Puerto Rico Ocean Technology Complex

Proposed Roadmap for Development

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PREFACE

The use of deep ocean water (also known as deep sea water) technology has been on discussion globally since the 1960’s and more specifically in Puerto Rico since the 1970’s. Numerous studies and discussions have been ongoing through the years.

No major effort or studies have been performed since the 1980’s leaving this as a forgotten dream. In September 2017 two catastrophic natural disasters, Hurricanes Irma and Maria, changed the game rules relating to energy generations and new technologies. This provide for the opportunity to explore that untapped resource.

The goal of this technical report is to analyze and determine the pre-feasibility and most suitable site for the development of the Puerto Rico Ocean Technology Complex (PROTECH). PROTECH will be the tip of the spear in the economic regrowth of the Puerto Rico’s south-eastern Region.

The main driver of this development is the use of deep sea water for multiple uses that will be presented in a comprehensive manner throughout this document. The objective is to catapult Puerto Rico into context-aware, responsible infrastructure and technology precinct planning and development, capable of transforming the existing energy scenario of the island, and hopefully, the world.
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1 EXECUTIVE SUMMARY

The Puerto Rico Department of Economic Development & Commerce (DEDC) proposes the development of the Puerto Rico Ocean Technology Complex (PROTECH, also referred in this document as Project, Complex or Park). This development will be the beginning of a series of milestones that enable Puerto Rico to develop and invest in ocean related industries efforts and to create the technologies required to adapt to the transition from conventional energy and fuels, to more responsible and sustainable alternatives.

PROTECH will take advantage of a cluster of institutions, small-medium size enterprise and academic research that will enable a new approach to bridging with investments in complementary facilities on the Puerto Rico southeast coast.

The main driver of this development is the use of deep seawater focused in ocean thermal energy conversion (OTEC) and sea water air conditioning (SWAC) systems. The byproducts of those systems offer several products and services, such as production of bottled water, cosmetics, aquaculture, leisure medical treatments and food components.

Since deep seawater maintains its low temperature, 10-12 degrees Celsius (52-54°F), and unique mineral properties after use in OTEC power generation, the water can be used in agriculture, industry, cooling, and other fields. Research continues into multiple uses of the water, opening new ways to harness the resources and energy of the sea.

Since OTEC facilities must be located near islands or within several miles of coastal zones due to cabling constraints, near-shore circulation patterns play a crucial role in determining the thermal structure of the water column. Upwelling, bringing deep water closer to the surface, can benefit an OTEC facility by reducing the required length of a cold-water intake pipe.

Puerto Rico’s east-southeast coast was found to meet the key characteristics of previous preliminary studies, including a sufficient temperature differential (more than 20° C difference from deep water to surface water) and a favorable seafloor environment for anchoring the physical system.

The best OTEC locations are those that have high surface temperatures and access to cold deep water such as Puerto Rico. Without adjacent deep water (a significant constraint for many locations due to their continental shelves) the capital cost of lengthy pipelines or offshore OTEC can be a considerable economic deterrent.

As a matter of fact, the report An Evaluation of the U.S. Department of Energy’s Marine and Hydrokinetic Resource Assessments, from 2013, recommends that “Any future studies of the U.S. OTEC resource should focus on Hawaii and Puerto Rico, where there is both a potential thermal resource and a demand for electricity”. Additionally, it states that “the main potential for ocean currents is in the Florida Straits, and the coastal regions of the Hawaiian Islands and Puerto Rico are the most likely places for efficient OTEC siting.” Refer to Appendix 1 for the complete document.

On this Proposed Roadmap for Development (Master Plan), a site feasibility evaluation is performed in order to assess the most desirable location on Puerto Rico’s southeast coast, for the project development.

The following organizations have collaborated in the preparation of this document:
Integra Design Group – Responsible for the Master Plan development and coordination.

MAKAI Ocean Engineering – Responsible for the sea water supply pipeline and OTEC technical aspects of the project.

Technical Consulting Group – Responsible for the environmental & permitting aspects of the project, defined the minimum requirements for the main components of the deep seawater system, provided general technical review on OTEC and participated in the site selection.

Estudios Técnicos Inc – Responsible for the economic feasibility aspects of the project.
2 INTRODUCTION

2.1 Purpose and Need for the Project

After almost twelve (12) years of economic depression and the devastation caused by Hurricanes Irma and Maria in 2017, there is a unique window of opportunity for Puerto Rico.

The Government of Puerto Rico, through the Department of Economic Development and Commerce, has in place an industrial development strategy that seeks to position Puerto Rico as a global leader in the knowledge economy, based upon the Island's competitive advantages to generate sustainable economic growth and job creation.

Puerto Rico's New Plan for Economic Development creates the foundation for this development. Within this plan, the strategic priorities are to protect the existing industrial base and to enable the expansion of existing companies through cluster strategies. Also, the plan is designed to attract new global companies to invest in Puerto Rico, identify emerging segments that match Puerto Rico's capabilities and promote opportunities for renewable energy developments.

Furthermore, the Puerto Rico Energy Public Policy Law (Ley de Política Pública Energética de Puerto Rico – Ley Núm. 17) from April 11th, 2019, states the need to comply with a Renewable Energy Portfolio in order to reach a minimum of 40% renewable energy by or before 2025; 60% by or before 2040; and 100% by or before 2050. PROTECH will play an important role in the modifications that this law presents.

We have identified Puerto Rico's human capital, its infrastructure and its regulatory, financial and institutional environment as the major pillars supporting a diverse manufacturing economy that ranges from life sciences to knowledge services outsourcing.

By providing renewable energy and alternate cooling methods, tenants, entrepreneurs, companies and researchers will be attracted to establish their business in the area, creating jobs and inserting Puerto Rico into a new market.

2.2 Project Components

The successful operation of the Puerto Rico Ocean Technology Complex (PROTECH), is dependent on the interrelation of different components that must be developed for the project.

The PROTECH components are discussed on this section:

2.2.1 Research/Industrial Park

Based on the project scope and using an existing similar project located in Hawaii as reference, approximately between 150 to 300 acres will be needed to fully develop into a research/industrial park. The park shall have full infrastructure installations and related amenities for its success.
The Puerto Rico Industrial Development Corporation (PRIDCO), a component of the DEDC, has the largest inventory of industrial properties in Puerto Rico, with over 1,500 properties strategically distributed throughout the Island. The PRIDCO portfolio has industrial buildings, lots and raw land. PRIDCO offers business intelligence, facility selection, project management support, assistance with regulatory and permitting process and one-stop customer service. In addition, PRIDCO offers and manages a wide range of modern industrial parks and sites with relevant infrastructure ready for use.

The project can benefit from these properties under a rent agreement or, in some strategic instances, by sale. Currently there are industrial parks on all the Municipalities in the Eastern region where the project is envisioned.

If no property is identified as PRIDCO owned, they can assist with all the real state diligences and setup for establishing the framework for the proposed research/industrial park.

2.2.2 Deep Ocean Water (DOW) Uses

Deep ocean water (DOW), as previously mentioned it is also known as deep seawater (DSW), is typically used to describe ocean water at sub-thermal depths sufficient to provide a measurable difference in water temperature.

![Deep Ocean Schematic Definition](http://www.taiwanyes-dow.com.tw/eng/deepwater_1.php)
2.2.2.1 Ocean Thermal Energy Conversion (OTEC)

Ocean Thermal Energy Conversion (OTEC) is a technology that uses a turbine generator to create renewable energy from the temperature difference between cold, deep seawater circulating in the ocean and surface water warmed by the sun. In order to produce power with the low temperature range, a working fluid with low boiling point is used.

OTEC is constant and reliable power available 24 hours a day 7 days a week; a clean energy source, environmentally sustainable and capable of providing massive levels of energy. With current technology, an annual sea water temperature difference of 20°C (36°F) or more is needed for optimal results and locations with ocean depths equal or greater than 3,000 ft (1,000 m) on the equatorial region are the most suitable for this technology.
There is currently no major commercial plant in operation in the world but there are two small scale plants in operation:

➢ Makai Ocean Engineering's operates a 100kW OTEC power plant in Kailua-Kona Hawaii, USA.
➢ Okinawa Deep Seawater Research Institute and Xenesys Inc. operate a 50kW OTEC demonstrative plant in Jumejima Island in the Okinawa Prefecture, Japan

Puerto Rico has the best location, natural resources and market conditions to build and operate the first large scale OTEC commercial plant.

2.2.2.2 Seawater Air Conditioning (SWAC)

Seawater air conditioning (SWAC) takes advantage of available deep cold water from the ocean, a river, or lake, to replace conventional AC systems.

The concept of SWAC is thought to have been first conceived by the Natural Energy Laboratory of Hawaii Authority (NELHA) at its facility at Keahole Point on the Island of Hawaii in 1983. NELHA was the first location in the United Stated to successfully deploy a deep seawater pipeline to bring deep, cold seawater ashore for alternate energy research and development in 1981.
The primary purpose at the time was to support the technological advancement of the Ocean Thermal Energy Conversion (OTEC) principle. It was soon realized that utilizing this cold seawater as the primary chill water resource for air conditioning would be a great advantage and cost savings measure compared to conventional air conditioning processes.

A standard air conditioning process utilizes refrigerants (typically CFC’s and HCFC’s) as the primary source of “cold” medium for space cooling applications. The SWAC process eliminates the use of refrigerants and instead utilizes cold sea water as the primary thermodynamic chilling fluid.

A standard air conditioning process utilizes refrigerants (typically CFC’s and HCFC’s) as the primary source of “cold” medium for space cooling applications. The SWAC process eliminates the use of refrigerants and instead utilizes cold sea water as the primary thermodynamic chilling fluid.

Alternate applications of this technology utilize cold lake water or river water. Cornell University and Ithaca High School in New York utilize cold lake water from Cayuga Lake to air condition their entire campuses. The majority of the air conditioning needs of the City of Toronto, Canada today start with cold fresh water from Lake Ontario. In these cases, the process is commonly referred to as “Lake Source Cooling (LSC) or “Deep Lake Water Cooling (DWLC)”. Some of the most famous buildings in Paris, France are air conditioned and climate controlled using water from the River Seine. The largest seawater application of SWAC is for air conditioning and climate control for most buildings in Stockholm, Sweden.

The primary benefits of SWAC are that it can offset electrical demand by 75-85% (0.7 kW/ton), reduce the reliance on fossil fuels, reduce or entirely eliminate the need for chillers and cooling towers, achieve a rapid return on capital investment (typically 6-8 years), and is easily adaptable to conventional chill water air conditioning systems, a standard that most large commercial buildings and hotels currently utilize.

The basic concept starts with the construction a deep seawater or lake water intake pipeline and pumping station. Once this chilled water is pumped on shore it is passed through a heat exchanger facility to absorb some of the heat generated in the closed,
Proposed Roadmap for Development, July 2020

freshwater loop used to air condition the buildings. The chill water resource is then returned from whence it came (ocean, lake or river) or under certain conditions, can be used again for secondary applications.

2.2.2.3 Agriculture, aquaculture, and other uses

Since deep seawater maintains its low temperature (10-12 degrees Celsius) and unique mineral properties after use in OTEC power generation, the water can be used in agriculture, industry, cooling, and other fields. Research continues into multiple uses of the water, opening new ways to harness the resources and energy of the sea.

Deep seawater (DSW) commonly refers to a body of sea water that is pumped up from a depth of over 200 m. It is usually associated with the following characteristics: low temperature, high purity, and being rich with nutrients, namely, beneficial elements, which include magnesium, calcium, potassium, chromium, selenium, zinc, and vanadium. Less photosynthesis of plant planktons, consumption of nutrients, and organic decomposition have allowed nutrients to remain there.

The outputs of the SWAC's system offer an opportunity to develop a wide spectrum of products and services. These include among others:

- Agriculture development (cooling greenhouses through condensation for growing fruits and vegetables); Agricultural and aquacultural activities are enabled within a DSWI. Examples include the circulation of DSW in closed-loop underground piping in areas where the soil is naturally not suitable for plant growth, but by making the soil cooler and moist, this enables the cultivation of vegetable plants.
- Aquaculture development (growing tilapia/shrimps in clean ponds); Also using the DSW as effluent can be tapped to supply fish ponds and other dedicated facilities for algae production or other types of biomass;
- Algae cultivation (cosmetic, health/medical, and/or biofuels production);
- Desalinated deep ocean water for human consumption; Through several technology options, fresh water can be produced in a DSWI park. Depending on the backbone technology opted, there are different configurations possible to produce fresh water. In the case of the use of an open-cycle or hybrid designed OTEC system, the DSW effluent from the system can be desalinated, bottled, and sold on the local and international market.
- Use of DSW for environmental restoration and ensuring the DSW is replenished through natural mechanisms.

2.3 OTEC Historical Development Efforts in Puerto Rico

Timeline

1970’s
During the energetic crisis in the 1970’s, the Center for Energy and Environmental Research (CEER) in Mayaguez, an institution created by the U.S. Atomic Energy Commission (AEC), a predecessor agency of the U.S. Department of Energy (DOE), developed between 1978 and 1981, multiple oceanographic studies to determine a feasible site for the establishment of an OTEC plant in PR.
The results generated Punta Tuna as the most feasible location for an OTEC Plant. They performed oceanography, heat exchanger design and operation (biofouling, corrosion, microfouling), environmental studies.

After the lowering of the crude oil prices, the Department of Energy (DOE) cancelled subsidies to those studies and did not authorize new renewable energy projects.

1980’s
In 1981 the Puerto Rico Electric Power Authority (PREPA) proposed a 40 Megawatt OTEC Plant on an offshore structure located at 1 to 2 miles from shore at Punta Tuna, Maunabo.

This was going to be built with a close cycle ammonia power system. The proposal was submitted to the US Department of Energy (DOE), but it was never funded or constructed.

2.4 Comparative Similar Projects

Hawaii, USA

➢ The United States entered OTEC research in 1974 with the establishment of the Natural Energy Laboratory of Hawaii Authority (NELHA).

The State of Hawaii has invested over $100 million since 1974 to create the Hawaii Ocean Science & Technology Park (HOST Park), a unique outdoor demonstration site for emerging renewable and ocean-based technologies. Three sets of pipelines deliver deep seawater from up to 3000 ft depth as well as pristine sea surface water.

The Natural Energy Laboratory of Hawaii Authority (NELHA), founded in 1974, administers the HOST Park. At 870 acres (350 ha), HOST Park is perhaps the largest single green economic development project in the world solely devoted to growing a green economy. NELHA also administers a small site, 4 acres (1.6 ha), in Puna on the eastern side of the Island of Hawaii for geothermal research.

The original mission was to research the possible uses of Deep Ocean Water in Ocean Thermal Energy Conversion (OTEC), renewable energy production and in aquaculture. Makai Ocean Engineering’s OTEC power plant is the world’s biggest operational facility of its kind, with an annual power generation capacity of 100kW, which is enough to power 120 homes in Hawaii. Located at the Natural Energy Laboratory of Hawaii Authority (NELHA) in Kailua-Kona, the facility was connected to the US grid in August 2015 and is capable of providing base load power, meaning it can constantly produce electricity 24h a day throughout the year.
Figure 6. Aerial View of HOST Park

Figure 7. Makai’s OTEC Plant
Okinawa, Japan

➢ Ocean Thermal Energy Conversion demonstrating facility, Okinawa Prefecture

Over the past 17 years+ researchers at the 15 sites around Japan have been researching the properties and uses of Deep Seawater.

The Okinawa Deep Seawater Research Institute and Xenesys Inc. operate a 50kW demonstrative plant in Jumejima Island in the Okinawa Prefecture, Japan to promote the research and development of ocean energy, striving to reduce the environmental impact of local production of energy and promote the regional characteristics of Okinawa.

On Kume Island there are 18 companies harnessing deep sea water for use in various products. The Deep-Sea Water Research Institute uses a heat exchanger to cool water that runs through a system which cools the entire laboratory building.

Figure 8. Aerial View of Okinawa OTEC Facility
http://otecokinawa.com/en/Project/PostOTECSeawater.html
Southern Seas, China

- Floating Ocean Thermal Energy Conversion pilot facility (planning phase)

Lockheed Martin was planning a 10MW OTEC pilot power plant off the coast of southern China in collaboration with Reignwood Group. The current status of this project is unknown.
2.5 Project Goals and Objectives

According to the Economic Development Briefing Document, from the Resilient Puerto Rico Advisory Commission, dated February 2018, the Puerto Rico Department of Economic Development & Commerce (DEDC) is anchored on three goals and objectives that work together towards sustained, long-term growth:

- Reinvent and Reenergize established Industries
- Landmark High-Impact projects
- Implement Innovative Strategic Ventures

The project will be in tune with these strategies in the following ways:

2.5.1 Reinvent and Reenergize Established Industries

Existing industries such as energy production, manufacturing and others need to be redirected to changes according to the global market and demand. The project shall provide renewable energy to the existing electrical grid, provide seawater air conditioning for nearby industries and commerce and create synergies with existing industries that provides support, materials and services to the new industries to be established.

2.5.2 Landmark High-Impact Projects

The establishment of the PROTECH will be the first of its kind in the Americas. OTEC technology and deep-sea water industries is an uncharted territory that will create a high impact and will be a landmark not only for the PR eastern region but also for the whole Island and the world.

2.5.3 Implement Innovative Strategic Ventures

PROTECH will provide a strategic venture in the renewable energy field as the generation of electric power from an infinite source will benefit generators and clients. As stated previously, renewable energy generation is a goal established by public policy by reaching 20% compliance with the Renewable Portfolio Standard by the year 2025; 50% compliance by the year 2040; and 100% compliance by the year 2050, considering the amount distributed energy generated by prosumers.

In addition, in the Executive Summary from the Economic Development Plan 2018, the DEDC presents nine (9) different Strategic Sectors identified as opportunities for growth in the economic development for Puerto Rico. One of them is Ocean Economy, which is the main driver behind this project.

On that same framework, in the document Transformation and Innovation in the Wake of Devastation, An Economic and Disaster Recovery Plan for Puerto Rico, dated August 8, 2018, multiple objectives are presented as guidelines for opportunity and development of projects of various dimensions and scales. Under Strategic Initiatives, Ocean Economy is introduced as one (1) of eight (8) sets of actions that reflect the future economy of Puerto Rico.

The development of the PR Ocean Technology Complex (PROTECH) will pursue those goals though detailed analysis, design and implementation of the different project components, which will be presented throughout this document.
2.6 Technology Complex Needs and Requirements

The establishment of a deep ocean water industry requires the development of the essential facilities for research commercial enterprises. Typically, the governments must provide public goods, particularly infrastructure, for industrial firms to be competitive; interested firms generate agglomeration economies; and so, the public goods should be concentrated on designated areas.

The required components must provide state-of-the-art facilities that serve as a catalyst for the creation and enhancement of research and business collaboration. The facilities shall consider:

- Easy access to the shoreline
- Readily available infrastructure (transportation, potable water, electricity, sanitary sewer, telecom-data)
- Available land
- Favorable environmental conditions
- Service and support components

Acceptable uses that conform to the stated nature of the Park included aquaculture, biotechnology, deep water research, hospitality and renewable energy.

The park will be composed of eight (8) principal clusters:

1. Ocean Thermal Energy Conversion (OTEC) Facility
2. Seawater Air Conditioning (SWAC) Production
3. Economic Driver Industries (Deep Ocean Water)
4. Applied Research and Technology
5. Information and Academic Center
6. Industries Incubation
7. Tourism and Hospitality & Event Hosting
8. Natural Resources

These requirements, and the analyzed precedents, suggest that an approximate area of 300 acres will be needed for the development of the project.

2.6.1 Ocean Thermal Energy Conversion (OTEC) Facility

The establishment of an OTEC facility is one of the main drivers of the project. To achieve this goal the following land and capacity requirements must be met:

- Land based facility near shoreline
- Production capacity between 5 to 10 Megawatts
- Shortest distance for ocean depths equal or greater that 3,000 ft (1,000 m)

Land-based and near-shore facilities offer greater advantages over those located in deep water (on the continental shelf or floating). Plants constructed on or near land do not require specialized mooring, longer power cables, or continuous maintenance associated with open-ocean environments. In addition, land-based facilities provide protection from storms and rough seas.
Land-based or near-shore sites allow generation plants to operate closely with related industries such as aquaculture/mariculture or those that require desalinated water.

Puerto Rico has the best location, natural resources and market conditions to build and operate the first large scale OTEC plant in the world, with a capacity greater than 1 (one) Megawatt, and to become the world-wide leader on this technology.

2.6.2 Seawater Air Conditioning (SWAC) Production

A Seawater Air Conditioning (SWAC) shall be established in order to meet the cooling demand for the principal tenants of the Research Park. The system shall replace the equivalent loads of a conventional air conditioning systems

A SWAC distribution system (piping) must be considered as part of the basic infrastructure of the industrial park, as well as a measuring system consumption to the tenant, that can be a revenue to the SWAC generator. A policy requiring SWAC systems in all new construction as a condition of leases or building permits shall be established.

2.6.3 Deep Ocean Water Industries (DOWI)

The outputs of the SWAC system offer an opportunity to develop a wide spectrum of products and services. These include among others:

- Potable water. By desalinating, deep ocean water using reverse osmosis (RO) or distillation, a high-quality drinking water can be produced, which can be sold as a premium product;
- Agriculture development (cooling greenhouses through condensation for growing fruits and vegetables);
- Aquaculture/Mariculture development (growing fish/shrimps in clean ponds);
- Aquaculture (growing exotic species for aquaria);
- Algae cultivation (cosmetic, health/medical, and/or biofuels production) and;
- Use of DSW for environmental restoration and ensuring the DOW is replenished through natural mechanisms.

This scenario presents an important platform for emerging industries and/or companies that are interested in these possibilities.

Through several technology options, fresh water can be produced in a DOWI park. Depending on the backbone technology opted, there are different configurations possible to produce fresh water. In the case of the use of an open-cycle or hybrid designed OTEC system, the DSW effluent from the system can be desalinated, bottled, and sold on the local and international market. Another way to produce fresh water is through dew collection or the dehumidification of the air that can be used for agricultural purposes or landscaping.

Agricultural and aquacultural activities are enabled within a DOWI. Examples include the circulation of DSW in closed-loop underground piping in areas where the soil is naturally not suitable for plant growth, but by making the soil cooler and moist, this enables the
cultivation of vegetable plants. Also using the DSW as effluent can be tapped to supply fish ponds and other dedicated facilities for algae production or other types of biomass.

2.6.4 Education and Research

There are multiple educational and research opportunities at this type of facility. Some of the opportunities that shall be implemented include:

a) Expand knowledge of PROTECH as an educational resource for the benefit of the community, including local communities, students, researchers, and visitors, the Project can become an ecosystem for academic research on deep sea water technologies and resources.

b) Create partnerships or programs with private and public universities related to oceanography and deep seawater careers education. It is pertinent to note that the University of Puerto Rico, currently offers undergraduate and graduate studies on Coastal Marine Biology (Humacao Campus) and Physical Oceanography (Mayaguez Campus) and have researched microalgae and biofuel possibilities as renewable sources of energy. These educational components can benefit immensely from this Project, as it will be a living laboratory of areas of study medullar for their curriculum.

c) Define areas, criteria and support facilities for education and research as applicable, to allow for sustainable, integrated planning and management.

d) Technical training for high-tech industries based on PROTECH Technologies.

e) Research into fuel or pharmaceutical uses.

f) Research into energy and deep ocean uses.

The Education and Research zone would focus on more pure research and uses that are dependent on proximity to the ocean. It is hoped that a series of partnerships be developed with other research institutions and the place become a center for cutting edge programmatic research. A project that specializes in the production of base oils and blended lubricants through re-refining of used waste is already located here along with several other research partners of long standing.

2.6.5 Cultural and Recreational

The Park must embrace the cultural aspects of the surrounding communities where it is to be located. This goal will take in consideration the following parameters and requirements.

a) Identify physical cultural resources such as archeological and historic sites. The identified resources shall be protected and managed in a sustainable manner. Cultural resources can be identified and incorporated into the planning process.

b) Identify local cultural practices and protect the opportunities for individuals and groups to engage in cultural practices.

c) Define areas, criteria and support facilities for cultural resources and practices, as applicable, to allow for integrated planning and management.

The cultural objectives recognize that the location of the technology complex can be situated on historical or cultural significance areas. The future development plan must encourage preservation of cultural heritage and resources and at the same time supports use and further understanding of these resources by visitors and others.
2.6.6 Commercial

Commercial activities will be one of the main drivers for PROTECH and the PR Eastern region. Those activities will also support the research and institutional objectives of PROTECH.

The commercial activities shall include:

a) Those businesses engaged in compatible scientific and technological investigations;
b) Ocean-water commercial uses such as high intensity commercial mariculture, marine biotechnology, and renewable energy projects;
c) Technology Development & Incubation Campus;
d) Technology Commercialization;
e) Partnership Offices (Universities, public institutions, etc.);
f) Park Administrative Offices;
g) Work/Office/Visitor facilities and;
h) Retail zone

The retail zone should be developed in with a mix of retail, commercial and entertainment venues. Retail stores and restaurants shall include products from the community, fostering their involvement in order to generate a more deeply connection with the place and from the deep ocean water industries serving seafood and produce grown at PROTECH.

2.6.7 Hospitality and Tourism

Due to the location in a coastal zone, the development of hospitality and tourism facilities is a key element of the PROTECH. A location close to the shore shall be developed into a hospitality cluster for the development of a full hotel/lodging facility with an emphasis of ecotourism with all the necessary amenities and support facilities (meeting areas, restaurants, sports areas, etc.)

It is recommended that proponents follow the design guidelines for ecotouristic installations, established in document Guías de Diseño para Instalaciones Ecoturísticas y de Turismo Sostenible, dated January 2007, available on Compañía de Turismo Puerto Rico’s website.

As a complement to the hospitality and ecotourism component, scientific tourism shall also be encouraged through the establishment of a visitor’s center. The visitors center shall be a hub for information, education and coordination for guided tours to the various PROTECH components including fish and aquaculture hatcheries, the OTEC plant and other historical and archeological areas.

The development areas shall include:

a) Hotel or lodge
b) Restaurants, coffee shops and water related sports facilities or amenities
c) Visitors Center
2.6.8 Natural Resources

Puerto Rico eastern region has a variety of habitats, including forests, coral reefs, wetlands, lagoons, caves, and marshes. The range of natural formations encourages tourism but is also of value for research. Existing natural resources at or near the selected location shall be protected and incorporated into the development as a research, education and tourism component.

Sustainable development and natural resources management is an essential factor on this project. Natural resource management deals with managing the way in which people and natural landscapes interact. It brings together land use planning, water management, biodiversity conservation, and the future sustainability of industries like agriculture, mining, tourism, fisheries and forestry.

The proposed development shall be adjusted and carefully considered to prevent any conflict or damages to the existing natural habitat and terrain characteristics. Also, each individual PROTECH component shall consider the environmental and natural resources short- and long-term effects of its development and operation.
3 POTENTIAL SITES SCREENING PROCESS

3.1 Introduction and Process Description

The Puerto Rico Department of Economic Development and Commerce (DDEC), through its Secretary, Hon. Manuel A. Laboy Rivera, comformed a technical committee of consultants and advisors, with the task of analyzing and recommend the most suitable location and the pre-feasibility for the development of the Puerto Rico Ocean Technology Complex (PROTECH).

The technical committee is composed of the following members:

**Department of Economic Development and Commerce (DDEC)**
- Guillermo Fernández Mongil, Auxiliary Secretary for Projects
- Yolanda Díaz-Rivera, Special Assistant to the Secretary

**Integra Design Group (Master Plan Consultant)**
- Dwight Rodríguez, P.E.
- Carlos Báez Dotel, P.E.

**Technical Consulting Group (OTEC System Consultant)**
- Jose A Martí, P.E.

**Estudios Técnicos (Economic Analysis Consultant)**
- Joaquín Villamil
- Kevin González

**Makai Ocean Engineering (OTEC & SWAC System Consultant)**
- Richard Argall
- Steven Rizea

In addition, there is research collaboration with the Department of Marine Sciences of the University of Puerto Rico, in Mayaguez.

The site screening process defined by the committee, addressed the technical aspects of the physical, environmental, social and economic characteristics of each site to be considered. In addition, consideration to impacts on future stakeholders (communities, investors, tenants and government) are considered.

The main driver for suitable site location of PROTECH, is a location with a short distance from ocean depths equal or greater than 3,000 ft (1,000 m). This constraint reduces the possible site selection to locations on east-southeast of Puerto Rico. With distances ranging from 4 to 6 kilometers; this region is the most suitable in comparison to the next region with shortest distance (PR North Coast) with approximately 12 kilometers.
The approach began with a comprehensive list of initial nine (9) candidate sites in the east-southeast regions of Puerto Rico, based on recommendations by the committee.

The mapping of the initial nine (9) potential sites is based mainly on the following conditions:

a) Short distance from ocean depths equal or greater than 1,000 meters (3,000 feet);
b) Presence of non-residential land area of adequate size with a minimum 100 acres;
c) Accessible shoreline and;
d) Adequate topography to construct the research park and ocean related activities.

The initial potential sites list will be further reduced to three (3) final candidate sites.
### 3.2 Identification and Initial Screening of Potential Sites

The identification of the potential sites was defined primarily by the location of the shortest distance from shoreline up to a sea depth of approximately 1,000 meters (3,000 feet) on the east and southeastern coast of Puerto Rico.

The initial screening produced the following potential sites:

<table>
<thead>
<tr>
<th>Location ID</th>
<th>Location Name</th>
<th>Municipality</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Approx. distance to required depth (kms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Punta Figuras</td>
<td>Arroyo</td>
<td>17.967 W</td>
<td>66.048 N</td>
<td>9.7</td>
</tr>
<tr>
<td>2</td>
<td>Lamboglia</td>
<td>Patillas</td>
<td>17.975 W</td>
<td>65.973 N</td>
<td>6.0</td>
</tr>
<tr>
<td>3</td>
<td>Old Flor Quim</td>
<td>Patillas</td>
<td>17.978 W</td>
<td>65.921 N</td>
<td>4.0</td>
</tr>
<tr>
<td>4</td>
<td>Punta Tuna</td>
<td>Maunabo</td>
<td>17.996 W</td>
<td>65.897 N</td>
<td>4.0</td>
</tr>
<tr>
<td>5</td>
<td>Punta Toro</td>
<td>Maunabo</td>
<td>18.008 W</td>
<td>65.863 N</td>
<td>4.0</td>
</tr>
<tr>
<td>6</td>
<td>Finca Lucía</td>
<td>Yabucoa</td>
<td>18.042 W</td>
<td>65.842 N</td>
<td>4.7</td>
</tr>
<tr>
<td>7</td>
<td>Palmas del Mar</td>
<td>Humacao</td>
<td>18.099 W</td>
<td>65.794 N</td>
<td>13.5</td>
</tr>
<tr>
<td>8</td>
<td>Roosevelt Roads</td>
<td>Ceiba-Naguabo</td>
<td>18.233 W</td>
<td>65.641 N</td>
<td>17.5</td>
</tr>
<tr>
<td>9</td>
<td>Puerto Yabucoa</td>
<td>Yabucoa</td>
<td>18.055 W</td>
<td>65.843 N</td>
<td>4.7</td>
</tr>
</tbody>
</table>
A brief description of each site is presented here:

- **Punta Figuras**: This site is located at the coastline in the Palmas Ward of the Municipality of Arroyo; it is currently a vacant lot of approximately 350 acres. It is bounded on its North limit by State Road PR-3, on the West by residential and urban areas, and on the East by other vacant parcels. This site is currently classified mostly as agricultural land.

- **Lamboglia (Punta Viento)**: This site is located at the coastline in the Jacaboa Ward of the Municipality of Patillas; it is currently a vacant lot of approximately 200 acres. It is bounded on its North limit by State Road PR-3, on the West by the Punta Viento Natural Reserve, and on the East by residential communities. This site currently does not have a defined land use classification.

- **Old Flour Quim**: This site is located near the coastline in the Guardarraya Ward of the Municipality of Patillas; it is currently a lot with an abandoned industrial building of approximately 10 acres. It is bounded on its South limit by State Road PR-3, on the North, East, and West by the Sierra de Guardarraya Mountain Range. This site currently does not have a defined land use classification.

- **Punta Tuna**: This site is located at the coastline in the Emajagua Ward of the Municipality of Maunabo; it is currently a vacant lot of approximately 200 acres. It is bounded on its North limit by State Road PR-939, on the West by the Rio (River) Maunabo, and on the East by State Road PR-760. This site is currently classified mostly as urban land with agricultural uses.

- **Punta Toro**: This site is located at the coastline in the Emajagua Ward of the Municipality of Maunabo; it is currently a vacant lot of approximately 135 acres. It
is bounded on its North by residential lots and by State Road PR-901, on the West by vacant lots and on the East by residential lots. This site currently does not have a defined land use classification.

- **Finca Lucía**: This site is located at the coastline in the Juan Martín Ward of the Municipality of Yabucoa; it is currently a vacant lot and a portion of a public beach, with approximately 215 acres. It is bounded on its North by residential lots and by State Road PR-9914, on the West by State Road PR-901 and on the South by State Road PR-901 and residential lots. This site currently does not have a defined land use classification.

- **Palmas del Mar**: This site is located at the coastline in the Candelero Abajo Ward of the Municipality of Humacao; it is currently a mixed-use residential-touristic community which with approximately 150 acres of available land. It is bounded on its North by residential lots and by State Road PR-9914, on the West by State Road PR-901 and on the South by State Road PR-901 and residential lots. This site currently has a special urban land classification.

- **Roosevelt Roads**: This site is located at the coastline in the Municipalities of Ceiba and Naguabo; it was formerly a US Navy Station. Currently it only partially occupied by some institutional and commercial tenants. It is envisioned as a mixed-use residential-commercial hub in the near future. There are hundreds of acres of available land, but mostly discontinuous due to topographic and natural characteristics. It is bounded on its north and west by State Roads PR-3 & PR-53, and on the south by residential land and forest land. This site currently has a multiple mixed uses land classification.

- **Puerto Yabucoa**: This site is located at the coastline of the Municipality of Yabucoa, Camino Nuevo Ward, with approximately 270 acres. The parcel northwest of the Port is bounded on the north by Caño de Santiago (a natural stream), on the south by a vacant parcel property of the PR Land Administration (Administración de Terrenos de PR) and by Buckeye Terminals (fuel storage facilities), on the east by the Port of Yabucoa (property of the PR Ports Authority) and the coastline and on the west by Highway State Road PR-53. The parcel southeast of the Port is bounded on the north by State Road PR-9914 on the south by State Road PR-9911 and Palmas de Lucia Hotel, on the east by the coastline and the west by a vacant parcel property of the PR Land Administration (Administración de Terrenos de PR). This site currently does not have a defined land use classification.

After the initial screening, a parameter score matrix was prepared, to assess each site characteristics and determine the three (3) sites with the highest scores.

The following five (5) parameters were considered for evaluation and scoring. The scores will range from 1 being the lowest value and 5 being the highest value. In addition, a weight-value, according to the importance factor, is assigned to each parameter.

- **Distance to seabed gradient depth > 1,000 meters**: Shortest distance will receive the highest score. This is the most important parameter and will receive 100% weight in the selection matrix.

- **Available Land Area (>100 acres)**: Available land shall be readily accessible, with no major topographic hurdles and separated from residential sites. The largest area
with less constraints will receive the highest score. This parameter will receive 75% weight in the selection matrix.

- **Available Infrastructure**: Readily accessible road, electrical power, and potable water are critical for this project. Projects with greater accessible infrastructure will receive the highest score. This parameter will receive 75% weight in the selection matrix.

- **Project Objective Compliance**: Projects located on areas that are in need of economic regrowth and with larger potential job creation will receive the highest score. This parameter will receive 75% weight in the selection matrix.

- **Major Sensitive Environmental Conditions**: Sensitive environmental conditions and natural resources, such as protected lands or water bodies, should be taken into consideration in the site selection. Projects located on areas that have less sensitive environmental conditions will receive the highest score. This parameter will receive 75% weight in the selection matrix.

### Table 2 Parameters for each site

<table>
<thead>
<tr>
<th>Potential Sites</th>
<th>Approx. Distance (km) to seabed gradient depth &gt; 1,000 m</th>
<th>Approx. Available Land Area (acres)</th>
<th>Available Infrastructure (Approx. distance to major road and electrical system) (km.)</th>
<th>Project Objective Compliance</th>
<th>Major Sensitive Environmental Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Punta Figuras</td>
<td>9.7</td>
<td>350</td>
<td>1.2</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Lamboglia</td>
<td>6.0</td>
<td>200</td>
<td>1.0</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Old Flor Quim</td>
<td>4.0</td>
<td>&lt;10</td>
<td>0.5</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Punta Tuna</td>
<td>4.0</td>
<td>&gt;200</td>
<td>1.1</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Punta Toro</td>
<td>4.0</td>
<td>300</td>
<td>0.5</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Finca Lucía</td>
<td>4.7</td>
<td>150</td>
<td>1.2</td>
<td>yes</td>
<td>Yes (Protected Natural Reserve portions)</td>
</tr>
<tr>
<td>Palmas del Mar</td>
<td>13.5</td>
<td>&lt;100</td>
<td>3.0</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Roosevelt Roads</td>
<td>17.5</td>
<td>&gt;100</td>
<td>2.2</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Puerto Yabucoa</td>
<td>4.7</td>
<td>270</td>
<td>0.8</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>
### Table 3 Parameters Score Matrix

<table>
<thead>
<tr>
<th>Potential Sites</th>
<th>Distance to seabed gradient depth &gt; 1,000m</th>
<th>Available land area</th>
<th>Available infrastructure</th>
<th>Project objective compliance</th>
<th>Sensitive Environmental Conditions</th>
<th>Total Weighted Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Score Weight 100%</td>
<td>Score Weight 75%</td>
<td>Score Weight 75%</td>
<td>Score Weight 75%</td>
<td>Score Weight 75%</td>
<td></td>
</tr>
<tr>
<td>Punta Figuras</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>14.25</td>
</tr>
<tr>
<td>Lamboglia</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>12.75</td>
</tr>
<tr>
<td>Old Flor Quim</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>12.00</td>
</tr>
<tr>
<td>Punta Tuna</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>14.00</td>
</tr>
<tr>
<td>Punta Toro</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>14.75</td>
</tr>
<tr>
<td>Finca Lucía</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>13.50</td>
</tr>
<tr>
<td>Palmas del Mar</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>10.00</td>
</tr>
<tr>
<td>Roosevelt Roads</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>11.50</td>
</tr>
<tr>
<td>Puerto Yabucoa</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>15.00</td>
</tr>
</tbody>
</table>

From the parameter score matrix (Table 3) the conclusion is that the three locations with the highest scores are: Punta Figuras, Punta Toro and Puerto Yabucoa.

Those potential sites will be analyzed more in depth in the following sections, in order to make the final site selection and recommendations.
4 EVALUATION CRITERIA OF FINALIST SITES

4.1 Introduction

As previously explained, the selected three locations will be considered for further and detailed analysis.

Information obtained from site visits of the selection committee as well as data obtained from different public and private sources, including geographic information system (GIS) resources were used for the analyses.

Multiple parameters or characteristics will be evaluated, and a selection matrix will be prepared, to assign scores for each site particular characteristics. The site with the highest score will be selected as the recommended location for the project development.

The following characteristics will be taken in consideration for the in-depth analysis.

- Location, Physical Suitability & Land Use Designation
- Oceanographical Characteristics
- Environmental/Natural Resources & Hazards
- Cultural and Historical Resources
- Social and Economic Impact
- Available Infrastructure

A description of each characteristic, its implications and scoring values are indicated on the following sections.

4.2 Location, Physical Suitability & Land Use Designations

This criterion addresses the broad range of engineering and constructability issues associated with developing the project at a selected site, including earthwork and geology, soil, wastewater disposal, the availability of construction materials, etc. Each site presents design and construction challenges. This section is intended to establish the relative degree of difficulty associated with the physical implementation of the project at each site.

4.2.1 Location & Shoreline Access

The location with respect to the shoreline is one of the most fundamental criteria for the project, as it is an ocean dependent one.

The site shall have direct access to the shoreline to implement the installation and operation of the deep-sea water pipelines systems.

Site scores are based on the proximity to the shoreline, assigning the highest score for the shortest distance.
4.2.2 Available Land Area

Land status availability is one of the most fundamental criteria for locating capital improvements. The title ownership of the site should be free of legal encumbrances, platted and surveyed with an accurate legal description and have a single owner.

For the Park’s development, it is envisioned a land area between 150 to 300 acres.

Site scores are based on the feasibility of providing an appropriate layout and the flexibility to accommodate expansion, with the highest score for the largest land area.

4.2.3 Zoning/Land Use Designation

Current and projected zoning and land use should be compatible with the use of the site for the proposed project. If local regulations do not currently permit this type of facilities, it could be a lengthy process to obtain a change in zoning or a conditional use permit.

The ideal zoning shall be on an industrial and commercial setting, with a buffer zone from residential areas.

Site scores are based on the difficulty and associated risk of the land use permit process, with the highest score for compatible zoning or land use.

4.2.4 Topography

The site topography is one of the most important characteristics as it could affect significantly capital improvements cost. For terrain slopes, we will be looking for slopes not greater than 8% in order to avoid excessive earthwork operations to adjust to the project layout.

Site scores are based on the feasibility of providing flat to mild slopes without extensive earthwork or terrain improvements, with the highest score for flatter terrain slopes.

4.2.5 Soils and Geology

Ideal sites contain well graded, stable soils with high soil bearing pressure. Soil conditions should allow conventional, economical foundation systems which can meet or exceed a 50-year life expectancy with little maintenance. Soil conditions which can adversely affect construction include, silts and clays, substantial surface or sub-surface organic and high-water contents. Sites should be assessed for the quality of their soil based on known conditions or on-site investigations.

The site geological characteristics will be considered as this is essential to identify possible hazards related to landslide prone lands as well as increase seismic hazards due to liquefaction of fractures. Or other geological feature that could affect the stability of structures and infrastructure.

Site scores are based on the feasibility of providing adequate soil bearing capacity without the need for substantial terrain improvements and considering geological hazards, with the highest score for the most adequate soils and less geological hazards.
4.3 Oceanographical Characteristics

One of the main factors that influence the location of an OTEC/SWAC facility includes oceanographical characteristics, such as seabed geophysical and seawater characteristics. Site scores are based on the location with the required attributes, with the highest score for most suitable qualities.

4.3.1 Seabed Geophysical Characteristics

Favored locations include those with narrow shelves (volcanic islands), steep (15-20 degrees) offshore slopes, and relatively smooth sea floors. These sites minimize the length of the intake pipe. A land-based plant could be built well inland from the shore, offering more protection from storms, or on the beach, where the pipes would be shorter. In either case, easy access for construction and operation helps lower costs. One disadvantage of land-based facilities arises from the turbulent wave action in the surf zone. OTEC discharge pipes should be placed in protective trenches to prevent subjecting them to extreme stress during storms and prolonged periods of heavy seas. Also, the mixed discharge of cold and warm seawater may need to be carried several hundred meters offshore to reach the proper depth before it is released, requiring additional expense in construction and maintenance.

4.3.2 Seawater Characteristics

Through the comparisons of the different outputs of the various operational OTEC facilities, it was concluded that seawater with a higher salinity has a negative impact on the heat generated by the OTEC system. By decreasing the salinity by 10% the heat generated increased by up to 0.4%. This information conveys that ideal locations for OTEC power generation lie within the tropics, in regions with lower seawater salinity.

Regarding temperature, a difference of at least 21 °C is needed between the warmer surface water and the colder deep ocean water. In the oceans the temperature difference between surface and deep water is quite low in the order of 20–25 °C. So, the main technical challenge of OTEC is to generate significant amounts of power efficiently from small temperature difference. The greatest temperature differences can be found in the tropics, and these offer the greatest possibilities for OTEC. Tropical oceans have surface water temperatures between 24 °C and 33 °C, whereas the temperature 500 m below the surface temperature drops between 9 °C and 5 °C.

4.4 Environmental / Natural Resources & Hazards

4.4.1 Flood Zones & Tsunami Flood Areas

The flood hazards will be analyzed based on the most recent flood risk zones for the Federal Emergency Management Agency (FEMA) and the Puerto Rico Planning Board. The location shall be protected from flooding by providing terrain elevations above determined base flood elevations.

Highest score will be assigned to the location with the lowest flooding risk.
4.4.2 Wetlands

Wetlands perform valuable functions that increase water quality, provide habitat for fish and wildlife communities, increase floodwater storage, and enhance biological productivity. Activities that would result in direct or indirect impacts to jurisdictional wetlands, including dredging, filling or discharging to, require permits and mitigation to compensate for the impact.

Highest score will be assigned to the location with the lower presence of substantial number of wetlands within the site area.

4.4.3 Flora & Fauna

Historically, various species of fish, wildlife, and plants have become extinct due to development without concern of or knowledge of conservation. Congress passed the Threatened and Endangered Species Act in 1973 to conserve the various species that have either become so depleted in numbers that they are in danger of or threatened with extinction, and/or have aesthetic, ecological, educational, historical, recreational, and scientific value. These are identified as federally listed threatened and endangered species.

Highest score will be assigned to the location with the lower amount of endangered or threatened species.

4.4.4 Marine Environment

The physical presence in the ocean of the intake/discharge pipes of the OTEC/SWAC or deep ocean water systems itself has an impact on the ocean. The structures will become an attractive habitat for a wide range of organisms based on experience from artificial reefs.

Highest score will be assigned to the location with the most suitable marine environment.

4.4.5 Water Resources

The impacts to the quality and quantity of water resources need to be considered within any project. The Clean Water Act provides the authority to establish water quality standards, control discharges into surface and subsurface waters, develop waste treatment management plans and practices, and issue permits for discharges and for dredged or fill material.

Highest score will be assigned to the location with the lower impact of surface or underground waters.

4.4.6 Natural Reserves

Nature reserves are areas selected to preserve and protect, in perpetuity, representative (typical) and special natural ecosystems, plant and animal species,
features and natural processes. Scientific research and education are the primary uses of nature reserves and recreation is generally restricted.

Highest score will be assigned to the location with the lower impact on natural reserves.

4.5 Cultural & Historical Resources

Section 106 of the NHPA of 1966 and its implementing regulations (36 CFR Part 800) seek to accommodate historic preservation concerns with the needs of federal undertakings through consultation among the federal agency and other parties with an interest in the effects of the undertaking on historic, architectural, archeological, and cultural resources in or previously determined eligible for inclusion in the National Register of Historic Places (National Register). Collectively these resources are referred to as historic sites.

Highest score will be assigned to the location with the lower impact on cultural and historical resources.

4.6 Social and Economic Impact

Population and employment trends, among other factors, will be analyzed in this section.

Social and economic criteria strongly influenced the final outcome of this study as they relate directly to political and financial feasibility and community desires. In a planning effort such as this, that incorporates substantial public input, social and economic factors are pivotal.

4.7 Available Infrastructure

4.7.1 Roads and Transportation

Connection into an existing, reliable road and transportation system with adequate capacity is preferred. If a new roadways or access are required for the site, then sites should be rated as to their potential to support/provide the system.

A reliable transportation system is needed to provide the logistics for transportation of goods and visitors in an efficient manner.

Highest score will be assigned to the location with the best access to existing road networks.

4.7.2 Potable Water & Sanitary Sewer

Connection into an existing, potable water and sewer systems with adequate capacity is preferred. Reliable systems are needed to provide the needs and services to the different industries to be established in an efficient manner.

Sites closest to the existing water and sewer networks would be rated highest. If new systems are required for the site, then sites should be rated as to their potential to support/provide the system.
4.7.3 Electrical Power

Connection into an existing, reliable electrical system with adequate capacity is preferred. For new systems, space for generators, space for fuel storage and availability of fuel may be a factor.

Sites closest to the existing system would be rated highest. If a new electrical system is required for the site, then sites should be rated as to their potential to support/provide the system.
5 EVALUATION OF PUNTA FIGURAS, ARROYO SITE

5.1 Location, Physical Suitability & Land Use Designations

Punta Figuras site is located on Palmas Ward at the Municipality of Arroyo, on the southeastern political boundary limits with the Caribbean Sea. It is defined in geography as a coastal plain and is located on the “Llano Costero del Sur” or “South Coastal Plain”. This coastal plain is alluvial formation on its origins.

5.1.1 Location & Shoreline Access

The site approximate centroid geographical coordinates are, Latitude: 17.967°, Longitude: -66.048°

The site is bounded on the north by State Road PR-3, on the south by the Caribbean Sea, on the east by some vacant lots and on the west by a local road and residential developments.

It has direct access to the shoreline, on its southern boundary, with approximately 580 meters of shoreline extension.

The distance from the shoreline up to the 1,000 meters sea depth gradient is of approximately 6.4 kilometers.
Figure 13. Punta Figuras Location on Aerial Imagery

Figure 14. Punta Figuras Parcel Aerial Photo (South North direction)
Figure 15. Punta Figuras Parcel Aerial Photo (coastline)

Figure 16. Punta Figuras Distance to 1,000 meters Sea Depth Gradient on Bathymetric Map
5.1.2 Available Land Area

The parcel under consideration has an approximate area extension of 349 acres. According to the Puerto Rico Cadastral-Tax System (CRIM), the parcel is composed of four (4) contiguous lots, owned by private citizens or entities. One lot is owned by Judith Scott de Texidor, with approximate area of 83 acres (Tax Parcel ID # 443-000-001-000), another of 176 acres (Tax Parcel ID # 421-000-006-06), owned by Suc. Luis Mariani, another of 28 acres (Tax Parcel ID # 443-000-001-998), owned by Ferromer Inc. and another of 72 acres (Tax Parcel ID # 421-000-0067-34-000), owned by Gregorio Manatou.

All the parcels are on a suburban setting. Mostly all the lots are currently vacant, except approximately 80 acres dedicated to agriculture or for cattle feeding.

5.1.3 Zoning/ Land Use Designation

The site location currently has multiple zoning classifications according to the Municipality of Arroyo Land Classification Map effective date May 9, 2011.

One of the classifications is A-P Agrícola Productivo (Productive Agricultural). This land classification is defined as critical for the agricultural production in Puerto Rico. The terrain has a high agricultural production capacity.

Another classification is CR Conservación de Recursos (Resources Conservation) This land classification is identified to preserve natural resources for the scientific, recreational and tourism purposes.

On those lands the following activities can be considered:

- Agricultural and livestock production
- Wind turbines
- Recreational facilities,
- Specialized lodging
- Single dwelling - residential per parcel
In summary, residential uses shall not be developed on those lands.

Many of the proposed Park uses are compatible, except the commercial retail and office spaces. A formal process to obtain approval for the proposed land use, shall be submitted to the PR Planning Board.

![Figure 17. Punta Figuras Land Use Classification on the Land Use Plan Map](image)

5.1.4 Topography

The parcel under consideration can be described as coastal plain, part of the “Llano Costero del Sur” or “South Coastal Plain”.

The whole parcel has a flat terrain with elevations ranging from 0 up to approximately 8 meters above sea level and slopes ranging from 2% to 5% in a southeast direction to the coastline.

There is also a permanent depression that forms a pond (Pl just adjacent to the southeast portion of the parcel).
5.1.5 Soils and Geology

There are eight (8) soil types on this site according to the USDA Natural Resources Conservation Service Web Soil Survey:

- (Cf) Cataño loamy sand, 0 to 2 percent slopes. This type of soil is found on coastal plains and has a typical depth profile of 0 to 8 inches of loamy sand, 8 to 18 inches of sand. It is excessively drained.
- (Gm) Guamaní silty clay loam, 0 to 2 percent slopes. This type of soil is found on floodplains and has a typical depth profile of 0 to 6 inches of silty clay loam, 6 to 20 inches of silty clay loam, and 20 to 60 inches of sand and gravel. It is well drained.
- (McB) Machete loam, 2 to 5 percent slopes. This type of soil is found on alluvial fans and has a typical depth profile of 0 to 12 inches of loam, 12 to 18 inches of clay loam, and 18 to 30 inches of clay. It is well drained.
- (Po) Ponceña clay, 0 to 2 percent slopes. This type of soil is found on terraces and has a typical depth profile of 0 to 41 inches of clay and 41 to 60 inches of clay loam. It is moderately well drained.
- (Rp) Reparada clay, 0 to 2 percent slopes. This type of soil is found on coastal plains and has a typical depth profile of 0 to 18 inches of clay and 18 to 60 inches of muck. It is poorly drained.
- (Va) Vayas silty clay loam, 0 to 2 percent slopes. This type of soil is found on floodplains and has a typical depth profile of 0 to 8 inches of silty clay loam, 8 to 20 inches of silty clay, and 20 to 60 inches of clay loam. It is poorly drained.
• (Va) Vayas silt clay, frequently flooded, 0 to 2 percent slopes. This type of soil is found on floodplains and has a typical depth profile of 0 to 21 inches of silt clay, 21 to 60 inches of clay loam. It is poorly drained.

There are two (2) geologic map units on this site according to the US Geological Survey Geologic Maps:

• (Qa) Alluvium - Alluvial-plain deposits forming stream-channel and landslides deposits with a mixture of clay, silt, sand and gravel with thickness of 0-25+ meters.
• (Qb) Beach deposits - largely unconsolidated medium to coarse sand with a thickness of 0-5+ meters.

There are no identified faults on the parcels.

Figure 19. Punta Figuras Location Soil Types
5.2 Oceanographical Characteristics

5.2.1 Geophysical Characteristics

This location includes a narrow shelf of around 3.5 kilometers in extension with a sudden steep (80-90 degrees) offshore slopes, and it continues with milder slopes (15-30 degrees) on relatively smooth sea floors. This site geophysical characteristic extends the required length of the intake pipe.

One disadvantage of this site is the longer distance to the required depth.
5.2.2 Environmental / Natural Resources

5.2.2.1 Flood Zones and Tsunami Flood Areas

The flood zones for the site were obtained from the most recent flood risk maps from the Federal Emergency Management Agency (FEMA) and the Puerto Rico Planning Board.

The coastal portion of the site is located on a VE zone which are coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves, and with determined base flood elevations.

Inside portions are classified as A, Coastal A and AE which are areas with 1% annual chance of flooding. Zones AE have determined depths or base flood elevations. The other interior zones do not have determined base flood elevations.

![Figure 22. Punta Figuras Location Flood Zones](image)

5.2.2.2 Wetlands

The wetlands located on this site were identified on the National Wetlands Inventory Mapper by the Fish and Wildlife Service (FWS). There are two (2) types of wetlands:
• On the coastline: Estuarine and Marine Wetland habitat (M2US2P). The Marine System consists of the open ocean overlying the continental shelf and its associated high-energy coastline.

• On the southern portion: Freshwater Emergent Wetland habitat (PEM1F). It is a Palustrine System that includes all nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 ppt. This are related to the location of the Palmas Pond.

![Figure 23. Punta Figuras Location Wetland Areas](image)

5.2.2.3 Flora & Fauna

Regarding the flora & fauna on the parcel, there are numerous species identified thru field visits and critical habitat databases.

**Flora**

The area can be classified as a subtropical forest with humid life zones (Moist Forest-Volcanic and Sedimentary). The typical composition includes the following vegetation formations:

- Lowland moist seasonal evergreen forest or forest shrub;
- Lowland moist semi deciduous forest
It can also be classified as a riparian area. Those are areas of lands adjacent to a body of water, stream, river, marsh, or shoreline. These areas form the transition between the aquatic and the terrestrial environment. A riparian area may include several riparian ecosystems. Riparian ecosystems include the soil, surface structure (woody debris, rocks, depressions), and the plant and animal communities.

Currently, the vegetation that surrounds the pond is primarily cattail *Typha dominguensis*.

Fauna

The coast nearby is an important nesting area for the Leatherback turtle (*Dermochelys coriacea*) and the Hawksbill turtle (*Eretmochelys imbricata*), both of which are sea turtles in danger of extinction, according to the Fish and Wildlife Service IPAC Database. Another endangered species in the vicinity is the Puerto Rican Boa.

According to the PR Department of Natural Resources “Puerto Rico Critical Wildlife Areas” of 2005, the adjacent Palmas Pond area is classified as a Critical Wildlife Area (CWA). This area was classified first as a primary CWA, but currently is classified as one of secondary importance.

The area seems less valuable in terms of wildlife, although restoration could be possible if actions are taken.

Fifty-one (51) bird species have been reported in Palmas Pond. Some of the endangers and vulnerable species are:

- Brown Pelican- *Pelecanus occidentalis*
- Ruddy Duck- *Oxyura jamaicensis*
- Masked Duck- *Nomonyx dominicus*
- Caribbean Coot- *Fulica caribaea*
- Least Tern- *Sternulla antillarum*

5.2.2.4 Marine Environment

According to the Coral Reef Information System of the National Oceanic and Atmospheric Administration (NOAA), there are various marine habitat along the coastline. The habitat includes:

- Reef on colonized hardbottom (Bedrock)
- Reefs/ Patch Reef (Aggregated)
- Reef/ Colonized Pavement
- Lineal Reef
- Seagrass/ (30-50%) and continuous

Some of those ecosystems could be affected with the project’s pipelines installation.
Figure 24. Punta Figuras Location Marine Ecosystems

Figure 25. Punta Figuras Location Environmental Sensitivity Map
5.2.2.5 Water Resources

The parcel is located within the principal aquifer in the region, the South Coast Aquifer. The alluvial deposits of Quaternary age are the most important lithologic unit in the Santa Isabel-Patillas region, containing its only sizeable aquifer. This aquifer is generally under water-table conditions, although flowing-artesian conditions have been observed throughout the area. Aquifer thickness may range from zero at the edge of the bedrock-alluvial contact, to about 3,000 feet in the vicinity of Santa Isabel. East of the Río Jueyes and west of the Río Coamo, aquifer thickness decreases to no more than 300 feet along the shore. The aquifers in the fractured volcanic and plutonic rocks sustain very low yields.

Regarding surface waters, there is only one body of water known as Palmas Pond. This pond is located outside the parcel on its southeast boundary. It is continuously flooded and is considered a wetland.

![Figure 26. Punta Figuras Location Water Resources](image)

5.2.3 Cultural & Historical Resources

According to an inventory of archeological/historic sites in the Municipality of Arroyo published by the PR State Historic Preservation Office, there are two (2) archeological sites adjacent to the parcel, but none inside of it. They are identified as:

- AY0200015 (AY-6) Hacienda Belvedere: It is described as an old sugarcane windmill at a former sugarcane plantation. It was established between the
17 and the 20th centuries. It is located on Cangrejos Street on the west boundary of the property.

- AY0200006: It is also a remnant of Hacienda Belvedere plantation. It is located on State Road PR-2 on the north boundary of the property.

There is one structure in the National Register of Historic Places (National Register), the Faro (Lighthouse) de Punta Figuras, that is located at approximately 600 meters south-east of the parcel. It is also archeological location AY020008.

![Figure 27. Punta Figuras Location Archeological Sites](image)

### 5.3 Social and Economic Impact

According to the latest published data on March 2019 by the PR Department of Labor, the unemployment rate for the Municipality of Arroyo was of 15.4% compared to 15.3% in March 2018. This is a very high rate when compared to San Juan with a rate of 5.8%. The available workforce is of 4,651 persons with an estimated year 2019 population of 19,309 persons.

### 5.4 Available Infrastructure
5.4.1 Roads and Transportation

The parcel can be accessed from State Road PR-3 in the north, and from Cangrejos Street in the west. State Road PR-3 is a rural highway that connects PR Eastern and Southern Regions. Cangrejos Street is a local municipal road that connects the coastline and the urban area of Arroyo.

The project will need intersection improvements on Road PR-3, as well as a new entrance from Cangrejos Street to provide a direct and efficient access to the facilities, and to accommodate the proposed development.
5.4.2 Potable Water & Sanitary Sewer

There is a 4” diameter potable water line provided by the PR Aqueduct and Sewer Authority (PRASA) into the property north boundary and along the east boundary. The 4” lines are fed from an 8” diameter main line on Stat Road PR-3.

The 8” main line shall have adequate capacity for the proposed development.

Regarding sanitary sewer, there are 8” gravity sewers at adjacent developments on the western boundary of the project and force line systems (8”) along the south and north boundaries.

It will be necessary to install sanitary sewer system, a new lift station and force line system and a new connection with the nearest PRASA system, in order to accommodate the proposed development.
Figure 29. Punta Figuras Potable Water Distribution Systems

Figure 30. Punta Figuras Sanitary Sewer System
5.4.3 Electrical Power

There are both a 4.16 and 38.0 kV electrical distribution systems in the area. The 4.16 system have aerial lines along the north, east and west boundaries of the project, through local roads and on State Road PR-3.

The 38.0 kV system is located farther north at approximately 0.6 km from the north property boundary. Based on the voltages, there shall be enough capacity for providing service and for interconnecting power generation to the Puerto Rico Electric Power Authority (PREPA) system at the 38.0 kV lines.

A new connection line will be required in order to interconnect the project with the existing 38.0 kV system.

Figure 31. Punta Figuras Electrical Distribution Systems
6 EVALUATION OF PUNTA TORO, MAUNABO SITE

6.1 Location, Physical Suitability & Land Use Designations

The Punta Toro site is located on Emajagua Ward at the Municipality of Maunabo, on the southeastern region of Puerto Rico. Punta Toro is at the northeastern political boundary limits between Maunabo and the municipality of Yabucoa. Punta Toro is defined in geography as a “cape” as it is a headland extending into the sea. The mountains that make up the point are part of the Pandura Ridge, whose rocky formations are volcanic in origin.

6.1.1 Location & Shoreline Access

The site approximate centroid geographical coordinates are, Latitude: 18.008°, Longitude: -65.863°

The site is bounded on the north by residential and vacant lots and by State Road PR 901km., on the south by the Caribbean Sea, on the east by residential and vacant lots and on the west by vacant lots and portions of State Road PR-53.

It has direct access to the shoreline, on its southern boundary, with approximately 2.0 kilometers of shoreline extension. Some portions of its total length, of approximately 1.0 kilometer, are less accessible due to topographical constraints.

The distance from the shoreline up to the 1,000 meters sea depth gradient is of approximately 3.96 kilometers.
Figure 32. Punta Toro Location on Aerial Imagery

Figure 33. Punta Toro Parcel Aerial Photo (South-North direction)
Figure 34. Punta Toro Parcel Aerial Photo (Coastal Zone)

Figure 35. Punta Toro Parcel Aerial Photo (Cliffs on Coastal Zone)
6.1.2 Available Land Area

The parcel under consideration has an approximate area extension of 135 acres. According to the Puerto Rico Cadastral-Tax System (CRIM), the parcel is composed of two contiguous lots owned by a private entity, Redmag, Inc.

One lot has an approximate area of 55 acres (Tax Parcel ID # 401-000-006-14) and the other 80 acres (Tax Parcel ID # 401-000-007-06).

Currently the parcel is on a rural setting and is vacant and unoccupied, but there is a residential dwelling unit structure on the premises.

6.1.3 Zoning/ Land Use Designation

The site location currently does not have an official land zoning classification, as it is located on a rural setting, outside the urbanized or developed zone.

Even as there is no available land zoning classification, the Puerto Rico Planning Board does have a “Plan de Uso de Terrenos de Puerto Rico” (PR Land Use Plan) for the whole Island, which consider future land uses for the location.

Under the PR Land Use Plan, the parcel is classified as “Suelo Rústico Común-SRC (Common Rustic Land). This classification is defined for lands with great potential for non-urban and rural activities. On those lands the following activities can be considered:
o Heavy industrial
o Quarries
o Waste landfills,
o Penitentaries
o Infrastructure activities

In summary, residential uses shall not be developed be on those lands.

The proposed Park uses are compatible with the PR Land Use Plan, but for this type of project, a formal process to obtain approval for the proposed land use, shall be submitted to the PR Planning Board.

6.1.4 Topography

The parcel under consideration can be described as two areas divided by the Emajagua Creek and other minor creek which forms a ridge-valley in the north-south direction.

The western portion of the parcel has a rolling terrain with elevations ranging from 0 up to approximately 40 meters above sea level and slopes up to 9%. The eastern portion has a combination of a valley and have mountainous characteristics, with elevations ranging from 0 up to approximately 30 meters and slopes up to 10% and then, the mountainous zone with elevations from 0 to 110 meters and slopes up to 35%.
The existing topography presents major challenges for the establishment of the required infrastructure.

6.1.5 Soils and Geology

There are four soil types on this site according to the USDA Natural Resources Conservation Service Web Soil Survey:

- (PdF) Pandura - Very stony land complex, 40 to 60 percent slopes. This type of soil has a typical depth profile of 0-3 inches of loam, 3-19 inches of sandy loam and 19-35 inches of weathered bedrock.
- (PeC2) Parcelas Clay, 5 to 12 percent slopes, eroded. This type of soil has a typical depth profile of 0-60 inches of clay and is subject to shrink and swell.
- (TeE) Teja gravelly sandy loam, 12 to 40 percent slopes. This type of soil has a typical depth profile of 0-14 inches of gravelly sandy loam, 14-18 inches of unweathered bedrock.
- (Vw) Vivi loam. This type of soil has a typical depth profile of 0-14 inches of loam, 14-20 inches of very fine sandy loam, 20-30 inches of loam and 30-60 of sand and sandy loam.

There are four geologic map units on this site according to the US Geological Survey Geologic Maps:
• (Qa, Qaf, Qb) Alluvium - Alluvial plain deposits forming stream-channel and landslides deposits with a mixture of clay, silt, sand and gravel with thickness 0-25+ meters. There are also beach deposits largely unconsolidated medium to coarse sand with a thickness of 0-5+ meters.

• (Kd) Diorite - Medium to dark grey, medium grained rock with granular texture.

• (Ki) Granodiorite Quartz of San Lorenzo - Medium to dark grey, medium grained rock with granular texture.

• (QI) Landslide Deposits – Debris-avalanche type and composed of abundant boulders, in sandy clay matrix. Thickness 0-10+ meters.

There is also a concealed fault along the center (in the east-west direction) of the parcel.

The different types of soils and geological formations, which includes clays, alluvium deposits and a concealed fault, presents some challenge for the establishment of buildings and other vital structures for the Project development.

Figure 39. Punta Toro Location Soil Types
6.2 Oceanographical Characteristics

6.2.1 Geophysical Characteristics

This location includes a narrow shelf of around 2 kilometers in extension and then a steep (25-40 degrees) offshore slopes, and relatively smooth sea floors. This site characteristic minimizes the length of the intake pipe.

One disadvantage of this site is a rocky cliff to the shore location and turbulent wave action in the surf zone.
6.2.2 Environmental / Natural Resources & Hazards

6.2.2.1 Flood Zones and Tsunami Flood Areas

The flood zones for the site were obtained from the most recent flood risk maps from the Federal Emergency Management Agency (FEMA) and the Puerto Rico Planning Board.

The coastal portion of the site is located on a VE zone which are coastal area with a 1% or greater chance of flooding and an additional hazard associated with storm waves, and with determined base flood elevations.

Some small portion of the coastal area is also classified as A zone which are areas with 1% annual chance of flooding without determined depths or base flood elevations.

![Figure 42. Punta Toro Location Flood Zone](image)

6.2.2.2 Wetlands

The wetlands located on this site were identified on the National Wetlands Inventory Mapper by the Fish and Wildlife Service (FWS). There are four (4) types of wetlands:
On the coastline: Estuarine and Marine Deepwater habitat. The Marine System consists of the open ocean overlying the continental shelf and its associated high-energy coastline.

At the discharge of an unnamed creek: Freshwater Emergent wetland habitat.

At the creeks: Freshwater Forested/Shrub wetland. The Palustrine System includes all nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 ppt.

At the creeks: Riverine habitat. The Riverine System includes all wetlands and deep water habitats contained within a channel. This subsystem includes channels that contain flowing water only part of the year.

6.2.2.3 Flora & Fauna

Regarding the flora & fauna on the parcel, there are numerous species identified through field visits and critical habitat databases.

Flora
The area can be classified as a subtropical forest with humid life zones (moist forest alluvial). The typical composition includes the following vegetation formations:
**Proposed Roadmap for Development**, July 2020

- Lowland moist evergreen hemi-sclerophyllous shrubland
- Lowland moist seasonal evergreen forest or forest/shrub
- Lowland moist coconut palm forest
- Seasonally flooded evergreen forest
- Tidally and semi-permanently flooded evergreen sclerophyllous forest

**Fauna**

The coast nearby is an important nesting area for the Leatherback turtle (*Dermochelys coriacea*) and the Hawksbill turtle (*Eretmochelys imbricata*), both of which are sea turtles in danger of extinction. The Leatherback turtle (carey) has been identified during the spawning seasons at the Maunabo Coastline. This specie is in the list of endangered species.

According to the Fish and Wildlife Service IPAC Database, these are the five (5) endangered species in the vicinity:

- West Indian Manatee
- Hawksbill Sea Turtle
- Leatherback Sea Turtle
- Puerto Rican Boa
- Coqui Guajón

There are twelve (12) species of migratory birds which are Birds of Conservation Concern such as the American Oystercatcher and the Antillean Mango among others.

6.2.2.4 Marine Environment

According to the Coral Reef Information System of the National Oceanic and Atmospheric Administration (NOAA), there are various marine habitat along the coastline. The habitat includes:

- Reefs on colonized bedrock;
- Reefs on scattered Coral-Rock;
- Reef/ Colonized Pavement with Sand Channels;
- Macroalgae (Patchy 10-50%)

Some of those ecosystems could be affected with the project’s pipelines installation.
Figure 44. Punta Toro Location Marine Ecosystems
6.2.2.5 Water Resources

The principal aquifers in the Naguabo-Maunabo region are in the alluvial deposits that fill the valleys. Ground-water levels in the plutonic and volcanic rocks in the mountains and uplands follow the topography. Water levels within the alluvial aquifers of the Naguabo-Maunabo region vary from 100 feet above mean sea level near the bedrock-alluvium contact, to near mean sea level in coastal areas.

Regarding surface waters, there are two perennial streams (creeks) flowing through the parcel. One of them is the Emajagua Creek. This Creek has a drainage area of 0.91 square miles and flows in north-south direction thru the mid-west portion of the parcel.

There is another unnamed creek that also flows in north-south direction thru the mid portion of the parcel.
6.2.3 Cultural & Historical Resources

According to an inventory or archeological/historic sites in the Municipality of Maunabo published by the PR State Historic Preservation Office, there is one archeological site inside the parcel. It is identified as MU0100022, Punta Toro Beach. It is described as a Pre-columbine (Saladode ca 250ac-600dc)/A pre-columbine deposit close to the coast. It consists of a clay pot inside another one. Nearby, fragments of other pots and lithic material such as stone axes were found.

There is one structure in the National Register of Historic Places (National Register), the Faro (Lighthouse) De Punta de la Tuna located at approximately 3 kilometers south of the Punta Toro location.
6.3 Social and Economic Impact

According to the latest published data on March 2019 by the PR Department of Labor, the unemployment rate for the Municipality of Maunabo was of 19.3% compared to 18.0% in March 2018. This is a very high rate when compared to San Juan with a rate of 5.8%. The available workforce is of 2,994 persons with an estimated year 2019 population of 11,608 persons.

6.4 Available Infrastructure

6.4.1 Roads and Transportation

The parcel can be accessed from State Road PR-901. Km. 11.0. This is a secondary state road with a total width of 9.00 meters, that connects the town of Maunabo with the town of Yabucoa. It also provides a connection to the State Road PR-53 tunnel. From the state road, the lot is accessed through a local public road, with a limited width of 5.00 meters.

The lot will need major improvements and widening to the local road in order to accommodate the proposed development.
6.4.2 Potable Water & Sanitary Sewer

There is a 4" diameter potable water line provided by the PR Aqueduct and Sewer Authority along State Road PR-901. Based on the diameter, it is a secondary line for the users along the State Road between Maunabo and Yabucoa.

It is possible that a new line with a larger capacity will be needed in order to accommodate the proposed development.

There is an 8" diameter gravity sanitary sewer about 500 meters West along State Road PR-53. Based on the diameter, it is a secondary line for the users along the State Road.

It will be necessary to install a new lift station, a force line system and a new connection in order to accommodate the proposed development.
Figure 49. Punta Toro Water Distribution system
6.4.3 Electrical Power

There is a 4.16 kV electrical distribution system along the local access road and on State Road PR-901. Based on this voltage, there is no sufficient capacity for providing service or for interconnecting power generation to the Puerto Rico Electric Power Authority (PREPA) system.

The project will need major improvements from a major power substation facility in Maunabo or Yabucoa in order to accommodate the proposed development.
**Figure 51.** Punta Toro Electrical Power System
7 EVALUATION OF PUERTO YABUCOA SITE

7.1 Location, Physical Suitability & Land Use Designations

The Puerto (Port) Yabucoa site is located on Camino Nuevo Ward at the Municipality of Yabucoa, on the southeastern region of Puerto Rico. The Puerto Yabucoa is at the eastern political boundary limits with the Caribbean Sea. Puerto Yabucoa is defined in geography as a valley and is located on the Valle de Yabucoa or “Yabucoa Valley”. The mountains that bound the site on its southern portion are part of the Pandura Ridge, whose rocky formations are volcanic in origin.

7.1.1 Location & Shoreline Access

The site approximate centroid geographical coordinates are, Latitude: 18.055°, Longitude: -65.843°

This site is located at the coastline of the Municipality of Yabucoa, with approximately 270 acres divided on two separate parcels.

The parcel northwest of the Port has an approximate area of 214 acres and is bounded on the north by Caño de Santiago (a natural stream), on the south by a vacant parcel property of the PR Land Administration (Administración de Terrenos de PR) and by Buckeye Terminals (fuel storage facilities), on the east by the Port of Yabucoa (property of the PR Ports Authority) and the coastline and on the west by Highway State Road PR-53.

The parcel southeast of the Port is located at Lucia Beach and has approximately 48 acres and is bounded on the north by State Road PR-9914 on the south by State Road PR-9911 and Palmas de Lucia Hotel, on the east by the coastline and the west by a vacant parcel property of the PR Land Administration (Administración de Terrenos de PR). This site currently does not have a defined land use classification.

The parcel southeast of the Port (Lucia Beach) has direct access to the shoreline, on its eastern boundary, with approximately 1.3 kilometers of shoreline extension, divided on two portions.

The distance from the shoreline up to the 1,000 meters sea depth gradient is of approximately 4.7 kilometers.
Figure 52. Puerto Yabucoa Location on Aerial Imagery

Figure 53. Puerto Yabucoa (Lucia Beach) Parcel Aerial Photo (east-west direction)
Figure 54. Puerto Yabucoa (northern) Parcel Aerial Photo (west-east direction)

Figure 55. Puerto Yabucoa Distance to 1,000 meters Sea Depth Gradient on Bathymetric Map
7.1.2 Available Land Area

According to the Interactive Map of Puerto Rico from the Planning Board Information System, the parcel under consideration has an approximate area of 1,306 acres (Tax Parcel ID # 377-000-003-09-903); it is owned by the public corporation Puerto Rico Land Administration (Administración de Terrenos de Puerto Rico) and it is leased to various private and public entities.

The suggested land area needed for the project development is comprised of approximately 270 acres, so a land segregation process is recommended.

7.1.3 Zoning/ Land Use Designation

The site location currently does not have an official land zoning classification, as it is located on a rural setting, outside the urbanized or developed zone.

Even as there is no available land zoning classification, the Puerto Rico Planning Board does have a “Plan de Uso de Terrenos de Puerto Rico” (PR Land Use Plan) for the whole Island, which considers future land uses for the location.

Under the PR Land Use Plan, the parcel two main classifications:

Suelo Rústico Común - SRC (Common Rustic Land). This classification is defined for lands with great potential for non-urban and rural activities. On those lands the following activities can be considered:
- Heavy industrial
- Quarries
- Waste landfills,
- Penitentiaries
- Infrastructure activities

Suelo Rústico Especialmente Protegido Agrícola - SREP-A (Specially Protected Common Rustic Land - Agricultural). This classification is defined for lands with great potential agricultural activities. On those lands the following activities can be considered:
- Agricultural activities
- Livestock industries

In summary, residential uses shall not be developed be on those lands.

Most of the proposed Park uses are compatible with the PR Land Use Plan, but for this type of project, a formal process to obtain approval for the proposed land use, shall be submitted to the PR Planning Board as “Consulta de Ubicacion” process.
7.1.4 Topography

The parcel under consideration can be described as two areas divided by an industrial zone, a port facility and a secondary road. The terrains are part of the coastal plains part of the Yabucoa Valley.

The northern portion of the parcel has a flat terrain with elevations ranging from 0 up to approximately 4 meters above sea level and slopes up to 2% in direction to the coastline.

The southern portion, near Lucía Beach, presents a high point area of approximately 2 meters above sea level, and slopes to lower elevations towards the west and another portion towards the coastline.
7.1.5 Soils and Geology

There are seven (7) soil types on this site according to the USDA Natural Resources Conservation Service Web Soil Survey:

- (Me) Maunabo Clay - 0 to 2 percent slopes. This type of soil has a typical depth profile of (H1) 0 to 10 inches of clay, (H2) 10 to 39 inches of clay and (H3) 39 to 48 inches of sandy loam.
- (Ad) Aguadilla Loamy Sand - 0 to 2 percent slopes. This type of soil has a typical depth profile of (H1) 0 to 8 inches of loamy sand and (H2) 8 to 58 inches of sand.
- (Cf) Catano Loamy Sand - 0 to 2 percent slopes. This type of soil has a typical depth profile of (A) 0 to 8 inches of loamy sand, (AC) to 18 inches of sand and (C)18 to 80 inches of sand.
- (Cr) Coloso Silty Clay - 0 to 2 percent slopes. This type of soil has a typical depth profile of (Ap) 0 to 7 inches of silty clay, (Bw) 7 to 18 inches of silty clay loam, (Bg) 18 to 27 inches of silty clay loam, (Cg1) 27 to 35 inches of silty clay loam and (Cg2) 35 to 80 inches of silty clay loam.
- (Ta) Talante Soils - 0 to 2 percent slopes. This type of soil has a typical depth profile of (H1) 0 to 4 inches of clay loam, (H2) 4 to 10 inches of sandy clay loam, (H3) 10 to 18 inches of loam, (H4) 18 to 40 inches of loamy sand and (H5) 40 to 58 inches of coarse sand.
• (Cm) Coastal Beaches - 1 to 5 percent slopes. This type of soil has a typical depth profile of (H1) 0 to 6 inches of sand and (H2) 6 to 80 inches of coarse sand.

• (Wa) Wet Alluvial Land - 0 to 2 percent slopes. This type of soil has a typical depth profile of (H1) 0 to 60 inches of variable types.

There are two (2) geologic map units on this site according to the US Geological Survey Geologic Maps:

• (Qb) Beach Deposits - largely unconsolidated medium to coarse sand, predominantly composed of subrounded to subangular quartz grains and rounded feldspar grains derived from reworking of older alluvial deposits, but locally containing sparse to abundant shell fragments with a thickness of 0-5+ meters.

• (Qap) Alluvial-Plain Deposits – Stratified, weakly consolidated deposits composed largely of sand, silt, and clay, and containing scattered pebbles, cobbles, and boulders in some layers, with thickness of 0-63+ meters.

Figure 58. Puerto Yabucoa Location Soil Types
Figure 59. Puerto Yabucoa Location Geologic Quadrangle

7.2 Oceanographical Characteristics

7.2.1 Geophysical Characteristics

This location includes a narrow shelf of around 4 kilometers in extension and then a steep (70-90 degrees) offshore slopes, and relatively smooth sea floors. This site characteristic extends the length of the intake pipe.
7.2.2 Environmental / Natural Resources

7.2.2.1 Flood Zones and Tsunami Flood Areas

The flood zones for the site were obtained from the most recent flood risk maps from the Federal Emergency Management Agency (FEMA) and the Puerto Rico Planning Board.

The coastal portion of the site, near Lucía Beach, is located on a VE zone which is defined as a coastal area with a 1% or greater chance of flooding and an additional hazard associated with storm waves. Inside portions of that lot are classified as AE which are areas with 1% annual chance of flooding.

The northern parcel is classified as A, which are areas with 1% annual chance of flooding.

VE zone has a base flood elevation of 4.1 meters, zone AE has base flood elevations above 4.1 meters and zone A has base flood elevations between 4.55 to 5.20 meters.

![Figure 61. Puerto Yabucoa Location Flood Zones](image)

7.2.2.2 Wetlands
The wetlands located on this site were identified on the National Wetlands Inventory Mapper by the Fish and Wildlife Service (FWS). There are three (3) types identified.

- On the coastline: Estuarine and Marine wetland habitat (M2US2P). The Marine System consists of the open ocean overlying the continental shelf and its associated high-energy coastline.
- On the inland areas there are two types:
  - Freshwater Emergent Wetland habitat (both PEM1A & PEM1C classifications). In general terms, it is a Palustrine System that includes all nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 ppt. Its vegetation is present for most of the growing season in most years. These wetlands are usually dominated by perennial plants. Surface water is present for brief periods (from a few days to a few weeks) during the growing season, but the water table usually lies well below the ground surface for most of the season.
  - Freshwater Forested/Shrub Wetland habitat (PFO3A classification). In general terms, it is a Palustrine System that includes all nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 ppt. It is characterized by woody vegetation that is 6 m tall or taller. Surface water is present for brief periods (from a few days to a few weeks) during the growing season, but the water table usually lies well below the ground surface for most of the season.
7.2.2.3 Flora & Fauna

Regarding the flora & fauna on the parcel, there are numerous species identified through field visits and critical habitat databases.

Flora

The northern portion of the project area can be classified as an agricultural land with humid life zones. The typical composition includes the following vegetation formations:

- Lowland moist seasonal evergreen forest or forest shrub
- Agricultural Crops (Bananas and Plantains)

The southern portion (Lucía Beach) of the project area can be classified as a subtropical forest with humid life zones (Moist forest: Volcanic and Sedimentary). The typical composition includes the following vegetation formations:

- Lowland moist seasonal evergreen forest or forest shrub
- Lowland moist semi deciduous forest

It can also be classified as a riparian area. Those are areas of lands adjacent to a body of water, stream, river, marsh, or shoreline. These areas form the transition between the aquatic and the terrestrial environment. A riparian area may include...
several riparian ecosystems. Riparian ecosystems include the soil, surface structure (woody debris, rocks, depressions), and the plant and animal communities.

**Fauna**

The coast nearby is an important nesting area for the Leatherback turtle (*Dermochelys coriacea*) and the Hawksbill turtle (*Eretmochelys imbricata*), both of which are sea turtles in danger of extinction.

According to the Fish and Wildlife Service IPAC Database, these are the five (5) endangered species in the vicinity:

- West Indian Manatee
- Hawksbill Sea Turtle
- Leatherback Sea Turtle
- Puerto Rican Boa
- Guajón

There are thirteen (13) species of migratory birds which are Birds of Conservation Concern such as the American Oystercatcher, the Antillean Mango and the Brown Bobby among others.

**7.2.2.4 Marine Environment**

According to the Coral Reef Information System of the National Oceanic and Atmospheric Administration (NOAA), there are various marine habitat along the coastline. The habitat includes:

- Reef on colonized bedrock
- Reefs/ Patch Reef (Individual)
- Reef/ Colonized Pavement with Sand Channels
- Macroalgae (Patchy 10-50%)

Some of those ecosystems could be affected with the project’s pipelines installation.
Figure 63. Puerto Yabucoa Location Marine Ecosystems

Figure 64. Puerto Yabucoa Location Environmental Sensitivity Map
7.2.2.5 Water Resources

The Yabucoa valley area is characterized by the Río Guayanés valley that has incised down through the San Lorenzo batholith, which is a granodiorite intrusion (plate 1). The bedrock surface is irregular and lies within 50 meters of land surface along most of the coast. The bedrock is overlain by alluvium, which forms the principal aquifer in this area. The alluvium largely consists of clay with appreciable amounts of sand.

Regarding surface waters, on the northern portion of the project there are two (2) water bodies, one is Caño Santiago, a perennial creek bounding the northern property limit. This stream discharges into the coastline. There is also one (1) non-perennial stream flowing in the west-east direction through the parcel, that probably was man-made to provide irrigation to agricultural crops. The Caño Santiago will not be affected by the development, as its natural course will be protected and maintained. The irrigation stream could be relocated and improved in order to provide a runoff collection system for the development.

On the southern portion (Playa Lucia) of the project there are two (2) water bodies, both are non-perennial streams. One of them is an unnamed creek that flows in west-east direction through the southeast boundary and discharges in the coastline. This creek is born at the Pandura’s Ridge and also collects runoff from the El Negro Community.

The other one is a man-made earth channel at the northern boundary that also flow in west-east direction and discharges in the coastline. Both streams will not be affected by the development, as their natural courses will be protected and maintained.
7.2.3 Cultural & Historical Resources

According to an inventory or archeological/historic sites in the Municipality of Yabucoa published by the PR State Historic Preservation Office, there is one (1) archeological site inside the parcels. It is identified as:

- YB0100015 Playa Lucía Pre-Histórico

There is one structure in the National Register of Historic Places (National Register), the Yabucoa Fire Station, that is located at approximately 3.5 kilometers west of the Puerto Yabucoa location.
7.3 Social and Economic Impact

According to the latest published data on March 2019 by the PR Department of Labor, the unemployment rate for the Municipality of Yabucoa was of 14.3% compared to 16.0% in March 2018. This is a very high rate when compared to San Juan with a rate of 5.8%. The available workforce is of 8,650 persons with an estimated year 2019 population of 34,743 persons.

7.4 Available Infrastructure

7.4.1 Roads and Transportation

The parcels can be accessed from State Roads PR-53, PR-901, PR-9914 and PR-9911.

State Road PR-53 is a major highway that connects PR Eastern Region and ends in Yabucoa adjacent to the project site. State Road PR-901 is a secondary state road.
with a total width of 9.00 meters, that connects the town of Maunabo with the town of Yabucoa. State Road PR-9914 is a tertiary road for local access to the coastline and the existing fuel storage facility. This road has a limited width of 8.00-10.00 meters approximately. Finally, State Road PR-9911 is a tertiary road for local access and has a limited width of 8.00 meters approximately.

The project will need to create a new intersection with highway PR-53 and from PR-9914 to provide a direct and efficient access to the facilities, and to accommodate the proposed development.

![Figure 67. Puerto Yabucoa Road Accesses](image)

7.4.2 Potable Water & Sanitary Sewer

There is a 4" diameter potable water line provided by the PR Aqueduct and Sewer Authority (PRASA) along State Road PR-901 and along highway PR-53. Based on the diameter, it is a secondary line for the users along the State Roads.

It is possible that a new line with a larger capacity will be needed in order to accommodate the proposed development.

Currently there are no identified sanitary sewer facilities in the vicinity.

It will be necessary to install sanitary sewer system, a new lift station, a force line system and a new connection with the nearest PRASA system in order to accommodate the proposed development.
Figure 68. Puerto Yabucoa Potable Water Distribution Systems

Figure 69. Puerto Yabucoa Sanitary Sewer System
7.4.3 Electrical Power

There is a 13.20 kV electrical distribution system and a 115 kV transmission system on State Road PR-901 adjacent to the project site. Based on the voltages, there shall be sufficient capacity for providing service and for interconnecting power generation to the Puerto Rico Electric Power Authority (PREPA) system.

No major improvements are expected in order to accommodate the proposed development.

Figure 70. Puerto Yabucoa Electrical Distribution Systems
8 FINAL SITE SELECTION

8.1 Methodology Description

For the final selection, a parameter score matrix is presented, to assess each site characteristics and determine the site with the highest score.

The following parameters were considered for evaluation and scoring. The scores will range from 1 being the lowest value and 5 being the highest value. In addition, a weight-value, according to the importance factor, is assigned to each parameter.

- **Distance to seabed gradient depth > 1,000 meters**: Shortest distance will receive the highest score. This is the most important parameter and will receive 100% weight in the selection matrix.

- **Available Land Area (>100 acres)**: Available land shall be readily accessible, with no major topographic hurdles and separated from residential sites. The largest area with less constraints will receive the highest score. This parameter will receive a 75% weight in the selection matrix.

- **Land Zoning**: A compatible uses land zoning classification will provide for a more expedite permitting process for the project. The most compatible uses zoning classification will receive the highest score. This parameter will receive a 75% weight in the selection matrix.

- **Topography**: A terrain with mild slopes or flatter land is the most suitable for the project development. The milder and flatter slopes terrain will receive the highest score. This parameter will receive a 75% weight in the selection matrix.

- **Soil-Geology**: A terrain with adequate soils (firm soils without highest load support capacity) and with low potential for landslides or without geological faults will receive the highest score. This parameter will receive a 75% weight in the selection matrix.

- **Oceanographical Characteristics**: A location with adequate soils (firm soils without highest load support capacity) and with low potential for landslides or without geological faults will receive the highest score. This parameter will receive a 100% weight in the selection matrix.

- **Flood Zones**: A location with less areas prone to flooding will receive the highest score. This parameter will receive a 75% weight in the selection matrix.

- **Wetlands**: A terrain with less wetland areas to be impacted will receive the highest score. This parameter will receive a 75% weight in the selection matrix.

- **Flora & Fauna**: A location with less endangered species of flora & fauna to be impacted will receive the highest score. This parameter will receive a 75% weight in the selection matrix.

- **Marine Ecosystems**: A project with less marine ecosystems to be impacted will receive the highest score. This parameter will receive a 100% weight in the selection matrix.

- **Water Resources**: A location with less water resources to be impacted will receive the highest score. This parameter will receive a 75% weight in the selection matrix.
• **Cultural & Historical Resources**: A location with less cultural & historical resources to be impacted will receive the highest score. This parameter will receive a 75% weight in the selection matrix.

• **Social and Economic Impact**: A location with the highest unemployment will receive the highest score. This parameter will receive a 100% weight in the selection matrix.

• **Roads and Transportation**: A location with the best access roads will receive the highest score. This parameter will receive a 75% weight in the selection matrix.

• **Potable Water & Sanitary Sewer**: A location with potable water and sanitary sewer systems closest to the site and with adequate capacity will receive the highest score. This parameter will receive a 75% weight in the selection matrix.

• **Electrical Distribution System**: A location with an electrical distribution system closest to the site and with the largest capacity will receive the highest score. This parameter will receive a 75% weight in the selection matrix.
### 8.2 Selection Matrix Parameters and Scores

Following is the parameter score matrix, with all the characteristics evaluated and their weight-value considered for each of the three finalist sites.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Score Weight</th>
<th>Punta Figuras, Anoyo</th>
<th>Punta Toro, Maunabo</th>
<th>Puerto Yabucoa, Yabucoa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance to Seabed Gradient Depth &gt;1,000m</td>
<td>100%</td>
<td>1</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Available Land Area</td>
<td>75%</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Compatible Use Land Zoning</td>
<td>75%</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Topography</td>
<td>75%</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Soils-Geology</td>
<td>75%</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Oceanographical Characteristics</td>
<td>100%</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Flood Zones</td>
<td>75%</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Wetlands</td>
<td>75%</td>
<td>4</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Flora &amp; Fauna</td>
<td>75%</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Marine Ecosystem</td>
<td>100%</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Water Resources</td>
<td>75%</td>
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<td>2</td>
</tr>
<tr>
<td>Cultural &amp; Historical Resources</td>
<td>75%</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Social and Economic Impact</td>
<td>100%</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Roads and Transportation</td>
<td>75%</td>
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<td>2</td>
</tr>
<tr>
<td>Potable Water &amp; Sanitary Sewer</td>
<td>75%</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Electrical Distribution System</td>
<td>75%</td>
<td>3</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td><strong>TOTAL WEIGHTED SCORE</strong></td>
<td><strong>38.25</strong></td>
<td><strong>34.75</strong></td>
<td><strong>39.75</strong></td>
<td></td>
</tr>
</tbody>
</table>

The conclusion from the matrix scores created for this analysis, demonstrate that the site with the highest score is Puerto Yabucoa.
9 SITE SELECTION SUMMARY AND RECOMMENDATIONS

The most suitable location for the establishment of the Puerto Rico Ocean Technology Complex was analyzed on this document. As discussed before, multiple site characteristics such as natural resources, available infrastructure and land zoning were considered.

The Puerto Yabucoa site in the Municipality of Yabucoa was selected. This site has the appropriate characteristics to develop a project of this scope and magnitude. There are some natural characteristics that must be addressed, such as wetland and surface waters that can be impacted.

A careful planning can provide avoidance and mitigation to adverse effects on natural elements. In the following sections of the Master Plan, those matters will be addressed more in detail.

It is recommended that technical and detailed studies be performed to determine adequate compliance with local and federal laws and regulations. In addition, it is important to establish communications with different local and federal agencies to receive feedback and recommendations for infrastructure improvements, as well for complying with the preservation of resources.
INTRODUCTION TO THE SELECTED SITE: PUERTO YABUCOA

The chosen parcels for the Project, located in the Camino Nuevo Ward of the Municipality of Yabucoa in the southwestern region of Puerto Rico, consists of approximately 270 acres of land. The suggested land area needed for the project, as it is part of a larger parcel, will need to be segregated as part of the project development.

Based on preliminary data, the land is owned by the Puerto Rico Land Administration (Administración de Terrenos de Puerto Rico). Negotiation and legal procedures for due diligence will need to be considered; there are two possible scenarios for the transaction: an interagency negotiation between the Puerto Rico Land Administration and the Department of Economic Development and Commerce or a sales agreement with the chosen developer.

The southern lot has access to the Caribbean Sea to the east through Lucía Beach and the northern parcel is easily reachable via Puerto Rico Highway 53 (for a full description of the site’s geographical characteristics, see Chapter 7 of this document).

The site is approximately two miles to the east of the city of Yabucoa’s urban center. Single family detached houses abound to the southwest of the parcels in the “El Negro” sector, and another smaller cluster to the southeast, near the Palmas de Lucía Inn (“Parador”). This small hotel is named after the Lucía Beach, which contains two registered archeological sites, and which lies next to the Project’s eastern lot limit. It is a beautiful beach which has an extensive palm grove.

On the northern parcel of the project there are two (2) water bodies; one is Caño Santiago, a perennial creek bounding the northern property limit. There is also one (1) non-perennial streams flowing in the west-east direction through the parcel, that probably was man-made to provide irrigation to agricultural crops.

On the southern portion (Lucía Beach) of the project there are two (2) water bodies, both are non-perennial streams. One of them is an unnamed creek that flows in west-east direction through the southeast boundary and discharges in the coastline. The other one is a man-made earth channel at the northern boundary that also flow in west-east direction and discharges in the coastline.

An electrical substation is located in the intersection of street “4” and Road PR-901 to the southwest and a recreational and fishing facility are sited to the northeast.
Figure 71. Context features (proposed Project’s lot limit in black): 1. Buckeye company marine terminal and fuel tanker docks (this area was apparently developed later, as it did not exist in the 1930’s, to accommodate the docks; date of this work is unknown), 2. Buckeye company fuel storage tanks, 3. Electrical substation, 4. Lucía Beach abandoned parking lot and food concessions buildings, 5. Recreational area, 6. Fishing village, 7. Palmas de Lucía Inn, 8. Creek, 9. Lucía Beach Prehistoric archeological site, 10. Single family houses in El Negro Ward, 11. State Road PR 53, 12. Lucía Beach.

The parcels are mostly flat and almost completely accessible by existing roads. As stated, previously in Chapter 7, the parcels can be accessed from State Roads PR-53, PR-901, PR-9914 and PR-9911, which are a system of major highway, secondary and tertiary roads.
The project will need to create a new intersection with highway PR-53 and from PR-9914 to provide a direct and efficient access to the proposed development.

**Fig. 72.** South view of the southern parcel of the Project, with Lucía Beach towards the east and Road 9914 at the foreground.

**Fig. 73.** West view facing the fuel storage tanks.

**Fig. 74.** Northwest view of the northern parcel of the Project, with Yabucoa Port towards the east.

**Fig. 75.** North view of the northern parcel of the Project, with Buckeye company marine terminal and fuel tanker docks at the foreground.

**Fig. 76.** Northwest view of the northern parcel of the Project, with Yabucoa Port at the foreground.

**Fig. 77.** North view of the northern parcel of the Project, with Buckeye company marine terminal and fuel tanker docks at the foreground.
Fig. 78. Northeast view, with Yabucoa Port at the foreground.

Fig. 79. East view, with Yabucoa Port and the Caribbean Sea at the foreground.

Fig. 80. Northeast view, with PR-53 at the foreground and the northern parcel of the Project at the background.

Fig. 81. Northeast view, with PR-53 at the foreground and the northern parcel of the Project at the background.

Fig. 82. North view, with PR-53 at the center and the northern parcel of the Project towards the east.

Fig. 83. East view, with the northern parcel of the Project the foreground.
After the María storm event, as of today, damages to the beach are not very evident, although some palm trees were lost. Also, the beach has an excessive accumulation of seaweed on the shore and no cleaning procedures seem to have been undertaken, making it difficult to reach the water for bathing. The existing bathroom and food concessions buildings are abandoned, vandalized, and its walls covered with graffiti.
An array of large crude and fuel oil storage tanks lies to the south of the site, and a marine terminal and tanker docks, all owned by the Buckeye Global Marine Terminals Company, are located to the north of the proposed PROTECH’s lot, in the Yabucoa Port.

Figure 87. Accumulated seaweed along the shore, May 2019

Figure 88. Fuel storage facility entrance
Figure 89. Marine terminal and docked tanker

Fig. 90. Recreational area entrance to the northeast of the Project

Fig. 91. Recreational area to the northeast of the Project. The tsunami siren warning loudspeakers can be seen at the back

Fig. 92. Electrical Substation to the southwest of the Project

Fig. 93. View of Road PR 901 toward El Negro Sector
Fig. 94. View of Road PR 901 toward El Negro Sector

Fig. 95. Fishing village to the northeast of the Project. Marine terminal at the back

Fig. 96. Drainage canal to the northeast of the southern (Lucía Beach) lot

Fig. 97. View of the southern lot towards Lucía Beach

Fig. 98. Creek to the southeast of the southern (Lucía Beach) lot
10.1 Site: context and determinants

Since the parcels are located in rural land, but near suburbia and the small-scale urban built environment of Yabucoa’s town center, a development sensitive to the landscape should be considered.

Most of the land in the proposed site is dedicated to agriculture, and the view toward the beach and the hills to the south could be exploited for design strategies concerning views and contextual design decisions.

Special attention related to some of the site’s characteristics should be taken into account when planning the master plan’s development.
11 PARK COMPONENTS

The Puerto Rico Ocean Technology Complex (also referred as “Park”, “Complex” and “Project” in this document) should accomplish several goals which will interact among them to create the desired multiuse functionality and character of in-depth research and technological advancement with a user friendly and pleasant environment. These qualities must be obviously noticeable and felt by both the workers of the different industries included in the Complex and the various types of visitors who will come as tourists, to learn, to buy goods or to use the amenities that the Park will offer.

The Park should be defined as a comprehensive technological, industrial, office and educational / research eco-park. “Tenants should seek to minimize or eliminate waste generation, energy use, and other environmental impacts through symbiotic arrangements with other facilities in the Park. Because of the interrelationship among the tenants, eco-industrial parks often require a more sophisticated management and support system than traditional industrial parks… Because of the reduced impacts of these facilities, they may be more compatible with nonindustrial uses than conventional industrial parks. Eco-industrial parks can be described as generally having the following characteristics:

“Energy: They use existing energy sources efficiently, use waste energy from other facilities, and use renewable energy sources such as wind and solar energy.

Material reuse: Waste generated by one facility becomes input material for other facilities in the Park or is marketed elsewhere. Water used by one facility may be reused by another, with pretreatment conducted as needed. Stormwater runoff can be captured and used for certain facility needs. All the facilities work to optimize use of all input materials and to minimize toxic materials use.

Natural systems: Facility and park design minimizes environmental impacts and reduces operating costs by using natural drainage systems, native planting, and low-impact construction materials.

Design and construction: Buildings and infrastructure are designed to be energy-efficient; minimize pollution generation; and be durable, easily maintained, and flexible in their use. Established standards such as Leadership in Energy and Environmental Design (LEED) and ISO 1400—or similar programs—can be used to design and develop structures within industrial parks that are more sustainable in their construction and operation.” ¹

The Park will have an equally important research component dedicated to the ocean, which could expand to include weather/environment components and the study of natural disasters. The facilities provided for the ocean studies will be prepared to bring researches and ocean study specialists to investigate about their related fields, but also convene with other disciplines in planned periodically symposiums and conferences. Puerto Rico could become an important center for ocean studies for institutions around the globe and also incorporate the marine biology program of the University of Puerto Rico.

¹ Steiner, Frederick R. and Butler, Kent, Planning and Urban Design Standards, John Wiley and Sons, Hoboken, New Jersey, 2007
11.1 PROTECH General Goals and Master Plan Observance

The project development shall incorporate and comply with the following goals of PROTECH:

1. Bring researchers from environmental and specialized ocean studies from institutions of the country and from abroad to contribute and cooperate with existing oceanic programs and help in developing new ones for the benefit of both specific location regions and coastal zones.
2. Attract visitors with several and different pursuits: transitory learning and research opportunities, specialized and out of the ordinary - as well as casual - tourist interests, sale of goods produced in the Complex (agricultural, maricultural, aquacultural, nutraceuticals, spa and cosmetics products, among others) that could not be obtained easily anywhere else in the Island.
3. Involve the community by offering an employment source, amenities and needs. A community-based cooperative can be created to foster locals' interest and connection in the commercial, touristic and cultural offerings the project offers, by being a medullar component of those developments.
4. Respect the natural environment by not discharging hazardous emissions and chemicals and by generating energy with natural sources such as ocean water, rainwater harvesting and solar collectors.
5. Ensure harmony with the surrounding contexts by prioritizing views toward the natural landscapes and developing a sensitively built and landscaped environment, lessening the technological and industrial character and aesthetics traditionally only associated with their functional aspects.
6. Rescue, and restore, the Lucía Beach and shore, without surpassing the maritime zone limit, and developing a thorough cleaning and recovering recurring environmental plan.

11.2 PROTECH Specific Goals

11.2.1 Research/Education

1. Expand and disseminate knowledge of PROTECH as an educational/research resource for the benefit of the island of Puerto Rico, its communities and students of various levels, from elemental schools to college, and engage and interest them in pursuing activities related to such knowledge.
2. Promote ocean research and all its components, including climate, life forms, its different types of habitats, protection from storms and recuperation procedures.
3. Advance energy research and stimulate the use of alternate energy sources and technologies.
4. Define areas of study and offer them to schools and governmental entities to allow for the implementation of sustainable planning, including those that could apply to storm aftermaths.

11.2.2 Cultural

1. Advocate, respect and restore cultural heritage resources, including archeological sites.
2. Manage cultural resources in a sustainable manner.
3. Propagate cultural practices by providing areas for exhibitions, performances and gatherings in the visitor center/community/retail zone and other areas of the Project.
4. Provide opportunities for the celebration of cultural events in which members of communities and schools could participate.
5. Identify the natural landscape as part of a culture.
6. Help in associating the environmental-friendly technology with the natural evolution of culture of the country.

11.2.3 Natural Resources

1. Preserve natural resources such as fauna, flora and geographical elements—and environmental quality—fostering optimal planning.
2. Restore natural resources for recreation, contemplation and appreciation.
3. Show how natural resources can contribute to different beneficial purposes as in the case of alternate energy production.

11.2.4 Recreational

1. Provide recreational amenities for the community and to attract local and international tourism to reveal the benefits provided by PROTECH and, in this way promoting the dissemination of the ocean related technology and research being performed in the site.
2. Define and develop recreational activities including sightseeing and tours and marine non-invasive and environmental-friendly hobbies and interests such as snorkeling, scuba diving and kayaking.

(Also refer to the description of each of the Master Plan’s components for further specific information)

11.3 Ocean Thermal Energy Conversion (OTEC) Plant

“Most of the electricity we use comes from heat engines of one kind or another. A heat engine is a machine that cycles between two different temperatures, one hot and one cold, usually extracting heat energy from a fuel of some kind. In a steam engine or a steam turbine, for example, coal heats water to make hot, high-pressure steam, which is then allowed to expand and cool down to a lower temperature and pressure, pushing a piston and turning a wheel as it does so. The greater the temperature difference between the hot steam and the cooled water vapor it becomes, the more energy can be extracted (and the more efficient the engine).

In OTEC, we use the temperature difference between the hot surface of the ocean and the cooler, deeper layers beneath to drive a heat engine in a broadly similar way—except that no fuel is burned: we don’t need to create a difference in temperature by burning fuel because a temperature gradient exists in the oceans naturally! Since the temperature difference is all-important, we need the biggest vertical, temperature gradient we can possibly find (at least 20° and ideally more like 30–40°). In practice, that means a place where the surface waters are as hot as we can find and the deep waters (perhaps 500–1000m or 1000–3000ft beneath) are as cold as possible. The best place to find such a combination is in the tropics (between the latitudes of about 20°N and 20°S).

Considering how big and deep the oceans are, it comes as no surprise to find they soak up and retain vast amounts of solar energy. Some years ago, ocean engineer Richard Seymour
estimated that the oceans and atmosphere between them "intercept... about 80 trillion kW, or about one thousand times as much energy as used by man globally." How much of that could we recover from the sea? According to the US Department of Energy's National Renewable Energy Laboratory (DOE/NREL), on a typical day, the tropical oceans mop up heat energy equivalent to 250 billion barrels of oil. Converting a mere 0.005 percent of this into electricity would be enough to power the whole of the United States! However, impressive-sounding estimates like this don't take account of the tremendous practical difficulties involved in harvesting ocean energy."

There are three different kinds of OTEC plants:

Closed cycle
“In closed-cycle OTEC, there is a long, closed loop of pipeline filled with a fluid such as ammonia, which has a very low-boiling point (−33°C or 28°F). (Other fluids, including propane and various low-boiling refrigerant chemicals, have also been successfully used for transporting heat in OTEC plants.) The ammonia never leaves the pipe: it simply cycles around the loop again and again, picking up heat from the ocean, giving it up to the OTEC power plant, and returning as a cooled fluid to collect some more.

How does it work? First, the pipe flows through a heat exchanger fixed in the hot surface waters of the ocean, which makes the ammonia boil and vaporize. The heated ammonia vapor expands and blows through a turbine, which extracts some of its energy, driving a generator to produce electricity. Once the ammonia has expanded, it passes through a second heat exchanger, where cool water pumped up from the ocean depths condenses it back to a liquid so it can be recycled. You can think of the ammonia working in a broadly similar way to the coolant in a refrigerator, which is also designed to pick up heat from one place (the chiller cabinet) and carry it elsewhere (the room outside) using a closed-loop cycle. In OTEC, the ammonia picks up heat from the hot, surface ocean waters (just as the coolant chemical picks up heat from the chiller compartment), carries it to a turbine where much of its energy is extracted, and is then condensed back to a liquid so it can run round the loop for more heat (just as the coolant in a refrigerator is compressed and cooled in the fins around the back of the machine).”

Open cycle
“In open-cycle OTEC, the sea water itself is used to generate heat without any kind of intermediate fluid. At the surface of the ocean, hot sea water is turned to steam by reducing its pressure (remember that a liquid can be made to change state, into a gas, either by increasing its temperature or reducing its pressure). The steam drives a turbine and generates electricity (as in closed-cycle OTEC), before being condensed back to water using cold water piped up from the ocean depths. One of the very interesting byproducts of this method is that heating and condensing sea water removes its salt and other impurities, so the water that leaves the OTEC plant is pure and salt-free. That means open-cycle OTEC plants can double-up as desalination plants, purifying water either for drinking supplies or for irrigating crops. That's a very useful added benefit in hot, tropical countries that may be short of freshwater."³

Hybrid cycle:
“As its name suggests, it combines both the open and closed cycles which can produce power and potable water. The warm water is steamed by flash evaporation which is similar to the open cycle process. The steam then heats the working fluid as in the closed cycle.

³ https://www.explainthatstuff.com/how-otec-works.html
Vaporization of the working fluid rotates the turbine to generate electricity. The cold water condenses the steam to be desalinated water."^{4}

The type of plant to be used in PROTECH will be of the closed cycle type, located near the shore. It will include four large hot and cold pipelines (a hot water input, a hot water output, a cold-water input, and a cold-water output), submerged into the depth of the sea. Because of its location, measures will have to be taken to protect it from coastal erosion and storm surges and high velocity winds of hurricanes and tropical cyclones. It would be beneficial to consider adding a second stage of desalinization to add industries and broaden the scope of PROTECH’s offerings.

The proposed plant for Yabucoa could be based on the closed-cycle one installed in Hawaii, owned by MAKAI Ocean Engineering, with similar operational characteristics, as well as research activities, including additional marine applications:

“Makai’s OTEC plant forms part of its OTEC heat exchanger test facility and marine corrosion lab, named Ocean Energy Research Center (OERC), located at the NELHA site, which was opened in 2011 following the award of a fund by the US Navy in 2009.

The OERC is capable of testing six heat exchangers simultaneously and also conducts research programs on seawater air-conditioning (SWAC), corrosion prevention and heat exchangers for other marine applications.

The research and development work at OERC were funded by the Office of Naval Research (ONR) through the Hawaii Natural Energy Institute (HNEI), whereas the funding for the OTEC plant’s infrastructure was provided by Naval Facilities Engineering Command (NAVFAC).

The US Navy’s special engagement in the research center is driven by its target of generating 50% of its shore-based energy from renewable sources by 2020. The heat exchanger research facility is necessary as their components are estimated to make up approximately one-third of the overall cost in developing a commercial OTEC plant, primarily suited for offshore locations.

As of 2014, the research center completed the test of seven heat exchangers that are constructed of either aluminum or titanium. The US Navy awarded Makai a contract to add a turbine generator to complete the power plant and test the working of OTEC technology on the grid, in 2013."^{5}

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^{5} https://www.power-technology.com/projects/makais-ocean-thermal-energy-conversion-otec-power-plant-hawaii/
**Figure 99.** MAKAI’s Ocean Thermal Conversion Plant in Hawai’i. National Energy Laboratory of Hawai’i. Photo: https://www.makai.com/2013_04_29_makai_100kw_otec_facility/

**Figure 100.** Closed Cycle Ocean Thermal Energy Conversion (OTEC) Plant diagram

### 11.4 PROTECH Technological Offerings

Deep Ocean Water uses include, among others:

1. Deep ocean water is very clean and has a highly inorganic nutritional value.

2. Its uniform 0°-3° C temperature allows a constant and reliable source for its various benefits, including energy generation (24 hours a day, 365 days a year), research and commercial applications and as a source for several industrial pre-commercial processes. These consist of agriculture (hydroponic, greenhouse and soil orchards and crops) and aquaculture (fresh water)/mariculture (sea water) - fisheries for food and aquariums, algae and spirulina cultivation - activities, production of potable and mineral water by condensation (if a second stage - desalinization - is included), nutraceuticals, and as source of a natural air conditioning cooling agent for nearby buildings (thus, reducing or replacing the amount...
of electrical power and refrigerants). OTEC can also be used to produce methanol, ammonia, hydrogen, aluminum, chlorine, and other chemicals. Some of the possible uses of these products are:

a. Methanol is a liquid chemical used in thousands of everyday products, including plastics, paints, cosmetics and fuels. Methanol is also an energy resource used in the marine, automotive, and electricity sectors, and an emerging renewable energy resource.

b. Ammonia is used as a refrigerant gas, for purification of water supplies, and in the manufacture of plastics, explosives, textiles, pesticides, dyes and other chemicals. It is found in many household and industrial-strength cleaning solutions. About 80% of the ammonia produced by industry is used in agriculture as fertilizer.

3. Develop and support indirect industries such as research, tourism, manufacture (bottling, cosmetics, medicine), education, retail and other types of businesses that can benefit from its direct technological applications.

4. To ensure that the Park includes a larger variety of industries, desalination and waste energy conversion technologies should be considered for inclusion in the Park’s components.

11.5 Master Plan Physical and Social Concept

Since the most important goal of the PROTECH Project is to attract visitors to ensure its viability and validity, the designed environment of the Park comprised of buildings and open spaces has to be able to successfully intertwine two apparent, but not opposite (although at times wrongly considered to be), traits:

1. Rigorous technological and scientific functionalities and;

2. Pleasing and entertaining leisure and tourist activities. In other words, encourage and demonstrate a merging of cultural interest, natural environment conscience and scientific knowledge.

A highly technological overall character for the Park would probably result in an intimidating and alienating atmosphere for the existing surrounding communities, countering the wish to interact with them and the Yabucoa urban center dwellers. Thus, the types of architecture and of landscaping must be very carefully crafted to achieve a welcoming and well-being sensation. It would be wise to remember that technology is not the enemy of enjoyable habitats, but rather its closest supporter. Progress through technology is a concept that has been evolving in the last decades as the technological advances have become more in tune with the natural environment’s survival, and the Park must emphasize these intentions and purposes. Therefore, as part of the Master Plan guidelines for companies wishing to be a part of the Park, it would be extremely important to emphasize the inclusion in their buildings and facilities of environmentally friendly technologies such as solar power generation, rainwater

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harvesting, green roofs and recycling. The deep ocean thermal energy conversion plant will - apart from all its other benefits - be able to supply some of the power and air conditioning cooling needs to them, but they may need more, depending on their particular types and scales of their operations. As this type of technology advances, these other type of natural resources uses will function as complements.

A “village” typology could be considered when conditioning regulations for the built components of the Park, meaning that harmony between them is of the essence. To achieve this type of context, pedestrian circulation should be prevalent, as well as the use of bicycles to move around the Complex in a faster pace. Buildings should be required to respect the continuity of the sidewalks alignment and provide sheltered protection against the rain and the heat of the Island’s climate, which will promote walking. If parking lots are included in the lots, they should not be visible from the exterior. Additional possible requirements for the site planning are included in further sections of this document.

The linear configuration of the Plan will make the circulation sequence engaging by providing areas of interest along the way. The organization of the parcels was based on understanding the site, taking into consideration the existing natural conditions, the ocean views, the technological and physical conditions necessary for the OTEC plant’s operation and the overall experience that the Complex seeks to offer its daily users and visitors.

Along the way, the visitors will be able to choose to traverse the Park by ambling along a raised walkway that will offer them views of the agricultural and maricultural installations, connect from the multiuse lot to the OTEC plant and hotel parcel, or walking through a boulevard-type vehicular way with ample or covered sidewalks and trees that connect to the retail, office and industrial lots, research campus, museum, aquarium and other facilities. For these options, bicycle lanes will be provided, as well as walking paths. Workers of the industries and office buildings will therefore also be able to use bicycles to move inside the Complex, and visitors too, by using their own bicycles or renting them on-site.

Workers and visitors will have access to several complementary amenities. Landscaped park areas will be accessible in the ground level for passive recreation and various plazas will provide users with food concessions, small market areas and leisure zones in the ground level.

It will be recommended or required that structures near the beach be raised above the ground, preferably by structural elements leaving voids between them so as to permit views of the beach and ocean from the ground level. This prerequisite will also protect the facilities from storm surges and can leave the ground characteristics with less disturbance and in accord with the environmental concerns and preservation goals of PROTECH.

Most of all, in general, chosen designers should strive to achieve a one-of-a-kind project that would stand out from the usual repetitive developments associated with industrial parks. Therefore, innovation and an aesthetic expression and planning. In addition, less expensive solutions, making the most of all types of resources, are welcome. Important precedents for PROTECH are the Hawai’i Ocean Science and Technology Park (HOST Park), which was created by the High Technology Development Corporation (of Hawai’i), established in 1983, to meet the intent of Hawai’i’s Legislative Act 152 “… to establish an instrumentalitly and agency of the State and to grant to such agency the power to develop
industrial parks for the location of such high technology enterprises, to assist such high
technological enterprises in the construction and equipping facilities to be used for such
enterprises and related facilities, and to issue special revenue bonds to finance the cost of
such development, construction, and equipping." Before that, in 1974, Hawai‘i had issued a
Revised Statute Chapter 227, which established the Natural Energy Laboratory of Hawai‘i
(NEHL). In 1990, NELH and HOST Park were merged to form the Natural Energy Laboratory of
Hawai‘i Authority (NELHA).

The primary aesthetic criteria of the 1989 HOST Park Master Plan were:
1. The HOST Park should have a relatively low density of development, with emphasis on open
spaces, attractively designed ponds and ocean-related facilities, island-style architecture
and ample landscaping.
2. The visual clutter typical of industrial parks should not be permitted.
3. The High Technological Development Corporation should maintain high standards for
architecture and other aesthetic considerations. These standards should be achieved
through the County administered Design Rules and the HOST Park Rules through a carefully
designed lease agreement.
4. Land areas that are not developed should not be disturbed. It is essential that the natural
appearance of the lava fields be preserved by avoiding permanent, defacing scars. 7

As can be noted, the above aesthetic parameters, although locally applied to Hawai‘i, are
not different in concept to what’s being pursued in PROTECH’s Master Plan.

Finally, it must be understood that this roadmap is not meant to be neither final nor a strict
document. It must act as a guide and should be organic, in the sense that the proponent could
accommodate continuous or natural development as it begins to take shape financially and
physically. Many studies of different kinds are yet to be performed, and once approved by the
client, the permitting process will commence.

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7 Master Plan for Natural Energy Laboratory of Hawai‘i Authority, 2011
It is important to note that for the Park to function properly, its different zones will have to interact and not be totally separated from one another. This would be the proper way to mix uses and visitors and maintain a constant general administration of the Complex. It would also be a model for cooperation encouragement, as mentioned above, between the Park’s tenants, by stimulating the re-use and sharing of resources and waste material that could be recycled.
11.6 Park Master Plan Components Description and Character

11.6.1 Components 1 and 2: Vehicular and Pedestrian Accesses to the Complex

The Master Plan proposes two accesses from the exterior of the Complex:

For the main (northern) parcel:
1. An entrance from the southwest, by developing a new intersection with State Road PR53, to readily access the Industrial & Research Park parcel and;

For the southern (Lucía Beach) parcel, for accessing the OTEC Plant and the proposed Hotel:

1. An entrance from the northwest, by developing a new access from State Road PR-9914.

2. An entrance from the southwest, by improving the existing access from State Road PR-9911.

In addition, a service connector road shall be developed along the eastern boundary of the Buckeye Terminal and the PR Ports Authority facilities. This connector road will provide a path for the proposed power and cooling piping systems between the OTEC plant and the Industrial & Research Park.

11.6.2 Component 3: Access controls

Even though the Complex should have some uniform components to ensure an identifiable character, the controlled accesses can be different to accommodate their particular contextual locations and hierarchy. This will depend on the exterior and interior characteristics of said contexts (retail, hotel). See also related components (Components 1 and 2) for their relationship with this element.

These accesses will be the gateways to the Complex, and as such, should be designed with special care and aesthetic considerations. The small buildings for the personnel occupying them should include bathrooms, a counter for paperwork, a coffee maker, a microwave, a small refrigerator (as a minimum), and storage cabinets and lockers. The materials must be easy to clean and maintained, and sturdy.

The buildings should also be air-conditioned but have openable windows, internet connection and have a small emergency generator in case they are not connected to a general generator for the Park. Adequate illumination and access control devices should be studied and installed.

The Access control located near the main entrance may be the ideal place to position the principal facilities for the security office, because of its location. These should include the communications equipment, showers, a rest-lounge room, a meeting place and whatever other rooms are deemed necessary.

11.6.3 Components 4, 5 and 6: Retail, multi-use and communal spaces

This facility is a very important component of the Master Plan for several reasons:

1. It is next to the main entrance to the Project,
2. It is very visible and accessible from the exterior, being in a corner from which visitors from other municipalities reach the Project – it is the place to install the Project’s main sign.
3. Because of the two previous reasons, it is the initial image-maker for the Project,
4. It can incorporate many functions in a harmonious whole,
5. Although linked to the rest of the Complex, it can also function independently at different time schedules,
6. It is a main source of income and helps in advertising the products manufactured or harvested in the Complex by selling them,
7. It will offer needs to the surrounding communities and the dwellers of the urban center of Yabucoa, some of which could be essential in nature,
8. It could become a meeting place for the community and the Complex's workers and researchers, offering entertainment, educational and cultural events,
9. It has the potential of becoming a place-making facility, with all of what that quality implies,
10. It could become the “magnet” that attracts visitors and make them want to stay and explore the whole Complex,
11. It is one of the destination “anchors” that start or end the circulation throughout the Complex, helping in that other spaces and places within the Park be visited.

There will be a visitor center in this area to serve as an introduction of PROTECH’s facilities, goals and offerings. It will contain a shop with books related to the technologies and productions of the companies inside the Complex, and souvenirs. The center will also contain a small theater to show an introductory video of PROTECH’s facilities and goals. A guide program could be implemented for those interested in knowing more about the technological aspects and benefits of the several programs included in the Park. The retail spaces can offer different types of merchandise, and mix retail modes and scales such as outlets, markets (supermarkets, specialized food products), warehouse club stores, personal and family needs (barber shop and beauty salon, drugstore, gym, laundry, automobile parts, eyeglasses shop, etc.), library, day-care center, food court, entertainment spaces such as movie theaters and also offer medical and other service offices and even co-working spaces. The visitor center could also provide exhibition spaces for cultural manifestations. The Complex’s administration offices will also be located in this zone.

As in Hawai’i’s Natural Energy Laboratory of Hawai’i Authority’ master plan, this commercial zone is intended to become a priority retail outlet for its tenants and secondary for other products of Puerto Rico. It could also contain a natural products store, with items from the companies of the Project, including those derived from nutraceuticals. The variety in types and areas of these premises would help in attracting clients from the community and town center, provide employment and offer spaces for businesses owned by the community and municipality populations. It would also include a bicycle rental shop.

A main attraction will be a plaza for outdoor recreation and gatherings which could offer musical concerts, fairs (product, industry and professional oriented, educational, gastronomical, among others). This outdoor assembly area could be roofed with a lightweight structure so as not to look imposing and retain the informal character of the space to attract impromptu activities as well as open concerts of different musical bands and groups of different types of music, and comedy acts and performances for different age groups. It could also be used as stage for educational purposes and be available for fairs of various themes (environmental education, natural disaster preparation, community services).
The retail and multi-use area of the Master Plan is also the ideal place for including a multi-use large meeting space for temporary events of different nature, and most importantly, for a shelter and Community Resilience Center in case of natural disasters. This facility can include programs such as sleeping, shower and cooking areas, back-up generation capacity and storage, among other components.

Figure 103. Concept plan diagram of retail, multi-use and communal spaces area
11.6.4 **Component 7: Parking garages**

Five parking garages, **two of which will be located near the Complex’s entrances**, one near the administrative office areas, one next to the main research facilities and one near the OTEC plant and hotel will provide parking spaces for all the Park’s premises workers and visitors. **Their locations also respond to the need to be near places where people will concentrate the most.** They will include bicycle rental shops so that visitors, workers and researches can move around the Park as an alternative to walking.

These garages should be designed in an attractive way, with facades that conceal their purpose, and in harmony with the rest of the Parks’ general character. **They could be roofed with solar panels and include vegetation in planters.**

The buildings’ capacities to supply parking spaces will be determined depending on their respective location according to the specific needs. However, this will not be the only determinant for such condition. It must also consider a surplus of spaces for the project workers and visitors that will visit for special occasions and events.

11.6.5 **Component 8: Elevated walkways**

The elevated walkways will serve as one of the ways visitors and workers can use to cover the distance between the two main zones of the Project: one walkway threads the mariculture/aquaculture areas with the research and communal zones and, the other walkway will serve as a connection with the OTEC plant and hotel site, near the beach.

Since the height of the walkways has not yet been determined, **the general idea is that it could include, apart from the walking surface, bicycle lanes and resting green spaces with benches and vegetation overlooking the maricultural and agricultural lots below.** The stretches above the main street will have the required height as required by the transportation authorities. **It is proposed that the walkways be covered with solar panels to provide shade, and since they can be oriented toward the south, their installation orientation would easily point toward this direction.**

**These walkways have also several functions.** Apart from providing a leisurely manner to circulate along the whole Park’s distance length, **it would also function as observation deck to watch the agricultural and mariculture/aquaculture facilities** (orchards, fisheries, crops – see components 12 and 21) next to it from above with the intention of satisfying the visitors’ curiosity, and with learning and touristic purposes. And, since it’s elevated, part of the natural landscape surrounding the Project’s lot could also be contemplated from it, **as well as other components of the Complex, in an entirely transparent way, helping in attenuating the potentially misunderstood technological aspect of the Project. In other words, it would help in assuring and demonstrating that the Project’s several technological aspects will not be threatening to the environment in any way.**

The other proposed elevated walkway connects the Industrial Park parcel with the deep ocean thermal energy conversion plant (OTEC, component 14) and hotel (component 19) parcel. An important feature of this specific walkway is that it can house the infrastructure needed from the OTEC plant to distribute the energy towards the Industrial Park parcel.
These elements will also contain vertical circulation modules to connect with the ground level. This space is further described below (see component 11).

**Figure 10.14.** Conceptual section diagram through levee, elevated walkway, crops, boulevard and educational hubs

11.6.6 **Component 9:** Land berm/levee and canal

Portions of the Project’s site are located on a flood zone. This can be remediated in several ways, and it is being proposed that, depending on the conclusions of a hydrology and hydraulics study, **an earth levee with a canal be considered.** One of the advantages of this strategy is that a natural appearance that can be landscaped as a limit of the Project.

11.6.7 **Component 10:** Photovoltaic panels array (above elevated walkway)

Installations of photovoltaic panels are an essential component of the project. In addition to its solar energy collecting function, it also serves as cover for the elevated walkway. This type of natural energy production could also be used in other premises and buildings of the Complex, even if it helps in reducing the dependency on the grid in the particular cases.

The energy produced by the deep ocean water plant will cover its most related production and part of the research functions depending on their determined viable areas. However, as this technologies advances, it is expected to become much more productive and widespread because of its nature, and because an ongoing research is taking place in cooperation between companies (Makai Ocean Engineering and Lockheed Martin, for example\(^8\)) and with government entities (U. S. Navy and others).

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\(^8\) U.S.-Designed No-emission power plant will debut off China’s cost. E&E News, May 1, 2013.  
https://www.eenews.net/stories/1059980380
Photovoltaics can also be installed in free-standing structures, some of which can be sculptural to mark places or to add interest to the area, when covering the place while walking.

11.6.8 **Component 11:** Park/Plaza for gatherings, open food venue and small market

An open space with an outdoor food venue for visitors and workers from the Park’s industries, offices and research premises will be another component of the Project. It would include a market for local small-scale shops that would operate during weekends and special dates, with booths leased to community arts and crafts and food and beverage delicacy artisans.

This space will have the character of an oasis-like meeting place in which small scale live music can also add to an occasional entertaining and festive atmosphere for informal social interaction activities, with a connection to the elevated walkway (see also component 8). It could also serve as an area for celebrations and get-togethers of the employees of the industries and companies inside the Complex.

**Figure 1025.** Concept diagram plan of Park/Plaza for gatherings and lunch
11.6.9 **Component 12:** Crops and orchards

Cultivation in open land and in greenhouses: These lots will be reserved for the agricultural components of the Master Plan and will also include hydroponic crops of cucumbers, tomatoes, peppers and lettuce, among other fruits and vegetables. Aeroponic techniques for the production of seed germination and propagation and the cultivation of micro-greens could also be included.

These facilities will use the water extracted from the ocean, which is rich in inorganic nutrients, while organic ones can be extracted from the fisheries near these crops. The produce will be sold in the retail area of the Complex and exported for wholesale and small markets.

11.6.10 **Component 13:** Educational and Research hubs

Located in the center of the main parcel, the Plan proposes a zone with buildings related to educational and research functions for companies that would like to share their field of production or business with visitors from the general public, schools and researchers, with showcases of different types (open lobbies with exhibitions, storefronts and areas dedicated to these activities within the buildings’ interiors) and informational or instructional activities by allocating interior and/or exterior gathering spaces such as lecture rooms, amphitheaters and open areas that could be temporarily covered. These hubs would also create additional foci of interest for the technological and research tourism and for employment recruiting.

The hubs will be accessible from the ground level and from the elevated walkways through vertical circulation modules. **It is suggested that the companies occupying these lots engage in environmentally-friendly strategies and incorporate natural systems in their facilities such as solar energy, rainwater harvesting, green roofs and recycling, among others. In this way, these institutions could become ambassadors, sponsors and supporters of PROTECH’s environmental technology goals.**

In front of the vertical circulation modules and the receiving space for exhibition halls there will be drop-off driveways for buses to bring visitors that will not park inside the Complex, such as students and tourists.
11.6.11 **Component 14: Ocean Thermal Energy Convention Plant (OTEC)**

The deep ocean water power generation plant will be the main landmark of the Project. As such, it will be the other “anchor” destination of the Complex’s circulation and the main technological attraction of the Park. It will be placed near the ocean for functionality purposes, but the location is also ideal for showcasing it, with the ocean view as its backdrop. (In 2016, NOAA conducted surveys for coast bathymetry, which can be used for initial studies for the location of the pipe system – they are available on the agency’s website).
The new approach of considering infrastructure elements beyond its purely functional aspect has become a way of better integrating them to the architecture and urban contexts, and also to the landscape. It means that not only engineers should be involved in infrastructure projects, but that architects, urbanists and landscaped architects should too. Since the appearance of the plant is purely functional, with pipes and machinery exposed in it exterior, it would be ideal to surround it with a more aesthetic façade treatment to attenuate its hardened and intricate appearance. To achieve this, we suggest to cover it with a semi-transparent type of perforated “skin” that would let natural ventilation and limited light in, as well as showing the plant structure and elements in a way that it could not be discerned completely from the exterior. The new and more pleasing appearance will be more in tune with the aesthetics of the whole Complex while not hiding the technological aspects completely. Technology, again, does not have to ignore other aspects of human perception, and every infrastructure constituent can be built with sensitivity to its surroundings while contributing to the aesthetics of the built environment.

Another important issue to address with the deep ocean thermal energy conversion plant is that, being the main attraction of the Project, it can have more than one function. By this we mean that it can also be used as an additional amenity by incorporating some type of amusement and enjoyment function to attract the visitors who come for touristic and leisure reasons. It would be a way to mix technological implementation with pleasure, resulting once more in dispelling the erroneous notion that these two concepts can’t be related. And, by introducing a new aesthetic and an inviting appeal for the plant, a heightened curiosity for what the deep ocean water technology can achieve would help in educating and promoting its further use elsewhere.

The type of amenity that could be integrated with the plant will be open for proposals. As for now, we’ve devised a potential design option for the proposed amenity, but in no way should it be considered as the only one possible. As the design process of the Master Plan components advance with the chosen financial, planning and qualifications procurement methods – which will probably be carried out by issuing requests for proposals (RFPs), and the subsequent development contract award, there could be a myriad of design alternatives, some of which could result in more imaginative ones.

Our suggestion - again, in no way the only one possible - is to create a surrounding circulation/observation path around the plant from the inside of the “skin” enclosure so that visitors could look at the technology involved in the plant’’s functioning appurtenances and processes, which will not be directly revealed from the exterior of this enclosure. The attraction strategy is not to make it obvious from the exterior, but rather not reveal itself until the visitors enter the confined space. The curiosity in itself would create a sense of anticipation, increasing the desire to discover what’s inside the covered structure.

As an attraction bait, it will not be very different from what some amusement parks do with some of theirs features. This path around the plant would be accessible from the ground level as well as from the elevated walkway mentioned above (component 8) and it would also draw schools to bring their students and researchers. It would include elevators so that the circulation could be around the plant could begin from different levels from the lower to the top or vice versa, and for the benefit of the physically disabled.

An observation deck will be provided at the top of the enclosure structure to contemplate the ocean and mountains (to the south) landscape. By using the elevators, the observation deck will be accessible without the need to walk around the plant if there’s no wish to do
so, and would work as an attraction by itself, independently from the surrounding observation corridor. This observation deck could include a snack/refreshment concession and a souvenir small shop, or even a small restaurant with indoor and outdoor seating.

The plant will be raised from the ground level to avoid potential damage from storm surges with structural supports covered with a landscaped earth berm. The wall system used around the plant can also help in protecting the plant from storms as if it were a perforated storm shutter. Design considerations for this purpose should be taken into account.

As proposed previously, the infrastructure needed from the OTEC plant to distribute the energy towards the Industrial Park parcel, can be attached to the elevated walkway that connects the Industrial Park parcel this lot.

Two concept schemes are presented, with both vertical and horizontal configurations, for further in-depth analysis and discussion.

Figure 107. Concept diagram of Ocean Thermal Energy Conversion Plant suggested amenity (Vertical Plant)
11.6.12   **Component 15**: Park for passive recreation and leisure

Various parks located in strategic places inside the parcels, help organize and unify the zones that compose the Complex, providing areas for lunch breaks or simply resting and contemplating, and paths for strolling and cross between the premises’ areas.

If decorative and flowering plants are grown in the orchards for sales, they could be also be planted in this park to exhibit them and a place for a flower and a houseplant market could be allocated within it. Ponds in the park could be habitats for tropical, aquarium and pond fish, such as koi, cichlids and native species, with signs identifying them.

Also, paved areas are provided for outdoor activities such as group exercising (calisthenics, tai chi, Zumba) for the Complex workers and for visitors alike. A pavilion will provide a semi-sheltered area for other types of activities that require a stage-like structure.

A children’s playground will be included, as well as exercising stations for adults along the walking paths. These paths can also become a route for exercise walking or jogging.
Figure 109. Concept plan diagram of park for leisure and outdoor passive recreation

Figure 110. Passive recreation park concept
11.6.13 **Component 16: Ocean Flora and Fauna Aquarium**

It is suggested that the theme and purpose of this aquarium be more related to environmental research and to deep ocean habitats, to complement the main technological feature of the Project, and to have a dedicated theme in order to make it unique. Aquariums in general have been suffering from a declining number of visitors and have been forced to add marine attractions such as swimming with sharks or rays. Although that may not be feasible in this case, deep ocean creatures would be attractive enough if they could be kept successfully. However, depending on the interested building and managing parties, a marine attraction should not be ruled out. In that case, it could be also help in financing the facility and provide income for research and for profit.

The exhibitions of the aquarium would include the properties of the deep ocean environment and the characteristics of the water at the depth from which it will be pumped from by the deep ocean water plant, which could reach 3,000 feet. It could also contain tanks with specimens of the different ocean and habitats in Puerto Rico, including mangroves and estuaries, where a mix of fresh and seawater exist. The aquarium will be closely linked to the research facilities and could be administered by it, forming also part of the research campus (see component 18).

![Figure 11. Deep ocean creatures (5,000 – 10,000 ft.). Photos by National Geographic](image)

11.6.14 **Component 17: Ocean Flora and Fauna Museum**

A deep ocean water museum would serve as a sister facility to the aquarium, exhibiting the effects of climate (and climate change) on these habitats and the species that dwell in them, and a timeline of these weather effects. It would show how the different depth of an ocean affect water quality and how fauna and flora have adapted to them. It could also emphasize how efforts to mitigate environmental damage are being carried out and the technologies and processes being applied to help with this endeavor.

The museum will also be closely related to the research premises and be part of its campus. It may contain exhibits of the different research types being carried out in the research labs and areas (see component 18).
11.6.15  **Component 18:** Research Campus

The main research area and facilities of the Project is one of the main destinations and it is meant to bring visitors to participate in activities planned in the campus and attend lectures. Since the aquarium and museum are also related to the other research spaces, visitors can also access them through these installations and a circulation sequence is possible if lectures and conferences include visits to the aquarium and the museum.

The Research Campus is meant to attract students or faculty researchers from the higher education institutions and from public and private companies of Puerto Rico as well as from those abroad. Being a campus, it is meant also to attract all kinds of visitors. Therefore, its buildings and open spaces must be inviting and interesting in character and make use of all the environmental-friendly and passive technologies available for power and rainwater collection, and most importantly, those provided by the deep ocean water plant, with which a close relationship should be developed. Apart from laboratories, classrooms and other research areas, it would include meeting rooms, a lecture hall, a multiuse space and all the support areas needed for the particular research programs being offered. One of the Complex’s parking garages will be built close to it. The premises would also include dormitories and a dining or food hall which could also be accessible to the public. The campus will provide bicycle facilities.

Sponsors from companies interested in the deep ocean water technology as well as from the other fields represented in the Complex could create alliances and help in funding the research activities, with additional financial aids from government programs and institutions grants.

![Concept plan of ocean research/educational campus with aquarium and museum](image)

**Figure 112.** Concept plan of ocean research/educational campus with aquarium and museum
Component 19: Hotel

A hotel for international and local tourism will be one of the main incomes and employment generating components of the Complex. Its particular location provides visual connection with the ocean and vegetation around, while being close to the OTEC plant. It will be located close to one of the Project’s entrances to ensure proper servicing and access and next to one of the parking garages for the guests and employees, and also for the workers and visitors of all the Park.

Its position next to the Lucía beach will dictate its room configuration and guest room building orientation to ensure that all the rooms balconies have a view toward the ocean, avoiding the heat from the west. It should be lifted from the ground with structural members to avoid potential damage from storm surges. This means that only the spaces that absolutely need to be on the ground level will make contact with the existing landscape, obstructing in the least possible way the view while not affecting the natural habitat in a significant manner.

The hotel will have at least 220 rooms, a pool, tennis courts, beach volleyball courts, landscaped areas using the same vegetation that grows in the area, open terraces, and other amenities. It will also feature a casino.

A “parador”-type inn, Palmas de Lucía, is located to the south of the east of the Complex, close to where the Project’s hotel will be built. It offers modest accommodations, but some type of partnership complementary relationship with the hotel should not be discarded as they could work in tandem if arrangements are made.
Figure 113. Concept Hotel layout diagram
The hotel could also be used to host conventions, including those of the scientific communities, and as such, a limited symbiotic arrangement could be achieved with the research campus either for additional guest rooms or entertaining and receptions.

11.6.17 **Component 20: Lucía Beach**

The Lucía beach is currently abandoned, but it used to be a frequently visited destination for bathing and leisure and could again become an attractive asset for the Yabucoa community and for the Project’s visitors, thus the Project will help in restoring its original character and work with the municipality of Yabucoa to maintain it.

Apart from the natural landscape it provides, it’s important to recognize it as a significant complement for the Project because the ocean is the source used in the main technology showcased in the Park, and the object of the research programs that could be implemented or transferred in the Complex’s premises. Also, one of the main goals of
PROTECH is to mix leisure entertainment and touristic applications with technological innovation and rigorous studies.

Lucía Beach also offers other types of interests as it’s the home of one archeological site, as mentioned before in the Geographical and Physical Context chapter of this document. This means, of course, that its territory is partially protected, but also that it could be also visited by historic tourism enthusiasts. The beach provides a high value shoreline for sea related recreation for different local and international scales of tourism. In conjunction with municipal and state authorities, a beach park with the facilities described in the following paragraph could be developed, including environmental-friendly water sports such as snorkeling, scuba diving and kayaking. However, it is important that these activities be administered, and certain enforcement be implemented by the Complex’s hotel and/or research center in coordination with the Municipality of Yabucoa to avoid detrimental activities. Other events and uses with recreational or research purposes, such as a controlled camping area could be incorporated.

The restoration of the beach would have to include the demolition of a concrete building that contains bathrooms and food concessions no longer in use and an asphalt paved parking lot. With the permission of the Municipality of Yabucoa, new facilities could be included as part of the Project outside of the Projects limit.

11.6.18 **Component 21:** Mariculture (seawater), aquaculture (fresh water) and fisheries

Along with the agricultural component, the maricultural products would become one of the important industries present in the Project for food production and exports. Again, as in the case of the agricultural crops, these products could be too sold and consumed in the Project’s restaurants and food concessions, which could feature local cuisine for tourists from other countries either in permanent premises or in gastronomical fairs. Apart from seafood, algae harvesting can also be an activity that could be used to produce biofuel, medicinal products and food for livestock. Shellfish such as lobsters, crabs, shrimp, abalone, clams and oysters, a variety of fish, octopus and seahorses are being raised in Hawai‘i. Another potential industry is growing fish and plants for the tropical aquarium hobby.

11.6.19 **Component 22:** Offices and Industrial Lots

These lots could be occupied for several types of companies: professional and technical services, warehouses and different types of product manufacturing. However, in the latter case it’s important to restrict their use to environmentally safe and non-hazardous processes.

**The buildings of the companies occupying the lots would have to comply with certain bylaws to ensure the order and uniformity set forth in the Master Plan design and character.** Parking lots could be permitted, but limited, and not visible from the streets, to encourage the desired and safe pedestrian qualities of the Park’s components. The creation of interior landscaped yards would be ideal to motivate a sense of community between the employees and to provide additional natural light and ventilation if needed. **All buildings would have to align with the sidewalks to develop a continuity and incorporate the human scale in its design to relate to pedestrians.** It would be required for the buildings along the
boulevard, facing stretches of sidewalk, to provide shade and protection from the rain in the form of arcades and galleries. The buildings shall also provide bicycle stands for employees and visitors coming from the parking garages.

It would be preferable that these facilities use some types of environmental-friendly technologies, and, if possible, green roofs. The bylaws will be stipulated in later stages of the Project.

The range of tenants’ industries could be varied, but, if possible, those with applied technology related to the ocean and the environment, and, as mentioned before, also those that could share resources with other tenants, would be preferable. Desalination and waste reuse companies would be ideal tenants as they could operate in a cooperative manner and in tandem with the Ocean Thermal Energy Conversion plant. A containerization research facility and industry could also be part of the Complex as well as energy related enterprises such as biodiesel, solar thermal technology and waste to energy gasification.

11.6.20 **Component 23:** Lots for administrative offices and manufacturing processes of the water related industries

The administration and manufacturing facilities for the water related industries (mariculture and aquaculture) are located in the parcel as a prelude to those lots. The buildings occupying these lots would have to comply with the same characteristics as those of the buildings mentioned in the previous component 22, but in this case, it would be preferable that green roofs be mandatory. These green roofs could be utilized for more orchards or small-scale crops. The buildings could also showcase their products with storefronts and include small selling spaces along the sidewalks, although income from these shops should not be considered a constant income generating venture since visitors would not be as abundant in working days as in weekends.

However, in the weekends, the shops would help in creating a village-type atmosphere. These shops could include the sale of flowers, house plants, fruits and vegetables, seafood and fish for the aquarium hobby.

11.6.21 **Component 24:** Landmark Monument

The central park/plaza area would be the ideal place to erect some type of pylon or sculpture to provide an orientation and identity landmark for the entire Park.

This monument could include connotations about the ocean water thermal conversion technology or locally applied sustainable strategies, as a reminder of how technology can make a difference in the quality of life of a population.

It could also include some type of allusion to the town of Yabucoa and include the name of the Project. It could also incorporate some type of useful infrastructure technology, and not only be a commemorative structure. The design of this monument could be the object of an open competition.
11.6.22 **Component 25: Boulevard**

The main street should be designed as a boulevard. This would mean that sidewalks should be wide, with trees, benches and other urban furniture, and a distinctive pavement pattern and material. The inclusion of bicycle lanes would also be important. The general character of this street should promote walking at different rhythms and bring a sense of well-being.

More details about the boulevard components and materials are included in Chapter 12 of this document.

![SECTION](image)

*Figure 115. Concept section through boulevard*

11.6.23 **Component 26: Public bathrooms and refreshment building for the bathers at Lucia Beach.**

This building should have bicycle stands and designed in an attractive way. It would be part of the renovation of Lucia Beach. Small food concessions would be included, but the building would not be located inside the Project’s lot so that they can function independently from it and may be leased by the Municipality of Yabucoa. In this way, they could be open at times that do not need coordination with the Complex’s administration.

11.6.24 **Component 27: Available Area for Industrial Park Extension**

This area will be reserved to expand the industrial park components in the future, if needed be.
12.1 Introduction

As stated above in this document, the general character of the Complex must be conceived as environmentally friendly with a pleasing atmosphere for visitors and workers alike. The technological aspects of the project must be incorporated in such a way that it blends with all other aspects of the Park, instead of standing out.

This does not mean that the different technologies should or must be hidden or camouflaged. Instead, they should be treated with sensitivity to the contexts—both of the Project itself, and its surroundings. It is very important that visitors not familiar with technical know-how don’t feel intimated, and that they can accept it as part of the daily life of a society in a completely natural way and not menacing at all. Instead, they, particularly people of certain age not used to these types of advances, must be able to understand, accept and embrace the fact that new technology is already—and will even be more in the coming decades—a very important component of better qualities of life. This does not intend to mean that the traditional ways of carrying out work, manufacturing or bringing services to the population are all necessarily obsolete. But, although the manner in which social interactions should remain the same, there’s no way we can, or should stop, progress in many areas of the society. In fact, social interaction must also be improved and better encouraged by technology, and this must be one of the messages of PROTECH, the impression left in those who visit the Complex and the sense of those who will work in it.

An administrative entity will be in charge of formulating the final design parameters of the Park and reviewing and approving the design submittals. The standards presented here have no detailed specifications. But, in general, they must strive to:

- Institute buildings forms, layouts, materials and circulation components that will enhance the Project’s realm
- Ensure a sense of place and identity through harmonious and thoughtfully designed buildings and outdoor spaces
- Encourage outstanding design in accordance to the established Project standards

12.2 Context

To maintain the particular identity, sense of place and unified context of the Project, the vehicular circulation, sidewalks and buildings’ configurations and typologies must follow some standards.

Due to the proximity of the ocean, storm surges and high velocity winds are a possibility. Thus, it is recommended that in certain cases nearest to the ocean, some buildings be lifted from the ground. This strategy could result in not only in a safety measure, but also as a way of adding attractions and outdoor amenities without affecting the land beneath the bulk of the buildings.
Although the Lucía Beach is not within the proposed Project limit, it should be cleaned and restored as part of the master plan in coordination with all the governmental agencies with jurisdiction. This not only will benefit the Project, but it will also help in attracting visitors and help the community.

![Lucía Beach before Hurricane María, a long stretch of clean sand and transparent water. Photo by Apple Maps.](image)

**Figure 116.** Lucía Beach before Hurricane María, a long stretch of clean sand and transparent water. Photo by Apple Maps.

Inside the Project’s premises, as mentioned before in this document it would be in the best interest of the Project’s visitors and working population to be able to walk in the shade and protected from the rain as much as possible. **Buildings along the main street-boulevard should provide covered galleries and arcades to cover sidewalks.** Industries and companies that would like to showcase their products and services could use this to their advantage by **exhibiting their activities with the use of storefronts** and, in this way, arouse curiosity and invite people to enter their premises as an advertising strategy. All the Project’s buildings would also be required to provide, at least in its ground level a continuous perspective along the streets by joining their façades. Open spaces and landmarks would break this continuity to make them stand out and establish a clear hierarchy.

### 12.2.1 Buildings

Similar features, forms, patterns and materials should be repeated in the Complex’s buildings to relate to the overall built character. An architectural “vocabulary” that permits variations within uniform parameters will be developed.

Apart from creating optimum conditions for workers, buildings within the Project must invite and engage visitors whenever this is desired. It is important, then, that the relationship between the exterior and interior be addressed with this in mind. Building designers will have to address issues such as orientation, entrance character, views, and, of course, as stated earlier, materials and systems.

As much as possible, always orient building entrances to circulation components so that they are readily visible and identifiable in a way that they contribute to the social experience. Emphasize the architectural design of entrances, lobbies and exhibition spaces within the
buildings. Avoid opaque walls and heavily tinted glass at ground levels facing sidewalks and open spaces. As stated in the Context section above, provide shelter to pedestrians.

Parking lots, service areas, loading areas, garbage stations and mechanical areas should be visually minimized. They should not conflict with public rights of way and screen them with built elements. Using landscaping to entirely cover these areas is not advisable because of the non-permanent nature of plants. If the buildings do not contain parking lots, provide at least parking for the disabled.

12.2.2 Open Spaces

Outdoor spaces and natural amenities - green areas, parks, gathering spaces, beach - provide spaces for leisure, respite and social interactions.

Buffer open spaces from traffic with trees, but not with bushes that could obstruct the view toward them from the streets and surrounding buildings. Define its edges with different pavement types or urban furniture devices such as bollards, lighting (posts or floor installed) and benches, but, again, do not block views.

Provide urban furniture as specified below in the Urban furniture, Wayfinding, Building Signage section of this document.

12.2.3 Materials, systems and utilities

Materials must be similar in finish, size, scale and tonality in both buildings and open spaces, except where extraordinary conditions are desirable such as in the Project’s landmarks. But, even in these cases, they should not deviate excessively from the assigned parameters.

The materials chosen for the building’s façades, exterior surfaces and interiors should be sensible, pragmatic and aesthetically pleasing. Again, this does not mean at all that materials developed with new technologies are not desirable, but instead, that the technologies used for manufacturing new materials should have incorporated aesthetic qualities, and that special care should be taken when choosing them. However, a novelty factor should not overshadow the rest of the Complex’s surfaces nor clash with them. If this occurs, a clear hierarchy between the Project’s components may be disturbed. On the other hand, traditional and natural materials can look perfectly in accord with more recently developed ones to contribute with the Project’s character intention of mixing traditional and progressive characteristics, if incorporated in a balanced manner. In fact, the materials selected can be very good communicators. Glass, for example, is always welcomed for several reasons and it implies transparency, which is one of the goals PROTECH should convey in its mission to demonstrate its environmentally friendly intentions.

Materials should also be weather resistant, considering Puerto Rico’s humid and hot tropical climate, as well as the Project’s location microclimate. The lot is next to a beach, and the most important function of the Complex is ocean research and its most significant component is the Deep Ocean Water Plant. It would be contradictory to choose materials that would easily corrode with salt air and water, and more so when corrosion research may be one of the main fields of study. This, of course, means that selecting metals will require special attention. Also, the use of available local materials, whenever possible, is encouraged.
Another condition to consider is resistance to natural disasters. It is imperative to comply with all applicable codes, and, if possible, surpass its requirements, which, in some cases, go beyond purely structural ones. Glass, for example, when required by codes, or when deemed desirable as a mean for avoiding damages, should be impact resistant.

Much of the discussed above not only applies to buildings, but to circulation pavements and open spaces as well. It is important that walking surfaces not be slippery and that their materials be durable, aesthetically pleasing and have low-maintenance properties.

**Energy and water saving systems**, including water tanks, cisterns and rainwater harvesting must be included in all buildings. Green roofs should be considered whenever possible, and environmental-friendly waterproofing with high albedo reflective membranes and low maintenance and easy repair properties should be contemplated. However, waterproofing system warranties should comply with wind speed resistance according to the latest version of the American Society of Civil Engineers (ASCE) and the Puerto Rico Codes wind speed micro zones. Solar panels and even photovoltaic sculptures could be provided on building's roofs and in open spaces.

**A recycling program** should be established in all the premises. These requirements should be considered as complementary to the deep ocean water technology and send a clear message of PROTECH's intentions regarding a cleaner and less wasteful environment. Heat gain caused by exposure to the sun should be kept to a minimum. The designers of the buildings must take into account the buildings' orientation and protect windows and openings with shading devices. Again, some of the water for chillers would be provided by the ocean thermal energy conversion plant, but if cooling needs become less, it could serve more buildings.

Do not place mechanical rooms with chillers, air handling units or other similar equipment adjacent not near spaces such as meeting rooms, classrooms, laboratories and conference rooms. If cooling towers are placed on ground level, they should be covered in an aesthetically pleasing manner.

**Utilities** should be located according to the governmental agencies requirements unless a waiver is obtained. They should be installed underground whenever and wherever possible. Do not place utility cabinets uncovered and neither in landscaped areas nor in public rights of way, and, preferably, if allowed by the government, do not place meters in front of buildings. Install backflow preventers.

Other systems such as communications are also extremely important. Antennae could be installed on top of the deep ocean water plant, as long as their installation is orderly. Cables should be covered. Also, make sure that hot spots exist in all public areas.

**12.2.4 Circulation: Pathways and Streets**

Walkways, bicycle lanes and streets are defined by the character of their boundaries. These boundaries not only should ensure safety and efficiency, but also provide a clear hierarchy and effective orientation. They also should provide special traversing and destination experiences.

All traffic, pedestrian and bicycle related elements such as crosswalks, signs, dividers, steps, curbs, drain inlets and traffic calming devices should be of high-quality materials, rust proof and aesthetically pleasing. Do not paint street curbs (use signs for non-parking zones) or ramps
for the disabled if alternatives are possible and acceptable by codes and government requirements and consider not specifying height differences between open areas and street surfaces if bollards or other open barrier options can be used. Traffic calming devices and speed limits must be installed and implemented. Crosswalks should be identified with different surface materials such as pavers instead of paint if possible. Be especially careful when using planters or dividers that are difficult to see at night, or have a height not easily discerned from the drivers’ field of view. Provide a woonerf street design on secondary streets.

A different type of pavement would be preferable for bicycle lanes, but if paint is used, do not paint over pavers and use a paint specifically formulated for this use with the stringent possible specifications for our climate. Use low “armadillo” type dividers with reflectors instead of bollards. Parking will not be permitted along the main boulevard street nor on secondary streets.

The administration could also consider adding a small electrically powered shuttle service as a way of moving people from the retail center to the deep ocean water plant, the amenities to the east, and the beach.
Figure 117. Covered sidewalks concept along main street-boulevard with storefronts
Figure 118. Concept plan and section through main street – boulevard
Figure 119. Concept plan and section through main street – boulevard (showing only one-way traffic lanes)
Figure 120. Concept plan and section through typical street between tenant lots
**Figure 121.** Concept plan and section through raised walkway for pedestrians and bicycles
12.2.5 Landscaping

The type of landscaping chosen must also respond to the microclimate of the area where the site is located, including the amount of rainfall, the average temperature, the type of soil, etc. It is therefore important to consider trees and vegetation that grow naturally in this environment rather than plant exotic specimens. The latter could be specially cultivated for commercial or research purposes in the agricultural fields provided for industries within the Complex, but not be part of the general landscaping.

In general, shrubs that may become visual obstructions should be avoided in some areas inside the Project’s perimeter for different reasons such as security and maintenance. Generally, plants should not be used to cover unsightly areas or equipment because if they do not thrive, these areas will become exposed. Ground covers needing little maintenance is preferred to grass, unless the species of grass selected is sturdy and easily maintained. Take special care by not selecting plant species that are poisonous to humans and animals, or that may cause allergies. Trees or shrubs that have a destructive root system should not be planted anywhere in the Project, neither those with thorns, spines or spinose teeth. Trees with fragile trunks and branches should be avoided (such as Casuarina, also known as “Australian Pine”, which grow naturally near the shore and are common in this type of habitat). Species that have proven to be able to withstand high velocity winds must be considered. Fruit trees should also not be allowed except only in the agricultural fields. Trees that produce food for birds or pests won’t be acceptable. Coconut palms will not be permitted inside the Project’s area. Evergreen or semi-deciduous trees are preferable for the obvious maintenance reasons. Flowering plants should be native.

When adding other landscaping components, take into account the dangerous effects of potential projectiles (do not use stones or any hard component that may also be blown away by the wind, such as small pebbles) and consider any measure that would help in not retaining water. It is very important to achieve the best possible drainage if grading variations are designed either for optimum discharge, aesthetic reasons or any other function.
Finally, trees and plants located inside the Project, including those along streets and in open areas, could be species cultivated in the agricultural fields of the Complex. This, along with species identification by way of a Wayfinding program, would advertise the production of the several companies using the premises.

12.2.6 Urban furniture

Urban furniture and wayfinding elements such as benches, signs, banners, streetlamps, planters, traffic barriers, kiosks, outdoor sculptures, waste receptacles, tree grates, bicycle racks and stands, among others, should be similar throughout the whole Project, with distinctive appearance and materials. However, this does not discard the use of different types in special areas if deemed appropriate or desirable.

All the urban furniture should be manufactured with durable, rust proof, and, if possible, recycled materials, and simply styled so as not to compete with the natural landscaping.

Street lighting should be solar-powered (but also optionally connected to the electricity system as a backup measure), LED type, and not causing light pollution. This latter condition would also apply to building signs. Lamps in posts and their anchors to the posts (including the solar collectors) should be able to resist at least 180mph wind gusts. All the lighting components must be rust and salt air corrosion proof.

12.2.7 Wayfinding, General and Building Signage

A wayfinding program must be considered and designed as an important element of the overall identity of the Project. Apart from that, the benefits of orientation also help by anchoring the sense of place and belonging to the working population of the Park and helping with the educational aspects and its fields of interest. Also, and still more important, it can disseminate one of the fundamental missions of PROTECH: advancing the beneficial properties of new technology to be accepted as part of the daily life of a society.

Materials used for the wayfinding components, and its fabrication and assembly, are of the utmost importance due to their exposure to the environment, and more so in this case, where saltwater spray and air will be present. The range of materials vary according to their category: metals, glass, wood, stone, plastics, composites and recycled. Vitreous or porcelain enamel would be a good choice.

Information included in the wayfinding components include orientation, information about specific areas of the Complex, (buildings, open spaces, landmarks and premises), history (the Lucía Plantation), environmental information (how some energy saving systems and rainwater harvesting operate), services locations (bathrooms, first aid, hot spots, rest areas), the Complex’s behavioral rules and identifications of the tree and plant specimens inside the Project could be added as an educational tool. In that same way, if fish are included in the Project’s leisure park ponds, signs could also be posted with information about them.

The wayfinding components will be divided into those meant for pedestrians and those directed at vehicle drivers (traffic signs and orientation) with the appropriate scale for each case (cyclists will be able to access both).

Wayfinding components can also be used to educate and explain the technologies used in the Project along its pedestrian routes, with basic information and graphics in a casual.
way, but with a clear purpose: increase awareness about the need to achieve a better quality of life in the present and its consequences for the future. This information could also be accessed through the use of Quick Response (QR) codes to serve as guides with more detailed information and with audio tours.

The wayfinding program can also include literature of different types: brochures, maps, guides, facilities information (and their products) and technological information.

Figure 123. Wayfinding concept components
13 COOLING, POWER, AND SEAWATER SUPPLY (CPSS) SYSTEM & OTEC TECHNICAL ASPECTS

13.1 Minimum Requirements for Deep Ocean Water System Major Components

Proposers are required to design, build, test, commission and provide initial operation and maintenance services for a deep ocean water (DOW) system that will serve an ocean technology compound. The Complex will include (1) a land-based ocean thermal energy conversion plant (OTEC), (2) sea water air conditioning for the various components of the Complex; (3) aquaculture; (4) production of various commercial products related to DOW; (4) research in DOW applications. The key components in the Complex will be the DOW (cold) and surface (hot) water intakes, the OTEC plant and the water return lines. This document presents a number of minimum technical requirements for these critical components, which must be included in all proposals.

Proposers are free to offer alternate systems that exceed these requirements, in addition to, and not in lieu of, the basic proposal that must address these minimum requirements.

(1) Deep Ocean Water Supply Pipeline: As a minimum, must have sufficient capacity to supply the following demands.

- 0.5 MWe net OTEC plant in baseload (continuous) operation. See section (3)
- 3,250-ton sea water air conditioning system
- 35,250 gallon per minute flow to aquaculture system
- 1,000 gallon per minute “clean” DOW line for critical applications

The intake pipe from the ocean should include a main discharge to the OTEC plant, with a secondary smaller discharge to directly feed critical applications (such as potable water and pharmaceutical production) where ultra-clean DOW is needed. Intake system must be provided with equipment that will trap and remove any suspended or impinged materials and organisms from the DOW before it is sent to the various uses.

For the installation, construction and deployment of the ocean water supply pipelines there are available port facilities (Port of Yabucoa) north of the proposed site, that can be used for that purpose. The Port of Yabucoa is managed by the PR Ports Authority and has a navigation channel depth between 45' - 60'.
(2) **Surface (hot) Water Supply System:** As a **minimum**, must have sufficient capacity to feed the proposed OTEC plant (see section (3) below). Either a surface channel or submerged intake pipeline may be used for this purpose. The surface water system must be providing with systems that remove sand ("grit"), algae, debris, and other suspended or impinged materials and organisms from the surface water before it is sent to the OTEC plant.

(3) **Ocean Thermal Energy Conversion (OTEC) Plant Minimum** design requirements are the following:

- OTEC plant must be **closed (Rankine or similar) cycle**.
- Thermal fluid used must not contain chlorofluorocarbons (CFCs)
- Plant must be capable of **continuous, baseload operation (24/7)**
- Net electrical output (after parasitic losses) must be at least **0.5 MWe**
- Plant must be composed of **at least two parallel flowsheets**, so that in case a flowsheet is temporarily removed from service for maintenance or repairs, at least 50% of the total capacity is maintained.

(4) **Water Discharge System:** Minimum requirements are:

- Joint (spent DOW + surface water) or separate discharges may be used
- Discharge may use a single large pipe or several parallel pipes, as appropriate
- Discharge system must be configured to avoid affecting the temperature of warm surface water used as intake for the system.
- Effluents containing deep ocean water (DOW) must be discharged at a minimum depth of **100 meters** and at a distance of **not less than 500 meters** from the shore.

(5) **General Design Requirements**

The proposed system is meant for **continuous baseload operation**. For this reason, it must be based on **commercially available components**, these include pipes, pumps, heat exchangers, turbines, etc.

Proposers **may** elect to offer alternate designs based on components to be developed ad-hoc for this application. However, any such proposal must be submitted **in addition to**, and **not in lieu of**, a basic proposal that must address the minimum requirements presented in this document.

### 13.2 OTEC Technical Aspects

**Preliminary Assumptions**

The minimum array of pipes necessary to operate an OTEC plant is three: one cold water intake pipe, one warm water intake pipe, and one discharge pipe. The three pipes reach different depths based on their specific requirements. The depths assumed for each pipe is presented below along with Makai’s rationale for the depth selection:

- **Cold water intake pipe**: 1000 m intake depth. A 1000 m cold water intake is typical for OTEC designs and has been found to represent an economic optimum on previous projects. Different intake depths will be considered during the conceptual design phase.

- **Warm water intake pipe**: 10 m intake depth. At 10 m water depth, the warm water intake will be just outside the wide reef found at all the proposed sites. If it is discovered that a shallower intake might be permitted, then alternate warm water intake depths can be considered during the conceptual design phase.

- **Discharge pipe**: 100 m discharge depth. At 100 m water depth, the discharge will be below the photic zone, minimizing the risk of nutrient-rich deep seawater triggering excessive algal growth in the area. If it is discovered that a shallower discharge might be permitted, then alternate discharge depths can be considered during the conceptual design phase.

The following figure, extracted from this document, shows the bathymetric profile at each site and the table shows the length of pipe required to reach the three different depths specified above:
The long distance to 100 m water depth makes it questionable whether a single discharge pipe is adequate. Therefore, Makai used two discharge pipes, making the minimum OTEC configuration a set of four pipes. The number of discharge pipes will be further evaluated during the conceptual design phase.

HDPE manufacturers offer pipe diameters up to 2.5 m in diameter. However, pipes larger than 2.0 m in diameter present significant technical and financial risk. Large diameter pipes are very buoyant when filled with air and therefore need large concrete weights attached to them. During deployment, when most of the pipeline length suspended in the water column is flooded, these weights pull the pipeline down which results in a reduced top bend radius. To overcome this radius reduction and to protect the pipe from overbending/kinking during deployment, very large pulls on the offshore end of the pipeline are necessary. While few tug boats exist that can exert the necessary pulls, they are usually booked for years in advance by the offshore oil industry. Two complications arise from this scenario: Firstly, the difficult scheduling creates a financial risk for the contractor, which he will pass on to the client. Secondly, in case of any technical issues/failures on the boat, there probably won’t be a second one available to maintain the offshore pull which would potentially lead to the destruction and loss of the whole pipeline.

Makai therefore recommends to limit the pipe diameter for deep water deployments to 2.0m. Additionally, there are only a few manufacturers worldwide that can produce large diameter pipes with sufficient wall thickness. A2.0m pipe can potentially be purchased in North America, which would greatly reduce shipping costs.
**Results**
Makai developed preliminary designs for 1 MW OTEC plants at each site with the minimum array of 4 x 2.0 m pipes. The cold-water intake pipe at Arroyo is so long (and suction head so great) that the minimum pipe array was not able to supply 1 MW. Therefore, the Arroyo site is unique in that its minimum pipe array includes two cold water intake pipes, for a total array of 5 pipes.

A sensitivity study was carried out on the net power production of each design to determine if more than 1 MW could be extracted from the minimum pipe array. The results of the sensitivity study are:

- 1 MW is the maximum net power output that is technically feasible at Arroyo and Yabucoa (with Arroyo requiring 2 cold water intake pipes).
  - A net power output of 800 kW may be more cost effective at Arroyo and Yabucoa. The actual recommended power output will be determined during the conceptual design phase if one of those two sites is selected.

- The Maunabo site can support a net power output of 1.2 MW. Producing 1.4 MW is technically feasible, but it may not be cost effective. That will be investigated during the conceptual design phase if the Maunabo site is selected.

The following table summarizes Makai’s view of technical and economic feasibility of various size OTEC plants at each site.

<table>
<thead>
<tr>
<th>Site</th>
<th>0.8 MW</th>
<th>1 MW</th>
<th>1.2 MW</th>
<th>1.4 MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maunabo</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Possibly</td>
</tr>
<tr>
<td>Yabucoa</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Arroyo</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

**Figure 126.** Technical and economic feasibility of various size OTEC plants at each site

**Recommendations**
Considering the above analysis, OTEC plants larger than 1 MW do not warrant further analysis. The pipe arrays required for the larger plants represent significant technical risk, environmental impact, and high cost. For example, 2 MW plants would likely require arrays of 6-8 pipes, while 5 MW plants would likely require arrays of 14-24 pipes. Makai does not believe such large pipe arrays could be installed cost-effectively.

**Conclusion**
Makai has completed an initial review of OTEC systems with a net power capacity of 1 MW at each of the three sites. The results suggest that the original array of OTEC capacities to be evaluated (1 MW, 2 MW, 3 MW, and 5 MW) are not all practical.

However, as stated before, although the previous analysis suggests specific elements for plant feasibility under various scenarios, proponents are strongly encouraged to recommend alternatives that can work in the selected premises for the project.
14 PERMITTING PROCESS

14.1 Environmental Impact and Permitting Issues

General

Environmental management is a key component in the implementation strategy. PROTECH is a high-importance project with major national, and even international, visibility. For the effort to be successful, public information and participation is essential, as well strict compliance with all applicable environmental laws and regulations.

To successfully implement and operate the project, environmental issues must be properly addressed and presented to the public in an open manner. This approach will ensure that PROTECH is supported by the public and will also expedite the permitting steps that are necessary to bring the project to fruition as soon as possible.

Environmental Review Process

Given these considerations, the environmental review process which is prescribed by both the National Environmental Policy Act (NEPA) and the Puerto Rico Environmental Public Policy Act (LPPA, by its Spanish acronym) will serve as a major tool, not only in the permitting process, but also as a key tool for planning, and project management.

Both federal and local laws require that the environmental review process be completed before the actual permitting stage for the project starts. However, the process should not be viewed as an obstacle to development, but rather as a very useful tool that will ensure that a project is properly evaluated and presented to the public; this will result on the support of both stakeholders and the general public and expedite subsequent permitting stages.

A properly conducted environmental review process provides an opportunity for community members and other stakeholders to be involved in the decision-making process. It will help the community and concerned agencies to understand what is being proposed, to offer thoughts on alternative ways for the project to be implemented, and to present comments on the proposer’s analysis of environmental effects, and the ways any such effects can be mitigated. The process also requires key aspects such as potential impacts on natural, social, cultural, and economic resources to be properly addressed.

At the local level, the environmental review process is based on the requirements of Article 4 (B) (3) of the 2004 Puerto Rico Environmental Public Policy Act (Law #416 of September 22, 2004), which requires agencies to properly assess the environmental effects of proposed actions prior to making decisions (such as undertaking a project or issuing permits). Compliance with this requirement is mandatory for all projects undertaken in Puerto Rico.

If a project involves significant federal actions, such as an issuing endorsement, permitting or providing funding, compliance with the requirements of the National Environmental Policy Act (NEPA) is also required. Requirements of NEPA are similar to, but more structured and stringent than, those required by the Puerto Rican LPPA. For this reason, current Puerto Rican regulations consider that compliance with the NEPA environmental review process also serves to comply with local review requirements (Refer to Appendix 2 for a visual guideline for the environmental review process, obtained from the “Citizen’s guide to NEPA”, Council for Environmental Quality).

An environmental review can have three different levels of analysis. These are:
• **Categorical Exclusion determination (CATEX)**, for actions that will not have significant impacts on the environment.

• **Environmental Assessment and Finding of No Significant Impact (EA/FONSI)**, a more detailed process in which the potential effects of a project are formally assessed. If it is found that the project will not have significant environmental impacts, a Finding of No Significant Impact (FONSI) is issued. This is a document that presents the reasons it has been concluded that there will be no significant environmental impacts.

• **An Environmental Impact Statement (EIS)** is required when it is determined that a proposed action has the potential to significantly affect the environment. Requirements for an EIS are more detailed and rigorous than the requirements for an EA/FONSI. Exceptions to the normal EIS requirements may apply for certain specific cases, such as some actions covered by the PROMESA act, and some defense or emergency projects.

However, as a major project of significance, it is anticipated that PROTECH will require a full NEPA EIS process, unless it is found that some of the PROMESA provisions can be used to expedite the review process. For example, PROTECH can be considered as a strategic project under Puerto Rico Act. No. 19-2017, which states that projects that “are considered major, or for which the state has a compelling interest, either because of its nature or its impact on economic development, shall have priority over other projects before all state agencies”.

The EIS process requires public information and participation activities be conducted, and that a draft EIS, a detailed document describing the proposed action, its potential environmental impacts, and alternatives to the proposed action, be prepared. The draft EIS is circulated to concerned agencies, stakeholders and the public, all of whom are allowed to provide comments. Public hearings, where members of the community can comment and provide suggestions for the project, are conducted.

In order to ensure the successful implementation of the project, PROTECH development efforts will need to comply with several federal and local laws and permits:

- Clean Air Act
- Clean Water Act
- Endangered Species Act: Habitat Conservation Plan
- Marine Mammal Protection Act
- National Environmental Policy Act
- Ocean Thermal Energy Conversion Act of 1980
- Energy Policy Act of 2005
- Mitigation, Adaptation and Resilience to Climate Change Act of 2019 (Ley de Mitigación, Adaptación y Resiliencia al Cambio Climático de Puerto Rico, Ley Núm. 33).
- General requirements for construction in Puerto Rico, as defined throughout the Reglamento Conjunto para la Evaluación y Expedición de Permisos Relacionados al
Desarrollo, Uso de Terrenos y Operación de Negocios, in effect since June 7, 2019, including, but not limited to, Chapter 9.

- Green Permit (Permiso Verde) as stated on Chapter 3.3 of the Reglamento Conjunto para la Evaluación y Expedición de Permisos Relacionados al Desarrollo, Uso de Terrenos y Operación de Negocios. Proposed projects that obtain a green design certification and meet the requirements contained in the aforementioned chapter, will be exempt from the contributions of impact levies.

It is foreseen that the federal agencies consulted will include, but not be limited to:

- U.S. Environmental Protection Agency (EPA) (Ammonia Tier I & II)
- Federal Energy Regulatory Commission (FERC) (Office of Energy Projects: Division of Hydropower Administration and Compliance)
- Federal Emergency Management Agency (FEMA)
- National Oceanic & Atmospheric Administration (NOAA)
- U.S. Army Corps of Engineers (COE) Jacksonville
- U.S. Geological Survey
- United States Fish & Wildlife Service (Regional Office – PR)
- National Marine Fisheries Service (Office of Protected Resources & Office of Ocean Minerals and Energy)
- Federal Aviation Administration
- U.S. Coast Guard
- U.S. Department of Energy
- Department of the Interior (Minerals Management Service) (Outer Continental Shelf Lands Act)
- Department of Health and Human Services
- Public Health Service
- U.S. Department of Commerce
- Council on Environmental Quality
- Federal Aviation Administration

Permits and reviews, from a federal level standpoint, can include, but not be limited to:

- USCoE Permit
- USCG Bridge Permit (Rivers & Harbor Act, Section 9)
- USCG Marine & Harbor Activities Notice
- Environmental Impact Assessment
- NOAA:
  - Incidental Take Statement (Section Endangered Species Act, Sec. 7(a)(2))
  - Incidental Take Permit (Section 10 (a)(1)(B))
  - Letter of Authorization
- USAWS:
  - Incident Take Statement (Section 7(a)(2))
  - Endangered Species Act
- FERC Hydroelectric Project Authorization (Section 10(a)(1)(B)) – Licenses & Exemptions
- EP Act – DOE (Section 931 (a)(2)(E)) Renewable Energy Miscellaneous Projects
- Deep Water Port Act of 1974
- Outer Continental Shelf Lands Act
At the state (local) level, it is anticipated that the agencies and entities to be consulted will include, but not be limited to:

- Puerto Rico Planning Board
- Puerto Rico Permits Management Office (OGPe)
- University of Puerto Rico
- Puerto Rico Electric Power Authority (PREPA)
- Puerto Rico Aqueduct and Sewer Authority (PRASA)
- Municipalities of Yabucoa and Maunabo
- Department of Natural and Environmental Resources (DNER) (including the Environmental Quality Board and the Coastal Zone Management Program). It is recommended that the following procedures be managed at the beginning of the permitting process:
  - Habitat Certification
  - Hydrologic and Hydraulic Studies
  - Wetland Delineation
  - Water Quality Certification (Section 404)
- Coastal Zone Management Program
- Puerto Rico Energy Regulatory Bureau
- Puerto Rico Telecommunications Regulatory Bureau
- Puerto Rico Planning Board
- Puerto Rico Ports Authority
- State Historic Preservation Office
- Puerto Rico Department of Health
- Puerto Rico Department of Agriculture
- Fire Bureau of the Puerto Rico Public Safety Department
- Department of Transportation and Public Works
- Puerto Rico Highway and Transportation Authority
- Puerto Rico Tourism Company
- Department of Economic Development and Commerce
- Pertinent NGO’s and community organizations
- Third tier permits, such as, but not limited to:
  - Utility Permits (Puerto Rico Electric Power Authority)
  - Puerto Rico Energy Regulatory Bureau
  - DEDC Energy Policy Program

All pertinent comments must be addressed. When the process is completed, a final version of the document, incorporating responses to all comments is prepared and provided to the public and concerned agencies. The EIS process ends with the issuance of the Record of Decision (ROD) by the sponsoring agency. The ROD is a document that explains the agency's decision, describes the alternatives the agency considered, and discusses the agency's plans for mitigation and monitoring, if necessary.

Permitting Phase
As previously noted, the environmental review process must be completed before the actual permitting stage for the project starts. If, as expected, the environmental review process for the project is successfully completed, permits that may be required will include, but not be limited to:
• Puerto Rico Planning Board
• NPDES permit from EPA for OTEC discharges
• Water Quality Certification (WQC) from EQB/DNER Water Quality Area
• Air emissions permit from EQB/DNER Air Quality Area
• Water Extraction Franchise ("franquicia") from Puerto Rico DNER
• PREPA interconnection and power purchase and operating agreement
• PREPA endorsement to design of connection for auxiliary electric service
• Endorsement from the Puerto Rico Aqueduct and Sewer Authority (PRASA)
• Endorsement from the Puerto Fire Bureau
• Access endorsement from the Department of Transportation and Public Works
• Endorsement from the Municipality of Yabucoa
• Construction (building) permit from the Permits Management Office (OGPe)
• OGPe “Permiso Único Incidental”
• EPA Notice of Intent (NOI) and plan for coverage under the Construction General Permit
• Corps of Engineers 404 permit for intake and discharge line construction
• EPA NOI for stormwater associated with industrial activities
• EPA Risk Management Plan (RMP) requirements (if ammonia is used as working fluid and more than 10,000 pounds will be present in the system)
• Spill Prevention, Control and Countermeasures Plan (SPCC) plan for petroleum product
• Any other permit or endorsement identified in the environmental review phase.

In summary, the proposed PROTECH project will comply with all applicable review, endorsements and permitting requirements at the federal and state levels.
15 DEVELOPMENT PHASES

15.1 General Timeline

The following timeline provides a general framework to understand the project’s development phases composition.

**Figure 127.** General Timeline for the Project
16 ECONOMIC AND FINANCIAL FEASIBILITY

16.1 Introduction
A financial model for the industrial park was built in order to test the sensitivity of some key assumptions on the development of the industrial park.

16.2 Methodology
The first step was to build a set of assumptions that reflect the most likely revenues and costs estimated underlying the project. The second step involves an estimation of the value added to the park by having an OTEC energy plant on site. Using industry standards on financial analysis, a projection of the expected accounting headlines for the first years of operations of the Park was developed. The analysis of these projections provides an assessment of the feasibility of this project.

16.3 Financial Assumptions
The following images represent the analysis made to understand the Project’s feasibility:

Capacity and Park Size

Figure 128. Capacity and Park Size
### The Value Added by the OTEC Plant to the Park

The key consideration in the financial estimates is the value added by having an OTEC plant within an industrial park. To determine the monetary value of having an OTEC Plant, the savings in electricity and water were considered as the main drivers. This value will depend on the amount of energy and water consumed by the tenants.

It is assumed that the OTEC Plant will reduce electricity and water costs by an aggregated average of 40%.

This percentage of savings include the cost to warm and/or to cold water for use in other processes, including HVAC.

Also, the expected electricity cost of the tenants most likely to occupy the park was considered.

### Other Assumptions

According to a survey in 11 cities conducted the Boyd Company in 2017, the energy cost for food and beverage processing plants is around $2.66 per sq. ft.

- This is based on a cost of industrial electricity of 11 cents per kwh.
- In Puerto Rico, where the industrial rate is around 19 cents per kwh, the energy cost per sq. ft. should be around $4.60 for a food processing plant.
According to The Pharmaceutical Engineering Magazine (vol. 33 no. 5, 2013) the median energy consumption of a pharmaceutical is 410 kWh per sq. ft. In Puerto Rico this will amount to $80/sq. ft. of annual energy cost for a pharmaceutical.

**Conclusion on the Value Added by the OTEC Plan to the Park**

In terms of the development of an industrial park, the main value proposition of the proposed Yabucoa facility depends on the potential savings for industrial customers who benefit from such utilities, but who also have strong synergies with the area. For an average food processing plant, this can represent on average $1.84 of operational cost savings per square feet of construction.

<table>
<thead>
<tr>
<th>VALUE ADDED BY AN OTEC FACILITY TO AN INDUSTRIAL PARK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline cost of electricity, $ / sq ft (1)</td>
</tr>
<tr>
<td>Percent savings by OTEC in baseline electricity cost</td>
</tr>
<tr>
<td>Value Added by OTEC to an Industrial Facility (1), $ / sq ft</td>
</tr>
</tbody>
</table>

(1) For industrial uses with energy requirements similar to Food Processing

**Figure 13.1.** Value added by an OTEC Facility to an Industrial Park

In terms of the financial simulation, this fact translates into the assumption that tenants will be willing to pay $1.84 of extra rent -above market rent- to locate in a park serviced by an OTEC plant (all other things remaining constant).

**16.4 Baseline Financial Projections**

Based on the previous assumptions, the following table summarizes the headline financial projections for the operation of the Park:

**Figure 13.2.** Headline Financial Projections for the operation of the Park
16.5 Conclusion: Requirements for Project Feasibility

Based on the financial model developed for the project, it is possible to estimate how much additional investment in the form of federal grants or other grants under local law will be required to make the project feasible.

The previous analyses show that the project’s feasibility is heavily burdened by the size of the OTEC Plant. If the state decides to promote and partially subsidize the project, it is expected strong forward and backward linkages with the local economy. Moreover, the economic impact in the area will be substantial due to the low economic activity of the region.

Under the aforementioned assumptions this project would require an initial subsidy of around 54 to make the project break even.

The financial model can be made to work backward to determine how much subsidy the initial investment need to turn this project into a financially feasible one.
• If a 500 kW plant is to be built, and if other assumptions are as depicted in the baseline scenario, then, to make this project financially feasible, a subsidy of $54 million is needed.

Research has shown that Puerto Rico is in a unique geographic location to develop a project such as the one proposed: “Recommendation: Any future studies of the U.S. OTEC resource should focus on Hawaii and Puerto Rico, where there is both a potential thermal resource and a demand for electricity.” Source: An Evaluation of the U.S. Department of Energy’s Marine and Hydrokinetic Resource Assessments, The National Academies of Engineering, Sciences and Medicine, 2013.

Scenarios on basic rent:
To make this park work without a subsidy, the estimate basic rent per square feet must be around $14.50. This number is outside normal market rent ranges in this part of the Island for industrial spaces. But it is no unlikely that, if the park becomes a niche hub for specialized industries, these rent levels may be achieved.

**Figure 135. Sensitivity of the Project to Changes in OTEC Plant Size**

Scenarios on value added by OTEC to Park:
The baseline scenario assumes that the OTEC power plant add value to the industrial park by supplying cheap power and cold and warm water to the tenants. This value, in form of utility savings, are estimated at $1.80 per sq. ft. for the tenants, assuming a typical food processing plan needs.

But this value is heavily sensitive to the nature of the tenant operations. In the table we present several scenarios on the feasibility of the park based on several value-added assumptions.
Only, when the value-added reaches $9.94 per sq ft, the park is feasible. This number is achieved when the energy consumption of the tenants is $25 of electricity per sq. ft, which is a heavy load.
17 Funding Strategy

17.1 Introduction
The Puerto Rico Ocean Technology Complex (PROTECH) provides a unique opportunity to diversify the Island’s technological and industrial base, while also adding resiliency to an economically depressed area. This can be achieved due to various reasons such as:

- The main factor endowments for economic development are concentrated in a single location.
- Leverage on current public infrastructure (Yabucoa Port, deep water capacity, road infrastructure, waterfront access and ample land and natural assets for visitor-oriented economic activities).
- Strong potential for creating new job opportunities and technological development in a single location.
- Opportunity to focus reconstruction efforts in an area with strong multiplier effects, rather than small scatter developments with low impact.

This scenario can work if DDEC could become the main partner for public infrastructure improvements in the area, which are necessary for a research park.

17.2 Strategic Alliances
As part of the funding request for the PROTECH, ETI recommends using DDEC’s institutional capacity to engage local stakeholders and lead the infrastructure funding strategy. Strategic alliances could be developed with non-governmental organizations such as Invest Puerto Rico.

Such process must not be underestimated, as most of the funding sources incentivize the development of activities and programs which render benefits for multiple geographic locations. Thus, emphasis should be placed on spillover effects in a single location with multiple economic activities (academia, industry, municipality, central government, and visitor economy).

The particular planning typologies of the area will provide an opportunity to facilitate the development of the area. Beyond the use of focalized permitting procedures such as a “Consulta de Ubicación”, ETI recommends converting the master plan into a Special Area Plan. Such process will allow a deeper integration with the municipality and other key stakeholders.

17.3 Institutional Capacity – Responsible Entity
A Special Economic Development Corporation or a close collaboration with Invest Puerto Rico could be undertaken to improve the institutional capacity of the proposed development (i.e. legal figure within the Ley de Municipios Autónomos).

- Depending on the funding source and its method of distribution, a specific plan must be developed to improve the internal capacity to manage federal monies.
• Recommendations could include outsourcing the grant management process or partnering with the local government to access a particular set of funds.

NOTE: Certain fund categories are exclusively managed by local governments. These could include funds such as Section 108 Loan Program, Federal Transportation Authority, Critical Infrastructure Resilience Program and other planning possibilities.

DDEC Actions
Several of the funding sources will require matching funds or leveraging other sources of fund.

• DDEC or a newly created entity could provide long term maintenance agreements with the Municipality, as in-kind contribution.

• DDEC as a public entity will leverage public property and resources for basic infrastructure development. Infrastructure could include new streets, sidewalks, public plazas, green landscape, recreational waterfront facilities, stormwater control systems, energy resiliency systems, among others.

17.4 Proposal Planning (Pre-Award)
The development of multiple proposals for several funding sources will entail a constant monitoring of funding opportunities and creating internal capacity to manage the proposal writing and development process.

Based on our preliminary research PROTECH’s proposed development is best suitable for a mix of funds which include ordinary state development subsidies, FEMA Hazard Mitigation, private sources, Federal Transportation Authority, among others. For each of the funding sources a particular proposal must be developed and cross cutting issues must be addressed along the way.

Statutory deadlines and budgetary/disbursements cycles will vary in each of the funding sources.

The requirements will vary by type of fund and the specific activity within that fund. Even though PROTECH initiative may qualify for several funding opportunities, an analysis must be developed of the most suitable funding source, based on the program requirements and the organization’s internal capacity.

Although there are potentially several funding opportunities within the Community Development Block Grant – Disaster Recovery (CDBG – DR), it is important to understand that their availability will depend on final implementation of these programs and other requirements.

The proposal writing process will be focused on a set of programs or funding sources, which have the highest chance of success.
17.5 Economic Incentives

Several opportunities of economic incentives are available for this project. Puerto Rico is uniquely placed for a research and development outfit, and in terms of tax framework, the legislature has enacted several acts to move towards a knowledge economy, development and application of sustainable strategies.

Act 73, Act 74, Act 82, Act 83, Act 20 & Act 22

Following, a brief description of each one:

The Economic Incentives for the Development of Puerto Rico (Act 73), from May 28, 2008, is established to provide the right environment and opportunities to continue developing a local industry; offer an attractive tax proposal to attract foreign direct investment and promote the economic development and social improvement of Puerto Rico. Among its tax benefits are:

- 4% corporate income tax rate for manufacturing and related activities
- 50% tax credit for eligible research and development activities
- 90% exemption for 15 years on real and personal property taxes
- 60% exemption on municipal license tax

The Puerto Rico Tourism Development Act of 2010 (Act 74), from July 10, 2010, is established to provide incentives for the development of world-class tourism activities. Benefits granted under this law will be in effect for 10 years from the time the tourism project is eligible and eligible may be extended to apply to the operational phase for an additional 10 years. Among its tax benefits are:

- 10% tax credit of total eligible project cost or 50% of cash invested by investors (whichever is less).
- 100% exemption from special municipal taxes on construction
- 100% exemption from sales and usage taxes

The Public Policy of Energy Diversification through Sustainable and Alternate Renewable Energy in Puerto Rico Act (Act 82), from July 19, 2010, establishes the norms to promote the generation of renewable energy, according to the Renewable Energy Portfolio; create the Puerto Rico Renewable Energy Commission as the entity responsible for monitoring compliance with the Renewable Energy Portfolio established by this Law and clarify its duties; clarify the duties of the Energy Affairs Administration in relation to the Commission and the Renewable Energy Portfolio and other related purposes.

The Green Energy Incentives Act of Puerto Rico (Act 83), from July 19, 2010, is established to promote renewable energy generation; empower the Energy Affairs Administration to encourage compliance with the required goals, the development of sustainable and alternative renewable energies; create measures aimed at stimulating the development of sustainable energy systems that promote savings and efficiency in energy use, through the establishment of a special fund, called the Green Energy Fund, in accordance with the objectives of the new energy policy of the Government of Puerto Rico; reform, organize and standardize existing incentives related to the creation or use of renewable and alternative renewable energy sources and create new incentives that stimulate the proliferation of these energy sources, among other intentions. Some of its tax benefits are:
• 4% fixed preference rate on income tax
• 4% contribution on profits made in the sale or exchange of shares or assets
• 50% exemption from municipal license taxes and patents from Green Energy Exempt Businesses
• 100% exemption from sales and use taxes and excise on certain items used in connection with the green energy project
• 100% exemption from any tax, law, license, excise tax, rate or fee levied by municipal ordinance on the construction of works related to the green energy project
• 100% exemption from income taxes for dividends paid from income derived from renewable energy activities.

The Tax Incentives to Promote Export Services in Puerto Rico Act (Act 20), from January 17, 2012, is established to provide the right environment and opportunities to develop Puerto Rico as an international service center, promote the permanence and return of local professionals and attract foreign capital, thus promoting the economic development and social improvement of Puerto Rico. Among its tax benefits are:

• 4% maximum corporate tax rate
• Dividends and distributions from earnings and profits are tax exempt for Puerto Rico residents
• Certain investment income also qualifies for 4% tax rate 60% exemption on municipal gross receipts tax

The Individual Investors Act (Act 22), from January 17, 2012, is established to grant tax exemption with respect to income, product of investments, accrued by individuals who become residents of Puerto Rico, not later than the year ending December 31, 2035. Among its tax benefits are:

• Passive Income Exemption
  • New residents will enjoy a 100% tax exemption from Puerto Rico income taxes on all dividend and interest income.
• Capital Gain Exemptions
  • All capital gains accrued after becoming a new resident will be 100% exempt from Puerto Rico taxes. These gains will no be subject to federal taxes.

**Incentives Codes (Act 60)**
The Puerto Rico Incentives Codes Act (Act 60), from July 1, 2019, is established to consolidate the decrees, incentives, subsidies, refunds, or existing tax or financial benefits; promote the right environment, opportunities and tools to promote the sustainable economic development of Puerto Rico; establish the legal and administrative framework that will govern the request, evaluation, grant or denial of incentives by the Government of Puerto Rico; promote the effective and continuous measurement of the costs and benefits of the incentives granted to maximize the impact of the investment of public funds; give stability, certainty and credibility to the Government of Puerto Rico in everything related to private investment; improve the economic competitiveness of Puerto Rico and other related purposes.
This law should be implemented during the first half of 2020.

**PROMESA Critical Infrastructure & Strategic Projects**

On June 9, 2016, the Puerto Rico Oversight, Management and Economic Stability Act (PROMESA) was approved by the United States Congress, and thereafter enacted into law on June 30, 2016.

As such, the Fiscal Oversight Management Board (the “Board”) was appointed pursuant to PROMESA. The Board has the following principal responsibilities: (1) approving the fiscal plans submitted by the Governor of Puerto Rico in relation to the Government of Puerto Rico and its public corporations and instrumentalities; (2) approving annual budgets, enforcing the same, and ordering any necessary budget reductions when needed; (3) approving voluntary agreements with creditors; (4) providing an expedite process of approval for key infrastructure projects; (5) and reviewing laws, regulations, rules, executive orders, contracts for purposes of ensuring compliance with approved fiscal plans.

PROMESA generally applies to all agencies, departments, instrumentalities and public corporations of the Government of Puerto Rico, including DDEC, PRIDCO, and the LRA, which have been specifically listed by the Board as covered entities under PROMESA.

**Critical Infrastructure Projects under PROMESA and Act No. 76-2000**

Title V of PROMESA allows for several types of emergency infrastructure projects (including energy, water, sewer, solid waste, highways or roads, ports, telecommunications and other similar infrastructure) to be considered as “Critical Projects”. The approval, consideration, permitting, and implementation of a Critical Project shall be expedited and streamlined pursuant to local Act No. 76-2000 with regards to requirements under state law.

As to requirements under federal law, PROMESA provides that federal grants and loans applications for Critical Projects shall be reviewed in an expedited manner. Similarly, it provides that all reviews conducted, and actions taken by any federal agency relating to a Critical Project shall be expedited in a manner consisting with completion of the necessary reviews and approvals by the deadlines under the Expedited Permitting Process.

**Strategic Projects under Act No. 19-2017**

Puerto Rico Act. No. 19-2017, a comprehensive permits reform that was proposed and enacted by the current Administration, creates a special procedure for “Strategic Projects” that are considered major, or for which the state has a compelling interest, either because of its nature or its impact on economic development. Strategic Projects shall have priority over other projects before all state agencies.

These considerations will have a direct effect on the permitting phase of the Project.

**EB-5**

One of the major opportunities for investors interested in the Project is the Immigrant Investor Program (also known as EB-5). According to the United States Citizen and Immigration Services webpage, it was created by Congress in 1990 to stimulate the U.S. economy through job creation and capital investment by immigrant investors by creating a new commercial enterprise or investing in a troubled business.
There are two distinct EB-5 pathways for an immigrant investor to gain lawful permanent residence for themselves and their immediate family - the Basic Program and the Regional Center Pilot Program. Both programs require that the immigrant make a capital investment, a minimum of $900,000, depending on whether the investment is in a Targeted Employment Area (TEA) or not, in a new commercial enterprise located within the United States. TEA is defined by law as "a rural area or an area that has experienced high unemployment of at least 150 percent of the national average."

As a government sponsored program, DEDC will assist private EB-5’s (Regional Centers) in developing a business plan, engaging an escrow agent and a securities attorney to ensure that the investments are properly structured and are in compliance with SEC regulation. Rather than competing against Puerto Rico’s EB-5 private entities, the DEDC will help market their projects, at an international level, and provide assistance with their U.S. Citizenship and Immigration interaction.

**Opportunity Zones**

Under Puerto Rico rule of law, Opportunity Zones (“OZ”) have two major components:

1. The Puerto Rico Incentives Code ("Incentives Code"), grants local tax incentives to businesses: (A) that operate in qualified opportunity zones ("QOZ") in Puerto Rico, designated as such under Section 1400Z-1 of the US Internal Revenue Code of 1986, as amended, and by the Committee of Priority Projects in Opportunity Zones ("PPCommittee"); and (B) that qualify as a Priority Project in Opportunity Zones ("Priority Project"). Said tax incentives can be summarized as follows:
   - an 18.5% tax on the net income of an exempt business;
   - a tax exemption on dividend income;
   - 25% exemption on license and property tax;
   - 25% tax exemption on construction excise taxes;
   - transferable credit for investment up to a 25% maximum;
   - tax exemption on interest earned on loans to exempt businesses and;
   - swift permit evaluation and issuance process for exempt businesses and projects agreed under a Partnership Contract pursuant to Act No. 29-2009, as amended.

   If an eligible business is interested in an Opportunity Zone tax decree ("OZ Decree") to avail itself of the mentioned benefits, it must file a tax incentives application ("OZ Application") at the Office of Incentives of the Department of Economic Development and Commerce ("Office of Incentives").

2. The Puerto Rico Internal Revenue Code of 2011, as amended, which grants, essentially, the same tax benefits afforded by Section 400Z-2 of the US-IRC to the investment of capital gains from the sale or exchange of property to or with an unrelated party, or any portion thereof, in a qualified opportunity fund ("QOF") that invests directly or indirectly in a qualifying business in a QOZ in Puerto Rico. For these benefits to be effective, the filing of the Application is not required.

These OZ’s components provide the adequate environment to attract new capital into the Island, while fostering the local economy with the creation of innovative business opportunities.
18 ECONOMIC IMPACT

18.1 Introduction
With the location of the Puerto Rico Ocean Technology Complex next to the Yabucoa Port, a substantial impact on the surrounding municipalities of the southeast region is expected. The limited economic activity in the area provides a fertile environment for a large-scale development that provides an anchor institution/facility in the region.

18.2 Methodology: Input-Output Model
An Input-Output simulation was used to estimate the impact of the proposed project. The simulation is based upon the joint probability density function of the historical matrices (1982-2007) using a multivariate Laplace kernel estimator.

Three forms of impact were estimated:
1. Impact from the construction of the 1MW OTEC Plant and research park basic infrastructure;
2. Impact from the construction of the Puerto Rico Ocean Research Center, that is, research and technology park around the OTEC plant and;
3. Impact from the Puerto Rico Ocean Research Center’s operations.

The following assumptions were made in order to create the simulation:

Assumptions 1
- Based on client estimates $300M will be required for plant construction and park basic infrastructure
- Plant will be operated with 30 direct jobs

Assumptions 2
- Construction costs were estimated using the upper bound of industry standard for a 1-10mW OTEC plant ($35,400 per kW)
- For basic infrastructure estimates, a 114-acre park size was assumed. Site work is estimated at $15 per Sq. Ft.

Assumptions 3
- Per NEHLA analysis of 134 research and technology parks a profile of a typical research center was developed.
- The median for total building space was estimated at 314,400 Sq. Ft.
- 750 employment creation in average U.S. research park (per Master Plan)

18.3 Economic Impact - Plant Construction
Total direct, indirect and induced employment from OTEC plant and park infrastructure (impact of $300M):
18.3.1 Benchmark Economic Impact - Plant Construction

According to the International Renewable Energy Agency (IRENA) two of the main drivers of construction costs are:

- **Generation Capacity**: large scale plants (More than 10 MW) have significantly lower construction costs per KW produced.
- **Land-based vs Floating Plants**: OTEC plants can be built on land or on a floating platform on the sea; Floating plants are less expensive to build.

![Diagram showing cost per kW for different types of plants](image)

**Figure 138. Benchmark Economic Impact - Plant Construction**

To estimate infrastructure development costs, it was assumed that PRORC would have the median size of Research and Technology Parks in the US:

- **114 Acres**

The cost index used is the upper bound of site works construction cost for a university in Puerto Rico:

- **$15 per sf**
18.3.2 Impact of Construction per Benchmark

Given the planned capacity of production for the proposed plant (1 MW) the construction cost is based on the upper bound cost per kw for a small-scale plant; the total cost is estimated at $35,400,000. The impact also includes investment in basic infrastructure for site work. The impact of this investment is presented in the following table. Employment includes direct, indirect and induced:

![Figure 139: Benchmark Economic Impact - Plant Construction](image)

<table>
<thead>
<tr>
<th>SIC Code</th>
<th>SIC Description</th>
<th>Employment</th>
<th>Total Wages</th>
<th>Share</th>
<th>Cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td>15100</td>
<td>New Construction</td>
<td>1,189</td>
<td>$13,562,042</td>
<td>58.0%</td>
<td>58.0%</td>
</tr>
<tr>
<td>73200</td>
<td>Other Business Services</td>
<td>190</td>
<td>$3,060,181</td>
<td>9.3%</td>
<td>67.3%</td>
</tr>
<tr>
<td>50000</td>
<td>Wholesale and Retail trade</td>
<td>131</td>
<td>$3,099,254</td>
<td>6.4%</td>
<td>73.7%</td>
</tr>
<tr>
<td>32100</td>
<td>Stone, Clay, Glass and Concrete Products</td>
<td>77</td>
<td>$1,100,584</td>
<td>3.7%</td>
<td>77.4%</td>
</tr>
<tr>
<td>75300</td>
<td>Automotive Repair and Other Repair Services</td>
<td>74</td>
<td>$513,857</td>
<td>3.6%</td>
<td>81.0%</td>
</tr>
<tr>
<td>81400</td>
<td>Accounting and Auditing Services</td>
<td>40</td>
<td>$1,519,822</td>
<td>2.0%</td>
<td>82.9%</td>
</tr>
<tr>
<td>49200</td>
<td>Gas and Sanitary Services</td>
<td>28</td>
<td>$700,123</td>
<td>1.4%</td>
<td>84.3%</td>
</tr>
<tr>
<td>29100</td>
<td>Petroleum Refining</td>
<td>25</td>
<td>$470,695</td>
<td>1.2%</td>
<td>85.5%</td>
</tr>
<tr>
<td>36200</td>
<td>Electrical and Electronic Machinery</td>
<td>22</td>
<td>$924,956</td>
<td>1.1%</td>
<td>86.6%</td>
</tr>
<tr>
<td>81900</td>
<td>Engineering and Architectural Services</td>
<td>22</td>
<td>$666,179</td>
<td>1.0%</td>
<td>87.7%</td>
</tr>
<tr>
<td>24000</td>
<td>Lumber and Wood products</td>
<td>17</td>
<td>$205,417</td>
<td>0.8%</td>
<td>88.5%</td>
</tr>
<tr>
<td>34000</td>
<td>Fabricated Metal Products</td>
<td>17</td>
<td>$375,885</td>
<td>0.8%</td>
<td>89.3%</td>
</tr>
<tr>
<td>48100</td>
<td>Telephone, Telegraph, and Cable</td>
<td>14</td>
<td>$586,586</td>
<td>0.7%</td>
<td>90.0%</td>
</tr>
<tr>
<td>45000</td>
<td>Air Transportation</td>
<td>14</td>
<td>$207,455</td>
<td>0.7%</td>
<td>90.7%</td>
</tr>
<tr>
<td>30000</td>
<td>Rubber and Plastic products</td>
<td>12</td>
<td>$154,568</td>
<td>0.6%</td>
<td>91.3%</td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td>179</td>
<td>$5,267,201</td>
<td>8.7%</td>
<td>100%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,051</strong></td>
<td><strong>$32,416,628</strong></td>
<td><strong>100%</strong></td>
<td></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

![Figure 140: Impact of Construction per Benchmark](image)

18.3.3 Benchmark Economic Impact – Park Development

To estimate PRORC’s construction cost it was assumed that it will have a size equivalent to the median of available built space in Research Parks in the US:

- 314,400 sf
An average cost of $250 per square foot was assumed. This results in an estimated total construction cost of:

- $78,600,000 (these costs are estimated for the construction of facilities and buildings within the park)

### 18.4 Impact of PROTECH Facilities Construction

The impact of PRORC’s construction of buildings and facilities are presented below. Estimates are based on $78.6M construction cost. Employment includes direct, indirect and induced:

#### Table 18.3. Employment Impact of PROTECH Facilities Construction

<table>
<thead>
<tr>
<th>SIC Code</th>
<th>SIC Description</th>
<th>Employment</th>
<th>Total Wages</th>
<th>Share</th>
<th>Cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td>15100</td>
<td>New Construction</td>
<td>1,611</td>
<td>$18,372,357</td>
<td>58.0%</td>
<td>58.0%</td>
</tr>
<tr>
<td>73200</td>
<td>Other Business Services</td>
<td>257</td>
<td>$4,136,897</td>
<td>9.3%</td>
<td>67.3%</td>
</tr>
<tr>
<td>50000</td>
<td>Wholesale and Retail trade</td>
<td>176</td>
<td>$4,174,786</td>
<td>6.4%</td>
<td>73.6%</td>
</tr>
<tr>
<td>32100</td>
<td>Stone, Clay, Glass and Concrete Products</td>
<td>103</td>
<td>$1,487,694</td>
<td>3.7%</td>
<td>77.3%</td>
</tr>
<tr>
<td>75300</td>
<td>Automotive Repair and Other Services</td>
<td>100</td>
<td>$696,891</td>
<td>3.6%</td>
<td>81.0%</td>
</tr>
<tr>
<td>81400</td>
<td>Accounting and Auditing Services</td>
<td>54</td>
<td>$2,048,100</td>
<td>1.9%</td>
<td>82.9%</td>
</tr>
<tr>
<td>49200</td>
<td>Gas and Sanitary Services</td>
<td>38</td>
<td>$944,465</td>
<td>1.4%</td>
<td>84.3%</td>
</tr>
<tr>
<td>29100</td>
<td>Petroleum Refining</td>
<td>35</td>
<td>$639,574</td>
<td>1.2%</td>
<td>85.5%</td>
</tr>
<tr>
<td>36000</td>
<td>Electrical and Electronic Machinery</td>
<td>30</td>
<td>$1,259,066</td>
<td>1.1%</td>
<td>86.6%</td>
</tr>
<tr>
<td>81300</td>
<td>Engineering and Architectural Services</td>
<td>29</td>
<td>$900,833</td>
<td>1.0%</td>
<td>87.7%</td>
</tr>
<tr>
<td>24000</td>
<td>Lumber and Wood products</td>
<td>23</td>
<td>$277,930</td>
<td>0.8%</td>
<td>88.5%</td>
</tr>
<tr>
<td>34000</td>
<td>Fabricated Metal Products</td>
<td>23</td>
<td>$509,265</td>
<td>0.8%</td>
<td>89.3%</td>
</tr>
<tr>
<td>48100</td>
<td>Telephone, Telegraph, and Cable</td>
<td>19</td>
<td>$796,417</td>
<td>0.7%</td>
<td>90.0%</td>
</tr>
<tr>
<td>45000</td>
<td>Air Transportation</td>
<td>19</td>
<td>$281,414</td>
<td>0.7%</td>
<td>90.7%</td>
</tr>
<tr>
<td>30000</td>
<td>Rubber and Plastic products</td>
<td>17</td>
<td>$208,674</td>
<td>0.6%</td>
<td>91.3%</td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td>243</td>
<td>$7,140,655</td>
<td>8.7%</td>
<td>100%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>2,777</td>
<td>$43,875,218</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Figure 14.1. Impact of PROTECH Facilities Construction**

### 18.5 Operations of PROTECH

To estimate the impact of PRORC’s operations, the median number of employees for research parks in the US was used as a benchmark. This renders:

- 750 direct jobs created
  - 30 direct jobs were subtracted to avoid double counting the jobs already in the plant.

The number of total employees per industry in Research and Technology Parks in the US was used to distribute total jobs created among the industries expected to operate in PROTECH.

- Since commercial and manufacturing uses are not contemplated for PROTECH, the jobs created by business in these sectors were subtracted.
18.6 Impact of PROTECH

The following table presents the estimated impact of the PROTECH’s operations on the economy. Employment includes direct, indirect and induced:

<table>
<thead>
<tr>
<th>SIC Code</th>
<th>SIC Description</th>
<th>Employment</th>
<th>Total Wages</th>
<th>Share</th>
<th>Cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td>81400</td>
<td>Accounting and Auditing Services</td>
<td>349</td>
<td>$13,235,477</td>
<td>16.1%</td>
<td>16.1%</td>
</tr>
<tr>
<td>50000</td>
<td>Wholesale and Retail trade</td>
<td>320</td>
<td>$7,579,421</td>
<td>14.8%</td>
<td>30.9%</td>
</tr>
<tr>
<td>73200</td>
<td>Other Business Services</td>
<td>260</td>
<td>$4,190,563</td>
<td>12.0%</td>
<td>43.0%</td>
</tr>
<tr>
<td>49200</td>
<td>Gas and Sanitary Services</td>
<td>216</td>
<td>$5,397,104</td>
<td>10.0%</td>
<td>52.9%</td>
</tr>
<tr>
<td>81300</td>
<td>Engineering and Architectural Services</td>
<td>210</td>
<td>$6,492,052</td>
<td>9.7%</td>
<td>62.6%</td>
</tr>
<tr>
<td>28300</td>
<td>Drugs and Pharmaceutical Preparations</td>
<td>171</td>
<td>$10,469,867</td>
<td>7.9%</td>
<td>70.5%</td>
</tr>
<tr>
<td>75300</td>
<td>Automotive Repair and Other Repair Services</td>
<td>131</td>
<td>$911,227</td>
<td>6.1%</td>
<td>76.6%</td>
</tr>
<tr>
<td>28400</td>
<td>Other Chemical Products</td>
<td>47</td>
<td>$364,352</td>
<td>2.2%</td>
<td>78.8%</td>
</tr>
<tr>
<td>27000</td>
<td>Printing and Publishing</td>
<td>38</td>
<td>$962,724</td>
<td>1.8%</td>
<td>80.6%</td>
</tr>
<tr>
<td>81200</td>
<td>Educational Services</td>
<td>33</td>
<td>$760,554</td>
<td>1.5%</td>
<td>82.1%</td>
</tr>
<tr>
<td>29100</td>
<td>Petroleum Refining</td>
<td>27</td>
<td>$492,072</td>
<td>1.2%</td>
<td>83.3%</td>
</tr>
<tr>
<td>30000</td>
<td>Rubber and Plastic products</td>
<td>26</td>
<td>$326,921</td>
<td>1.2%</td>
<td>84.5%</td>
</tr>
<tr>
<td>20610</td>
<td>Sugar Mills, Refineries &amp; Confectionery</td>
<td>22</td>
<td>$16,874</td>
<td>0.1%</td>
<td>85.6%</td>
</tr>
<tr>
<td>00300</td>
<td>Agricultural Services</td>
<td>18</td>
<td>$180,331</td>
<td>0.9%</td>
<td>86.4%</td>
</tr>
<tr>
<td>36000</td>
<td>Electrical and Electronic Machinery</td>
<td>17</td>
<td>$707,039</td>
<td>0.8%</td>
<td>87.1%</td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td>278</td>
<td>$7,307,018</td>
<td>12.9%</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Figure 142.** Estimated impact of the PROTECH’s operations on the economy.

Additionally, it is projected that this type of complex incites three forms of impact for potential spillover effects:

- Impact from the construction of an OTEC Plant and research park basic infrastructure.
- Impact from the construction of a research and technology park around the OTEC plant.
- Impact from the research park operations and ancillary industries.

There are approximately 611,082 sq. ft. of industrial parks in the area that are vacant that could benefit from the activity that will bring PROTECH to the area. The available area is divided by municipality as follows:

- Yabucoa: 200,568 sq. ft.
- Naguabo: 48,709 sq. ft.
- Maunabo: 69,630 sq. ft.
- Las Piedras: 22,621 sq. ft.
- Humacao: 207,794 sq. ft.
- Arroyo: 61,760 sq. ft.

Likewise, there are approximately 1,482,120 sq. ft. of industrial parks in the area that are currently in use that could benefit from the activity that will bring PROTECH to the area. These are divided by municipality as follows:
Yabucoa: 11,271 sq. ft.
Naguabo: 93,508 sq. ft.
Maunabo: 22,653 sq. ft.
Las Piedras: 264,447 sq. ft.
Humacao: 532,868 sq. ft.
Arroyo: 465,657 sq. ft.
Guayama: 69,045 sq. ft.
Patillas: 22,672 sq. ft.

This potential impact could benefit this region, by encouraging commerce and industries outside the project that provide services and support to the tenants and operation of the park. This effect could extend towards Vieques and Culebra, providing these municipalities with new opportunities for development.

18.7 Summary of Economic Impact

The table below shows that jobs in these areas have increased their wages over the years.

<table>
<thead>
<tr>
<th>OCC Code</th>
<th>OCC Title</th>
<th>2000</th>
<th>2010</th>
<th>2015</th>
<th>Employment Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>11-000</td>
<td>Management Occupations</td>
<td>$36,719</td>
<td>$32,072</td>
<td>$36,302</td>
<td>$7,420</td>
</tr>
<tr>
<td>12-000</td>
<td>Business and Financial Operations Occupations</td>
<td>$28,430</td>
<td>$22,080</td>
<td>$28,430</td>
<td>$6,320</td>
</tr>
<tr>
<td>13-000</td>
<td>Computer and Mathematical Occupations</td>
<td>$5,990</td>
<td>$5,210</td>
<td>$5,990</td>
<td>$0,780</td>
</tr>
<tr>
<td>17-000</td>
<td>Architecture and Engineering Occupations</td>
<td>$12,640</td>
<td>$12,640</td>
<td>$12,640</td>
<td>$0,000</td>
</tr>
<tr>
<td>19-000</td>
<td>Life, Physical, and Social Science Occupations</td>
<td>$7,390</td>
<td>$7,390</td>
<td>$7,390</td>
<td>$0,000</td>
</tr>
<tr>
<td>21-000</td>
<td>Community and Social Service Occupations</td>
<td>$14,390</td>
<td>$14,390</td>
<td>$14,390</td>
<td>$0,000</td>
</tr>
<tr>
<td>23-000</td>
<td>Legal Occupations</td>
<td>$4,150</td>
<td>$4,150</td>
<td>$4,150</td>
<td>$0,000</td>
</tr>
<tr>
<td>25-000</td>
<td>Education, Training, and Library Occupations</td>
<td>$4,150</td>
<td>$4,150</td>
<td>$4,150</td>
<td>$0,000</td>
</tr>
<tr>
<td>29-000</td>
<td>Health Practitioners and Technical Occupations</td>
<td>$2,170</td>
<td>$2,170</td>
<td>$2,170</td>
<td>$0,000</td>
</tr>
<tr>
<td>31-000</td>
<td>Healthcare Support Occupations</td>
<td>$1,940</td>
<td>$1,940</td>
<td>$1,940</td>
<td>$0,000</td>
</tr>
<tr>
<td>33-000</td>
<td>Protective Service Occupations</td>
<td>$3,480</td>
<td>$3,480</td>
<td>$3,480</td>
<td>$0,000</td>
</tr>
<tr>
<td>36-000</td>
<td>Food Preparation and Serving Related Occupations</td>
<td>$6,250</td>
<td>$6,250</td>
<td>$6,250</td>
<td>$0,000</td>
</tr>
<tr>
<td>37-000</td>
<td>Building and Grounds Cleaning and Maintenance Occupations</td>
<td>$4,470</td>
<td>$4,470</td>
<td>$4,470</td>
<td>$0,000</td>
</tr>
<tr>
<td>39-000</td>
<td>Personal Care and Service Occupations</td>
<td>$3,170</td>
<td>$3,170</td>
<td>$3,170</td>
<td>$0,000</td>
</tr>
<tr>
<td>41-000</td>
<td>Sales and Related Occupations</td>
<td>$26,470</td>
<td>$26,470</td>
<td>$26,470</td>
<td>$0,000</td>
</tr>
<tr>
<td>43-000</td>
<td>Office and Administrative Support Occupations</td>
<td>$13,700</td>
<td>$13,700</td>
<td>$13,700</td>
<td>$0,000</td>
</tr>
<tr>
<td>45-000</td>
<td>Farming, Fishing, and Forestry Occupations</td>
<td>$1,080</td>
<td>$1,080</td>
<td>$1,080</td>
<td>$0,000</td>
</tr>
<tr>
<td>47-000</td>
<td>Construction and Extraction Occupations</td>
<td>$73,140</td>
<td>$73,140</td>
<td>$73,140</td>
<td>$0,000</td>
</tr>
<tr>
<td>49-000</td>
<td>Installation, Maintenance, and Repair Occupations</td>
<td>$18,300</td>
<td>$18,300</td>
<td>$18,300</td>
<td>$0,000</td>
</tr>
<tr>
<td>51-000</td>
<td>Production Occupations</td>
<td>$111,340</td>
<td>$111,340</td>
<td>$111,340</td>
<td>$0,000</td>
</tr>
<tr>
<td>53-000</td>
<td>Transportation and Material Moving Occupations</td>
<td>$32,490</td>
<td>$32,490</td>
<td>$32,490</td>
<td>$0,000</td>
</tr>
</tbody>
</table>

Figure 143. Jobs have increased their wages over the years.

As noted in the table above, if the PROTEC is developed, jobs, wages and salaries in the area are expected to improve local economic conditions. The fact that jobs will be created in the areas of technology, education, research, among others, will bootstrap current salaries. Such improvements are beyond the economic benefits from construction activity.

The following table presents the total impact of the proposed development:
PROTECH can:
- Enable technology – OTEC capacity to generate new research in the Caribbean and potential spinoffs
- Create a new productive capacity for Puerto Rico’s southeast region
- Industry is not dependent on tax incentive

The following table presents the Total Proposed Development Cost:

<table>
<thead>
<tr>
<th>Uses</th>
<th>Suggested Square Meters</th>
<th>Development Cost per sq ft, $</th>
<th>Total Development Costs, $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture/Mariculture</td>
<td>50,896</td>
<td>$145</td>
<td>$79,437,033</td>
</tr>
<tr>
<td>Office/Industrial Space</td>
<td>73,087</td>
<td>$220</td>
<td>$173,074,018</td>
</tr>
<tr>
<td>Retail, Multi-Use and Cc</td>
<td>23,428</td>
<td>$250</td>
<td>$63,044,162</td>
</tr>
<tr>
<td>Total Proposed Investor</td>
<td>147,411</td>
<td>$200</td>
<td>$315,555,214</td>
</tr>
</tbody>
</table>

(1) Does not include the cost of the OTEC facility

**Figure 145.** Total Proposed Development Cost

The following table presents the Economic Impact of Construction:
### Jobs Generated by Construction Activity

<table>
<thead>
<tr>
<th></th>
<th>2025</th>
<th>2026</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture/Fisheries</td>
<td>719</td>
<td>730</td>
</tr>
<tr>
<td>Office/Industrial</td>
<td>1,973</td>
<td>2,003</td>
</tr>
<tr>
<td>Retail, Multi-Use and Common Spaces</td>
<td>906</td>
<td>919</td>
</tr>
<tr>
<td><strong>Jobs from Construction, total</strong></td>
<td><strong>3,598</strong></td>
<td><strong>3,652</strong></td>
</tr>
<tr>
<td>Construction- Direct jobs (#)</td>
<td>1,583</td>
<td>1,607</td>
</tr>
<tr>
<td>Construction- Indir &amp; Induced</td>
<td>2,015</td>
<td>2,045</td>
</tr>
</tbody>
</table>

### Salary Income Generated by Construction Activity

<table>
<thead>
<tr>
<th></th>
<th>2025</th>
<th>2026</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct income</td>
<td>$47,936,937</td>
<td>$49,142,551</td>
</tr>
<tr>
<td>Indirect and Induced Income</td>
<td>$54,530,658</td>
<td>$55,902,104</td>
</tr>
<tr>
<td><strong>Income from construction activity</strong></td>
<td><strong>$102,467,594</strong></td>
<td><strong>$105,044,654</strong></td>
</tr>
</tbody>
</table>

### Revenues to Government Generated by Construction Activity

<table>
<thead>
<tr>
<th></th>
<th>2025</th>
<th>2026</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal income taxes from Construction</td>
<td>$9,047,889</td>
<td>$9,275,443</td>
</tr>
<tr>
<td>Income taxes from soft costs</td>
<td>$241,170</td>
<td></td>
</tr>
<tr>
<td>Corporate taxes from Contractors</td>
<td>$2,587,813</td>
<td>$2,626,630</td>
</tr>
<tr>
<td>Sales Taxes from employee consumption</td>
<td>$5,891,867</td>
<td>$6,040,068</td>
</tr>
<tr>
<td><strong>Government Revenues from Construction</strong></td>
<td><strong>$17,768,759</strong></td>
<td><strong>$17,942,141</strong></td>
</tr>
<tr>
<td>Fiscal Revenue to Municipal Government</td>
<td>$512,337.97</td>
<td>$525,223</td>
</tr>
<tr>
<td>Fiscal Revenue to State Government</td>
<td>$17,015,250</td>
<td>$17,416,917</td>
</tr>
</tbody>
</table>

*Figure 146. Economic Impact of Construction*
CONCLUSIONS AND RECOMMENDATIONS

The message of PROTECH is clear: we must continue to push forward all initiatives that endorse, disseminate, facilitate, benefit and advance a healthy environment because we can’t afford to continue the harm that’s been inflicted upon it anymore. As much as this may sound repetitive, new reports come out more and more frequently that reminds us of the urgency with which we are dealing.

In October of 2018, the world’s leading climate scientists warned us that we have only 12 years left to reach and keep a maximum growth of global temperature of 1.5°C. Beyond this measurement, the rise in number of natural catastrophes will become unstoppable and poverty and hunger could affect hundreds of millions of people:

“The authors of the landmark report by the UN Intergovernmental Panel on Climate Change (IPCC) released on Monday say urgent and unprecedented changes are needed to reach the target, which they say is affordable and feasible although it lies at the most ambitious end of the Paris agreement pledge to keep temperatures between 1.5°C and 2°C.

The half-degree difference could also prevent corals from being completely eradicated and ease pressure on the Arctic, according to the 1.5°C study, which was launched after approval at a final plenary of all 195 countries in Incheon in South Korea that saw delegates hugging one another, with some in tears.

‘It’s a line in the sand and what it says to our species is that this is the moment and we must act now,’ said Debra Roberts, a co-chair of the working group on impacts. ‘This is the largest clarion bell from the science community, and I hope it mobilizes people and dents the mood of complacency.’”

Climate change is, of course, being occurring because of many factors, and not just the traditional energy generation and polluting technologies. The growing global population causes an abundance of waste and resource depletion, including food and water. So, the aspects of sustainability related to the utilization of diversified waste reuse and renewable energy processes are no longer a goal for the future. Instead, they are a primary task for the present.

The rising levels of the oceans and the change in global temperatures are causing, not only an increase in the number of storms, but also in their rapid intensifications and their duration. In at least the last three and a half centuries the oceans have had a steady increase in temperature with a peak in 2017.

The following graphics appeared in The Guardian, October 10, 2018

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9 We have twelve years to limit climate change catastrophe, warns UN, The Guardian, October 8, 2018.
Proposed Roadmap for Development, July 2020
But - and this is a big “but” - no improvements can be achieved to start a process of prevention and decreasing the negative environmental ongoing conditions until appropriate limits are reached to commence a recuperation without increasing the awareness of the urgency. This is why the research and educational aspects of any endeavor, such as PROTECH, directed to improve the quality of the environment, are of the utmost importance. We need to acquire an attitude about saving resources that should reach beyond the scientific community.

The Ocean Thermal Energy Conversion technology is still in a development phase with goals of reaching its full potential. However, the concept and the functioning and practical purposes already exist. “Ocean thermal energy conversion (OTEC) is one of the significant energy resources that could play a prominent role in the future. This technology started as a conceptual idea in 1881 by the French physicist Jacques Arsene. Then, Dr. Georges Claude implemented it as a practical system in 1930 in Cuba (Matanzas Bay). Many development projects and research papers were done between 1950 and 1960 by few research organizations. However, it appears that OTEC was not desirable by governments by the end of the 20th century because the nuclear energy was not only more interesting than other energy resources at that time but also the oil price dropped in 1990s. To be more specific, in the latter period of that time, renewable energy had been a neglected resource without taking into account the environmental future. At the beginning of the 21st century, the oil price increased by more than 1400% per barrel and global warming became a more crucial issue, posing threats to the planet. Consequently, renewable energy has resurfaced and become a strongly desirable resource.

Since the ocean water has the most percentage on the earth surface (70%), it is logical to take advantage of this natural source to satisfy the energy demand. OTEC is considered a renewable energy technology since it derives the hot energy from the sun which means it is a huge solar energy.”

To reach a potential optimum plan for the implementation and use of renewable and sustainable energy, the OTEC technology will have to be combined with others. PROTECH will showcase its technology, but it won’t ignore photovoltaics, solid waste or aeolic energy applications. Because of the amount of land necessary to build solar and wind power farms, they could be developed in nearby lots.

“The search for renewable, carbon-free energy sources has intensified in recent years for a number of reasons... The focus has so far been on wind power, because costs have been comparable with those of oil or gas fired power plants while costs associated with other renewables have been higher. Now that fossil fuel prices have tripled in the last 20 years, other types of renewables may become cost-effective and even prove to have advantages over wind under certain conditions.

“Ocean waves, currents, and offshore winds tend to provide power more continuously than wind over land; unsteady supply and storage issues continue to constrain wind farms. Steadier still is Ocean Thermal Energy Conversion (OTEC), which conceptually can provide base-load power almost continuously.”

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12 Rod Fujita, Alexander C. Markham, Julio E. Díaz Díaz, Julia Rosa Martínez García, Courtney Scarborough, Patrick Greenfield, Peter Black Stacy E. Aguilera. Revisiting ocean thermal energy conversion, Marine Policy Journal 36, September 18, 2011
Energy is not the only type of production that has to be addressed for the future, although it may be one of the main drivers for others. As has been presented in this document, there are multiple additional benefits that also provide environmental responsibility and tangible rewards. Products such as food sources, clean water, minerals extraction, nutraceuticals and ingredients for the pharmaceutical and cosmetics industries, and processes that include waste management and recycling, among others, are all potential enterprises.

The advantages for helping the **economic growth** of the country have also to be added when evaluating the PROTECH operation. Apart from the income sources related to the industries mentioned above, they include retail (of different and very varied kinds), employment, tourism (and recreation), and education and research programs.

The following section about **Economic Considerations and Market Potential** included in the analysis Ocean Thermal Energy Conversion Primer, was conducted by L. H. Vega, PhD, from the Pacific International Center for High Technology Research (PICHTR), Honolulu, Hawai’i in the winter of 2002-2003. Although technological advances and further research have been put into effect after this document was published, and some of the observations may not be applicable anymore to our present, the author analyzes **four scenarios under which the OTEC technology should be economically feasible under certain circumstances.** We include here this information purely as reference and because Puerto Rico appears as a potential site for including a 2nd stage (desalinization) to an OTEC plant. New information from our present reality would be needed to update the analysis.

“In considering the economics of OTEC, it is appropriate to determine if multiple-product systems, e.g., electricity, desalinated water, mariculture and air conditioning (AC) systems yield higher value by, for example, decreasing the equivalent cost of electricity. Because mariculture operations, in the case of AC systems, can only use a relatively minute amount of the seawater required for the thermal plants they should be evaluated independent of OTEC. For example, the cold water available from a 1 MW OTEC plant could be used for daily exchanges of twenty-five 100 m x 100 m x 1 m mariculture ponds, requiring more than 25 Ha of land. **Therefore, it is recommended that OTEC be considered for its potential impact in the production of electricity and desalinated water and that mariculture and AC systems, based in the use of deep ocean water, be considered decoupled from OTEC.**

OTECH is capital-intensive and the very first plants will most probably be small requiring a substantial capital investment. Given the relatively low cost of crude oil, and of fossil fuels in general, the development of OTEC technologies is likely to be promoted by government agencies rather than by private industry. The motivation of governments in subsidizing OTEC may vary greatly, from foreign aid to domestic concerns. For the former case, ideal recipient countries are likely to be independent developing nations. If their economic standing is too low, however, the installation of an OTEC plant, rather than direct aid in the form of money and goods, may be perceived as inadequate help. In addition, political instability could jeopardize the good will of helping nations to invest. For the latter case, potential sites belong to, or fall within the jurisdiction of, developed countries.

Comparing production costs of electricity and desalinated water can identify scenarios under which OTEC should be economical, relative to conventional technologies. **One scenario** corresponds to small island nations, where the cost of diesel-generated electricity and fresh water is such that a small, 1 MW land-based OC-OTEC plant, with water production, would be cost-effective today.
However, only a few sites throughout the world meet this scenario. A second scenario corresponds to conditions that are plausible in several island nations where 10 MW land-based OC-OTEC plants could produce cost competitive electricity and desalinated water. One can envision these small plants deployed in, for example, Pacific islands such that 20 years from now a total of 100 to 300 MW would be installed.

A third scenario corresponds to land-based hybrid OTEC plants for the industrialized nations’ market producing electricity through an ammonia cycle and desalinated water through a flash (vacuum) evaporator. This scenario would be cost-effective in industrialized island nations with a doubling of the cost of oil fuel or with a doubling of water costs, and for plants rated at 50 MW or larger. The fourth scenario is for floating OTEC electrical plants, rated at 100 MW or larger, and housing a factory or transmitting electricity to shore via a submarine power cable. These plants could be deployed throughout the EEZ of numerous nations and could encompass a significant market”.

Estimates of their capital costs and resulting costs of electricity are given in the following figures:

<table>
<thead>
<tr>
<th>Nominal Size, MW</th>
<th>TYPE</th>
<th>Scenario</th>
<th>Potential Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Land-Based OC-OTEC with 2nd Stage for Additional Water Production.</td>
<td>Diesel: $45/barrel Water: $1.6/m³</td>
<td>Present Situation in Some Small Island States.</td>
</tr>
<tr>
<td>10</td>
<td>Same as Above.</td>
<td>Fuel Oil: $30/barrel Water: $0.9/m³</td>
<td>U.S. Pacific Insular Areas and other Island Nations.</td>
</tr>
<tr>
<td>50</td>
<td>Land-Based Hybrid CC-OTEC with 2nd Stage.</td>
<td>Fuel Oil: $50/barrel Water: $0.4/m³ Or Fuel Oil: $30/barrel Water: $0.8/m³</td>
<td>Hawaii, Puerto Rico If fuel or water cost doubles.</td>
</tr>
<tr>
<td>50</td>
<td>Land-Based CC-OTEC</td>
<td>Fuel Oil: $40/barrel</td>
<td>Same as Above.</td>
</tr>
<tr>
<td>100</td>
<td>CC-OTEC Plantship</td>
<td>Fuel Oil: $20/barrel</td>
<td>Numerous sites</td>
</tr>
</tbody>
</table>

Figure 150. OTEC potential sites as a function of fuel and water cost. Marine Technology Society Journal V.6, No. 4, Winter 2002-2003

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13 Marine Technology Society Journal V.6, No. 4, Winter 2002-2003
Another source, by the Global Research and Development Journal for Engineering coincides with the above analysis, and also mentions Puerto Rico:

"An economic analysis indicates that, over the next 5 to 10 years, ocean thermal energy conversion (OTEC) plants may be competitive in four markets. The first market is the small island nations in the South Pacific and the island of Molokai in Hawaii. In these islands, the relatively high cost of diesel-generated electricity and desalinated water may make a small [1 megawatt (electric) (MWe)], land-based, open-cycle OTEC plant coupled with a second stage desalinated water production system cost effective. A second market can be found in American territories such as Guam and American Samoa, where land-based, open-cycle OTEC plants rated at 10 MWe with a second-stage water production system would be cost effective. A third market is Hawaii, where a larger, land-based, closed-cycle OTEC plant could produce electricity with a second stage desalinated water production system. OTEC should quickly become cost effective in this market, when the cost of diesel fuel doubles, for plants rated at 50 MWe or larger. The fourth market is for floating, closed-cycle plants rated at 40 MWe or larger that house a factory or transmit electricity to shore via a submarine power cable. These plants could be built in Puerto Rico, the Gulf of Mexico, and the Pacific, Atlantic, and Indian Oceans. Military and security use of large floating plant ships with major life-support systems (power, desalinated water, cooling, and aquatic food) should be included in this last category.

OTECs greatest potential is to supply a significant fraction of the fuel the world needs by using large, grazing plant ships to produce hydrogen, ammonia, and methanol. Of the three worldwide markets studied for small OTEC installations—U.S. Gulf Coast and Caribbean regions, Africa and Asia, and the Pacific Islands—the Pacific Islands are expected to be the initial market for open-cycle OTEC plants. This prediction is based on the cost of oil-fired power, the demand for desalinated water, and the social benefits of this clean energy technology. U.S. OTEC technology is focused on U.S. Coastal areas, including the Gulf of Mexico, Florida, and islands such as Hawaii, Puerto Rico, and the Virgin Islands." 14

In a more recent analysis, Makai Ocean Engineering has developed a plan for Puerto Rico with a production of 1 megawatt (maximum net power output that is technically feasible at Yabucoa) or less for now15 for this specific location, after having considered options for 1, 2, 3 and 5MW scenarios, not deemed practical because of technical risks, environmental impact and high costs. This analysis includes the quantity, characteristics

15 CPSS Puerto Rico OTEC Feasability, Makai Ocean Engineering, October 10, 2018
and capacity of the pipes required to produce that amount of electricity. The amount of Sea Water Air Conditioning (SWAC) supply could not be determined due to lack of information for determining its financial feasibility. This sensitivity study will be updated when the missing information becomes available, and thus, it's not included in this draft.

Of course, to realize its full potential, PROTECH has to work with partnerships from the private and public sectors. Its mission is broad and inclusive, and it should be. Private foundations and technological and educational institutions, as well as governmental programs and agencies such as Sea Grant and the National Oceanic and Atmospheric Administration (NOAA) can share knowledge and resources.

As an additional function and proposal, PROTECH could also allocate space for weather research, such as a specialized center for natural disasters. This kind of investigation would offer a much-needed service considering that the particular zone of the Caribbean where Puerto Rico is located is favorable for hurricane routes and earthquake occurrences, and that, as seen in figures above, the risk of storm development has increased through the years. Spaces containing disaster simulators and weather labs for research and for education, as well as for exhibition, could be also part of the exhibits included in the Research Campus buildings or in separate facilities.

Finally, it is again very important to emphasize that, as acknowledged in the Makai master plan for Hawai‘i, the feasibility and success of PROTECH depends, not only on the optimal functionality of the technologies included in it, but also on the quality of its environment and the orderly, pleasant and healthy characteristics of its physical and psychological planning. All of these aspects must work in unison, and each one must depend on the others for the Project to operate as one.
20 REFERENCE RESOURCES

The following resources, not intended to be a bibliography (and thus, most are not presented in a bibliographic order and format), could be helpful to understand the scope of the planning, aesthetic and functional aspects of this Master Plan:

4. Lidsky, Arthur and Mathey, George, Perspectives on Campus Planning, Dober Lidskey Mathey, Belmont, MA, 2015
9. We have twelve years to limit climate change catastrophe, warns UN, The Guardian, October 8, 2018.