WHITE PAPER: Blue Infrastructure Supporting SDG 14 in Coastal Communities in Indonesia

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Contents

Executive Summary

This white paper outlines blue infrastructure solutions and blue alternatives and nature-based adaptations to traditional infrastructure that are best suited to address the needs of coastal communities in Indonesia, while also supporting U.N. Sustainable Development Goal (SDG) 14.

Indonesia's coastal ecosystems are among the country's most vital economic assets. The key economic sectors that benefit from the country's rich coastal ecosystems include fisheries, agriculture, forestry and tourism. Fisheries, agriculture and forestry make a combined contribution of over 8% to national GDP[1], while tourism contributes over 4%[2]. In addition to their economic importance, coastal ecosystems and their supporting blue infrastructure are critical to long-term sustainability and provide resilience in the face of external shocks, such as those associated with climate change, natural disasters, and pandemics.

Coastal communities, whose livelihoods are closely linked to their coastal resources, have a disproportionate influence on the management of coastal ecosystems. However, coastal communities are among the poorest communities in Indonesia. Their lack of access to services, such as wastewater management, dependable transportation infrastructure, or reliable energy sources, means that they are often unable to capture the full value of coastal resources. For example, fishers may be unable to transport their catch to outside buyers in a timely manner due to unpaved roads; the problem is exacerbated by weather events and underlying climate conditions. Coastal communities require infrastructure development in order to sustainably grow their economies.

Traditional gray infrastructure tends to have a negative environmental impact on the surrounding area and is less resilient than natural systems. In many cases, gray infrastructure is also more expensive than blue and green alternatives. Blue infrastructure, a more integrated approach to infrastructure development that incorporates nature-based solutions with sustainably designed gray infrastructure, is needed for coastal ecosystems and coastal communities to thrive. This white paper outlines types of infrastructure directly supporting coastal communities and identifies what blue architectural and nature-based adaptations to traditional gray infrastructure can be effective to support SDG 14.

The figure below illustrates the relationship between blue infrastructure capabilities and how they can be used to address both coastal community threats and SDG 14 targets.

[1] Rare calculations based on World Bank (2020b) data and adjusted to coastal areas based on Dahuri (2006).

[2] OECD (2019).

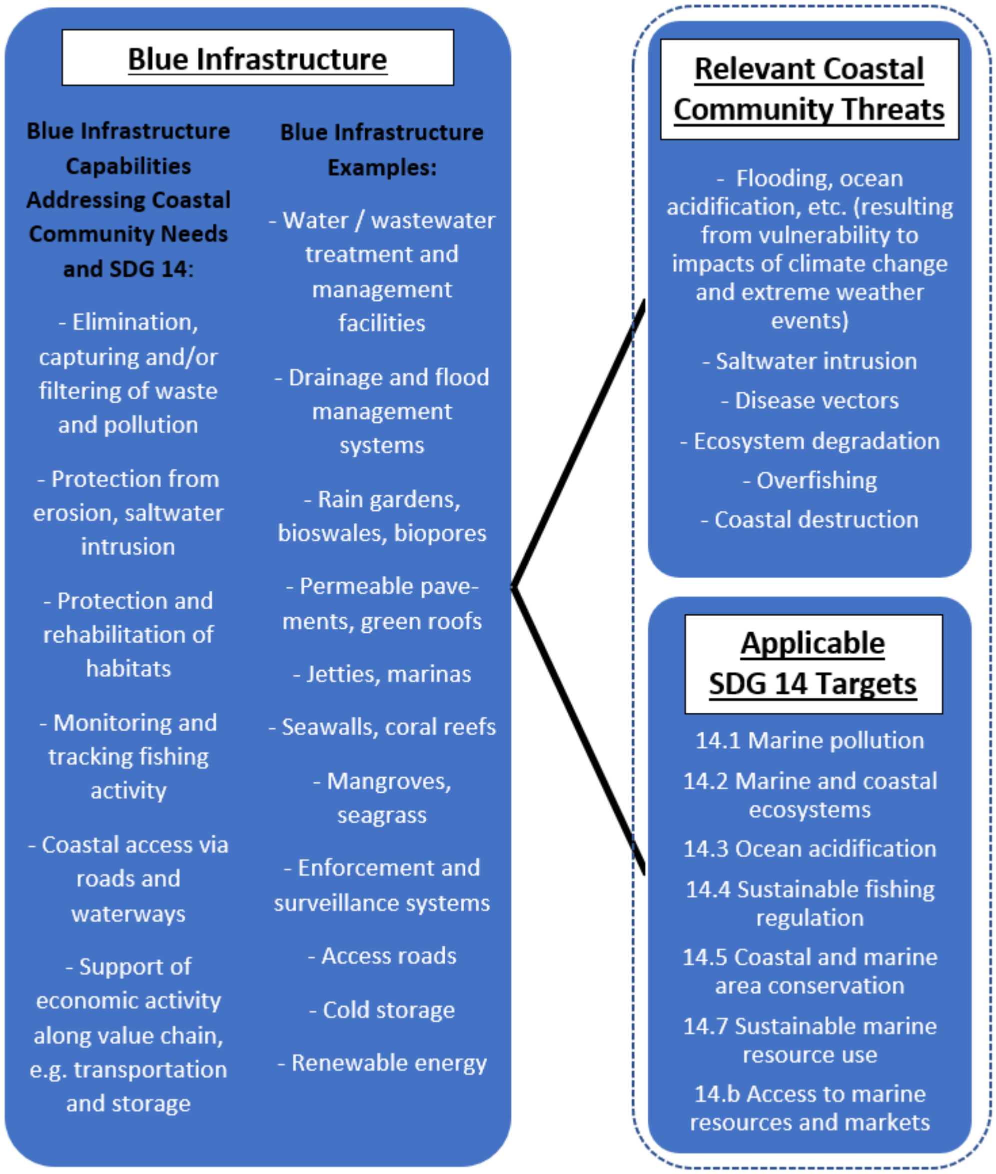

Figure 1: Relationship Blue infrastructure - Coastal community threats - SDG 14 targets, Source: Rare

Main findings

Blue infrastructure design provides an economical and environmentally sustainable way to address the need in coastal communities for infrastructure that can withstand impacts from climate change and natural disasters.

The possibility for natural disasters to damage critical infrastructure such as energy and telecommunications means that vulnerable infrastructure should be protected and reinforced to withstand such weather events. In the case of energy infrastructure, battery energy storage has a wide range of applications for communities, including emergency backup to overcome temporary outages from events such as storms. Microgrids that rely primarily on renewable energy may be the best option for communities without connection to already existing electricity grid networks, as they are more cost-effective, easier to manage and protect, and usually more reliable. In telecommunications infrastructure, redundancies and the availability of alternative infrastructure ensures continued service when communities most need it after external shocks. In some cases, shoreline stabilization measures may be necessary where erosion or extreme weather threatens the shoreline's integrity. Additionally, wastewater management and water treatment infrastructure are key to developing sustainable and resilient communities as they provide clean and reliable drinking water and prevent pollutants from reaching waterways and the coast, where they harm coastal and marine ecosystems. All infrastructure development in coastal communities is best designed to include drainage, particularly roads which can become impassable when flooded.

Blue infrastructure development will help Indonesia meet Sustainable Development Goal 14 targets for conservation and sustainable use of marine resources.

Blue infrastructure solutions can directly support seven of the ten targets under SDG 14. Target priorities such as preventing marine pollution, protecting coastal ecosystems, and increasing the economic benefits from the sustainable use of marine resources are supported by blue infrastructure development. Preventing marine pollution requires investments in wastewater treatment plants, landfills, drainage systems, and trash interceptors to divert waste before it reaches the ocean and to collect debris already in the ocean. It also requires the careful design of water management infrastructure, including infiltration trenches and bioswales, to slow stormwater runoff and filter out nutrient pollution that causes coastal eutrophication. Another example that highlights how blue infrastructure can be used to support the sustainable use of marine resources is the cross-cutting blue infrastructure integrated into the enforcement and surveillance of managed costal fishing areas, such as control centers and observation towers. Overall, blue infrastructure is aimed at solving the same problems indicated in SDG 14. By using SDG 14 as a guide for the desired impacts of blue infrastructure development, Indonesia will improve the sustainability and resilience of coastal communities and ecosystems.

Infrastructure design for coastal communities need to consider interdependencies of different infrastructure types and blue alternatives to traditional infrastructure.

Infrastructure is most effective when carefully planned to complement other infrastructure interdependences servicing the same area. Marinas and harbors, for instance, are highly dependent on available water management and transportation infrastructure. Hotels and tourist shopping boardwalks also require infrastructure interdependences such as access to stable electricity and telecommunications. Certain infrastructure may not be possible or desirable to develop until other interdependent systems are in place, such as cold storage facilities, which require energy to run.

Similarly, certain blue alternatives or adaptations to traditional infrastructure may not be feasible based on the level of coordination required for planning and maintenance. For example, telecommunication systems are typically planned at the regional level, therefore coastal communities at the local level have limited input into the planning process and options for installing blue alternatives. However, there are many cost-effective blue infrastructure alternatives and adaptions that coastal communities can adopt to be more sustainable and resilient. Examples include roads made from permeable pavement or porous asphalt to mitigate flooding and increase groundwater recharge; rain gardens and bio-retention basins to mitigate flooding, filter runoff, and increase groundwater recharge; and renewable energy systems.

Blue infrastructure often serves more than one function, making it an effective solution to challenges faced by coastal communities and ecosystems.

While gray infrastructure tends to be intrusive and single-purpose, blue infrastructure often complements or enhances the natural environment and serves multiple purposes. Mangroves, for example, promote biodiversity, prevent coastal erosion, sequester carbon, and protect shorelines against flooding. Green roofs absorb rainfall to mitigate flooding, harvest clean drinking water, provide insulation for homes, and have a cooling effect on the environment around them, reducing energy demand and costs for residents. Benefits delivered to communities from blue infrastructure adaptations are not limited to supporting SDG 14 targets; many adaptations support other SDGs by offering clean water and sanitation (SDG 6), providing resilient infrastructure (SDG 9), promoting climate change mitigation and adaptation (SDG 13), providing affordable and clean energy (SDG 7), and fostering sustainable terrestrial ecosystems (SDG 15).

In the section "Implementation strategies that successfully address SDG 14", this paper provides a sample strategy for implementing blue infrastructure interventions offshore, on the shoreline, and onshore to support SDG 14 based on the threats and opportunities particular to Indonesia's coastal communities and ecosystems.

A successful integrated approach to infrastructure development consists of three key components: the incorporation of blue infrastructure solutions; documentation of the economic benefits through a cost-benefit analysis (CBA); and support and engagement from key stakeholders in the community.

Benefits afforded by blue infrastructure installations build on one another. A single blue adaptation can have cascading positive impacts throughout a community or ecosystem, and integrating multiple blue infrastructure types magnify those positive impacts. As a result of these effects, studies indicate that the long-term economic benefits of investing in blue infrastructure far outweigh the initial cost of installation. In order to realize the full benefits of an integrated approach, early engagement with key stakeholders is critical to establish buy-in from the community. Local and regional governments, residents, businesses, as well as universities and research institutions all play important roles in planning, developing and maintaining blue infrastructure.

Understanding the economic value of investing in SDG 14 targets will help attract public and private sector capital. One example of how this type of CBA can be used to project environmental and economic returns is found in a 2020 study completed by Rare, "Asset Value Estimation for Managed Access with Reserves in Southeast Sulawesi, Indonesia." The study concluded that investing in managed access and reserves will recover fish populations both inside and outside the reserves while increasing the amount of fish harvested by small-scale fisheries, and thus enhancing food security in coastal communities. In specific, the study estimated that the total asset value of fish in the managed access and reserve areas across Southeast Sulawesi is US$39 million; the total asset value is the combined value of fish caught by community-based fishers (US$17.2 million) and the value of fish that remain in the water supported by 29,678 hectares of coral reef (US$21.9 million). Through this calculation, Rare projected that if the managed access and reserve areas are maintained across Southeast Sulawesi, the total asset value will increase 8-fold from US$39 million to US$327 million over 15 years. This type of illustrative data helps investors understand the economic value of investing in managed access and reserves while providing community stakeholders with the figures necessary to recognize the benefits that small-scale fisheries and community-based fishers will enjoy from a robust managed access and reserve program.

Recommendations

Blue infrastructure is integral to coastal community development and coastal resource protection because in comparison to traditional gray infrastructure, it is cost effective, sustainable, more adaptable and resilient to flooding and other extreme weather events, aligns with SDG 14 targets, and delivers multiple benefits and services for each type of blue adaptation. Blue infrastructure supports more prosperous communities in the long-term, making them self-reliant and less vulnerable to the impacts of climate change.

Based on the above findings, a set of recommendations has been developed for blue infrastructure solutions with the potential to maximize the benefits for Indonesia's coastal communities. The following solutions are recommended to be prioritized for coastal infrastructure development:

Offshore solutions:

- Jetties constructed from natural or eco-friendly materials, engineered to avoid disruptions to marine ecosystems
- Coral reef protection and restoration

Shoreline solutions:

- Mangrove protection and restoration
- Seagrass protection and restoration

Onshore solutions:

- Renewable energy and energy storage installation
- Wastewater management to protect coral reefs
- Permeable surfaces in construction
- Rain gardens, bioswales, and other stormwater management systems

Each solution provides benefits on its own, but an integrated approach to infrastructure development in coastal communities allows communities to realize the full environmental and economic benefits of investing in blue infrastructure.

Introduction

Indonesia has the second longest coastline in the world and possesses over 20% of the world's mangroves and 13% of the world's coral reefs.[3] Approximately 65% of Indonesians (over 173 million people) live within 50km of the coast, and a majority of these people rely in some way on coastal and marine resources for their livelihoods.[4] Small scale fishing in coastal areas alone supports over 2.4 million Indonesians. Overall, the coastal areas make an important contribution to the country's economic development: Indonesia's agricultural, fisheries, and forestry activities represent more than 8% of GDP[5], and tourism (much of it along the coast) represents over 4% of GDP[6].

As the country prioritizes developing the sustainable use of ocean resources for economic growth and improved livelihoods – also known as the blue economy – investing in coastal communities is critical.[7] Many coastal communities are impoverished and remote, lacking services that support a growing economy and improve quality of life, such as piped water, electricity, and public transportation. Providing these communities with the infrastructure to support such services is an important step to facilitating a sustainable blue economy.

However, a traditional approach to infrastructure development is not suitable for long-term sustainability in coastal areas, nor does it effectively capture the value of Indonesia's rich coastal resources. Infrastructure development needs to take into account the unique challenges coastal communities face, while recognizing the potential opportunities that a thriving coastal ecosystem provides.

Unique architectural requirements for infrastructure in coastal communities

Indonesia is particularly vulnerable to the impacts of climate change, including rising sea levels, increasing ocean temperatures, and ocean acidification. With the second longest coastline in the world and given its complex tectonics, Indonesia is also dramatically vulnerable to extreme weather events, and other natural disasters like tsunamis. Failure to address these challenges will come at a high economic and human costs. These impacts, combined with mangrove destruction, overfishing, and other human-made issues pose a major threat to coastal communities. Specific threats and their impact on coastal communities include:

- **Flooding from rising sea levels, poor drainage, and extreme weather events:** A 2016 USAID policy brief stated that annual losses in property value in the year 2050 from flooding in coastal communities are estimated to reach Rp 14.5 trillion (US$1.1 billion), while losses to agriculture and aquaculture are estimated to reach Rp 2 trillion (US$150 million) and Rp 686 billion (US$51 million), respectively.[8]
- **Saltwater intrusion:** Penetration of saltwater into the groundwater due to rising sea levels, coastal erosion, and freshwater aquifer depletion can dramatically increase water treatment costs and threaten the clean water supply. Lack of fresh water can have spillover effects as well, including increased use of bottled water, contributing to plastic pollution and reducing residents' income.

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[3] Rare – Fish Forever in Indonesia (2020).
[4] Dahuri, R. (2006) and Zikra, M., Suntoyo, L. (2015).
[5] Rare calculations based on World Bank (2020b) data and adjusted to coastal areas based on Dahuri (2006).
[6] OECD (2019).
[7] Yasmin, N. (2019).
[8] USAID (2016).

- **Disease vectors:** The estimated costs of increased incidences of mosquito-borne diseases, mainly malaria and dengue fever, by the year 2050 are Rp 45 trillion (US$3.3 billion) per year.[9] Most of this increase is due to standing water (drainage issues, flooding, etc.), which is a breeding ground for mosquito larvae.
- **Ecosystem degradation:** Biodiversity loss and declining ecosystem health from a host of drivers threatens the long-term sustainability of the communities that rely on them for their livelihoods. Climate change and ocean acidification from GHG emissions, pollution, and extreme weather events are particularly damaging to coral reefs and the fish populations that depend on them. Overfishing and other unsustainable fishing practices further harm ecosystems and biodiversity, leading to decreased catch over time. Additionally, degraded ecosystems attract less tourism, resulting in less revenue and fewer jobs for coastal communities.

Infrastructure in coastal communities can mitigate such threats by incorporating drainage, sea level rise management, coastal erosion management, and other sustainable adaptations.

Aligning with SDG 14

Indonesia has successfully integrated the United Nations Sustainable Development Goals (SDGs) into both national and subnational development planning and continues to measure development impacts against SDG indicators. Blue infrastructure solutions help to ensure that Indonesia meets its sustainable development targets, particularly by directly supporting SDG 14: Life Below Water.

SDG 14 aims to "conserve and sustainably use the oceans, seas, and marine resources for sustainable development[10]" through targets to reduce marine pollution, manage and protect marine and coastal ecosystems, and increase the economic benefits from sustainable use of marine resources in all countries, among others. Many of the challenges for coastal communities can be addressed by using SDG 14 as a guide for coastal development. Blue infrastructure is equally and often more effective than traditional gray approaches at delivering impacts in line with SDG 14. Specific blue adaptations supporting SDG 14 targets are outlined below in "Infrastructure Supporting SDG 14."

Problem statement

This white paper outlines both, blue infrastructure solutions, as well as blue alternatives and adaptations to traditional infrastructure which are best suited to address the needs of coastal communities in Indonesia, thereby also supporting SDG 14.

While traditional infrastructure approaches are most commonly used to mitigate issues for coastal communities, these "gray" solutions can have negative impacts on coastal communities and the environment. "Gray infrastructure" refers to the typical infrastructure engineered from man-made materials (typically concrete). Gray infrastructure is carbon-intensive, accounting for up to 70% of greenhouse gas (GHG) emissions globally[11] and is often built without following international best practices for infrastructure sustainability or adherence to environmental, social, and governance (ESG) requirements, which are the three key aspects measuring the sustainability of investments. Gray infrastructure alone provides few benefits to nearby ecosystems and can instead destroy coastal habitats

[9] Ibid.
[10] United Nations, https://sustainabledevelopment.un.org/sdg14.
[11] International Union for Conservation of Nature (2020).

if not properly designed. In many cases, it is also more expensive for small communities to install and maintain.

Instead, blue infrastructure is needed for these communities to thrive. "Blue infrastructure" refers to infrastructure incorporating nature-based solutions in coastal communities to support the communities and surrounding ecosystems. The nature-based solutions include what is typically considered as "green" infrastructure, such as bushes, forests, and swales, but also it include adaptations such as permeable pavement and infiltration trenches. All these elements are considered "blue infrastructure" when applied to coastal communities and aimed at protecting or enhancing coastal and marine ecosystems. Blue infrastructure solutions are often less expensive, equally or more effective, less carbon-intensive, and often more sustainable than traditional infrastructure approaches.

When planning or replacing infrastructure, it is strongly recommended for coastal communities to consider approaches that either integrate traditional infrastructure with blue elements or (where possible) fully replace traditional infrastructure to promote sustainability and resilience, and control costs for installation and maintenance. In the case of marine ecosystems, blue approaches are almost always superior to traditional infrastructure for maintaining and/or improving habitats.

An integrated, context appropriate approach to coastal development that utilizes the blue infrastructure solutions identified in this white paper create more resilient and prosperous coastal communities and ecosystems by meeting the unique challenges faced by coastal communities and supporting SDG 14.

Infrastructure needs in coastal communities

Communities require robust infrastructure to support their needs for energy and telecommunications, transportation, water/waste management, and economic sustainability. In addition to these basic needs, coastal communities also require infrastructure to manage the challenges and opportunities of being near water. For these communities, infrastructure must be able to withstand severe weather and natural disasters, co-exist with life on land and below water, and be economically and environmentally sustainable. Solutions that support SDG 14 as well as those addressing the issues in the section above are required. The appropriate combination of traditional and blue infrastructure solutions varies by community. The section below outlines the major infrastructure requirements for all communities, with specific insights into additions or variations for coastal communities. Blue infrastructure alternatives are also included in the following section.

Coastal infrastructure and livelihoods:

- **Marinas/harbors and jetties:** Infrastructure to secure the commercial areas of coastal communities include marinas and jetties where boats can moor and load and unload their wares (fish, people, other cargo), as well as other buildings to support commercial activities (fuel stations, warehouses, marinas to support tourist infrastructure like dive boats, etc.). This infrastructure is necessary to facilitate commerce regardless of scale, from a small jetty for local fishers, to a full-sized harbor or port that receives container ships.
- **Market infrastructure:** Coastal communities require at least some form of basic infrastructure to support markets for fishers and small-holder farmers. This includes stalls or other shopfront areas

for the fishers to sell their catch, as well as supporting infrastructure like shelter, cooking facilities, bathing areas, and security. This additional infrastructure can put stress on other community infrastructure if not properly implemented.

- **Shoreline stabilization:** Flooding, rising seawaters, natural and manmade erosion, and massive storm surges and/or tsunamis are major challenges for coastal communities. Infrastructure such as breakwaters, revetments, groins, and seawalls are all examples of traditional means for coastal communities to mitigate these challenges.

- **Small-scale fisheries infrastructure:** Infrastructure that supports management of small-scale fisheries such as the enforcement and surveillance of coastal fisheries' managed access areas. This infrastructure includes, but is not limited to, control centers, observation towers, boats, vessel monitoring systems, and technologies.

- **Tourism infrastructure:** In coastal communities near existing or potential tourist destinations, such as large beaches or reefs, investments in sustainable tourism infrastructure will greatly enhance the value of an underutilized tourism sector, which in 2015 contributed 4.3% to Indonesia's GDP[12]. In order to attract and maintain tourism, coastal communities require accommodations such as eco-resorts and hotels, restaurants, marinas and commercial infrastructure to support services such as tour operations, equipment, and automobile rentals. As with market infrastructure, tourism infrastructure depends heavily on other basic infrastructure, such as roads, electricity, and wastewater treatment, and may stress other infrastructure if not properly planned.

- **Value chain infrastructure:** The infrastructure required to bring fish, aquaculture, and agriculture from production to consumers. This type of infrastructure includes processing facilities, storage facilities, and a comprehensive cold chain distribution system. These systems allow fishers and small-holder farmers to prevent spoilage prior to sale and access wholesale markets and/or commercial customers.

Energy and telecommunications:

- **Electricity:** In coastal communities with access to reliable energy sources, electricity grids and energy installations require reinforcement to promote stability and resilience of the infrastructure and maintain a steady, reliable supply of energy for citizens. Storms, flooding, and other extreme weather events can interrupt the electricity supply to coastal communities and destroy critical infrastructure (power poles and power lines, energy installations). To foster the provision of a sustainable energy supply, coastal communities require either reinforced or underground power lines, reinforced or protected transformers and substations, and power installations that can withstand storms and sea swells, and/or be quickly repaired in the aftermath. Battery energy storage and (where necessary) generators serving as emergency backup systems may also be needed to help coastal communities maintain electricity in extreme situations.

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[12] OECD (2019).

Smaller coastal communities are unlikely to have the resources to install a single, reinforced power grid, nor is this likely the most practical solution. In smaller communities, renewable energy[13] micro-grids, and other sustainable energy solutions should be closely considered. Having smaller installations is not only economical but also can prevent community-wide blackouts in case one installation is damaged. These systems are also easier to reinforce and protect as opposed to large grids. Renewable energy technologies are becoming increasingly modular, which is well suited to smaller communities who can add installations (solar PV panels, wind turbines, mini or micro grids) as the electricity demand grows. That said, despite a rapid global decline in the cost of renewable energy technologies, making them often more cost effective than fossil fuel-based technologies, there are national and local policy and regulatory challenges across Indonesia that need to be taken into account when analyzing the potential to deploy renewable energy[14].

In communities without reliable access to a power grid or energy source, developers should design sustainable new infrastructure solutions that take into account context appropriate adaptations as described above.

- **Telecommunications:** As with energy infrastructure, coastal communities require telecommunications infrastructure (cell towers, traditional telephone poles, etc.) to be reinforced to withstand extreme weather events. Redundancy and other alternatives are needed in the event primary infrastructure is incapacitated. Where new telecommunications infrastructure is introduced to a community, it should be designed with the community and its particular challenges and needs in mind.

Transportation and access:

- **Access roads, bridges, and causeways:** Transportation and access in coastal communities is both on land (roads, bridges, causeways) and on water (sea lanes, jetties, marinas). These means of access are critical to coastal communities, as they support supply chains for coastal and community industry and commerce, facilitate tourism and citizen mobility, and are critical in times of natural disaster or other emergencies. Roads in coastal communities face the challenge of flooding from seawater as well as drainage challenges. Well-constructed and reinforced roads can be core means of transportation for evacuation, rescue, and maintenance of commerce during flooding and other extreme weather events. Some of the most important access roads for coastal communities include bridges and causeways, which are the main arteries connecting land masses such as islands and peninsulas, and are therefore critical to reinforce and maintain.

[13] Includes sources such as solar (+ storage), wind (+ storage), biomass, and geothermal energy. The appropriate source depends on the specific characteristics in the community (solar irradiation, wind speeds and capacity factor, feedstock for biomass, geothermal source and temperature).

[14] International Institute for Sustainable Development (2019).

Water/wastewater:

- **Drainage and flood management and prevention**: a robust system of roads, drains, catchment management systems, and barriers are required for coastal areas to effectively manage rainfall, extreme weather events, rising sea levels, etc. Some of the related key infrastructure includes:
  - **Culverts and drains**: A robust system of culverts, gutters, and other drainage mechanisms are needed to channel water away from streets and avoid or minimize flooding.
  - **Protective barriers**: Some coastal communities facing significant problems with rising sea levels or flooding from waves may need to build sea walls or other protective barriers. Walls or barriers cause waves to break far from shore, dissipating the volume and force of water that makes it to land. While barriers can be effective in mitigating the impact of rising sea levels and flooding, traditional sea walls can actually increase coastal erosion and hamper marine migration. Natural alternatives such as coral reefs, brushwood barriers, and other solutions conducive to promoting living shorelines are preferred. These are discussed in more detail in the section on blue infrastructure and structural adaptations.
  - **Retention/detention ponds:** Retention and detention ponds, often referred to wet and dry ponds, respectively, are used to capture storm water runoff or flood waters and slowly release them back into the groundwater or body of water through built-in outlets. Retention ponds are "wet" because they keep some water in the pond at all times, while detention ponds are designed to drain fully.
- **Waste management:** coastal communities need a system for managing and minimizing waste. These facilities include landfills, recycling facilities, and a network to deposit and collect waste. In addition, these communities also require a system to minimize and collect marine and river debris.
- **Wastewater management**: Effective wastewater management is critical in all communities, but especially so in coastal communities. Untreated wastewater discharged into the ocean kills coral reefs and the fish populations upon which coastal communities depend. Infrastructure needed for wastewater treatment includes sewer systems or septic tanks and associated drains and pipe networks to transport the wastewater to a treatment facility.
- **Water treatment:** A sustainable supply of clean drinking water can be a challenge in coastal communities due to saltwater intrusion in the water table, groundwater depletion and/or insufficient recharge, and contaminants. Coastal communities must have water treatment plants, storage facilities, wells, and other means to capture fresh water. Like properly treated wastewater, properly treated water minimizes the damaging impacts to marine ecosystems and support coastal community health and resilience. A lack of clean water also means a lack of clean ice, which fishers depend upon to preserve their catch for transportation and sale. Access to clean water for ice ensures more catch makes it to market and fishers preserve their income.

Infrastructure that Supports SDG 14

Figure 2: UN Sustainable Development Goals

Infrastructure needs in coastal communities should be addressed in accordance with the targets identified in the UN Sustainable Development Goals. The 17 SDGs are the result of nearly three decades of collaboration between UN member states focused on developing a global partnership to promote environmental and social sustainability on a global scale. Approved in 2015, the SDGs are a blueprint for an approach to "peace and prosperity" worldwide. The SDGs aim to address all aspects of sustainability, from poverty reduction to fostering peace and justice.

Sustainable Development Goal 14: Life Below Water serves as a guide for the development of coastal communities, as well as the blue economy. Protecting life below water is critical to the health and well-being of the planet. Oceans contribute up to US$1.5 trillion to the global economy, employing close to 60 million people, the majority of those in small-scale, developing country operations.[15] Fish provide more than 20% of the daily protein intake for more than 3 billion people.[16] From an environmental standpoint, coastal habitats such as mangroves and other vegetation absorb up to 25% of the carbon produced by humans and provide critical protection for coastal communities.[17]

SDG 14 Definition: Conserve and sustainably use the oceans, seas and marine resources for sustainable development.

This goal includes a set of ten targets that provide more guidance on the priorities for successful implementation. These include mitigating impacts of land-based pollution on the oceans, protecting coastal ecosystems, managing ocean acidity, and protecting marine life including fisheries. Addressing the infrastructure needs of coastal communities improves the coastal economy in the near-term, but does

[15] World Bank (2020).
[16] Ibid.
[17] Ibid.

not provide long-term benefits or improve coastal ecosystem health if it is not done in a way that supports SDG 14.

The table below takes the targets and indicators under SDG 14 and outlines the related infrastructure systems that are integral to their advancement.

Table 1: SDG 14 indicators and applicable infrastructure

#	Target	Indicator	Application to Infrastructure	Examples
14.1	By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	Index of coastal eutrophication and floating plastic debris density	Requires structures and systems to eliminate discharge of wastewater and solid waste into the ocean Requires structures and tools to capture ocean waste and divert it from coastal communities Requires stormwater management systems to filter nutrient pollution from stormwater runoff	• Water and wastewater treatment plants • Landfills • Recycling facilities • Drainage systems • Trash interceptors in rivers and oceans • Bioswales
14.2	By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans	Proportion of national exclusive economic zones managed using ecosystem-based approaches	Requires infrastructure to protect coastal ecosystems from erosion, saltwater intrusion (on land) Requires sustainable infrastructure to support economic activity (fishing, shipping, etc.) and minimize pollution	• Jetties • Marinas • Seawalls or coral reefs • Mangrove forests • Seagrass restoration • Small-scale fisheries infrastructure
14.3	Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels	Average marine acidity (pH) measured at agreed suite of representative sampling stations	Requires systems to prevent further acidification, pollution mitigation, reef protection and restoration	• Coral reefs • Mangrove forests • Seagrass restoration • Renewable energy

14.4	By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics	Proportion of fish stocks within biologically sustainable levels	Requires systems to monitor and track fishing activity
			
			Requires systems to protect and rehabilitate habitats
				• Coral reefs
				• Mangrove forests
				• Revetments
				• Marinas
				• Jetties
				• Infrastructure to support monitoring and enforcement of illegal fishing such as
				  ○ Vessel monitoring systems
				  ○ Automatic identification systems
				  ○ Fisheries monitoring centers

14.5	By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information	Coverage of protected areas in relation to marine areas	Requires infrastructure to demarcate protected areas
			
			Requires infrastructure to support enforcement/patrols
				• Boundary markers/buoys
				• Ranger/patrol stations
				• Infrastructure to support monitoring and enforcement of illegal fishing, e.g.
				  o Vessel monitoring systems
				  o Automatic identification systems
				  o Fisheries monitoring centers

14.6	By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation	Progress by countries in the degree of implementation of international instruments aiming to combat illegal, unreported and unregulated fishing	n/a	n/a
14.7	By 2030, increase the economic benefits to Small Island Developing States (SIDS) and Least Developed Countries (LDCs) from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism	Sustainable fisheries as a percentage of GDP in SIDS, LDCs and all countries	Requires integrated infrastructure systems designed to preserve, protect, and enhance the natural resources of marine/coastal communities	• Coral reefs • Mangrove forests • Jetties • Marinas • Eco-resorts and hotels • Small-scale fisheries infrastructure • Value chain infrastructure
14.a	Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to	Proportion of total research budget allocated to research in the field of marine technology	n/a	n/a

	enhance the contribution of marine biodiversity to the development of developing countries, in particular SIDS and LDCs			
14.b	Provide access for small-scale artisanal fishers to marine resources and markets	Progress by countries in the degree of application of a legal / regulatory / policy / institutional framework which recognizes and protects access rights for small-scale fisheries	Requires access via roads and waterways Requires infrastructure for local markets Requires infrastructure (accommodation, mooring locations, safety) for migrant fishers Requires infrastructure for storage and transport of harvest	• Jetties or marinas • Ports • Access roads • Cold storage • Sustainable structure for markets and gender-equal temporary housing, cooking, telecommunications, and bathing facilities • Additional solid waste and wastewater management facilities • Additional police or guard stations for safety and security
14.c	Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in UNCLOS, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of 'The Future We Want'	Number of countries making progress in ratifying, accepting and implementing through legal, policy and institutional frameworks, ocean-related instruments that implement international law, as reflected in the UN Convention on the Law of the Sea, for the conservation and sustainable use of the oceans and their resources	n/a	n/a

Interdependencies between infrastructure networks and blue infrastructure alternatives

The infrastructure required for sustainable coastal communities is part of an interrelated system, with significant interdependencies and coordination required to function properly. In designing new or upgrading existing systems, it is important not only to take into consideration how different structures and systems relate to one another, but also where blue infrastructure can be used in place of, or to enhance, traditional infrastructure.

The interdependencies between infrastructure networks for particular types of infrastructure needed in coastal communities are outlined in the table below. The table also identifies the scale or level at which coordination is required, and options for making infrastructure more blue.

Table 2: Infrastructure interdependencies and blue infrastructure enhancements

Infrastructure	Scale	Interdependencies	Blue Infrastructure Alternatives or Enhancements
Energy	Community / Regional	Energy installations require a stable distribution system (power lines, distribution grid, substations, transformers), as well as reasonable roads and locations for siting the projects and accessing them for operations and maintenance. Planning for energy also requires that supply is set to meet forecasted demand, and that there is certainty regarding the underlying regulation and tariffs.	• Renewable energy is critical for coastal communities to help reduce GHG emissions and other pollution from fossil fuels (spills, runoff, etc.). • Mini-grids, dedicated installations for industry (such as cold storage), and other modular renewable energy solutions can be more affordable, sustainable, and easily reinforced or replaced. Modularity reduces the need for sophisticated forecasting and dispatch systems and can be installed on an as-needed basis.
Telecommunications	Regional / national	Similar to energy installations, telecommunications systems require a system of cell towers that are easily accessible for operations and maintenance.	• Communication systems are largely regional or national, so the coastal communities should ensure that towers and other key installations are reinforced to the extent possible and have sufficient reach to remote areas (including marinas, etc.).
Access roads, bridges, causeways	Regional / national	A system of roads and bridges requires close coordination between jurisdictions to organize transportation networks and plan for and fund construction and maintenance. Transportation studies and engineering analyses are also required to properly size and locate roads and other infrastructure.	• Permeable pavement or porous asphalt in roads can help with flooding and groundwater recharge. • Bridges and causeways can be designed to facilitate marine migration and growth of coral and other marine species. • Natural materials such as coral should be used where feasible; concrete alternatives are also a good option. • Coral reefs and other natural barriers should be used for retaining walls or other barriers against rising seawaters.
Marinas / harbors	Community / regional	Depending on the size of the community and the size of the economic activity involving the sea, coastal communities need to integrate their planning with water and wastewater management, infrastructure to prevent sea water intrusion (sea walls, etc.) and planning for bridges and causeways to ensure that infrastructure is properly sited (e.g. away from water discharge or inside of sea walls).	• Natural structures such as coral or brushwood should be used where applicable for key structures. • Concrete alternatives should be used where natural structures are not viable. • Floating or flexible structures should be installed to facilitate marine migration. • Design should honor the natural topography of the coastline (e.g. shoreline, naturally deeper

Infrastructure	Scale	Interdependencies	Blue Infrastructure Alternatives or Enhancements
			areas) to minimize erosion and habitat destruction.
Water / wastewater management	Community / regional	All systems related to water management are interdependent. Drainage and sewer systems should be kept separate to prevent cross contamination. Treatment facilities should be inland and protected from extreme weather events and storm surges to prevent their destruction. Flood prevention must also be integrated with shoreline stabilization efforts.	• Constructed wetlands are a sustainable solution for some aspects of wastewater treatment as they can filter suspended solids and eliminate algal blooms.[18] • Rain gardens and bio-retention basins can help filter and treat storm and waste water.
Water treatment / water supply	Community / regional	All systems related to water management are interdependent. Drainage and sewer systems should be kept separate to prevent cross contamination. Treatment facilities should be inland and protected from extreme weather events and storm surges to prevent their destruction. Flood prevention must also be integrated with shoreline stabilization efforts.	• Green roofs and cisterns to harvest rainfall can help with the supply of freshwater and minimize stress on freshwater aquifers. • Bio-retention basins, bioswales and permeable pavement help with groundwater recharge.
Drainage and flood prevention	Community / regional	All systems related to water management are interdependent. Drainage and sewer systems should be kept separate to prevent cross contamination. Treatment facilities should be inland and protected from extreme weather events and storm surges to prevent their destruction. Flood prevention must also be integrated with shoreline stabilization efforts.	• Bioswales, rain gardens, bio-retention basins, biopores, constructed wetlands, and permeable pavement are all blue infrastructure options for mitigating flooding. • Coral reefs (in lieu of traditional breakwaters) and mangroves are effective blue infrastructure options to mitigate flooding from storm surges, rising sea levels, and tsunamis.
Waste management	Community / regional	Waste management is heavily dependent on transportation networks (land and sea) to haul waste and recyclables to landfills and recycling facilities. Community participation and awareness raising is needed to ensure citizens (and businesses) know what can be recycled and what must go into the waste stream.	• Facilities to promote source segregation of recyclables. • Composting facilities to manage the organic waste stream. • Waste to energy facilities for power and/or heat generation. • Trash interceptors to prevent waste from reaching the ocean.
Shoreline stabilization	Community / regional	Shoreline stabilization must be integrated with port/marina infrastructure to mitigate impacts of the offshore activity and structures including additional erosion, habitat preservation, and pollution.	• Natural structures such as rock groins and revetments, and brushwood walls or barrier allow for flow-through or water and marine species, and natural habitat growth either on or around the structures. • Overall, a living shoreline approach that works with the

[18] Water and Wastes Digest (2014).

Infrastructure	Scale	Interdependencies	Blue Infrastructure Alternatives or Enhancements
			natural contours of the location and uses natural materials is more effective and sustainable.
Market infrastructure	Community	Fish markets require structures for the sale of daily catches, cold storage, and potential facilities for migrant fishers (housing, cooking and bathing facilities, etc.). This infrastructure requires additional power, road and water access, and waste and wastewater management.	• Modular renewable energy and energy storage to support the additional market requirements. • Housing and facilities constructed from sustainable materials and with built in solar. • Extension of sustainable waste and wastewater facilities as described above.
Value chain infrastructure	Community/Regional	Value chain infrastructure has numerous interdependencies, which include energy, transportation, roads, and clean water supply.	• Renewable energy and energy storage installations to provide power for cold storage, processing, etc. • Paved roads with drainage • Composting facilities for processing waste
Tourism infrastructure	Community	Tourist accommodations require energy, telecommunications, clean water supply, wastewater treatment and safe and reliable transportation infrastructure in order to attract and serve tourists and maintain businesses.	• Renewable energy and energy storage for reliable energy access • Paved roads with drainage to maintain roads for easier tourism access and reinforcement against higher traffic. • Reinforced or protected telecommunications infrastructure to tourism accommodations • Wastewater treatment facilities in hotels and restaurants to mitigate pollution from the tourism industry.
Small-scale fisheries infrastructure	Community	Small-scale fisheries require telecommunications, electricity, and access to clean water.	• Natural structures such as coral or brushwood should be used where applicable for key structures. • Concrete alternatives should be used where natural structures are not viable. • Floating or flexible structures should be installed to facilitate marine migration.

Blue infrastructure and structural adaptations

Blue adaptations can address many, if not all, of the issues outlined above for traditional infrastructure. They often do this in a more affordable and less invasive way than traditional infrastructure. In addition, blue infrastructure solutions typically serve more than one function, in contrast to gray solutions, which are often single purpose (e.g. drainage systems). Some of the most relevant elements include:

- **Biopores:** Biopores are vertical holes in the ground that are filled with organic material (household waste, etc.) that improve the porosity and nutrient base of the soil and assist in groundwater recharge. They can be very useful in areas with high rainfall and/or drainage issues to help minimize flooding.
- **Bioswales**: A bioswale is a shallow channel filled with vegetation designed to filter and convey surface water (storm water, flood water, etc.) to a lake, river, or ocean. Bioswales are often used along streets or in parking lots to filter out coarse sediment and improve groundwater recharge.[19]
- **Brushwood barriers**: Brushwood barriers are fences built in shallow waters along shorelines from branches or small pieces of wood, such as bamboo. These structures slow waves and allow sediment to build-up on the landward side, helping to stabilize shorelines and facilitating mangrove restoration. In Indonesia, the installation of brushwood barriers is currently pioneered along the shoreline of northern Java. The hope is that the barriers reduce coastal erosion and allow mangrove seeds to settle and germinate in stabilized sediment.[20]
- **Concrete alternatives:** Concrete has a very high negative climate impact and may also be less resilient to shocks from natural disasters than other options. Innovations in alternatives to concrete are more eco-friendly, and some are specifically designed for coastal infrastructure.
- **Constructed wetlands**: Constructed wetlands can be surface basins designed to slow the flow of storm water, or subsurface basins that treat municipal and industrial wastewater. Vegetation can provide natural filtration and can be combined with mechanical and chemical filtration to remove pollutants before water is discharged into the sea or other bodies of water.[21]
- **Coral reefs as breakwaters (instead of sea walls):** Naturally occurring coral reefs or artificial reefs can be used in place of manmade sea walls to serve as breakwaters to minimize wave force. Coral reefs have the added benefit of creating new habitats for marine species.
- **Green roofs**: Green roofs are vegetated roofs with multiple layers of plants, soil, and drainage designed to absorb rainfall and mitigate the effects of rapid drainage on downspouts.[22] Green roofs also help with rainwater retention and can be combined with rainwater cisterns to harvest rainwater for drinking or other purposes. Green roofs can further help homes with insulation and climate

[19] Ibid.
[20] Pearce, F. (2020).
[21] Ibid.
[22] Ibid.

control, maintaining temperatures in the house or building on which they sit, potentially reducing cooling needs and costs.

- **Mangroves**: Mangrove forests are critical to promoting biodiversity, preventing coastal erosion, and maintaining fish stocks. They are also a natural first line of defense between the ocean and coastal communities in terms of flood protection.

- **Permeable pavement:** Permeable pavement includes pervious asphalt and concrete, interlocking pavers, and plastic grid pavers that allow water from rainfall, flooding, or seawater intrusion to seep into the surface and reduce water levels and pressure on drainage systems. Some permeable pavement solutions can also filter out pollutants, protecting both surface and groundwater from contamination while contributing to groundwater recharge.

- **Rain gardens/bioretention basin:** A rain garden (often called a bioretention basin) is a shallow depression designed to collect, filter, and treat storm or flood water through natural elements such as plants and soil nutrients. These gardens also prevent soil erosion and may serve as habitats for wildlife.[23]

- **Retention/detention ponds:** Retention and detention ponds are typically a form of gray infrastructure that aim to manage the flow of water. However, when combined with constructed wetlands, they perform the added function of water filtration and become more aesthetically pleasing."

- **Rainwater harvesting cisterns:** Cisterns are designed to capture and store rainwater that runs off the roofs of homes and businesses. This water can be used for purposes such as gardening, toilet flushing, and other uses where treated water would otherwise be used. This can result in significant savings to families and businesses and helps take the pressure off the demand for fresh water from community sources.

- **Seagrass:** Like mangrove forests, seagrass meadows serve several critical functions in coastal ecosystems. These include enhancement of fish habitats, erosion reduction, and improvement of water quality.

- **Trash interceptors:** New technology is being tested to collect trash and debris from rivers and canals to prevent it reaching the ocean. These floating barges could be used by communities to reduce ocean pollution, which contributes to acidification and habitat destruction.

[23] Liao, K. et al (2017).

Table 3: How blue infrastructure can improve coastal communities and address SDG 14 indicators

Blue infrastructure intervention	Structural adaptations to traditional infrastructure	Coastal challenge addressed				SDG 14 targets addressed through intervention							
		Flooding / drainage	Saltwater intrusion	Water treatment & supply	Water borne diseases	14.1	14.2	14.3	14.4	14.5	14.7	14.B	Other SDGs
Biopores	Biopores relieve pressure on traditional drainage systems and help recharge the groundwater.	X		X	X		X	X					6, 9, 11, 13, 15
Bioswales	Replace or complement manmade culverts, drainage canals, and gutters. Adds filtering aspect.	X		X		X	X	X					6, 9, 11, 13, 15
Boardwalks	Similar to jetties and pontoons, structures made of natural materials that allow for fish migration, and growth of vegetation and biota can maintain or enhance underwater habitats.								X			X	6, 8, 9, 11
Brushwood barriers	These natural barriers can be used in place of man-made barriers to protect shorelines; they are more economic and sustainable.	X	X				X	X	X	X			6, 9, 11, 13
Concrete alternatives	Made from more natural materials and textured to mimic natural features, concrete alternatives can reduce carbon emissions and encourage marine flora and fauna growth.	X		X			X	X		X		X	6, 11, 13
Constructed wetlands	Wetlands can complement traditional drainage systems and enhance water quality.	X		X		X	X	X					6, 9, 11, 13, 15
Coral reef restoration	Can replace sea walls, serve as a habitat for fish and other underwater life.	X	X				X	X	X	X	X		6, 11, 13

Blue infrastructure intervention	Structural adaptations to traditional infrastructure	Coastal challenge addressed				SDG 14 targets addressed through intervention							
		Flooding / drainage	Saltwater intrusion	Water treatment & supply	Water borne diseases	14.1	14.2	14.3	14.4	14.5	14.7	14.B	Other SDGs
Floating breakwaters and other "flow through" designs	Can improve water flow and transport of fish larvae and other biological material, and limit the inhibition of fish migration.								X		X	X	6,13
Green roofs	Green roofs reduce pressure on drainage systems and reduce cooling needs and therefore pressure on the electrical grid.	X		X			X	X					6, 9, 11, 13, 15
Jetties and pontoons	Structures that are made of natural materials, low profile (to minimize shading), vegetated, floating or otherwise facilitating waterflow and fish migration can enhance the habitats for fish and other underwater life.								X		X	X	8, 11
Mangrove planting / restoration	Mangroves are a natural, economic alternative to manmade infrastructure such as sea walls and filtration systems.	X	X				X	X	X	X	X		6, 9, 11, 13
Marinas	Structures and design that minimize footprint and maximize the use of existing natural features can mitigate flooding and sedimentation, and maintain or (in some cases) create new underwater habitats.								X		X	X	8, 11
Permeable pavement	Permeable pavement can complement or replace traditional pavement.	X			X		X					X	6, 9, 11, 13, 15

Blue infrastructure intervention	Structural adaptations to traditional infrastructure	Coastal challenge addressed				SDG 14 targets addressed through intervention							
		Flooding / drainage	Saltwater intrusion	Water treatment & supply	Water borne diseases	14.1	14.2	14.3	14.4	14.5	14.7	14.B	Other SDGs
Rain gardens / bioretention basin	Can be used in place of concrete retention ponds or serve as an inexpensive way to add to retention and treatment/filtering capacity.	X		X		X	X	X					6, 9, 11, 13, 15
Rainwater harvesting cisterns	By capturing rainwater, cisterns relieve pressure on the water treatment and delivery systems.			X			X						6, 9, 11, 13
Retention / detention ponds	Adding vegetation to originally concrete ponds adds water treatment (filtering) and beautification.	X		X	X	X	X	X					6, 9, 11, 13, 15
Revetments	Porous, undulating rock walls can help prevent erosion while minimizing sedimentation and turbidity caused by more artificial materials and designs, protecting underwater habitats.								X	X			6, 9, 11
Seagrass restoration	Seagrass meadows provide natural protection against erosion and acidification, they are critical to marine habitats.	X	X	X			X	X	X	X	X		6, 11, 13
Trash Interceptors	Interceptors can prevent trash and debris from entering oceans from rivers and canals.	X		X	X	X	X	X					6, 13

Implementation strategies that successfully address SDG 14

The interventions outlined in the sections above show a number of options for integrating blue infrastructure into a comprehensive approach to supporting coastal communities in alignment with SDG 14. The recommendations below group these interventions into infrastructure systems based on those offshore, at the shoreline, and onshore.

Offshore strategy: Investments in blue marine infrastructure

Indonesian coastal waters are the center of a US $2.4 billion small scale fishing industry, supporting 80% of all fishers in Indonesia. These waters also support other commercial activities such as shipping and tourism. These activities can stress the marine habitats through pollution, turbidity, and general destruction. Efforts to restore and protect these habitats are key to preserving coastal community livelihoods and preserving biodiversity.

Where coral reefs have experienced degradation due to water pollution damaging activities such as overfishing, efforts to restore reefs also restore the benefits reefs provide. Artificial reefs from man-made materials provide structures for coral and other reef organisms to grow on and offer new habitats for fish and crustaceans. Constructing artificial reefs is also used to introduce entirely new sections of reef in order to create new dive sites and mitigate the negative impacts of dive tourism in high-traffic areas.

For communities where offshore infrastructure such as marinas, jetties, or piers already exist, blue infrastructure can be introduced as appropriate when it is time to replace aging concrete or added as an enhancement (e.g. adding rock or coral reinforcement on causeways). For communities looking to establish infrastructure to support fishing and other marine activities, a comprehensive plan to develop natural structures that allow for movement and provide habitats marine species should be pursued.

SDG 14 Indicators addressed: 14.1, 14.2, 14.3, 14.4, 14.5, 14.7, 14.B

Shoreline strategy: Investments in living shorelines

Coastal communities should prioritize shoreline investments that will help minimize erosion, flooding, and saltwater intrusion, and preserve and restore marine habitats. Examples of such investments include protecting and replanting mangroves and introducing living revetments and breakwaters.

The 2004 Indian Ocean tsunami had dire consequences and showed that Indonesia is extremely vulnerable to coastal flooding. However, a recent report indicated that the tsunami had the potential to be even more devastating. Field research in Indonesia's Aceh province after the 2004 Indian Ocean tsunami found that mangroves in front of villages reduced casualties by an average of 8% – representing 13,000 lives saved. [24] The report further indicated that a 100-meter wide strip of mangroves can reduce the destructive force of waves by 90%.[25] Recommendations from the COREMAP program emphasize the importance of mangrove planting and restoration for facilitating more effective coral reef restoration.[26]

Indonesia is home to over 20% of the world's mangrove forests. These forests are rapidly disappearing for a number of reasons, including an increase in shrimp farming (primarily in Sumatra, Sulawesi, and East

[24] Pearce, F. (2020).
[25] Ibid.
[26] Asian Development Bank (2018).

Java), logging for conversion to agriculture or salt pans (Java and Sulawesi), and oil spills (East Kalimantan). These areas should be targeted for restoration.

When planning to develop shoreline-based blue infrastructure investments, the resulting economic benefits to coastal fisheries need to be taken into account, given that they directly depend on the preservation and restoration of coastal habitats.

SDG 14 Indicators addressed: 14.2, 14.3, 14.5

On-shore strategy: Investments in land-based interventions

Life below water is strongly impacted by what happens in life on land. Unchecked storm and wastewater discharge into coastal waters and poor solid waste management can rapidly impact marine habitats. Similarly, communities on shore can quickly feel the impact of storm surges, saltwater intrusion, and rising sea levels. It is therefore critical to introduce interventions that allow these two habitats to better co-exist and even flourish.

Blue infrastructure can be used on land to augment traditional infrastructure for water and wastewater treatment. This includes constructed wetlands, bioretention ponds, and bioswales, along with green roofs and cisterns to catch rainwater, thereby minimizing flooding and reducing strain on the water supply. Permeable pavement and biopores can help recharge groundwater aquifers while also mitigating the impact of flooding.

When planning for land-based blue infrastructure interventions, the resulting economic benefits also need to be taken into account, given that infrastructure supports tourism growth by making coastal areas more accessible for tourists and improves destination competitiveness by increasing environmental sustainability.

SDG 14 Indicators addressed: 14.1, 14.2, 14.3

Integrated planning approach to sustainable infrastructure development

Incorporating blue infrastructure

While the categories above are intended to help identify the types of infrastructure that are useful for each habitat, it is important that any plan or investment considers the impact and interdependence of infrastructure investments on coastal communities as a whole, not just in the immediate vicinity of the physical structure. Table 2 lays out the significant interdependencies between the infrastructure solutions needed in a community and offers blue infrastructure solutions, replacements, or enhancements for each.

In an integrated planning approach, where blue infrastructure solutions are considered for each infrastructure need (roads, energy, coastal management, etc.), the result is a set of blue infrastructure solutions that are mutually reinforcing. A recent report by the International Union for the Conservation of Nature (IUCN) compared the impact of an integrated approach that incorporates blue infrastructure solutions to a more siloed approach (see Appendix 2 for the illustrated comparison)[27]. Roads engineered to complement natural hydrology inland support higher water quality, leading to a healthier environment for coral reefs and fish populations and the marine ecosystem in general. Healthier coral reefs further support thriving fish populations and attract more tourism while reducing wave energy and coastal

[27] International Union for Conservation of Nature (2020).

erosion. A single blue adaptation can have cascading positive impacts throughout a community or ecosystem, and an integrated approach magnifies those positive impacts.

Cost-Benefit Analysis

The long-term benefits of investing in blue infrastructure far outweigh the short-term costs. The multiple and cascading positive impacts of blue infrastructure development can be reflected in a cost-benefit analysis (CBA). A CBA compares the cost of a particular project to the benefits it is expected to yield. In the case of blue infrastructure, in addition to offering the benefits of traditional infrastructure, blue infrastructure offers added benefits such as those related to reduced GHG and ocean acidification, protection from erosion, and habitat preservation (which also covers the concept of 'total asset value' – see page 7). There are different methodologies for calculating these benefits, but the IUCN report notes that separate analyses from the World Bank and the Global Ocean Accounts Partnership (GOAP) value the benefits of blue infrastructure interventions at a minimum of 5:1 compared to their cost[28].

Stakeholder Involvement

While this paper focuses on opportunities for incorporating blue infrastructure into coastal communities, the success of comprehensive infrastructure planning and investment depends on support from key stakeholders in the community, the province, and beyond. Some key stakeholders and their roles in ensuring successful blue infrastructure development are described below:

- **Local and regional governments:** Local governments play a critical role in developing an integrated blue infrastructure approach. Most of the space the infrastructure impacts (offshore, at the shoreline, and on-shore) is typically government-owned or is subject to government permitting. Governments can drive policy to encourage or require the use of blue infrastructure interventions in infrastructure planning and have convening capabilities to bring stakeholders together to develop and approve plans.

- **Local communities:** Raising community awareness about the importance of protecting fragile coastal resources and habitats is critical to winning support for more natural approaches to infrastructure. Some of the blue infrastructure interventions (such as green roofs, biopores, rain gardens) involve installations and maintenance on individual homes or properties, and therefore require direct support from local citizens. Regular consultations and educational efforts are needed to obtain and maintain community support.

- **Business community:** Local and regional businesses can play a critical role in successful blue infrastructure planning and installation. Businesses can invest in, develop, and build blue infrastructure installations, working independently or in a public-private partnership with government. Businesses can also promote blue infrastructure and environmentally sustainable practices through their core business, such as eco-tourism. Finally, businesses typically generate more waste and consume more energy than individuals, so encouraging them to support conservation efforts and show community leadership is critical.

[28] International Union for Conservation of Nature (2020).

- **Universities and research institutions:** Universities, think tanks, foundations, and NGOs can provide guidance on planning, researching appropriate interventions, carrying out cost-benefit analyses, and many other tasks in support of the planning and implementing a blue infrastructure strategy.

Blue infrastructure case studies

Global case studies

Blue infrastructure has been introduced in numerous communities globally with the aim of finding natural, more economic and sustainable alternatives to traditional infrastructure solutions. Some examples of where blue infrastructure have been implemented include:

Coastal rehabilitation in Tamil Nadu, India: The state of Tamil Nadu has implemented a pilot project designed to restore coral reefs and seagrass habitat in local fishing villages. The objectives of the project are to replace the reefs that have died due to climate change-induced coral bleaching, and restore the marine habitats affected. Low cost concrete and PVC frames simulate the structure of the reef, promoting the regrowth of the coral. Jute rope is used to create trellis structures to regrow seagrass. In the first year of implementation, the coral cover for the area increased by 10%[29].

Seychelles debt conversion for marine conservation and climate adaptation: The Nature Conservancy raised grant and debt capital to create the Seychelles Conservation and Climate Adaptation Trust (SeyCCAT)[30] to "swap" sovereign debt to fund marine conservation efforts. The US $20+ million program funds the creation and expansion of marine protected areas (including "no-take" fishing areas), replants mangroves and coral reefs, and establishes a permanent trust to manage marine conservation efforts into the future[31][32]. To date, SeyCCAT has distributed 13 grants[33] and helped the Seychelles reach its target of turning 30% of its coastline into Marine Protected Areas[34].

ABC Waters Program in Singapore: The national water authority and Public Utilities Board in Singapore have developed a program to transform the country's utilitarian drains, canals, and reservoirs into waterways and bodies of water integrated within the urban landscape. By removing significant portions of concrete channels and replacing them with natural, vegetated waterways, the city state has created parks and other public areas for its citizens to enjoy, while adding in the benefits of filtration, water treatment, and flow management provided by the soil and vegetation in the new canals. Specific types of interventions include vegetation swales, bio-retention swales and basins, and constructed wetlands[35].

Flood prevention and mitigation in New Orleans, Louisiana, USA: The devastating floods after Hurricane Katrina in 2005 resulted in around 1800 deaths, nearly a million people displaced, and the destruction of more than 40 schools and 16,000 businesses. One of the critical factors to the massive destruction was the failure of the human-made levees and floodwalls designed to protect the city. In the 15 years since Katrina, the city has worked to not only rebuild and reinforce that infrastructure, but also to incorporate

[29] Suganthi Devadason Marine Research Institute (2018).
[30] Seychelles Conservation and Climate Adaptation Trust: https://seyccat.org/.
[31] Convergence (2017).
[32] Global Environment Facility (2019).
[33] Seychelles Conservation and Climate Adaptation Trust (2020a).
[34] Seychelles Conservation and Climate Adaptation Trust (2020b).
[35] Liao et al.

blue infrastructure into its flood mitigation system. Research options indicated that levees contributed to the loss of marine wetlands, which serve as a natural defense against flooding. It is estimated that the state of Louisiana loses as much as 62 km^2 per year through erosion largely caused by the levees which prevent the deposit of sediment from the rivers flowing into the Gulf of Mexico.[36] While most conservation efforts are still in the planning stages, one project—the Golden Triangle Marsh Creation Project—is underway through funding assistance from oil spill penalty funds and the Coastal Impact Assistance Program. This project is restoring 600 acres of marsh land around New Orleans[37].

Gold Coast artificial reefs: In 1999–2000, the Gold Coast City Council (GCCC) implemented a project to construct artificial reef to stabilize beaches and provide a surf break. The reef was made of geotextile sandbags, which were designed to promote the preservation and growth of marine habitats. The project showed that complete algal coverage happened in only three weeks. Algae is an important component in a healthy coral reef, as it provides habitat and food for many small marine species. Other key species such as sponges, soft corals and anemones were established on the reef, along with more "hard" species like barnacles and abalone. Rock lobsters, shrimp, and octopi also visit the new habitat frequently[38].

Indonesia Case Studies

As noted in the executive summary and further outlined below, coastal communities in Indonesia impact the majority of the population. Preservation of coastal communities and their marine ecosystems is vital to the overall health, safety, and prosperity of the country.

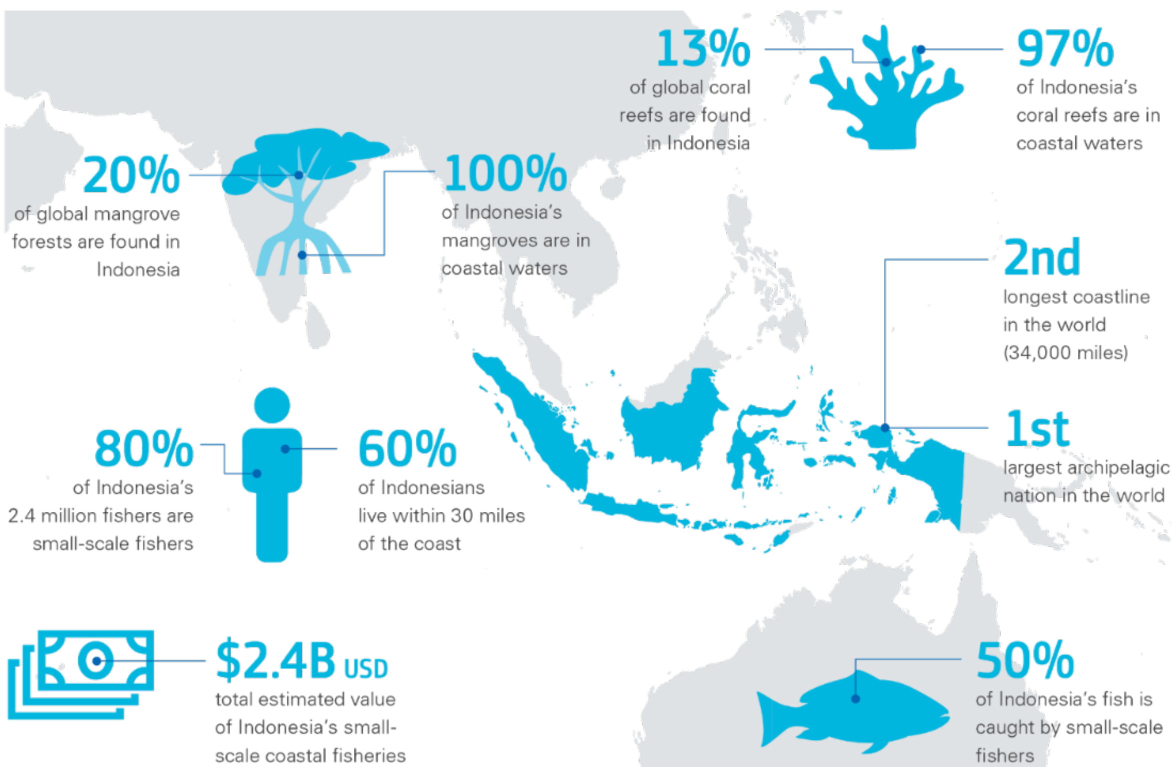

Figure 3: Coastal communities in Indonesia, Source: https://rare.org/program/fish-forever-in-indonesia/

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[36] Kazmierczak, A. and Jeremy, C. (2010).

[37] Moore, A. (2019).

[38] Derbyshire, K. (2006).

The Indonesian government, international organizations, donors, and NGOs have all recognized the importance of finding ways to protect coastal communities, including through blue infrastructure. A number of these initiatives are outlined below.[39]

COREMAP: The Coral Reef Rehabilitation and Management Program was initiated in 1998 with the aim to improve coastal resource management through provincial, local (municipal), and community involvement. Key program activities of have focused on a number of issues such as the preservation and restoration of coral reefs through coral reef management plans, reducing illegal and destructive fishing practices, and introducing marine protected areas (MPAs)[40]. Now in its third phase (COREMAP-CTI), the project is funded through both a loan facility and a grant facility by the World Bank and the Asian Development Bank. The Indonesia Climate Change Trust Fund (ICCTF) and the National Development Planning Agency (BAPPENAS) serve as the implementing agencies for the facility's grant making functions [41] and the Indonesian Institute of Science (LIPI) serves as the executing agency for loan funds[42]. The project has four main focus areas: Institutional Strengthening for Coastal Ecosystems Monitoring; Support for Demand-Driven Coastal Ecosystems Research; Management of Priority Coastal Ecosystems; and Project Management[43], and is supporting seven projects in East Nusa Tenggara, West Papua, Bali, and Lombok.[44]

Permeable sea barriers and mangroves restoration: The International Climate Initiative of the German Government (IKI) is sponsoring a program called "Building with Nature" that has installed nearly 30 km of permeable barriers along the coasts of Java, Lombok, and Sulawesi. The program will also restore mangroves that were destroyed in a 2018 tsunami in Palu Bay (also Sulawesi). In exchange for local residents' assistance with installation and planting, the program has further provided loan and grant capital to help them develop sustainable fishponds and tourism infrastructure, as well as receive training on sustainable fishing practices.[45].

Sustainable Blue-Green Infrastructure for Enhancing Flood Resilience in Semarang: BuGIS (Blue-Green Infrastructure in Semarang, Indonesia) is a research project that aimed to increase flood resilience of Semarang city by integrating blue-green infrastructure into urban development planning. This was a joint research project with Loughborough University (UK) and Universitas Diponegoro (Indonesia) with funding from the British Council and the Indonesian Ministry of Research, Technology and Higher Education. The project involved the study of a number of community-based blue infrastructure initiatives, including retention ponds, rainwater harvesting, permeable pavement, and biopores. The study produced a number of recommendations for implementing blue infrastructure according to social, economic, and climate context, as well as provisions for maintenance and integration with traditional infrastructure.[46]

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[39] There are many initiatives that focus on the consultative and legislative process for developing integrated coastal zone management plans and other important initiatives. While these initiatives are vital, as this paper focuses more on investment opportunities and specific BGI interventions, these have not been included with the exception of the long-running COREMAP program sponsored by the World Bank and Asian Development Bank.
[40] Asian Development Bank (2018).
[41] https://www.icctf.or.id/coremap-cti/.
[42] BAPPENAS (2019).
[43] Ibid.
[44] https://www.icctf.or.id/coremap-cti/.
[45] International Climate Initiative (2019).
[46] BUGIS (2019).

Mangrove conservation and restoration in North Sumatra: From 2012-2017, USAID and Yayasan Gajah Sumatera (Yagasu) supported a program to conserve and restore mangrove forests along the coast near the community of Langkat. Through these efforts, coupled with the introduction of sustainable fishing practices, the community restored 25,000 hectares of mangrove forests, resulting in a nearly 60% increase in monthly income for residents due to increased fish and shellfish yields. In addition, a local women's community group began using mangrove leaves and bark to make natural dyes for batiks. Fruit of mangrove trees has also been used for flour production to make cakes, and a number of small businesses have been created as a result[47].

Trash interceptor in Cengkareng (Jakarta): In May 2019, the Maritime and Investment Coordinating Ministry and Water Management Unit at the Jakarta Environment Agency, in cooperation with the non-profit The Ocean Cleanup (TOC) and Danone-AQUA Indonesia, began a pilot project for a trash interceptor designed to capture waste from the rivers in and around Jakarta before the trash reaches the ocean. The solar-powered interceptor sits at the mouth of the Cengkareng canal and collects and deposits waste into large dumpsters via a conveyor belt system. These dumpsters are then taken to the local landfill. In the future, the project aims to separate plastics and other materials for recycling.[48]

In addition to the examples above, there are a number of entities deeply involved in supporting conservation in coastal communities in Indonesia. These include:

- Rare's Fish Forever program, designed to improve and encourage sustainable fishing practices: https://rare.org/program/fish-forever-in-indonesia/
- USAID Coral Triangle initiative: https://www.usaid.gov/asia-regional/fact-sheets/us-coral-triangle-initiative
- USAID Lestari program to reduce GHG emissions and preserve biodiversity: https://www.lestari-indonesia.org/en/
- USAID Initiative to combat illegal fishing: https://www.usaid.gov/asia-regional/press-releases/aug-21-2017-usaid-oceans-announces-new-partnership-combat-illegal
- USAID Indonesia Marine and Climate Support (IMACS) Project: https://chemonics.com/wp-content/uploads/2017/10/Indonesia_IMACS_FinalReport.pdf
- World Bank Coral Reef rehabilitation program (ended 2019): http://documents.worldbank.org/curated/en/152621468040548322/pdf/PAD3760P127813010Box382121B00OUO090.pdf

[47] Swiny, A. (2016).
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Conclusion

This white paper outlines blue infrastructure solutions and adaptations to traditional infrastructure that support SDG 14 and are best suited to address the needs of coastal communities in Indonesia.

Challenges coastal communities face in preserving and protecting their ecosystems and livelihoods require integrated solutions that consider all infrastructure systems—from energy to transportation to flood management. Blue infrastructure can replace or enhance traditional infrastructure options in most communities, promoting sustainability, protecting ecosystems, and likely saving communities money through their lower installation and maintenance cost.

While there are numerous potential blue infrastructure solutions, and which need to be tailored to local circumstances, some of the options with the biggest social, environmental and economic impact potential include:

Offshore

- Jetties and other structures made from natural or eco-friendly elements. Jetties provide the connection between land and sea for fishers and tourists in coastal communities. They are significant structures that have the potential to disrupt the marine ecosystems surrounding them. Jetties made with natural materials or with concrete alternatives and with floating aspects to allow for marine migration and can protect and encourage the growth of marine flora and fauna.
- Coral reef restoration: Coral reefs provide multiple benefits, from storm surge protection to restoring marine ecosystems.

Shoreline

- Mangrove and seagrass restoration: Both of these natural features perform multiple functions in coastal communities, including preventing saltwater intrusion and coastal erosion, mitigating the impact of tsunamis and storm surges, protecting marine habitats, and reversing ocean acidification. Reintroducing these natural elements to a coastal community can have cascading positive impacts.

Onshore

- Pavement alternatives: Permeable pavement and concrete alternatives can have a significant impact on flooding, groundwater recharge, and emissions reductions. As road networks, even in the smallest communities, require a significant volume of materials to construct and maintain, introducing environmentally friendly materials have a significant positive impact. In addition, using concrete alternatives in the construction of gray infrastructure reduces carbon emissions, and when applied to offshore infrastructure like jetties, they can help support coral reef regrowth.
- Prioritized gray infrastructure: Prioritizing gray infrastructure that helps to protects coastal ecosystems and livelihoods will significantly benefit coastal communities. An example of a prioritized infrastructure investment is wastewater management. Sewage and wastewater pollution greatly threaten the health and life of coral reefs, but investing in wastewater management will benefit the marine ecosystems and the livelihoods of coastal communities. Another example of a prioritized gray infrastructure investment is water sanitation as piped, clean, water will make communities healthier while supporting integrated infrastructure interdependencies such as cold storage facilities.

- Rain gardens, bioswales, and other stormwater management systems: Solutions for reducing runoff and collecting stormwater can significantly reduce flood risk, improve water quality, offer sources of clean drinking water, and improve groundwater recharge, among other benefits. They are also less expensive and can be installed individually or as part of a large-scale, integrated water management plan.

- Renewable energy: Switching from fossil fuels to renewable energy sources (including energy storage) can significantly reduce GHG emissions and very often lower costs, particularly for communities that must import fuel for the power stations or generators.

It is important that any intervention (traditional or blue) be considered in the right community context—including the ability to operate and maintain installations, suitability for local terrain, availability and conditions of interdependent systems such as energy, community awareness and support, etc. Important steps to take in developing a comprehensive, blue infrastructure-focused approach to coastal infrastructure include:

- Always consider blue infrastructure options. As tables 1, 2 and 3 show, there are blue infrastructure options for nearly all types of infrastructure. Where it is not possible to install or completely replace a traditional structure with a blue infrastructure alternative, blue infrastructure options can be used to enhance existing structures. Blue infrastructure options also cover nature-based solutions like mangrove forests and adaptations such as permeable pavement and infiltration trenches.

- Carry out a CBA that takes a long-term view toward both economic and environmental sustainability. Blue infrastructure options should almost always perform better than traditional infrastructure when both cost and sustainability are factored in.

- Consider the interdependencies of different types of infrastructure before deciding on an approach.

- Consider where blue infrastructure options can help achieve the targets of SDG 14.

- Consider which stakeholders should be involved in the design, decision making, and implementation processes and bring them in early.

Blue infrastructure development alone cannot ensure sustainable development. However, it makes a crucial contribution to coastal communities and ecosystems with respect to their long-term sustainability and their resilience in the face of external shocks, such as those linked to climate change, natural disasters, and even pandemics. The most successful investments in coastal communities will emphasize blue infrastructure development along with community engagement and behavior change for more sustainable natural resource management.

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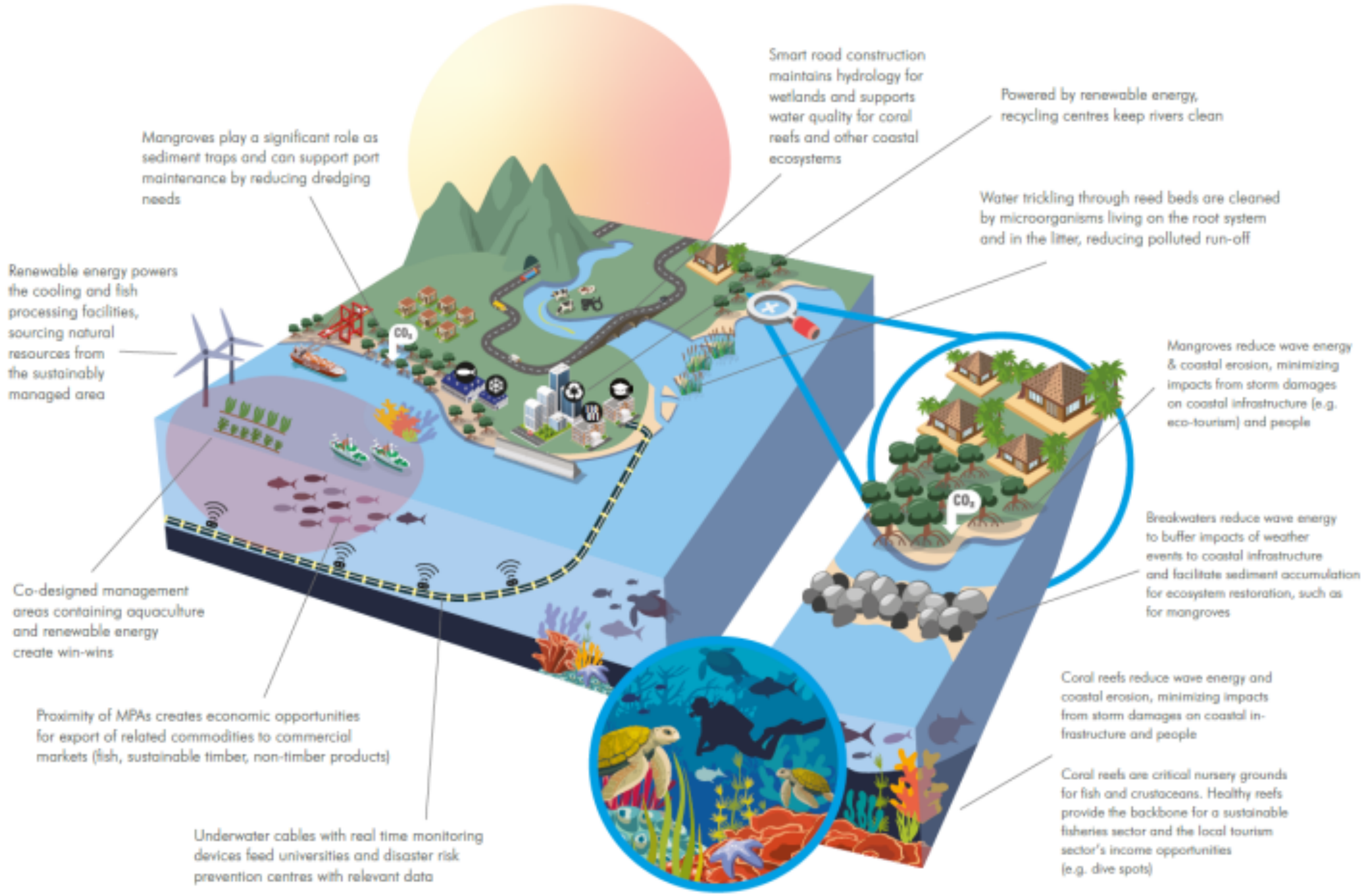
Appendix 1: Acronyms

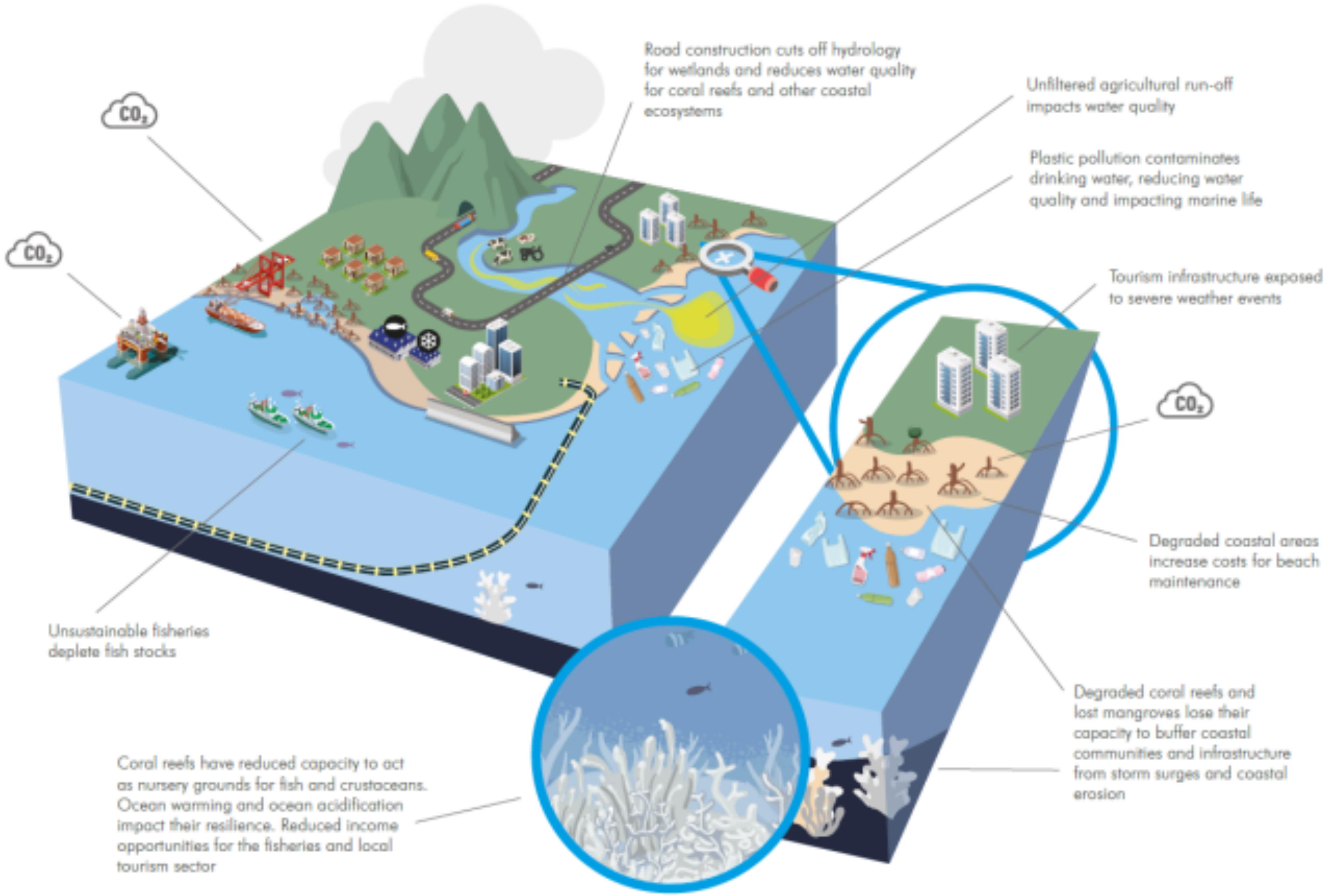
BAPPENAS	National Development Planning Agency (Indonesian: Badan Perencanaan Pembangunan Nasional)
CBA	Cost–Benefit Analysis
COREMAP	Coral Reef Rehabilitation and Management Program
ESG	Environmental, Social, and Governance
GCCC	Gold Coast City Council
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GOAP	Global Ocean Accounts Partnership
ICCTF	Indonesia Climate Change Trust Fund
IKI	International Climate Initiative (German: Internationale Klimaschutzinitiative)
IUCN	International Union for Conservation of Nature
LDC	Least Developed Country
LIPI	Indonesian Institute of Sciences (Indonesian: Lembaga Ilmu Pengetahuan Indonesia)
MPA	Marine Protected Area
OECD	Organisation for Economic Co-operation and Development
SDG	Sustainable Development Goal
SeyCCAT	Seychelles Conservation and Climate Adaptation Trust
SIDS	Small Island Developing States
TOC	The Ocean Cleanup
UNCLOS	United Nations Convention for the Law of the Sea
USAID	United States Agency for International Development

Appendix 2: Integrated infrastructure planning incorporating blue infrastructure solutions



Source: International Union for Conservation of Nature (2020)

Appendix 3: Traditional infrastructure planning without blue infrastructure solutions



Source: International Union for Conservation of Nature (2020)