Coastal Zones and Climate Change

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Small Island Developing States: Incubators of Innovative Adaptation and Sustainable Technologies?

Alain De Comarmond and Rolph Payet

Small island developing states (SIDS) form a distinctive group. Spread across the Atlantic, Pacific, and Indian Oceans and the Caribbean and Mediterranean Seas, each island possesses its own unique characteristics, but they all share similar challenges to their development. This was the conclusion of the United Nations General Assembly in 2001 when it recognized

> that within the context of the challenges of development, small island developing States can experience specific problems arising from small size, remoteness, geographical dispersion, vulnerability to natural disasters, fragile ecosystems, constraints on transport and communication, isolation from markets, vulnerability to exogenous economic and financial shocks, limited internal markets, lack of natural resources, limited freshwater supply, heavy dependence on imports and limited commodities, depletion of non-renewable resources and migration.[1]

One strategy to overcome these challenges is to work toward the transfer of appropriate technologies. Indeed, the international community, through such instruments as the 1992 Earth Summit and Agenda 21, has long highlighted technology transfer as a key determinant of sustainable development. SIDS governments have similarly embraced the goal of technology transfer, as reflected in the 1994 Barbados Programme of Action adopted at the First Global Conference on the Sustainable Development of SIDS and its 10-year follow-up report, the 2005 Mauritius Strategy of Implementation.[2] Nevertheless, a 2004 preparatory meeting on the 10-year review of the Barbados Programme of Action implementation noted that although technology transfer in SIDS remains an issue, no separate funding mechanism to support this aim had been made available.[3] Also, regional clearinghouses to enable access to appropriate technologies by SIDS have yet to materialize, leading the Mauritius Strategy of Implementation to reiterate the need to build resilience in SIDS through technology transfer. According to the Organisation for Economic Co-operation and Development (OECD), investments in R&D are crucial for economic growth, job creation, and improved living standards—which implies that R&D can play a significant role in sustainable development and resilience building.[4] Yet while the ratio of investment in knowledge (R&D,

higher education, and software) to GDP varies from 1.8 to 6.8 percent across OECD countries, it falls well below 1 percent in most SIDS and is even nonexistent in some.

SIDS are especially vulnerable to climate change, with serious risk of substantial economic and societal repercussions. To address these impacts, SIDS will need to implement a number of adaptation strategies requiring the development and transfer of appropriate technology. Such strategies may include purely technological options, such as engineered coastal protection works and water desalination plants; or they may entail a combination of community innovation, technology, and wise management, such as water harvesting and coastal beach dune conservation. Adoption of these measures will depend strongly on each country's capacity to innovate and implement adaptation solutions appropriate to its specific ecosystems and socioeconomic structures.

For example, in the Pacific, continuing expansion of the tourism sector and the demands of housing growing populations have led to poor planning and development in high-risk areas without adequate safety design considerations. Housing made with locally available materials and traditional methods, however, has typically proven able to survive extreme events and other natural calamities.[5] Similarly, SIDS depend almost entirely on imported fossil fuel for electricity generation and transport. Shifting to renewable energy technologies from sources such as the sun, wind, geothermal power, and the tides of the ocean could provide both environmental and economic benefits. Iceland, for instance, has succeeded in transforming its energy market by investing in the development of geothermal and hydroenergy, which in 2006 constituted 73.4 percent and 26.5 percent, respectively, of its total national energy supply.[6] Scotland has established a world center for ocean energy innovation and prototype testing facilities in the Orkney Islands, further demonstrating that islands can be important incubators for technology development and create significant opportunities for foreign direct investment, R&D, training, and employment.[7] To fund projects and facilitate technology transfer and capacity building in SIDS, the United Nations Framework Convention on Climate Change (UNFCCC) and the Global Environment Facility established the Special Climate Change Fund in 2001, but it has yet to be sufficiently financed.

Despite these challenges, the SIDS have made tremendous efforts in innovating and applying established technology to their context. This paper discusses the opportunities for and barriers to technology development in SIDS, with particular reference to the emerging issue of adapting to climate change. It presents three case studies that highlight efforts by SIDS to innovate and shows how SIDS can become technology incubators for climate change adaptation and mitigation.

Climate Change and Its Implications for SIDS

The Intergovernmental Panel on Climate Change has extensively examined the prospective impact of climate change on SIDS.[8] Rising sea levels present the biggest challenge for small island states. Sea level rise is expected to exacerbate coastal inundation, increase erosion, and magnify the effect of storm surges, thus threatening vital infrastructure, settlements, and facilities that support the livelihoods of island communities. Changes in precipitation will alter water resource availability, which would in turn affect agriculture, biodiversity, and natural ecosystems dependent upon water supplies. Elevated sea surface temperatures and ocean acidification are already causing coral bleaching and may cause changes in fisheries distribution that would critically undermine commercial and subsistence fisheries in many SIDS. Climate change will also have a direct impact on other important economic sectors such as tourism, as well as on human health.

Adaptation based on innovative and existing management techniques and technologies is therefore a priority for SIDS. Historically, much attention has focused on using hard structures such as seawalls to protect coastlines susceptible to sea level rise. A number of feasible "soft" protection and adaptation options are also possible, however. Integrated coastal zone management and ecosystem-based adaptation are proven frameworks that can facilitate the implementation of appropriate accommodation strategies.[9] These strategies include measures such as coastal forest rehabilitation, beach dune restoration, and design structures that take the dynamic changes in the coastal zone into consideration.[*] In many cases, these accommodation strategies—such as constructing homes on stilts rather than surrounding them with barriers—may provide a more cost-effective and resilient approach for adaptation.[10] Where such measures are not possible, some communities may have to undertake a policy of retreat, relocating away from vulnerable areas. Needless to say, this alternative has serious implications for land ownership and compensation. In cases where an entire nation has to be relocated, sovereignty issues arise.[11] Unfortunately, mounting evidence suggests that if no effort is made to reverse dangerous climate change, many low-lying island nations face forced evacuation to another country.

Barriers to and Opportunities for Technology Development in SIDS

A SIDS expert meeting on Science and Technology for Sustainable Development, held in Singapore in August 2004, outlined the main barriers to science and technology in SIDS:

- Nonexistent or poor allocation of resources for science and technology
- Poor legal infrastructure
- Limited value given to protecting and expanding traditional knowledge
- Science and technology poorly mainstreamed into the development process

[*]For example, the Institute for Business and Home Safety in the United States found that losses following Hurricane Rita were more than fourfold greater in houses that had ignored the 1996 Florida building codes. See Institute for Business and Home Safety, "The Benefits of Modern Wind Resistant Building Codes on Hurricane Claim Frequency and Severity: A Summary Report" (2004), www.ibhs.org/newsroom/downloads/20070810_102941_10167.pdf (accessed March 4, 2010).

- "Brain drain"
- Limited investment in the development of professional capacity
- Poor enabling environment for technology transfer[12]

In general, the main constraints faced by SIDS lie in the area of capacity building and the lack of R&D platforms such as academic institutions. Recent advances in information communication technology can alleviate some of these difficulties, reducing barriers to knowledge sharing and institutional cooperation, for instance. Nonetheless, significant constraints in access and optimal use of such technology persist, including insufficient access to high-bandwidth Internet communication and poor knowledge of globally available knowledge networks.

The allocation of resources in SIDS is based on revenues generated from a relatively limited set of economic activities such as tourism, fisheries, and financial services. Revenue from such activities, which are highly susceptible to global fluctuations such as the recent financial crisis, have been dedicated to basic education and health care rather than to technology R&D. Jacob and Groizard, for example, have looked at the number and type of technologies transferred from large tourism multinationals to the Dominican Republic.[13] They found that technological innovations in the areas of information communication technology and environmental protection were among the most valuable to local economies because many of these innovations were highly dependent upon local training programs and the recruitment of skilled labor. Empirical evidence shows that quality education and training can stimulate technology transfer with substantial economic impacts. Economic models developed by Ho and Hoon calculate that the quality of education combined with technology transfer accounted for at least 52.1 percent of Singapore's real GDP growth per worker from 1970 to 2004.[14] Some closely linked island groups in the Caribbean and the Pacific have sought to capitalize on this dynamic by coming together to build regional universities. Many small island states, though, do not have national universities or access to such knowledge and research institutions.

The same natural resources that provide the basis for many traditional livelihoods could also supply new economic opportunities. SIDS are exceptionally rich in ocean resources and endemic biodiversity, making them potential candidates for mineral/oil exploration and bioprospecting.[15] (Bioprospecting is the search for wild species useful for the development of new products and processes such as crops and pharmaceuticals.) For example, malamala (*Homalanthus nutans*), a medicinal tree from Samoa, has been found to be effective against HIV.[16] Since 1979, a tissue culture program on the island of Barbados aimed at improving the yam species *Discorea allata* has resulted in a multimillion-US-dollar industry benefiting several Caribbean islands.[17] Jamaica exports more than 2,000 tons of this yam species to Canada each year.

Even so, the lack of appropriate legal frameworks and cost/benefit-sharing mechanisms has resulted in lost opportunities and revenue for a number of SIDS. The brain drain of mobile professionals leaving SIDS is another important barrier to technological innovation and development. Despite their being potentially fertile grounds for R&D, the dearth of appropriate infrastructure and market opportunities in SIDS frequently pushes professionals to more hospitable countries. Singapore offers one positive example of a small island state fostering innovation-driven start-ups associated with universities that has increased retention of highly skilled professionals in key areas.

Solving Climate Change: Sustainable Technologies for Adaptation and Mitigation in SIDS

While climate change now receives widespread political attention, the planet faces a number of profound technical and economic challenges to mitigate global emissions and stabilize greenhouse gas concentrations at safe levels (defined by the UNFCCC as "a level that would prevent dangerous anthropogenic interference with the climate system"), and to adapt to those climate changes that cannot be avoided. Many scientists now consider the planet to be on the brink of a global shift in climate.[18] Although the science is compelling and the economic rationale for action credible,[19] the international community is at an impasse regarding whether and how vigorously the larger economies will commit to mitigating greenhouse gas emissions and adapting proactively to their impacts. The knowledge and technological requirements needed to address these challenges are unprecedented. The complex and discernible impacts of climate change on a wide range of sectors from public health to human settlements will require review and reconsideration of the ways in which technology transfer is evaluated and implemented at all levels, from the local to the global.

A first issue concerns the international intellectual property rights system, which provides the regulatory framework for technology development and transfer. The UNFCCC calls for developed nations to assist the developing world with technologies to address climate change.[*] However, the World Trade Organization Agreement on Trade-Related Intellectual Property Rights makes no special consideration for technologies that contribute to the "common good of humanity"—an omission that may present obstacles for developing countries seeking to obtain and deploy certain technologies on those grounds. In practice, the possibilities and constraints for technology transfer and technology development in the SIDS vary from case to case. A study commissioned by the International Centre for Trade and Sustainable Development evaluated numerous perspectives on intellectual property

[*]Article 4.5 of the UNFCCC states that "The developed country Parties and other developed Parties included in Annex II shall take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention."

and the transfer of renewable energy technologies.[20] The report concluded that the possibilities for developing countries to enter the photovoltaic sector are still much higher than for wind energy, which is currently dominated by a small group of companies. Biofuel technology, on the other hand, is based upon biotechnological advances and may be subject to patents in the long term.

Second, a related study by the Global Climate Network highlighted the importance of domestic policy in the deployment of grid-connected renewable energy technologies. It concluded that a lack of sector-specific feed-in tariffs,[*] and of regulations and incentives to promote such technologies, "is one of the most profound barriers of all."[21] This is particularly true in SIDS. For example, the initiatives aimed at introducing low-carbon technologies in Seychelles face unnecessary regulatory and tariff hurdles in bringing these technologies to the islands at a cost that would minimize the investment risk.

Finally, effective technology transfer depends on the emergence of new markets and on firms and individuals developing the skills and know-how to deploy and service those technologies. SIDS need to consider the institutional, infrastructural, and capacity implications when considering technology solutions for climate change. For example, an ongoing project to install wind power in Seychelles requires a complete overhaul of the regulatory framework to accommodate distributed power generation; significant upgrading of the distribution network to handle the load from decentralized wind farms; and training of local engineers, operators, and maintenance personnel.

To illustrate some of the challenges and opportunities in implementing climate change technologies in SIDS, three case studies are presented here. The first focuses on the adoption of an accommodation adaptation technology in Seychelles. The second considers a retreat adaptation strategy by the Maldives. The third examines a mitigation biofuel project in Vanuatu.

Case Studies

Implementing Protection/Accommodation Adaptation Strategies in Seychelles

The Seychelles archipelago, located 4 degrees south of the equator, consists of 115 islands, 41 of which are granitic with mountainous peaks and narrow coastal strips, and the remaining 74 coralline low-lying islands comprised mostly of sand cay formations. More than

[*]A feed-in tariff is designed to promote adoption of renewable energy sources by providing grid access for producers using renewable technologies and for the utility company to purchase the electricity so generated. See M. Mendonça, *Feed-in Tariffs: Accelerating the Deployment of Renewable Energy* (London: Earthscan, 2007).

90 percent of the population and all economic activities are located on the narrow coastal plateau, where the average elevation is 2 meters above sea level. Because of steep land conditions, extensive areas have also been reclaimed on the east coast of Mahe Island, the largest inhabited island in the group. The economy continues to rely heavily on tourism as a foreign exchange earner, accounting for about 21 percent of GDP in 2006.

Seychelles is highly vulnerable to climate change. Output from the Individual Global Circulation Model shows a maximum increase in rainfall of 5.9 percent (19 millimeters) for the year 2025, 9.3 percent (25.4 millimeters) for 2050, and 12.4 percent (38.6 millimeters) for 2100.[22] The range of percentage change in annual rainfall, however, is -2.4 to +5.0 percent, -4.8 to +8.5 percent, and -8.6 to +16.3 percent, respectively, for the years 2025, 2050, and 2100. Based upon these results, Chang-Seng concludes that the rainy season is more likely than not to be wetter, while the dry season is more likely than not to be dryer, with the exception of the June-September season of the year 2050. On sea level rise, Church et al., using tide gauge data combined with TOPEX/Poseidon satellite altimetry data from 1950 to 2001, estimated a rate of relative sea level rise of 0.5 ± 0.5 millimeters per year for Seychelles.[23] Against the global mean sea level rise (from 1961 to 2003) of 1.8 ± 0.5 millimeters per year, these results appear to fall below the global average, but not low enough to minimize the risks involved.[24]

Observations of coastal erosion in naturally stable areas have been linked to this increase in sea level, combined with coral bleaching and storm surges.[25] Because coastal beach erosion in particular is linked to human activities, a proper assessment of the root causes of changes should be undertaken before implementing any adaptation technology. Most economic activities in SIDS, especially tourism, occur in coastal areas, and such development pressures and related human stresses can have detrimental impacts on natural ecosystems such as beaches, wetlands, and coral reefs. Often these damages occur when setback policies are not applied, natural vegetation is removed, and coral reef ecosystems are destroyed via processes such as siltation and dredging. One hotel developer in Seychelles installed offshore breakwaters parallel to one of its beaches to create a more sheltered bathing experience for its guests. Over the years, the developer has had to put additional coastal protection measures in place because the first breakwaters aggravated coastline instability.

Setback limits constitute one very effective means of controlling impacts of coastal development in the narrow coastal areas of SIDS. They are also a retreat strategy against climate change risks such as sea level rise, storm surge, and flooding. In Seychelles, a 25-meter minimum setback distance requirement (unlegislated) has been imposed on developers as a planning tool as well as an adaptation strategy for the future. Further legal and institutional frameworks will be needed to support the implementation of chosen policies and technologies. For instance, sand poaching and extraction in beaches are direct causes of coastal erosion. In Seychelles, sand extraction from beaches was legal until 1982 when the Removal of Sand and Gravel Act prohibited the practice.

With the support of the Global Environment Facility and the Assessment of Impact and Adaptation to Climate Change project, Seychelles developed a pilot project aimed at demonstrating the potential value of soft engineering approaches to beach protection and restoration of dunes.[26] Beach tourism here as elsewhere hinges on the condition of the shores. Several Seychelles beaches are counted among the top 10 best tourist beaches in the world.[27] The economic value (in net present value terms) of one popular beach in Seychelles has been estimated at US$320 million.[28] Thus, loss of beaches from climate change or any other factor would directly affect the islands' economy.

Since most of the best beaches in Seychelles lie on windward coasts, it is reasonable to assume that wind-driven wave action is an important determinant of their stability and structure. Consequently, changes in wave action as a result of climate change will affect the nature of these beaches. The challenge has been to develop an adaptation technique based upon building the resilience of the beach to increased wave action, while maintaining the aesthetic appeal required by the tourism industry. Based upon these criteria, a research team evaluated various methods and technologies of beach protection and undertook a survey of the effectiveness of existing beach protection techniques. The team concluded that many of these efforts (ranging from seawalls, groins, rock armoring, and artificial sheet revetments) were not effective over the long term in maintaining beach formation and structure. Consequently, a modified version of a coastal protection method involving wooden logs of diameters not more than 20 centimeters driven into the sand was adopted. The modification entailed introducing a second layer of wooden logs, in the form of a sandwich, the middle of which is lined with geotextile and filled with medium-sized rocks for additional strength. This second layer would act as the ultimate barrier in the case of an extreme wave event and also create a topographic profile to enable the sand to cover the proposed structure.

After considering various alternative designs and discussions with engineers, contractors, and a few hotel operators, it was agreed that the model be tested in a real-life situation. A cost analysis was conducted, and a local contractor interested in implementing the technique jointly sponsored a pilot project in conjunction with the hotel concerned. After completing the construction phase, the next step involved restoring beach vegetation and the sand dune. Relatively mature seawater-resilient plants were acquired from a nursery and planted in the area just behind the wooden pillars, with the aim of further reinforcing the beach berm from potential wave spillovers. A number of beach-monitoring transects were set up along the restored part of the beach to determine the technique's effectiveness.

After one year of monitoring, an assessment was made. Because beaches in Seychelles are subject to varying wave action over two seasons, long-term monitoring is necessary. However, results from the first year were very encouraging, and several hotels located along the beach have since offered to implement the approach. Figure 1 shows the changes in the beach's appearance over time.

It must be noted that the method is not applicable to all erosion scenarios or intensities and wave environments, and no modeling of the dynamics and expected changes over time has been made.

Figure 1 shows that the chosen beach protection approach yields positive results in every possible wave regime at that location during different times of the year. The method has since been promoted nationally at several other hotels, as it met the original criteria under which the project was designed. A key consideration is the need for continuous coastal vegetation replanting to ensure long-term stability of the beach berm. As figure 1 reveals, this practice was not observed by the hotel because its management was more interested in providing a view of the sea for its clients than creating a natural coastal vegetation buffer to protect the infrastructure against storm surges and erosion.

Overall, the introduction of coastal adaptation technologies requires a thorough assessment of the coastal dynamics and close consideration of the various uses made of coastal zones. Nature-based approaches such as replanting can substantially increase the resilience of particular shorelines to extreme wave conditions, but such measures require constant attention and ongoing maintenance.

Figure 1: Seychelles Beach Before and After Installation of Coastal Protection

a: Erosion 2001 (before installation)

b: 2003, after installation

c: June 2009, during high wave conditions

Source: Alain De Comarmond.

Retreat and Relocation Adaptation Strategies in the Maldives

The Maldives consists of 1,192 islands on 26 natural atolls, forming a double chain on the Laccadive-Chagos submarine ridge in the Indian Ocean. All the islands are low lying and began forming between 3,000 and 5,500 years ago, primarily from reef-derived carbonate sediments deposited by ocean waves and currents. At least 80 percent of these islands are 1 meter or less above sea level, and only three have a surface area of more than 500 hectares. These characteristics make them highly vulnerable to sea level rise and extreme storm events (table 1).[29]

Table 1: Land Utilization in the Maldives Based on Island Size

Island size range (ha)	Total no. of islands	Land area (km^2)	Land area of utilized islands	No. of utilized islands	% of utilized islands	% of total area utilized
1–25	949	56.53	177	18.75	18.7	33.2
25–50	124	44.69	84	30.97	67.7	69.3
50–100	66	45.15	55	38.31	83.3	84.9
100–250	33	47.67	32	47.45	97.0	99.5
250–500	7	20.35	7	20.35	100.0	100.0
500+	3	16.4	3	16.4	100.0	100.0

Source: A. Shaig, *Climate Change Vulnerability and Adaptation Assessment of the Land and Beaches of Maldives*, Technical Papers to Maldives National Adaptation Plan of Action for Climate Change (Malé: Ministry of Environment, Energy and Water, 2006).

The population of 298,968 lives on 202 islands, presenting a communications and transport challenge.[30] Most of the islands have a population of not more than 1,000, and only 2 percent have a population exceeding 5,000.[31] Malé, the capital city-cum-island, houses 34 percent of the population, and is almost entirely occupied by infrastructure. With more than 53,000 people per square kilometer, Malé is one of the most densely populated cities in the world.[32] A report by the United Nations Development Programme estimated that nearly a quarter of the population lives in houses of 40 square feet or less.[33] Despite these physical and logistic challenges, the Maldives has been able to progress economically and socially in the last 30 years, primarily due to its tourism industry and social investment program. Tourism, which accounts for about 33 percent of GDP, creates employment for roughly half of the population and stimulates economic activity in other sectors such as agriculture, construction, and services. About 20 percent of the population depends on subsistence fisheries.[34]

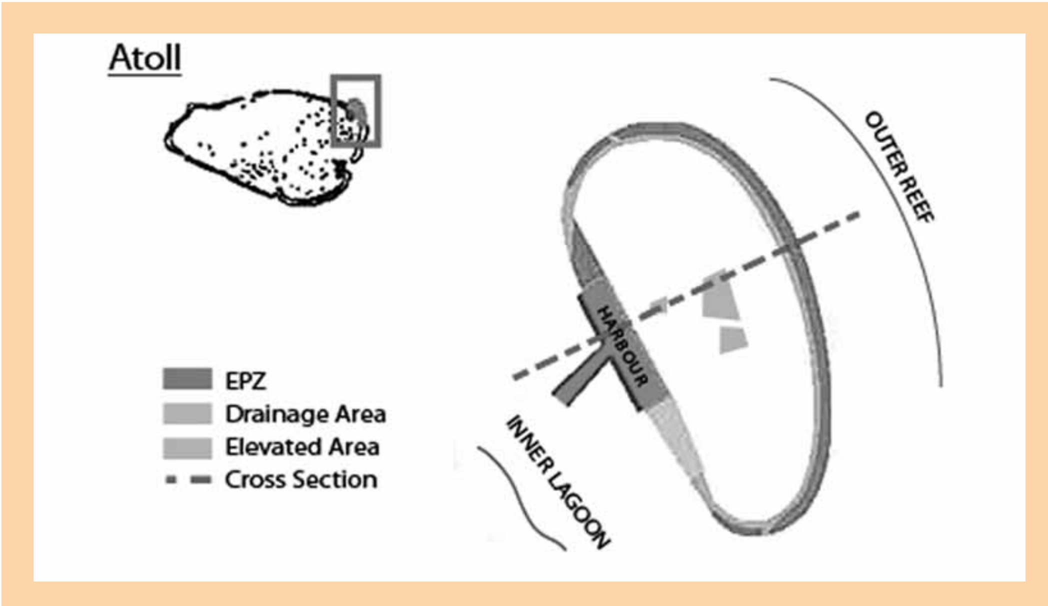
With economic growth averaging 9 percent since 1978, the Maldives will graduate from least developed country status in 2010.[35] While a commendable achievement, this will remove the Maldives from most official development assistance support, meaning that it will not be able to access development loans at grant or preferential interest rates. Research undertaken by the United Nations concludes that, irrespective of economic growth and GDP per capita improvements, SIDS remain extremely vulnerable to economic up- and downturns and thus require special consideration to ensure their continued sustainability.[36] Efforts to diversify away from traditional but volatile economic dependencies to sectors such as offshore financial and gambling centers have met with some opposition in developed countries.[37] The economic and survival challenges of the people of the Maldives were evident after the 2004 tsunami caused damage equivalent to 62 percent of national GDP.[38] As of 2009, the country still faced a deficit of more than US$150 million for reconstruction.[39]

The government of the Maldives has developed a National Implementation Strategy for Addressing Climate Change and submitted a National Adaptation Plan of Action in 2007.[40] A core component of this strategy is the development of one larger "focus island" or several "safe islands" per atoll. Such an approach will enable the establishment of more cost-effective and robust infrastructure, which will enhance the country's resilience to climate change and promote long-term environmental and social stability.

The Safe Island Program will involve the relocation from smaller and more vulnerable islands to these large islands (a retreat adaptation strategy). This strategy will enable the government to focus its adaptation efforts on a number of key large islands. Five focus islands have been identified: R. Dhuvaafaru, A. Sh. Maamigili, Dh. Kudahuvadhoo, Th. Vilifushi, and L. Gan. Some of the features planned for these islands include elevated areas for safe evacuation in case of storm surges (or another tsunami), raised buildings, appropriate drainage, and sand dune barriers (figures 2 and 3). A multipurpose safehouse system for about 1,000 people is currently under construction on the atolls of Muli and Meemu.[41] The shelter incorporates innovative designs such as an underground 45,000-liter rainwater tank, a storehouse for food and life-saving drugs, an operations center with communications equipment, and enough energy for up to three days. The building has also been designed to allow for vertical evacuation, which means people will be able to move upwards to a high central location in times of flooding. While the relocation policy will be voluntary, it is expected that inhabitants of smaller, more vulnerable islands will slowly move to those larger islands as economic centers are created.

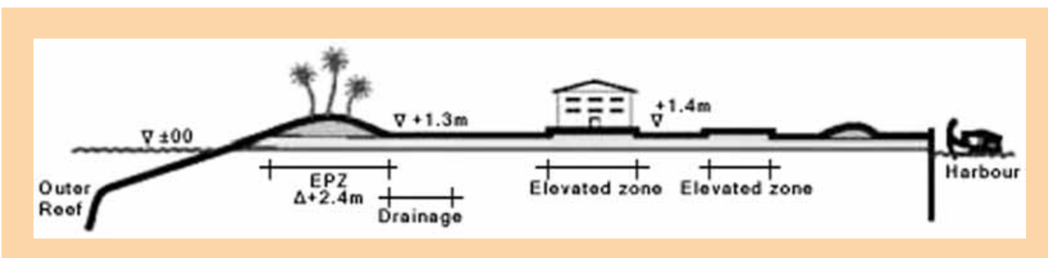
Historically in the Maldives, population movement between islands has been a means of overcoming stresses such as changes in resource availability and extreme weather conditions.[42] Modern progress and development, however, have resulted in significant investments in heavy infrastructure, which makes the relocation strategies of earlier times difficult and costly. Efforts at a more flexible approach to settlement development may provide some avenues for enhancing the resilience of island populations to coastal hazards and

Figure 2: Safe Atolls: A Retreat Adaptation Strategy Adopted by the Maldives



Source: United Nations Environment Programme (UNEP), *Maldives: Post-Tsunami Environmental Assessment* (Nairobi: UNEP, 2006), p. 24.

Figure 3. Cross-Section of an Atoll Showing Potential Adaptation Measures



Source: UNEP, op. cit., p. 24.

sea level rise. Such an approach should include the consideration of appropriate design to minimize waste and the use of energy and water, as well as built-in adaptation to future climate change.

Ultimately, the Maldives faces a far worse prospect—that of relocating the entire nation. It is estimated that sea level rise will eventually render the Maldives completely uninhabitable, although there is still some uncertainty as to whether the sea level in the Maldives region is rising at the same rate as the global average.[43] This issue has led to discussion of a number of relocation options: (1) individual or collective emigration to other countries, (2) purchasing land in another country for a mass relocation,[44] and (3) relocating to alternative islands in other large archipelagos. Each alternative raises important questions of sovereignty and national identity (statehood). According to the United Nations Convention on the Law of the Sea, an island or archipelago would automatically lose its claim on an Exclusive Economic Zone following inundation by the sea.* Although there are previous examples of governments in exile, international law is not clear on the case of forced relocation as a result of environmental factors or climate change caused largely by the actions (emissions) of other states. International consensus on this issue is crucial for the future of the Maldives and other island states facing the same dilemma.

SIDS Mitigating Climate Change: Developing Biofuels in Vanuatu

Most SIDS are heavily dependent on fossil fuels and devote a high proportion of their foreign exchange resources to importing fuel. For example, the ratio of the value of petroleum imports to the value of total exports ranges from 10 percent for Papua New Guinea to more than 400 percent for the Marshall Islands. Most SIDS depend on high-cost fossil fuels to produce very expensive electricity. Electricity prices are generally between US$0.20 and US$0.35 per kilowatt hour, which is much higher than prices in America or Europe. SIDS energy systems are frequently inefficient as well as expensive, exacerbating national economic vulnerability. Secure supplies of affordable and reliable energy are an essential element of economic and social development. Electricity is vital to the delivery of social services such as health, education, water, and sanitation; further, it enables job creation and frees time for productive pursuits. At present, however, 70 percent of Pacific island residents do not have access to electricity and depend on a mix of fuelwood, kerosene, and batteries for their energy supply.[45]

The 2007–08 oil crisis placed unsustainable financial pressures on the economies of many SIDS, prompting investigations into alternative forms of energy. For SIDS, the benefits of renewable energy are at least fivefold:

- Renewable energy offers a clean, green, dynamic image and marketing tool for a country.
- It preserves natural resources.
- It provides economic benefits, including reducing imports, thus saving scarce foreign exchange.
- It creates employment and generates new income.
- It furnishes cheaper and more reliable energy for businesses and individuals.[46]

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*The criteria defining a state are enshrined in Article I of the Montevideo Convention on the Rights and Duties of States of 1933. Article 56(1) of the UN Convention on the Law of the Sea outlines the sovereign rights of nations over the natural resources, whether living or nonliving, of the waters and seabed. See “Report of the Expert Meeting on Capacity Building for Renewable Energy and Energy Efficiency in Small Island Developing States” (2003), www.un.int/mauritius/Documents/AOSIS/Workshop%20Reports/Final%20Draft%20Energy%20Meeting%20Report%20revised.pdf (accessed March 4, 2010).

Historically, coconut oil was used for cooking and lighting in many island homes, but with the arrival of electricity supplied by centralized generators, these practices subsided. Recent advances in technologies such as coconut oil extraction, engine modifications, and blending have once again increased its potential as a source of fuel on the islands. Research on the calorific value of coconut oil has demonstrated its versatility and safety, making it an effective alternative to fossil fuel. Indeed, Virgin Airlines has successfully powered a 747 flight on a blend containing coconut biofuel.[47] Developing such biofuels offers a promising means of safeguarding the coconut oil industry, which remains a major source of income and is often the sole employment opportunity for large portions of rural island populations.

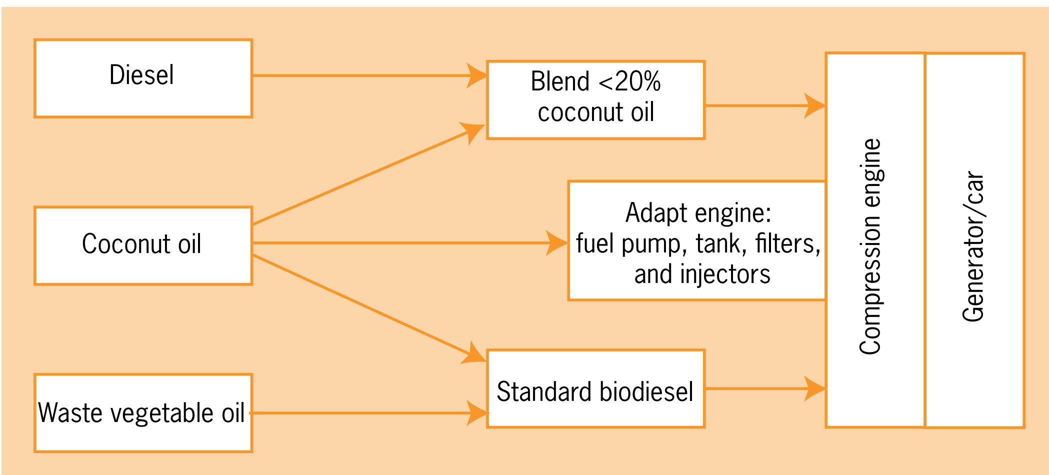
On the other hand, the biofuel industry has attracted much criticism, often linked to food security and environmental degradation. It is therefore imperative that SIDS adopt sustainable approaches throughout the life cycle of the biofuel process. Properly certified, coconut biofuels can be produced in climate-neutral fashion, thus effectively contributing to reducing the emissions that cause global warming. This is an important consideration, as it demonstrates that, despite their size, SIDS can contribute to global mitigation efforts.

At the 2002 World Summit on Sustainable Development in Johannesburg, the Pacific island countries launched a regional energy sector umbrella initiative. Its goal is to increase the availability of adequate, affordable, and environmentally sound energy for the countries' sustainable development, and to accelerate the transfer and adoption of clean and renewable energy technologies. The Cook Islands, Fiji, Kiribati, the Marshall Islands, the Federated States of Micronesia, Palau, Papua New Guinea, Samoa, the Solomon Islands, Tonga, and Vanuatu together spend more than US$800 million a year on fuel imports. If the Pacific islands replaced half of their diesel imports with coconut oil, the region's average fuel import bill would be cut by 10 percent.

One small island state that has made significant strides in the development of coconut as a biofuel is Vanuatu. Agriculture—dominated by the production of copra (from coconut), kava, beef, cocoa, and timber—provides employment to about 65 percent of Vanuatu's population of 243,000.[48] Tourism, fisheries, and offshore financial services are growing sectors on the island.[49] In 2008, Vanuatu exported US$11 million of copra and US$8 million of coconut oil;[50] it imports more than 24 million liters of diesel oil annually. Although the government collects over 40 percent of its taxes from the importation of diesel, it believes that substituting biofuels for diesel will have a positive impact on the balance of payments and reduce its dependency on imported energy. To stimulate the development of biofuel, Vanuatu introduced an excise tax (specifically a value-added tax) on biodiesel, while providing for customs duty exemptions or reductions on raw materials and machinery for the production of biofuels. With the price of coconut oil ranging from US$0.30 to US$0.70 per liter, it can be a viable substitute for diesel fuel. Fostering biofuels markets provides an outlet for local coconut plantations, which would otherwise be outcompeted by large coconut oil producers such as the Philippines.

Many studies have been undertaken in Vanuatu to determine the viability of coconut oil as a component of biodiesel or of fuel blends for electricity generation (figure 4).[51] As one outcome of these studies, a 2:1 coconut-diesel oil blend is currently being used in vehicles in Vanuatu. Although short-term results look promising, in the long term, the engines suffer from accumulation of deposits on internal engine parts, suggesting that substantial reliance on this fuel requires modifications to the standard engine. Additionally, Vanuatu is running its main generator in the city of Port Vila on a fuel blend containing 10 to 20 percent coconut oil with important financial benefits to the operators. Despite these promising successes, a number of challenges remain to be addressed, including price considerations, lack of public awareness of the fuel, and environmental concerns regarding the sustainability of the coconut plantations and risk of coconut palm diseases.

Figure 4: Overview of Biofuel Choices for Compression Engine



Source: J. Cloin, "Coconut Oil as a Fuel in Pacific Islands," *Natural Resources Forum* 31, no. 2 (2007).

Conclusions

SIDS can become effective incubators of sustainable technology. Despite the opportunities, technology development and transfer are often hampered by several key challenges. These constraints are not international or external in nature, but include a number of internal impediments that need urgent attention if SIDS are to adapt effectively to climate change. While the availability of external financing and opportunities remains an important concern, appropriate national frameworks and institutions to support technology development and transfer are imperative. At the same time, the examples discussed here demonstrate that technology development and transfer do not entail only hard engineering solutions, but also innovative, sustainable, and integrated approaches to provide the greatest resilience to societies and ecosystems.

Action must be taken to reduce the impact of climate change in SIDS through appropriate technology transfer frameworks. Lack of an integrated approach can result in higher costs without achieving resilience. Evidence abounds demonstrating that, with an effective and proactive strategy, the initial high costs of adaptation can be avoided or reduced. In extreme situations where islands might have to be evacuated, specific adaptation measures need to be put in place after an assessment of risk and vulnerability. Finally, it is important to ensure that subsequent adaptation or mitigation technology transfer does not lead to environmental degradation, unsustainable practices, or climate change.

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