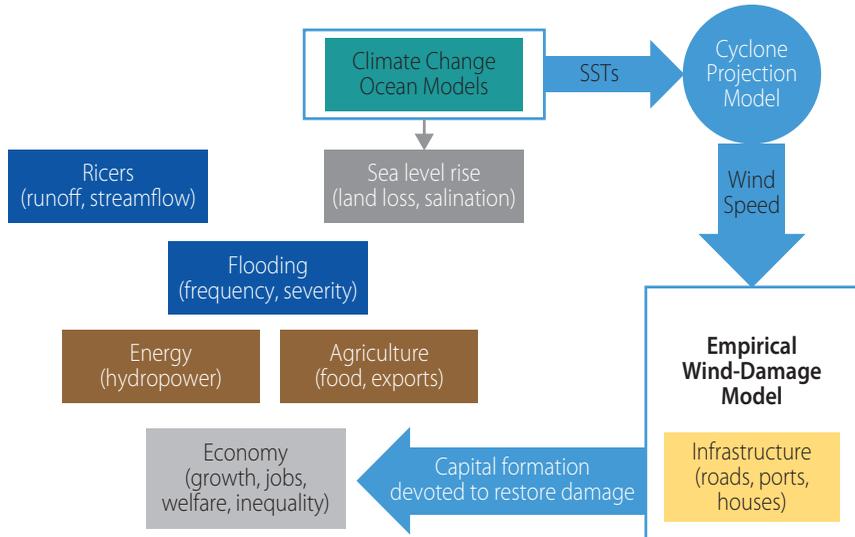
The 2012 document, *Mainstreaming Climate Change Adaptation in the Agriculture, Tourism and Fisheries Sectors in the Republic of Mauritius and in the Water Sector in Rodrigues* (MAIFS et al. 2012) acknowledges the actions of the government thus far to protect against climate related damages in the tourism and fisheries sector, such as mangrove replacement programs and building codes that reduce infrastructure risk, and calls for further progress in understanding and communicating the risks of climate change. According to the Second National Communication, the government has also undertaken several research initiatives to better understand climate trends and impacts including developing climate indices; monitoring possible salt water intrusion to freshwater sources; modeling projected water availability, soil erosion, and crop responses to climate change; and studying the contributing roles that affect the coastal zone, ecosystems, and biodiversity. In addition, the government has spearheaded several public education, training, and communication plans related to the impacts of climate change (Mauritius 2010). The following deep dive analysis seeks to provide an example of the risk of climate change that can be readily communicated to a wide audience.

A Deep Dive on Climate Change and the Ocean Economy: The Economywide Effects of Tropical Cyclones

Low-frequency, high-impact events such as tropical cyclones often cause damage to infrastructure and supplies that can ripple through the economy. For example, after a tropical cyclone the government may need to spend money repairing flood-damaged roads. That money likely could have been spent on a more productive program had the hurricane not occurred. Similarly, households and businesses might be forced to divert money that could be used for productive purposes to repair wind damaged roofs and equipment.

The case of Mauritius. The deep dive analysis of the risk of climate-change-enhanced extreme events (tropical cyclones) to the

Figure 8.6. Systematic Analysis for Climate Resilient Development (SACReD) Framework for the Ocean Economy of Mauritius



Source: Adapted from Figure 8.1.

planned growth of the OE of Mauritius described in this chapter does not need to engage the entire SACReD framework. The analysis is limited to change in damages coming from changes in frequency and severity (as measured by maximum wind speed) of cyclones. This led to development of a reduced-scope SACReD framework with a single impact channel, where fixed capital formation is devoted to restoring the damaged capital as the result of cyclonic winds. This framework, SACReD-OE, is illustrated in Figure 8.6.

The SACReD-OE framework demonstrated for this “deep dive” has four main components:

1. **GCM-based estimation of sea-surface temperatures (SSTs):** GCMs are climate models that project global climate characteristics such as sea-surface temperatures and air temperatures, which are important for cyclone formation. This analysis makes use of two of roughly 20 most-cited GCM results, which represent a broad range of projected climate outcomes for Mauritius.
2. **A probabilistic Cyclone Projection Model driven by projections of SSTs:** This step involves deploying the CHIPS framework mentioned earlier, which is also described in detail in a technical appendix. The CHIPS framework uses GCM inputs and generates a simulation of future storm activity that is specific to Mauritius. The results are for two future time periods (2021 to 2040, and 2041 to 2060) and

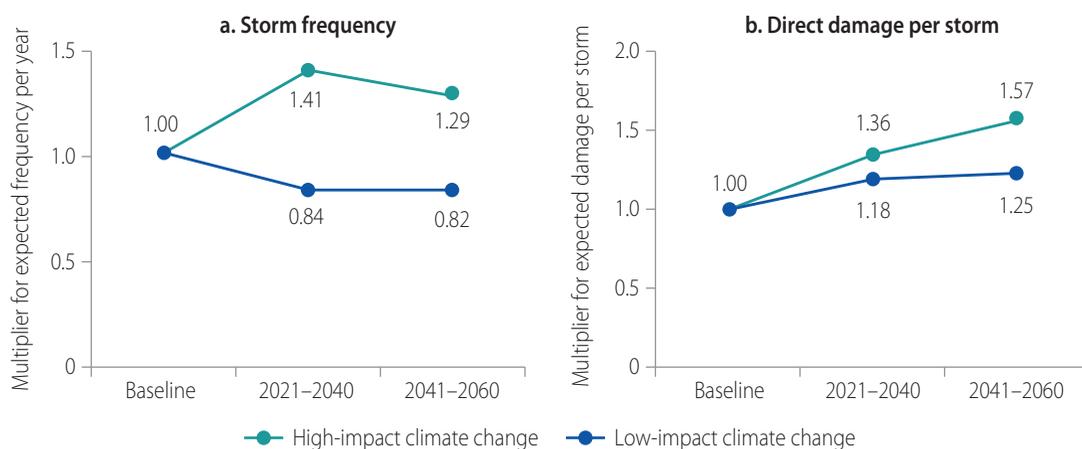
include a full exceedance curve that summarizes the frequency and severity of storms (as measured by both wind speed and rainfall intensity) that are projected to strike Mauritius in each of these periods. As indicated in the technical appendix, the frequency results are calibrated to data on historic storm strikes for Mauritius.

3. ***An empirical Wind-Capital Damage Model developed for Mauritius:*** Using the wind speed outputs from the previous step, the project team developed an empirical model to estimate the damage to capital on Mauritius. The model was parameterized by examining the damage to Mauritius' capital estimated for a range of events where damage is simulated by AIR Worldwide (2016) and relating the damage from each simulated event to the maximum wind speed associated with that event. A cubic damage function was then fitted to these data. The function was applied to the new, projected wind speed and storm frequency outputs from the climate change simulations to estimate the damage from the profile of future storms as they could be influenced by climate change.
4. ***A Computable General Equilibrium (CGE) model of the Mauritius economy focused on the OE with an impact channel of capital damage:*** The results of the projected damage to capital, both with and without climate change, were then used as inputs to the CGE macro-model described in Chapter 3 of this book. The CGE provides probabilistic results, so it makes use of the probabilities of a cyclone strike estimated by the CHIPS framework. As a result, the CGE can indicate the probability of damage to the broader economy in a given time period.

Total expected annual damage is a function of both the frequency of events and the intensity of the events that occur. The CHIPS model is used to project historic and future storm frequency and intensity, as defined by maximum wind speeds, for both the low- and high-impact climate scenarios. Storm damages are defined by a damage function relating storm return periods to a percentage of asset damage. Although the functional form used reflects the context of U.S. hurricane damage (Emanuel 2011), the damage calculation for a historical storm profile was calibrated against existing estimates for Mauritius (AIR Worldwide 2016). Note that the method used here probably underestimates damage from cyclone strikes, because it only provides estimates of damage to built infrastructure and capital and ignores effects on natural capital (such as clean water supplies, or wetland function, for example).

As seen in Figure 8.7, in the high impact scenario both frequency and intensity are projected to increase in both future eras (2021 to 2040 and

Figure 8.7. Projected Frequency and Damage Impact of Tropical Cyclones Under High and Low Climate Change Scenarios, Normalized to Historical Conditions



Source: World Bank analysis using CHIPS cyclone activity projection framework.

Note: The charts show how climate change affects the frequency (Panel A) and the severity (Panel B) of tropical cyclones over time, for two climate change scenarios, relative to the historic record of storms that strike Mauritius.

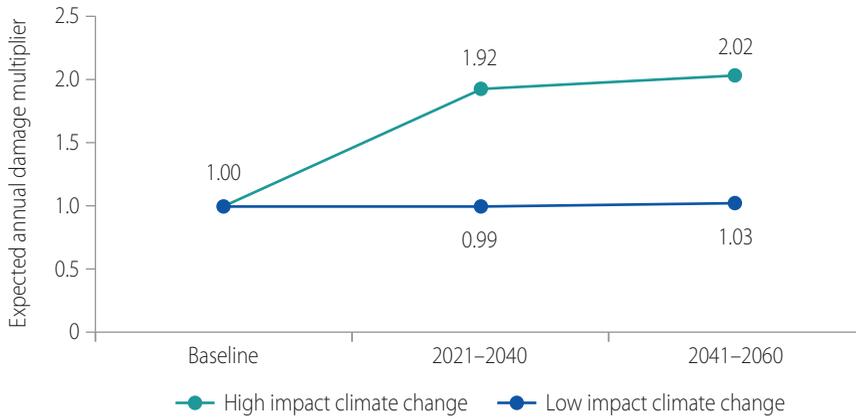
2041 to 2060). Under the low-impact scenario, the frequency of damaging tropical cyclones is expected to decrease slightly, while the damage per storm increases by a very similar magnitude.

When these two factors are combined, the low-impact model projects expected annual direct damage to be about the same as historic rates, while the high-impact model projects such damage to double, as seen in Figure 8.8. When input to the CGE, the economywide impacts of these changes in expected direct damage may be tempered by inflows of investment, particularly foreign aid or transfers of capital between sectors, or they may be intensified as damaged capital remains unproductive until fully repaired.

The Mauritius economy CGE model used in this analysis is able to capture the effects of these damages as they propagate through the economy. For example, it can estimate the impact of reduced government spending on new roads because of the need to repair existing roads, both as an immediate effect and as a lasting effect on maintenance budgets and productive capital formation. To do this, the CGE relies on a social accounting matrix (SAM) of Mauritius. The SAM includes 112 sectors that contribute to the Mauritius GDP. (Further details of the CGE model can be found in Chapter 2.)

The CGE incorporates storm damage as a fraction of the capital assets destroyed in a particular sector as a result of storm strike. To explore the role of climate change on the impact of tropical cyclone damages, this analysis looks at four future scenarios:

Figure 8.8. Projected Annual Direct Damage from Tropical Cyclones Under High and Low Climate Change Scenarios, Normalized to Historical Conditions



Source: World Bank analysis using CHIPS cyclone activity projection framework and wind damage functions described in the text.

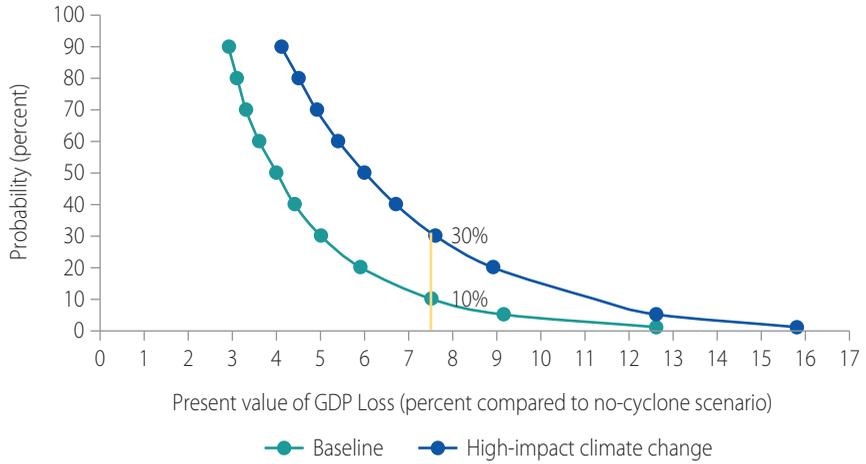
Note: The chart shows the combined effect of changes in the frequency and intensity of storms with climate change, normalized to the historic baseline record of storms striking Mauritius, for two future periods. The results are for direct damages to human capital assets only (the CGE is needed to assess secondary effects on the economy), and omit effects to natural capital such as wetlands and water resources.

- No tropical cyclones
- Tropical cyclone frequency and severity consistent with historical patterns
- Tropical cyclones expected under a high-impact climate scenario, and
- Tropical cyclones expected under a low-impact climate scenario.

The no-tropical cyclone baseline is described in Chapter 2. As described above, storm damage input to the CGE is identified based on a probabilistic representation of the frequency and severity of storms that are expected to strike Mauritius under each of the four scenarios.³ For each year from 2020 to 2060, the CGE model uses the probability of an event occurring, and the likelihood that any storm that does strike Mauritius will be a weak, moderate, or strong storm, and assigns damage from each selected event based on the damage function described above. The damages associated with tropical cyclones under both historical and future climate conditions are identified in five categories of loss: residential, commercial, infrastructure, industrial, and public.

³ Specifically: (i) a Poisson distribution of storm frequency as defined by the parameters projected in the CHIPS model, and (ii) a gamma function of storm damage defined by CHIPS model outputs and a maximum wind speed based damage function.

Figure 8.9. Projected GDP Losses from Tropical Cyclones: Baseline vs. High-Impact Climate Change



Source: World Bank estimates.

Note: The chart represents the relationship between the deciles of the distribution of the model simulation's results (vertical axis), and, on the horizontal axis, the corresponding present value of GDP loss (expressed as percentage of GDP in the no-cyclone scenario) over a 40-year time horizon. For each decile, the value of loss shown in the chart is an average across a distribution of intra-decile values. Further details are available in Appendix 5 of the full report.

The model enters “reconstruction mode” once hit with an extreme event. For a set number of years following the event or events, a defined proportion of GDP is directed to restore the damaged capital. As a result, that capital is not available to increase the productivity of the economy overall; rather, it is used to repair storm-damaged capital, so the long-term process of GDP growth is interrupted. This process is repeated for a high-impact climate scenario, a low-impact climate scenario, and a historical climate scenario.

Figure 8.9 shows the economic impact from the CGE simulations over the 40-year study period. The results underline not only the increase in mean damage to the economy from increased tropical storm intensity, but also the considerable increase in *risk of low-frequency, high-impact storms*. The simulations, in fact, suggest that climate change might have a more important effect in terms of the rarer but more catastrophic events than in terms of the average loss to be expected over any given period of time. This is because the variability of the extreme events and their combination tends to increase more than proportionally with time.

For example, under current climate conditions, a storm or a combination of storms causing a loss of 7.5 percent GDP (that is, a reduction of GDP compared to what would have happened with no cyclones) has, on average, a 10 percent probability of occurring; under climate change, this probability increases to 30 percent on average. This is because of

the higher destructive power of cyclones with any given return period; and/or, because for any given intensity of impacts, cyclones are expected to happen more frequently.

In a comparison of direct damage with the projected climatic conditions in the South-West Indian Ocean, a 100-year storm will cause almost double the damages as a storm with the same return period in the baseline. This effect is seen across a variety of return periods, and it is even more pronounced in relatively frequently occurring storms, with 5-year storm damage nearly tripling.

Figure 8.9 further highlights that storms influenced by climate change (shown in the red line) are much more damaging to the economy than storms that have struck Mauritius in the historical record (the blue line). Across the full range of the distribution of storms that could strike Mauritius over a 40-year period, the high-end climate change scenario greatly increases the chance of large GDP losses; and the probability increases as we look at impacts of increasingly larger magnitude. For example, the risk of losing 5 percent of GDP would go from a 30 percent probability in the current climate scenario to more than a 70 percent probability in the climate change scenario (a 2.3-fold increase).⁴ Similarly, the risk of losing 10 percent of GDP would increase from 3.2 percent in the baseline to about 12 percent in the climate change case (a 3.6-fold increase). While an increase in annual damage across all magnitudes of damage is problematic, the increase in loss for the largest damage years is most concerning. For the 10 percent most damaging years, losses are expected to increase by an additional 3.7 percent of GDP. A 3.7 percent loss is approximately equivalent to losing the entire contribution of the agriculture sector, since agriculture comprised 4 percent of GDP in 2016 (World Factbook 2016).

Another way to explore the impact of climate change on tropical cyclone damage is to assess the expected damage (under current and future climate scenarios) from storms with a given return period happening in a 10-years simulation period. In Box 8.2, we evaluate the damages associated with a 100-year storm under the mid-century high-impact climate scenarios (using the more severe consequence HadGEM climate model) compared to a 100-year storm under baseline climate conditions.

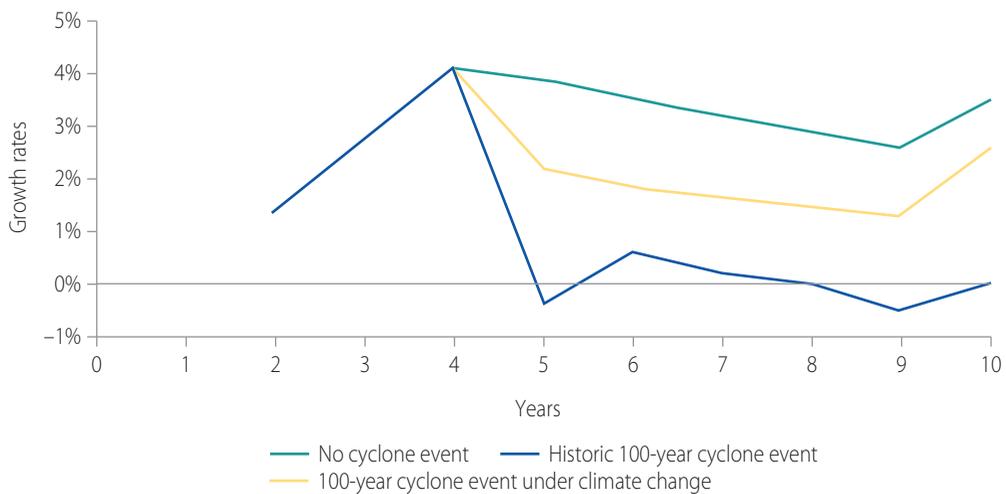
⁴ The results for the simulations using historical climate are consistent with those from the AIR Worldwide simulation but are not identical to those results. The AIR Worldwide results are effectively a snapshot of the direct effects on capital. The CGE results reported here simulate many snapshots of storm events occurring over a 40-year simulation period, in various sequences, while also capturing the long-term effects on the economy of the need for diverting investment to reconstruction.

Box 8.2. Economy-wide Impacts of a 100-Year Storm Under Current and Future Climate Conditions

A comparison of direct damage shows that under climate change, a 100-year storm will cause almost double the damages as a storm with the same return period in the baseline. This effect is seen across a variety of return periods and is even more pronounced in relatively frequently occurring storms, with 5-year storm damage nearly tripling.

The occurrence of the tropical storm under the climate change assumptions causes GDP to dramatically diverge from both the no-event and current climate baseline (i.e. the impact of the same type of storm without the strength induced by climate change). Over the 10-year period, the net present value of the loss due to a climate-change-amplified event is about 6.2 percent relative to the no-event baseline, or 3.3 percentage points more than the historical event scenario. As the figure below shows, this would be equivalent to losing more than 2 percentage points on average of GDP growth per year in the climate change scenario.

Box Figure 8.A. Impact of 100-Year Cyclone Event on GDP Growth Over Three Scenarios



Conclusions and Recommendations

Climate change in the form of increased heat, changes in precipitation patterns, and increased frequency and severity of tropical cyclones all suggest several areas of key vulnerability for the OE. Recent analyses of extreme event hazards have used the current (historical) climate scenario. These are important because they quantify and monetize the baseline risk of floods and wind storms damaging physical capital on the island (AIR Worldwide 2016), but they do not consider climate change. In addition, the CGE analysis conducted here considers both the direct

effects of storms (as the AIR Worldwide analysis does), but also the cumulative effects of storms on GDP, where the secondary effects of diverting resources to reconstruction have an important indirect effect on development in Mauritius. *Our analysis supports the important conclusions from prior work that storms associated with the current climate have led and will lead to significant damage in Mauritius, but extends that work to conclude that climate change will make those losses much worse.*

Climate change is therefore expected to operate as a “threat multiplier” in this context, exacerbating an existing natural hazard to the Mauritius OE. Magnified storms could affect the maintenance of productive tourism, fisheries, and industrial capital, as well as coastal residential structures. A less well-studied aspect of the climate change threat is the effect of more intense rainfall events on flood potential—a 2016 AIR Worldwide report reflects only the current climate flood risk (AIR Worldwide 2016), but another study of this region suggests that flood risks could be substantially increased (Cervigni et al. 2015). The potentially increased flood risk derives from both changes in routine patterns of rainfall associated with gradual climate change, and changes to rainfall patterns associated with extreme events such as cyclones.

The framework for analysis presented here can be applied to further assess the impact of natural hazards associated with climate change on Mauritius’ economy. The “deep dive” conducted for this book addresses only one channel of impact—the effect of climate change on cyclone wind speeds, and the resulting effect on capital assets and the broader macro-economy. Further, the application is limited to characterizing vulnerability, and stops short of assessing the performance and potential value of investments in climate change adaptive capacity (e.g., the construction of a breakwater to protect port assets). The framework can be applied to a much broader set of channels, however, and to both vulnerability and adaptation assessments. Acknowledging that a great deal of work has already been conducted by the Mauritian government to both assess physical vulnerability and initiate adaptive actions, gaps exist in the economic assessment of climate vulnerability and in identifying the economic benefits of adaptive actions to protect existing and new OE investments from those natural hazards that are significantly exacerbated by climate change.

The results of this review of climate stressor information, coupled with the deep dive, provide a strong argument for including analysis of climate change in the assessment of investments in new productive capacity to enhance the OE. Furthermore, key vulnerabilities identified here to more intense cyclones, including both higher wind speeds and more intense rainfall events, provide a starting point for application of the framework to finance of climate adaptation investments. Coastal adaptation and preparedness projects, for example, have already

been funded by the Green Climate Fund in some upper-middle-income countries (e.g., disaster readiness investments in the Cook Islands and in Antigua and Barbuda).⁵ Mauritius is particularly well positioned to prepare an application for adaptation investments as a member of the Small Island Developing States (SIDS) group, which represents a preferred class of potential GCF grant recipients.

To move forward in this area, recommended actions include the following:

1. **Refine the full island-scale risk assessments.** Analyses conducted to date by AIR Worldwide characterize the baseline, current climate risks associated with natural hazards, including the flood risk associated with rainfall events. These risks should be updated to reflect the latest climate science, including projections of cyclone and non-cyclone precipitation and flood events as well as the impact of rising sea levels on storm-surge-modelled losses. While the Mauritius Disaster Risk Reduction Strategic Framework and Action Plan (MOESD 2012) acknowledges the importance of mitigating the vulnerability to cyclone risk, it lacks the quantitative assessment of tropical cyclone risk under climate change. Updating these updated risk assessments will require that the hydrologic (rainfall-runoff) and hydraulic (flood mapping) analyses previously conducted be re-estimated. These new analyses ought to reflect the significant uncertainty in these projections, a dimension that is needed in the risk assessment to ensure that they support identification of robust adaptation options.
2. **Add climate resilience analyses to economic assessments of new OE investments.** Much work has been done so far by the Government of Mauritius to assess effects such as ocean acidification, which can have detrimental effects on fisheries productivity, and therefore on the return on investment in the fisheries sector, but those analyses clarify only the physical aspects of climate change and only in general terms. A key gap that can now be filled, however, is to assess how climate change affects the return on investment for port and tourism projects. For example, the cyclone forecast tools used in this chapter can be coupled with wave models to assess the benefits of building a breakwater to protect the port. Analyses such as these can then be used as part of the package to apply for climate finance funding.
3. **Consider disaster risk financing options to mitigate the social and economic impacts of low-probability, high-impact climate shocks.** Examples of such options include the sovereign insurance scheme

⁵ See <http://www.climatefundupdate.org/listing/green-climate-fund>.

developed by Africa Risk Capacity and the World Bank's Catastrophe Deferred Drawdown Option (or CAT DDO), a contingent credit line that provides immediate liquidity to World Bank member countries in the aftermath of a natural disaster.

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