ABSTRACT

Title of Thesis: OIL TO ISLAND: REPURPOSING SOUTHERN CALIFORNIA'S OFFSHORE DRILLING PLATFORMS

Michael Delash

Master of Architecture, 2019

Thesis Directed By: Lecturer Lindsey May, School of Architecture, Planning, and Preservation

This thesis aims to explore an untapped opportunity that exists between the industries of energy generation as we move beyond the fossil fuel era as society tries to change course for a more sustainable and positive future. Within this scope, the goal is to focus on offshore oil platform structures and reimagining them in a context of sustainable energy generation. The primary objectives are to design a satellite campus for the southern Californian universities to learn from the unique site and conditions of the platforms. This thesis will explore the potential of the offshore oil platform in a new light, not as a symbol of the fossil fuel industry as it is today but of a pinnacle of a sustainable design and production.

OIL TO ISLAND: REPURPOSING SOUTHERN CALIFORNIA'S OFFSHORE DRILLING PLATFORMS

by

Michael Delash

Thesis submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
Master of Architecture
2019

Advisory Committee:
Lindsey May, Lecturer, Chair
Karl DuPuy, Professor Emeritus
Ronit Eisenbach, Professor
Carl Bovill, Professor

Table of Contents

List of Figures

Background

The industrial revolution resulted in many new technologies that helped to advance humankind into the future. One of the key discoveries that aided the revolution was fossil fuel potential for energy generation. This industry led to a dramatic shift in production which resulted in greater connectivity amongst people around the world. The emergence and abundant usage of fossil fuel sources resulted in a wide variety of methods of extraction. Offshore oil platforms, designed to drill and pump oil to the surface for use, were first implemented in 1896 though the platforms seen today began appearing in 1947 and gained popularity around the world[1]. Offshore oil platforms, to date, have expanded to far-reaching lands from the North Sea to Australia totaling 1,332 active rigs worldwide with many more unoccupied. More offshore oil platforms are still being built and installed, regardless of the rigs unattended at sea[2]. The impact of the industrial revolution has not been solely positive. In fact, in January of 1969, the newly built oil platforms off of Santa Barbara ruptured deep underwater and released a thousand gallons of oil into the ocean per hour. This catastrophe led to the development of many environmental policies such as the National Environmental Policy Act and the Clean Water Act in the coming years[3]. Climate change is partially to blame of the combustion of fossil fuels and thus the production of carbon dioxide (fig. 1).

---

[1] United States. National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, *A Brief History of Offshore Oil Drilling* (Washington D.C., 2010).

[2] "Number of Offshore Rigs Worldwide as of January 2018 by Region," last modified 2019, accessed March 26, 2019, http://www.statista.com/statistics/279100/number-of-offshore-rigs-worldwide-by-region.

[3] Emmett FitzGerald, "Crude Habitat," *99% Invisible*, accessed April 25, 2019, https://99percentinvisible.org/episode/crude-habitat/.

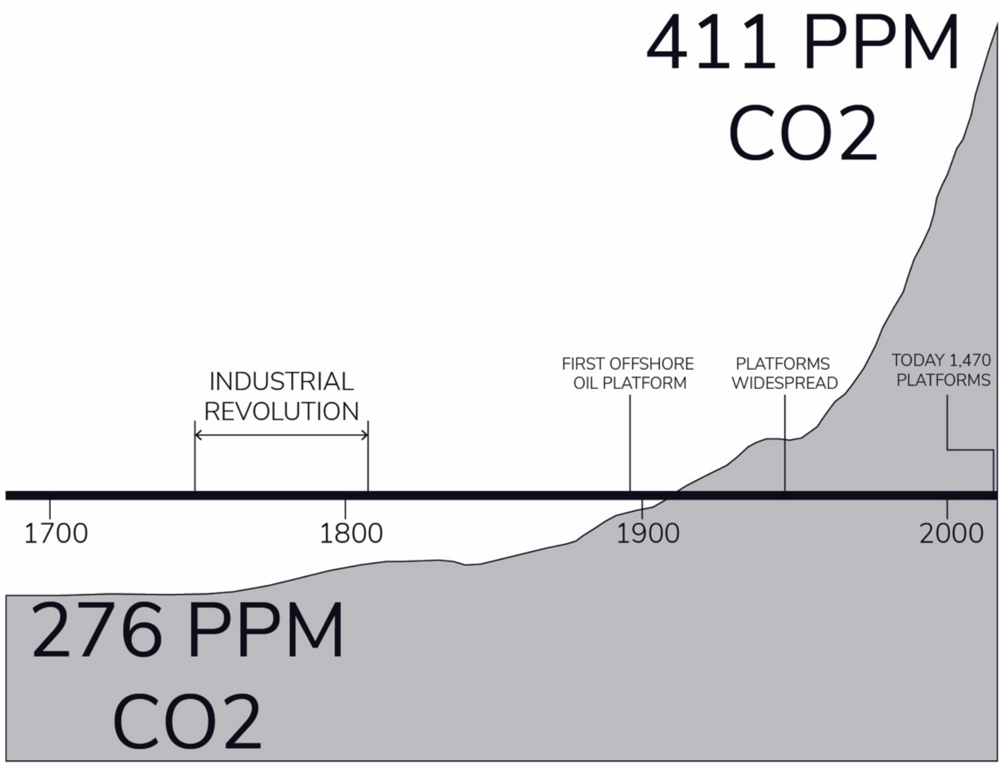

Figure 1: Timeline of CO2 Increase Since the Industrial Revolution (source: author)

Our civilization can only continue to thrive by abandoning fossil fuel usage and resorting to more sustainable practices to generate energy. This shift, however, does not necessitate the abandonment of the buildings and infrastructure created to mine fossil fuels, thus generating more needless waste.

There are currently 1,470 offshore platforms in the world with many countries planning to construct more (fig 2). A single offshore platform can have an embodied energy equal to that of 180 single family homes and cost $80 million to $8 billion whereas the 180 single family homes would cost about $45 million (fig 3). The possible outcomes for offshore rigs are to repurpose them, remove part of the structure, or to remove the complete structure (fig 4).

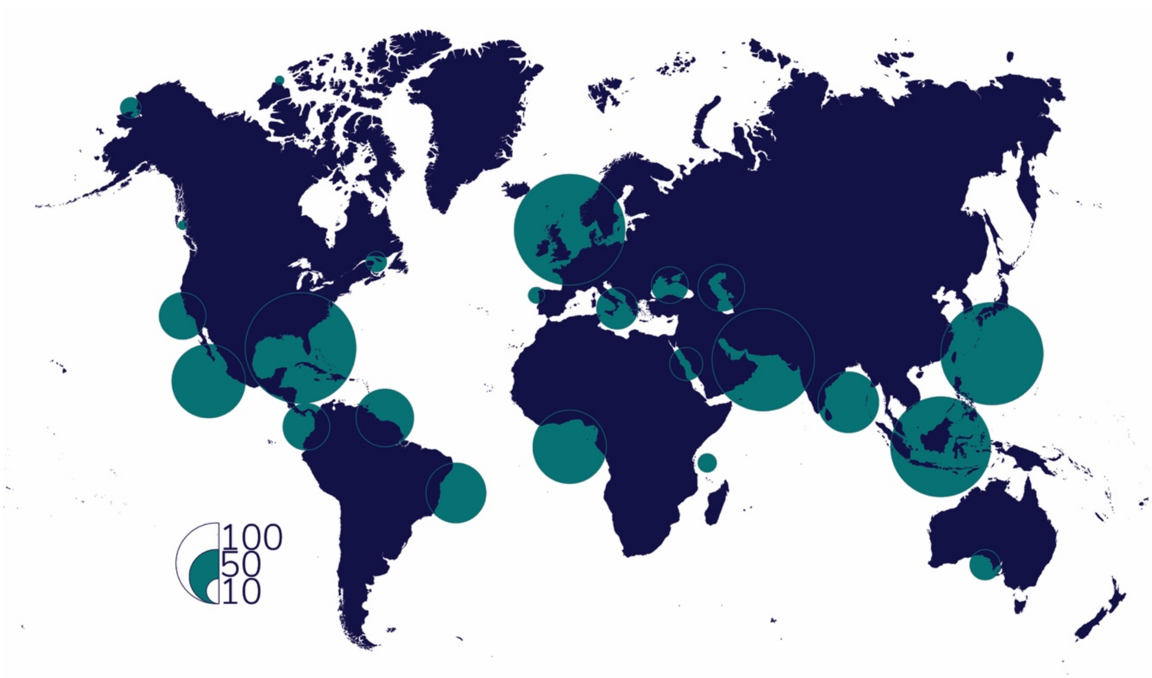

Figure 2: Distribution of platforms around the world. The size of the circle indicates quantity in that region. (Source: author)

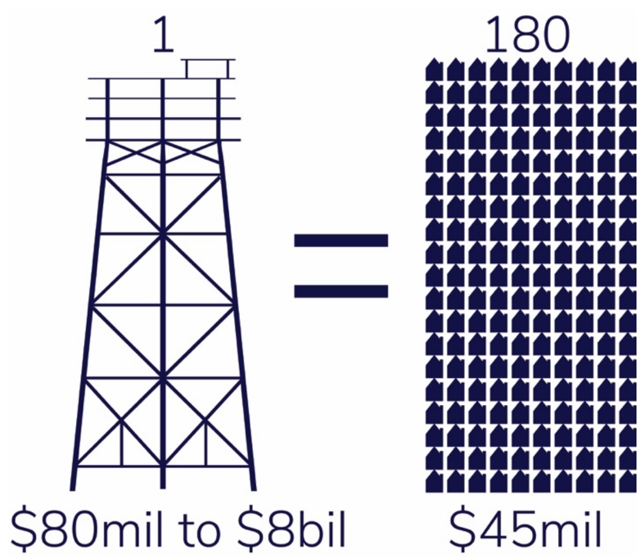

Figure 3: The comparison of embodied energy and cost of an offshore platform to single family homes. (Source: author with use of Athena)

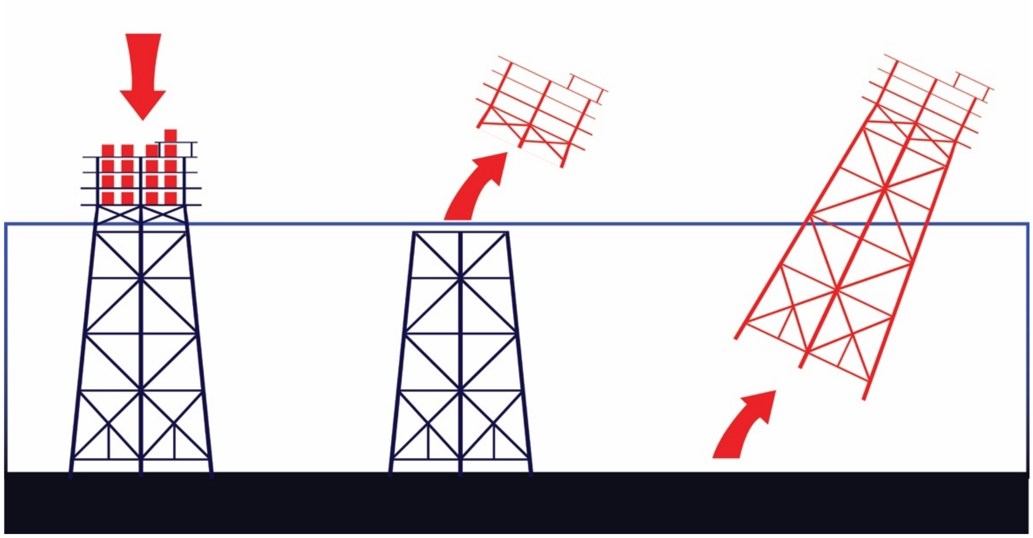

Figure 4: There are three possible outcomes for offshore platforms, repurposing, partial removal, and full removal. (Source: author)

It is also worth mentioning that in events such as Hurricane Harvey in 2017 which not only caused devastation to the gulf coast of Texas but also caused 22 thousand barrels of crude oil to be spilled into the Gulf of Mexico from offshore oil platforms. An example of a repurposed offshore rig is the Ocean Star Offshore Drilling Rig and Museum which was visited by the author in the summer of 2018. There it was apparent that the fossil fuel industry was using it to promote and glorify its work. This thesis aims to explore a more beneficial and realistic future for an offshore platform.

Site and Structures

Site

Site selection

In order to select a site, criteria were created by which potential platform candidates were judged including the following standards: platform type, distance from the coast, coastal infrastructure, platform size, available information about the platform, climate, and energy and food production potential (fig. 5).

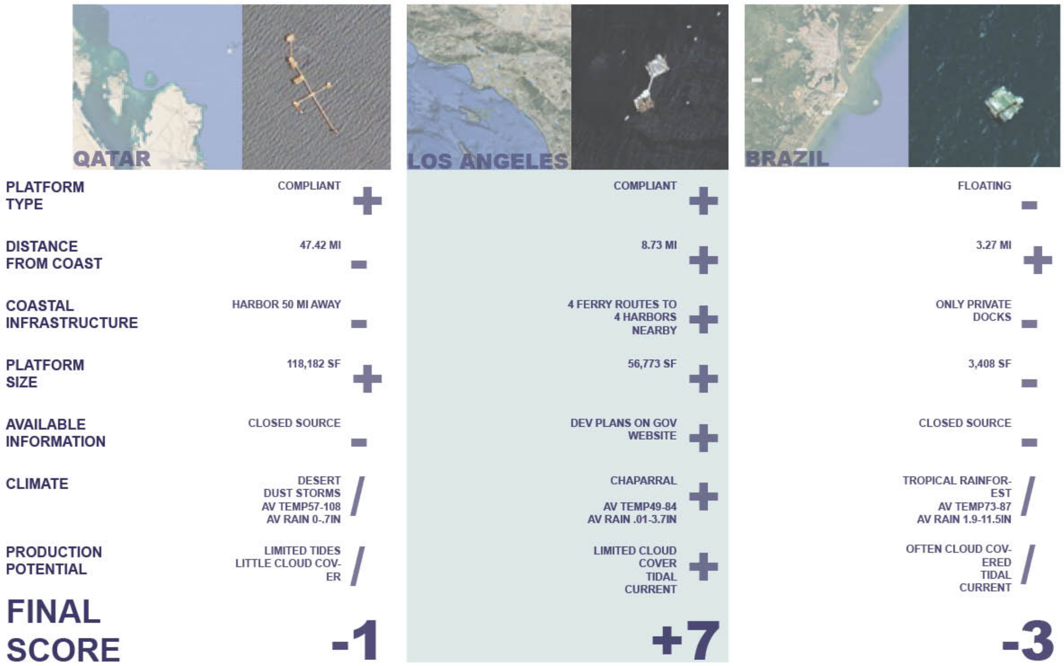

Figure 5: Site Selection Criteria Matrix and Rankings (source: Google Earth and author)

Potential sites included platforms off the coast of Qatar, Los Angeles, U.S. and Brazil. As the criteria were applied, the clear selection for the site was the platform off the coast of Los Angeles.

Environmental Considerations

These platforms are placed in the strait between Catalina Island and Los Angeles[4]. They are sited a safe distance from potential hazards such as the San Andreas fault and benthic soil instability. The seafloor at the location of the platforms is relatively featureless with slight slopes to the southeast at 2 degrees. Borings of soil to depths of 500’ indicated that the soil is composed of clayey silt, then silty clay towards the top before shifting to gravel and ultimately clayey silts[5].

---

[4] Shell Oil Company, *Beta Unit Plan of Development*.
[5] Ibid.

Faults in the area were investigated within 8.5 square miles of the platform site which concluded that the site is near the Palos Verde fault zone and the San Gabriel submarine canyon. The risk in these regions were not considered dangerous enough to withhold development[6].

The oceanic design criteria dictate that the Beta Unit is to be designed to withstand severe storms having less than a one percent chance of occurring in a given year. These criteria are a maximum wave height of 45' with a period of 9-15 seconds, a wind velocity of 64 knots (73.6mph), an ocean current of 2.8 feet/second (fps) at the surface, 1.6 fps at mid-depth, and 0.6 fps at the seafloor, and a tide of 6' including storm surge[7]. The wind in the area is generally from the northwest with occasional winds from the south as seen in the wind rose diagram in the zoomed in site plan[8]. The solar diagram shows that the sun is out from 8 a.m. to 5 p.m. on the winter solstice and from 5 a.m. to 7 p.m. on the summer solstice. Ocean surface currents in the area of the platform flow southeast with a predominant speed of 0.2-1.2 knots (0.5-2.0 feet per second)[9] (fig 7).

The situation of the Beta Unit in an area of known seismic activity dictated that all structures were to adhere to a heavily redundant series of design requirements. At first, the structures will resist shaking with a low probability of occurrence without damage while the members remain elastic. This criterion will withstand an earthquake with

---

[6] Ibid.
[7] Ibid.
[8] Midwestern Regional Climate Center, "Cli-MATE," last modified 2019, accessed March 27, 2019, https://mrcc.illinois.edu/CLIMATE/welcome.jsp.
[9] National Oceanic and Atmospheric Administration, "Ocean Currents," accessed March 27, 2019, https://www.noaa.gov/education/resource-collections/ocean-coasts-education-resources/ocean-currents; John Marshall and R. Alan Plumb, *Atmosphere, Ocean, and Climate Dynamics*, *Academic Press*, 2008.

peak horizontal acceleration at 0.25g, which is expected to occur in the area once every 200 years. Furthermore, the Beta Unit platforms can withstand the rare intense earthquake with 0.5g of horizontal acceleration—expected to occur at an interval exceeding 1,000 years—due to their member redundancy but would undergo some inelastic deformation[10].

Since the development of the offshore platforms in the 70s, there has been a growing concern for the effect on marine life that they would have. In the 90s, Milton Love, at the University of California, Berkeley, started to investigate this impact. He was surprised by what he found: the legs of the rigs had been colonized by schools of fish, invertebrates, and corals. Because of the continuous depth of the legs, organisms that live at the various depths were able to make homes for themselves, allowing for what has been called "[one of] the most productive habitats in the world's oceans." Marine organisms tend to do well with any sort of structure—whether it be a rock, a log, or a steel truss structure—because the surface area is what is useful for growth. Because of this finding, the "Rigs to Reefs" bill was passed in 2010 in California that allowed for the owners of the platforms to leave much of the structure once their contract was up to help aid the marine populations[11].

Effects of Climate Change

A highly disputed, yet highly relevant topic worth discussing is the impact of climate change. Focusing on southern California, the effects of climate change are already being noticed with a decrease in rainfall in the area over the past few years. It is

[10] Shell Oil Company, *Beta Unit Plan of Development*.
[11] FitzGerald, "Crude Habitat."

projected that, should the climate continue to change at the rate it is now, that southern California could receive a decrease of 10-30 percent of its annual rainfall by 2080. For temperature alone, the region is projected to increase by approximately 10 degrees Fahrenheit by 2080 if climate change is not reduced, and should it be reduced, the temperature is still expected to rise by 4 degrees Fahrenheit. In this scenario of unchanged climate change rates, there is a predicted extreme heat event to take place in southern California every 3 years. Globally, with emissions as high as they are today, the sea level is anticipated to rise by 3-4' with effects in various regions to differ based on geomorphology, ocean currents, and regional tectonics[12].

Main concerns for the pacific states are early snowmelt, degraded air quality, urban heat island effect, wildfires, heat waves, drought, tropical storms, extreme rainfall with flooding, and sea level rise—all the potential disasters of climate change are anticipated to affect this region. Heat waves and lack of water in the southern California region are expected to result in wildfires as already observed in present day. This has a compounding effect when sudden downpours are to be considered, which would result in flash floods, mudslides, and massive erosion[13].

This thesis design will integrate considerations for these effects of climate change while striving to be an example of sustainable development in the time of climate change.

Flora and Fauna

The platforms as they exist have become a home for what has been called an artificial reef. The legs of each platform have been utilized for their surface area for a wide range

---

[12] National Research Council (U.S.), *Adapting to the Impacts of Climate Change: America's Climate Choices* (Washington D.C.: National Academies Press, 2010).
[13] Ibid.

of species from the surface to the seafloor. This area of the ocean specifically has the most geologically diverse seafloor off the United States coast which allows for such species diversity as well as two important currents: the California current that flows south from Washington through the bight of southern California and the Counter California current that flows north in a spiraling motion. These conditions cause an upwelling of nutrients from the seafloor that supports an abundance of phytoplankton which initiates a thriving marine web in this region[14].

Many animals call the waters that extent from the bight of southern California home, whether that be a temporary or permanent home. This region experiences high traffic of migrating marine and terrestrial species including humpback, blue, right, and sperm whales, spawning grounds for great white sharks and other sharks[15]. This region is also a stop on one of the four largest migrations—of more than 350 species of birds—in the Americas traveling from Chile to Alaska and back[16]. The number of resident species is also significant with over 150 species of birds, 32 species of marine mammals, 4 species of sea turtles, and over 700 species of fish and invertebrates[17]. In this region exists a deep-sea reef that has begun to colonize the platform legs. At the seafloor where the legs are piled into the sediment, sea stars and carnivorous invertebrates feast on fallen mussels from above. Various groundfish, such as many species of endangered rockfish, thrive here and have had a remarkable rebound in population numbers since the rigs' installation. Moving up the legs of the rig, the lowest level is colonized by benthic coral reefs and anemones that inhibit the movement of sea stars and the like up

[14] "Healthy Habitat, Healthy Oceans," *Oceana - Protecting the World's Oceans*.
[15] Ibid.
[16] "Top Five Must-See Migrations in California," *The Nature Conservacy*.
[17] "Healthy Habitat, Healthy Oceans."

the legs. Further up the legs, near the tidal zone, barnacles and mussels have taken up residence on the surface of the steel. The numbers of the species found around the rig legs is unprecedented and estimated to be three orders of magnitude greater than in a natural environment. Within these numbers, the surveys have shown that members of the population are in all levels of growth, hence these creatures have lived here for their entire life as a testament to the production in these artificial reefs[18].

Flora in the region is minimal due to the marine nature of the site, however, this region is known for the presence of kelp which supports many marine faunae. Looking to land for potential species to incorporate into design, Santa Catalina Island has over 400 native and 200 non-native species of plants with seven of them being endemic to the island. Many of these species are found on the coast of California as well as more inland[19].

Structure

The Beta Unit was selected because of the organization of the platforms in this small network. The four platforms—Edith, Elly, Ellen, and Eureka—are situated within a 2.5mi radius of one another which would only be 2.5 minutes from the central point to the furthest most platform (fig 6, 7). For this thesis, the scope was limited to Ellen and Elly with the idea that expansion to the other two would be possible in the future.

In their current state, the platforms are equipped to engage with supply and travel ships as well as helicopters. However, the magnitude of the usage of such elements are not

---

[18] A. Wolfson et al., "The Marine Life of an Offshore Oil Platform," *Marine Ecology - Progress Series* 1 (1979): 81–89.

[19] "Plant Species," *Catalina Island Conservancy*.

capable of managing large sums of people as the current estimated occupancy of the platforms is between 20 and 100[20]. Therefore, this thesis will require amendments or complete redesigns of the access point to the platforms.

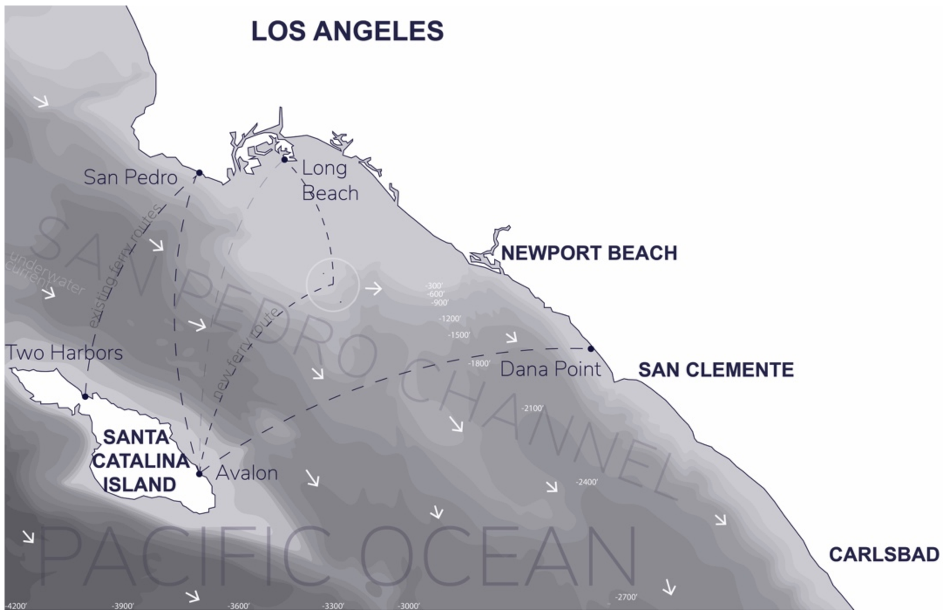

Figure 6: Location of platforms in relation to the coast. The white arrows show ocean current, the gradations of gray show the bathymetry and the deashed lines show ferry routes with the smaller dash replacing the lighter line to allow access to the platforms. (source: author)

[20] Samie, "Introduction to Offshore Platforms."

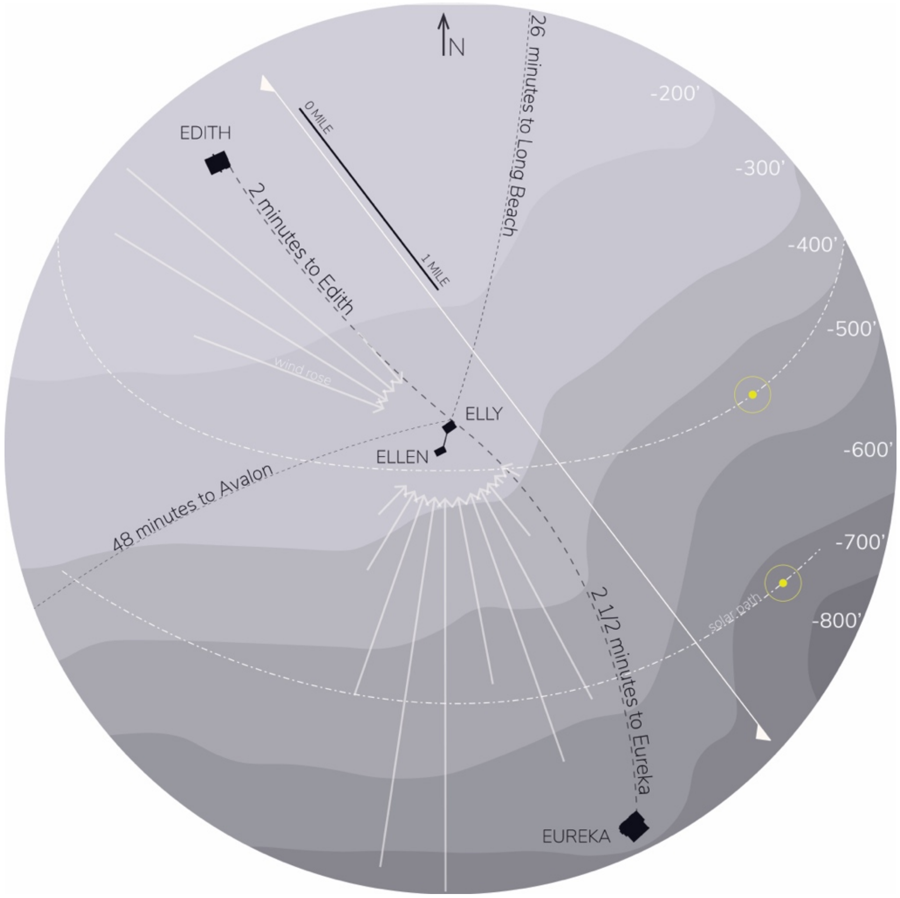

Figure 7: A zoomed in site plan shows the relationship of each platform to one another. The sun angles are shown here as well as the wind rose. The dashed lines show the travel times between the platforms and land.

In their current state, the platforms are fully functional. Ellen has three main decks which house a variety of tanks, rooms, and industrial equipment. Elly, the production platform is currently housing majority of the equipment of the two as well as most of the processing of materials. All this equipment is steel and utilizes the same techniques for preventing corrosion as mentioned earlier[21]. Relevant processes that currently take place on offshore platforms, including Ellen and Elly, include the housing of as many as 200 or more workers at a time, food storage, fire suppression systems, diesel generators, wastewater treatment in some instances, desalinization and water treatment

[21] Shell Oil Company, *Beta Unit Plan of Development* (Los Angeles, 1977), https://www.boem.gov/1977_Platform_Elly_Ellen_Eureka_DPPs/.

systems in platforms that are remote, aviation support systems including a helipad, and elevators[22].

Elly and Ellen

These platforms, Elly to the north and Ellen to the south, totaling 54,400 square feet (fig 8). Elly is about 35,784 sf (213'x168'), comparable to the Campidoglio square or a little more than half of a football field, while Ellen is about 25,665 sf (177'x145'), which is comparable to the Lincoln Memorial in Washington D.C. or a little less than half a football field. The platforms are placed in 265-foot-deep water, and another 62'4" from the surface of the water[23] (fig 9).

Access and Infrastructure

Platforms Elly and Ellen exist 8.73 miles from the nearest coast and 11.4 miles from the Long Beach port in Los Angeles. Because of the cultural significance of Catalina Island and the rest of the Channel Islands, established ferry routes already exist to two ports on the island from three ports on the coast (fig 6).

In their current configuration, the ferries that transport people and cars to and from Catalina Island travel between 22.5 and 35.3 miles five times a day. With this information, a simple route to the platforms for pedestrian use could be easily implemented at a more regular schedule to any or all the ports listed in the above figure 6.

[22] Naeim Nouri Samie, "Introduction to Offshore Platforms," in *Practical Engineering Management of Offshore Oil and Gas Platforms*, 2016.
[23] Shell Oil Company, *Beta Unit Plan of Development*.

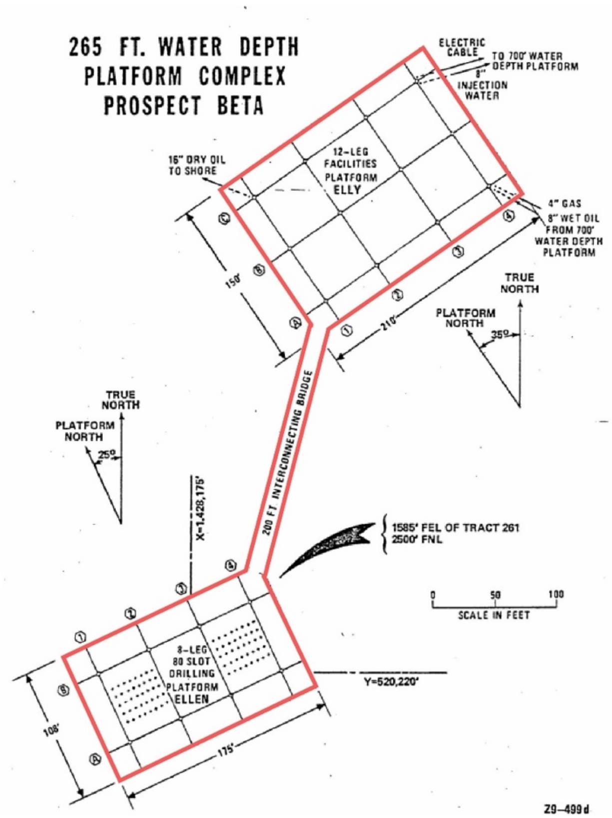

Figure 8: Plan of Platforms Elly and Ellen as seen in Development Plan (source: Shell Oil Company)

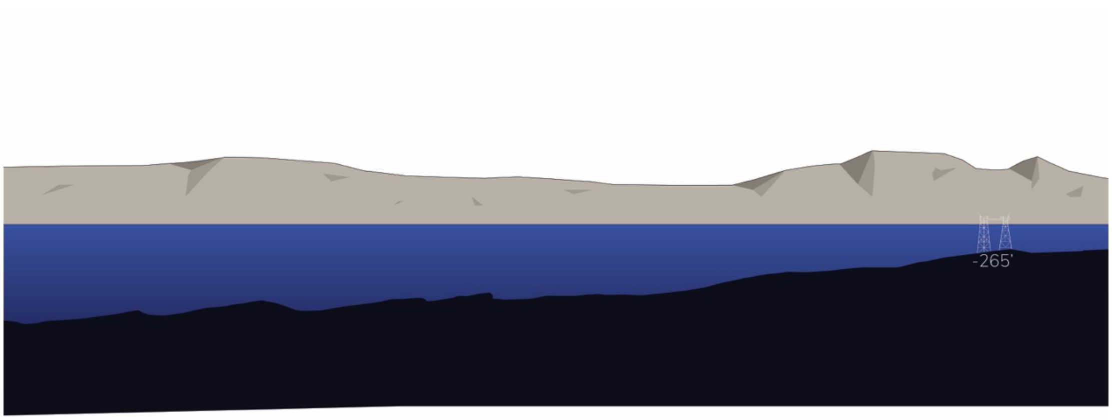

Figure 9: This site section shows the depth at which Elly and Ellen are located as well as the steep bathymetry. (Source: author)

Ellen, the drilling platform, is a standard 8-leg jacket, meaning it has 8 columnar "legs" and Elly, the production platform, has 12-leg jacket, all of which are piled into the seafloor at a depth determined by the structural needs to be covered in the following section. The platforms' structures are composed of steel members that are galvanized or painted with multiple coatings of an inorganic zinc-vinyl system to prevent corrosion near the surface while permanently submerged steel uses a sacrificial, cathodic, aluminum anode system[24].

Possibilities and Restrictions

Given the sum of structural considerations, the platforms were also designed with the combinations of loads from environmental conditions, operation, gravity, buoyancy, and forces associated with fabrication and installation[25]. With that information, the question of loading potential was brought up and in order to prove the capacity of the rigs to hold buildings, two experts were interviewed. Architect and structures teacher at the University of Maryland, College Park—Ming Hu—as well as a dynamics engineer at the University of Melbourne, who has published articles about the subject—Nicholas Haritos. Both experts concluded that the structural capacity of offshore oil platforms to hold buildings would be sufficient vertically[26]. However, there was a question of how lateral loads, mainly wave and wind loads, would affect the structure and the advice was to design with that in mind. Dr. Haritos also mentioned that there was a potential for fatigue of members due to the swaying back and forth caused by the waves. This will be addressed every twenty years and if needed, members can be supported with new addition of steel members[27].

Building on the ocean is a relatively new phenomenon and building codes for such a task are not developed in this area of the world. To understand the restrictions that are

[24] Shell Oil Company, *Beta Unit Plan of Development*.
[25] Shell Oil Company, *Beta Unit Plan of Development*.
[26] Ming Hu, "Structural Capability Interview" (College Park, MD, n.d.).
[27] Nicholas Haritos, "Structural Capability Interview" (Melbourne, AU, n.d.).

associated with building offshore that weren't already brought forth, a precedent investigation will take place later in this thesis.

Egress and Emergency

As they are today, offshore oil platforms are required by law to have an extensive firefighting system on deck. Codes require that the source of water for fire extinguishing is fixed and redundant. Foam systems can be used instead or together with water fire suppression. The helipad and the living quarters are placed in the same area of the platform and are protected by a fire wall. The helipad acts as an ultimate point of egress should a fire or emergency break out. The helipad area has its own fire suppression system with its own redundancy with foam suppression as well should the helipad hold aviation fuel. In the event of a total facility shutdown, a distress signal is sent to the mainland. Structural materials are selected or treated to be minimally combustible[28].

Lifesaving requirements necessitate an abundance of lifeboats, life rafts, life buoys, life jackets, and breathing apparatuses that could accommodate everyone on deck and are to be placed on opposite sides of the platform. Ladders or stairways to the water level must be near the lifesaving equipment. Guardrails are required to be 1 meter (39.5 inches) and trace the perimeter of all open deck areas, walkways, catwalks, and openings[29].

---

[28] American Bureau of Shipping, *Rules for Building and Classing Facilities on Offshore Installations* (Houston, United States, 2013), https://ww2.eagle.org/content/dam/eagle/rules-and-guides/archives/offshore/63_facilitiesonoffshoreinstallations_2014/fac_rules_e-feb14.pdf.

[29] American Bureau of Shipping, *Rules for Building and Classing Facilities on Offshore Installations* (Houston, United States, 2013).

These safety protocols will be considered and expanded upon in the design process to accommodate a much larger population and other potential risks of building on the ocean.

Building Tactics

Modular Design

Building on a platform offers a series of other challenges such as getting materials to the site and construction at the site itself. Choosing a construction technique was a key decision in this design process. Building in a remote site is often approached from a modular design approach given the difficult nature of getting materials to the site. That is the case for this project. Each module will be constructed on land and transported to the site where they can be assembled with the help of the existing cranes. The unit size of the modules for this thesis are shown in figure 10.

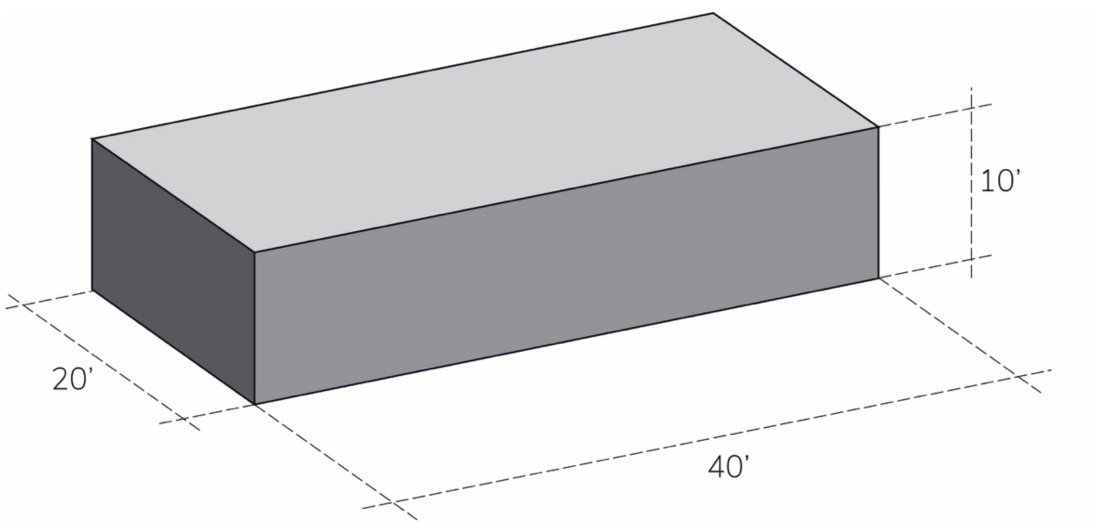

Figure 10: The selected module sizing. (Source: author)

As these modules get assembled on site, the spaces within them could expand and adapt to meet the various needs of the program. The configurations used are shown in figure

11, with stacking, aligning, and rotating of modules ultimately determining the shape of the shape of the unit.

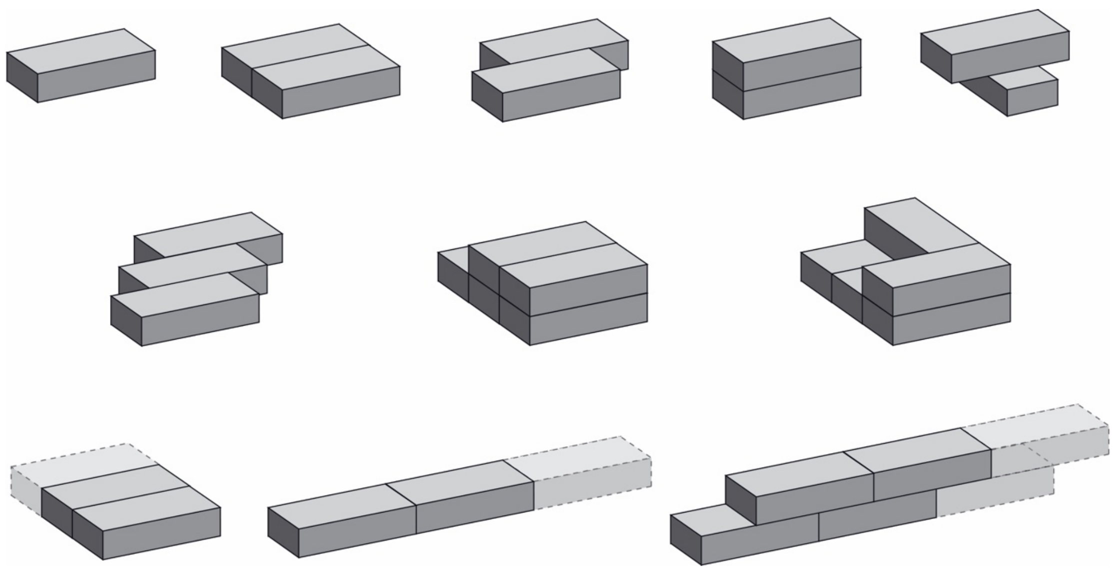

Figure 11: The configurations of the module used in this design with emphasis on stacking, aligning and rotating of modules. (Source: author)

These modules are constructed with steel tube frames and welded to steel footings on the existing decking to ensure a strong connection and tying new structure to the existing. Exterior materials chosen were stainless steel to withstand weathering from the saltwater spray as well as having a relatively low embodied energy due to the recycling of material in the US (fig 12). A decision was made early on that the modules needed to nestle into the structure without disrupting it, thus maintaining the structural integrity while simultaneously benefitting from the use of the expansive decking as overhangs to minimize solar gain (fig 13). Additionally, the walls, roofs, and floors consist of soy-based spray foam, a relatively low VOC insulation that has an R-value of 6.5 per inch (fig 14).

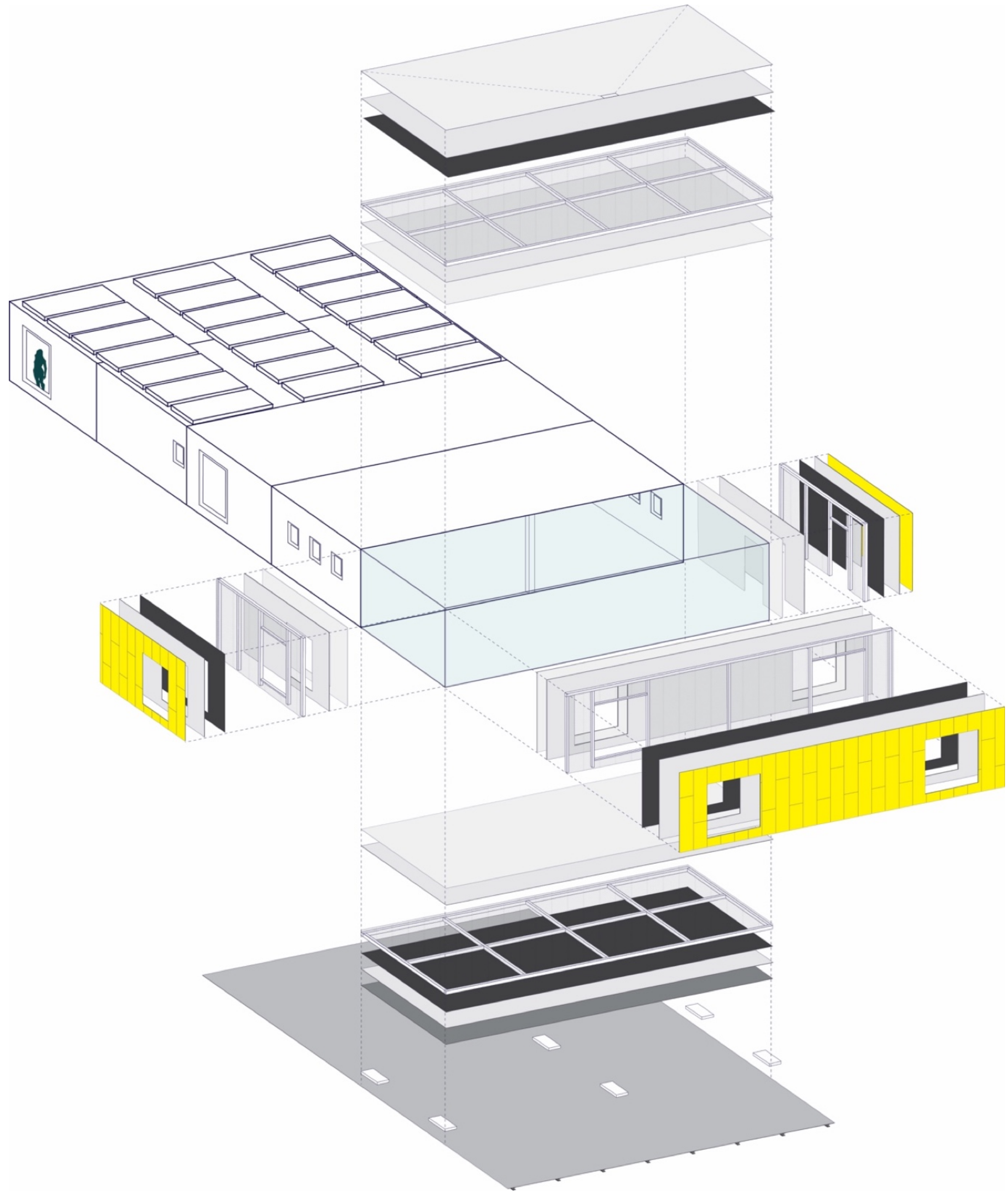

Figure 12: Exploded axonometric drawing of the structure of a module. The steel tube framing is infilled with soy-based spray foam. (Source: author)

Figure 13: This systems section shows how daylighting and the use of existing decking as overhangs benefits the interior spaces throughout the year. (source: author)

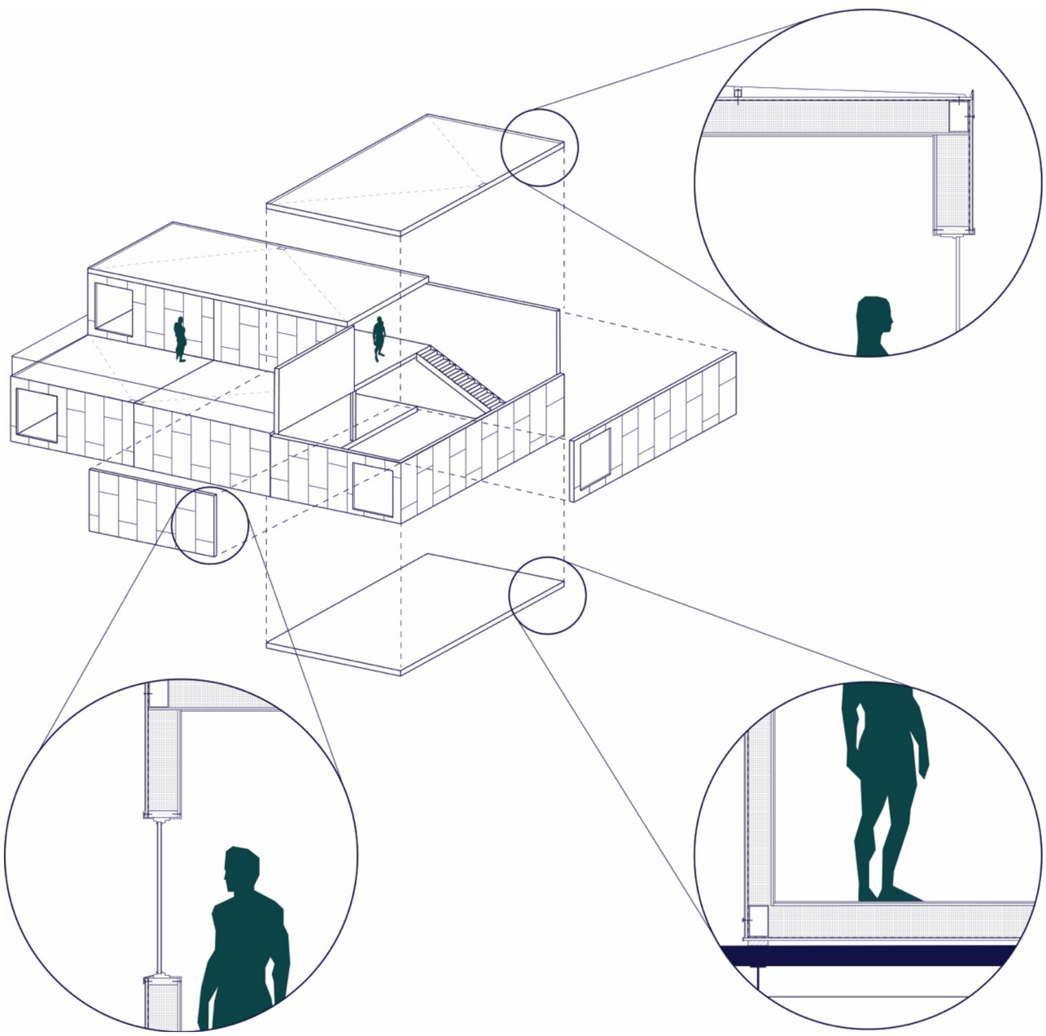

Figure 14: This axonometric shows call outs to the structure of the walls, floors, and roof. From exterior to interior: stainless steel panel, plywood sheathing, waterproof membrane, 4''x6'' steel tube frame, soy spray foam insulation, plywood sheathing, gypsum board. (Source: author)

Passive vs. Active design

In architectural design, there are two general ways to think about how the building will perform. Passive design is using energy within the building only to support and fill in the gaps that the environment cannot fulfill—those being using lights at night because the sun has gone down but not as much during the day because the sun will provide adequate lighting. Active design, however, uses mechanical systems to fully operate the building—lights will be used even if it is sunny. These building tactics need to be considered from inception to adequately fulfill integrate passive strategies.

In looking at passive design closer, it is important to understand the two different types of net zero design classifications: net zero site energy and net zero source energy. Net zero site energy is the requirement of on-site energy produced to cover the energy demand of the building as it's measured at the building. Net zero source energy measures the energy produced at the source and thus is a more complete covering of the building's operational load[30].

Sustainable Materials

Materiality is a big part of designing and building sustainably. There are five essential categories of building materials that are considered sustainable: products made from ecologically beneficial materials, products that are beneficial because of the reduction of detrimental materials, materials that reduce of environmental impact during construction, materials that reduce of the environmental impact of operation, and materials that contribute to the quality of indoor, inhabited spaces. The most sustainable

[30] Pablo La Roche, *Carbon-Neutral Architecetural Design* (Portland: CRC Press LLC, 2017).

method of building is to create something reusable or temporary with materials that will easily degrade in nature or that are easily recycled[31].

The site as it is houses large amount of steel and aluminum both for the quarters of the people who live there as well as the industrial equipment that is used in the drilling and processing of oil. These metals are recyclable and can be reused for structural purposes. Ultimately stainless steel was selected for much of the construction due to the steel being highly recycled in the United States—reducing its embodied energy—as well as resisting weathering and corrosion from saltwater spray as mentioned previously.

Sustainable Design Methods

When considering design techniques that will enhance the passiveness of the buildings, a few key tactics are important: passive heating and cooling, daylighting, stormwater management, and general protection of natural aspects of the site.

Passive heating and cooling can be done in a variety of ways, but most frequently they are utilized in the form of solar gain for heating and natural ventilation for cooling. There are many mechanisms in which these can be applied, as shown in figure 15. These include shading, thermal masses, and nocturnal ventilation to name a couple[32].

[31] Charles J. Kibert, *Sustainable Construction: Green Building Design and Delivery* (New York: John Wiley & Sons Incorporated, 2016).
[32] Ibid.

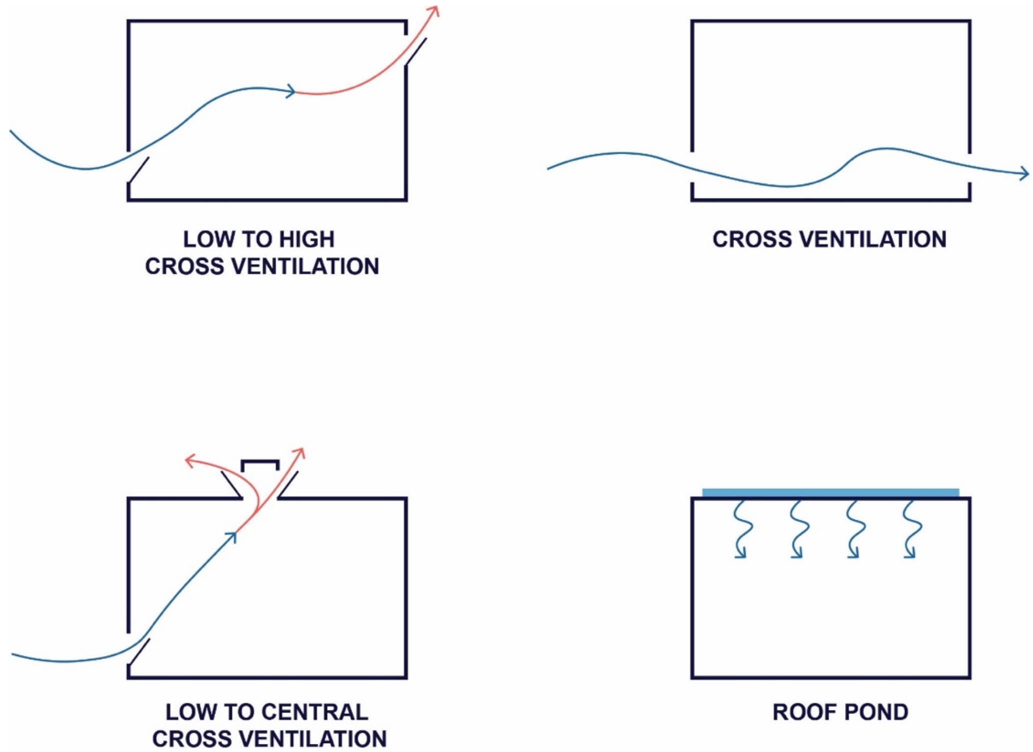

Figure 15: Examples of Passive Cooling Strategies (source: author)

Daylighting is a method of utilizing natural light to whenever possible to illuminate the interior spaces. Techniques for daylighting are as numerous as the techniques for passive heating and cooling, but the main principles are to be keen to the limitations and opportunities of the site, provide punctures in the walls and roofs to allow light to penetrate, and to generally avoid direct sunlight by bouncing light against bright surfaces to diffuse the light. Below are some techniques of daylighting shown in section (fig 16). Daylighting can be supplemented by the presence of lights that respond automatically to the brightness of a room, only activating when necessary to add more increase brightness[33].

---

[33] Ibid.

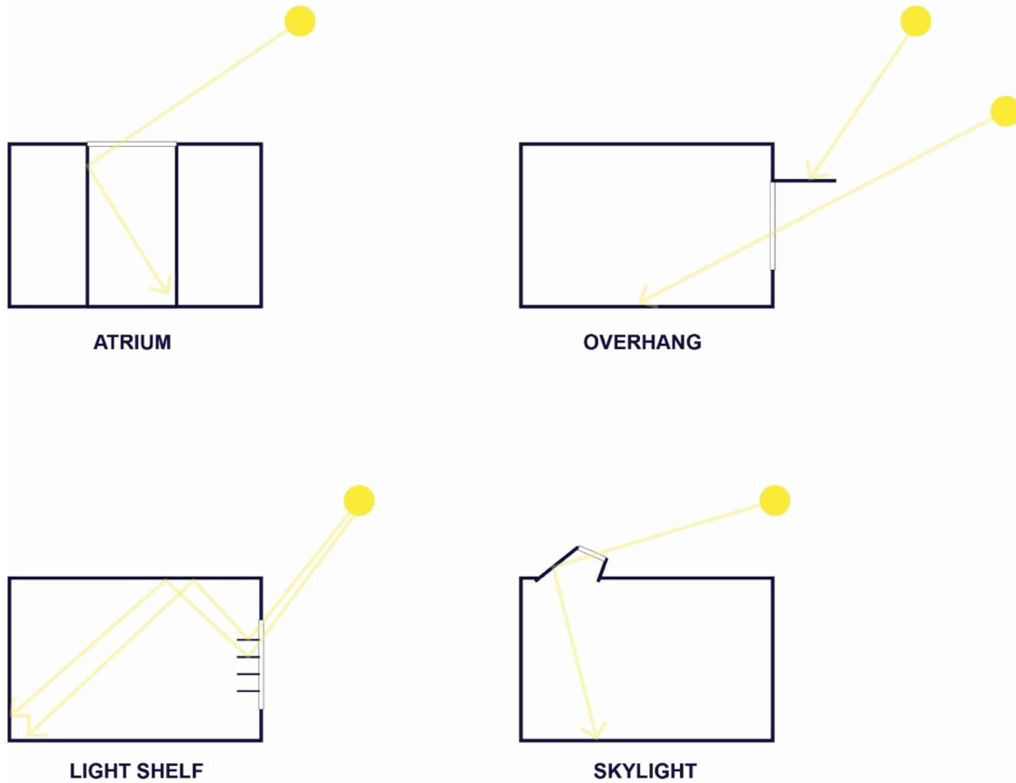

Figure 16: Examples of Daylighting Strategy Diagrams (source: author)

Stormwater management is something that for this site specifically has an atypical role when compared to other architectural projects. In southern California, the amount of rain received is already pretty minimal. Couple that with the examined site exists somewhere where there is no soil, no vegetation, and the only place for water to go is back into the ocean, and it becomes clear that not all aspects of stormwater management are applicable in this case. The primary goal for stormwater on site is to collect and filter it and use it for systems that can use non-potable water like toilets and irrigation. Collection and filtration can be implemented in various forms such as rooftop catchment, vegetated filter strips, retention ponds, green roofs, rainwater gardens, and other various filtration systems[34].

[34] Ibid.

Lastly, a tactic to help achieve maximum sustainability is to implement a type of smart grid that makes the most out of demand shifting. Demand shifting is when different buildings or parts of buildings get used at different times of day, therefore the need to condition spaces is only active in buildings that are being used at a given time. For example, the residential building will be mostly vacant during the day because people will leave for work, whereas the research center will be more active during the day. In the evening when the workers go home, the research center doesn't need conditioning while the residences will. This alternating of demand for conditioning can be utilized as a strategy to minimize the amount of energy is needed to keep people comfortable.

Program

Approach

Deciding on the program for this thesis was a challenge both in subject and in scale. Initial concepts were to create a village or community on the platforms that could be self-sustaining. This was later abandoned because of the feasibility of completing a project of that scale in one semester. Next there were considerations of civic buildings, hotels, and eventually it was concluded that a satellite campus for specific areas of study would be the best use of this site, both because access to sites such as this for education are rare and also because this thesis is calling out a negative infrastructural object and demanding an elevated purpose for it.

Final Program

Thus, the program includes five areas of study: marine science, hydrology, meteorology, sustainable engineering, and astronomy. Each of the five areas of study was given space for up to 25 students to live on site for a semester with office space for 10 research faculty that commute from the mainland. Each area of study also has 2 labs, one for education and one for research and 3 classrooms of various sizes.

The total area of programed space resulted in about 155,000 sf with communal spaces such as recreation and dining areas. Four studio apartments are also included to house any staff that needs to remain on site. The total occupancy would fluctuate between 130 and 200 people during a semester (fig 17).

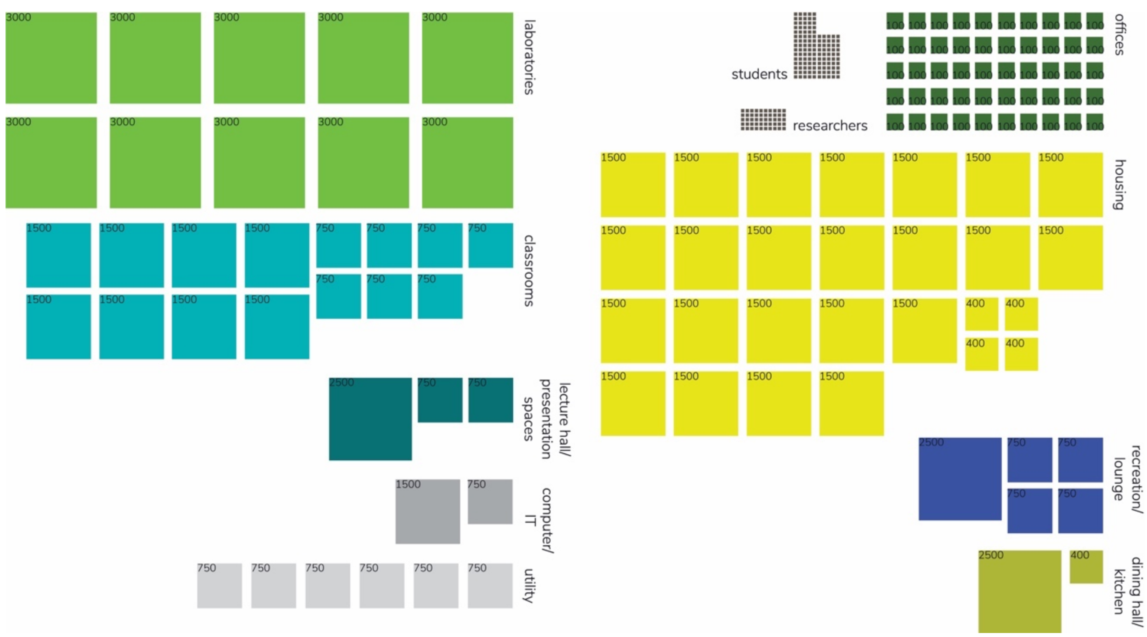

Figure 17: The total program includes 155,000 sf of building with housing for 125 students per semester and 4 on site staff. (Source: author)

Self-Sustainment

Intent

This thesis aims to develop a typology for sustainable development of a network of offshore oil platforms with a key focus on creating a sustainable, human-inhabited outpost of what was once a fossil fuel industry implementation tool. A goal for this project is to focus in on creating something fully sustainable from something that is far from it. Hence, this chapter aims to fill a project niche in determining how much of this project is sustainable, in what ways could it be made sustainable, and how would this network of islands need to function to maintain sustainability.

Energy

Solar

Solar energy, in the form of photovoltaic panels, is a renewable energy source that uses the sun's light waves and converts it to usable energy. This method is based on surface area. PV panels produce 30 kWh of energy for every 1 sf of surface area[35]. Panels will be implemented wherever possible—on facades, roofs, and if applicable, on other surfaces as well.

Wind

Traditional wind turbines produce 6 million kWh of energy per turbine and are generally low maintenance[36]. Because of the much smaller footprint of a turbine as

---

[35] "Lights On Solar," accessed April 25, 2019, http://www.lightsonsolar.com/solar-basics-kw-and-kwh/.
[36] "Wind Energy Frequently Asked Questions | EWEA," *EWEA RSS*, accessed April 25, 2019, http://www.ewea.org/wind-energy-basics/faq/.

opposed to PV panels, implementing wind turbines could be a more viable method for power generation. Wind turbines also come in various designs and shapes thus allowing for stylistic integration.

Ocean Current Turbines

The most traditional type of power generated using the ocean is that of underwater turbines that capitalize on the ocean currents and tides. Ocean turbines look like that of wind turbines but require much less velocity of medium to produce energy because of the density of the water. A recent project in Scotland is finding each turbine to produce 876 million kWh[37].

Kinetic Wave Power

This type of energy generation is done so with the movement of floating or submerged equipment that moves with the tide. These devices are usually attached to some sort of spring or mechanical element that captures converts the energy from the moving waves into usable energy. Though this type of energy is quite novel and still under development and testing, there are high hopes that this energy source could become a primary source of reliable, renewable energy predicted to be able to power 66% of the United States with full implementation. An example of this technology currently being tested successfully in Hawaii is a buoy that generates power via friction as it moves up and down with the waves in the water. Another type is an underwater kite that is

[37] "Tidal Power," *Tidal Power - Energy Explained, Your Guide To Understanding Energy - Energy Information Administration*, accessed April 25, 2019, https://www.eia.gov/energyexplained/index.php?page=hydropower_tidal.

tethered to the ocean floor with attached turbines. Both systems generate 500 kWh[38] per unit. Because of the scope of this project, this method of energy generation would be implemented in future development.

Ocean Thermal Energy Conversion

The final type of energy generation possible with the ocean is ocean thermal energy conversion. This type of energy functions basically how geothermal energy functions. Energy is produced by harnessing the temperature gradient from surface water to deep water. The temperature can be used to evaporate a working fluid which will in turn move a turbine and generate energy. Each unit produces 2.19 million kWh[39]. This type of energy is also usable in a similar way to ground source heating which uses the temperature differential of the earth to generate warm or cool air to condition interiors. Because ocean source heating is incredibly efficient to heat and cool, this mechanism will be the sole source of conditioning in this thesis, thus, the HVAC considerations were removed from the calculations[40]. Because of the scope of this project, this method of energy generation would be implemented in future development.

---

[38] "Wave Power," *Wave Power - Energy Explained, Your Guide To Understanding Energy - Energy Information Administration*, accessed April 25, 2019, https://www.eia.gov/energyexplained/index.php?page=hydropower_wave.

[39] "Energy Portfolio," *Energy Portfolio*, accessed April 25, 2019, http://nelha.hawaii.gov/energy-portfolio/.

[40] "Ocean Thermal Energy Conversion," *Ocean Thermal Energy Conversion - Energy Explained, Your Guide To Understanding Energy - Energy Information Administration*, accessed April 25, 2019, https://www.eia.gov/energyexplained/index.php?page=hydropower_ocean_thermal_energy_conversion.

<u>Water</u>

Desalinization

Treating ocean water for human consumption and farming is by no means a new technology. In countries such as Saudi Arabia, Israel, and the United Arab Emirates, desalinization is the main source of potable water. The process starts with the intake of water from the ocean which is put through at least 3 types of treatment before entering a storage tank for use. These processes include pretreatment to remove solid particulates, bacteria, and sediments, then desalination, which removes the salt through reverse osmosis, and finally, the water enters the post-treatment which chlorinates and mineralizes the water for taste and cleanliness[41].

<u>Wastewater</u>

Wastewater produced on site will be sent to a wastewater collection tank where it will be mixed with treated seawater. Then the water will be sent through a living wastewater treatment system that will make the water potable again as well as house vegetation to benefit the people on the platform.

[41] Paul Rogers, "California Water: Desalination Projects Move Forward with New State Funding," *The Mercury News*, accessed April 25, 2019, https://www.mercurynews.com/2018/01/29/california-water-desalination-projects-move-forward-with-new-state-funding/; Kent Harrington, "Saudi Arabia Creates New Solar-Powered Desalination Technology," *AIChE*, accessed April 25, 2019, https://www.aiche.org/chenected/2015/10/saudi-arabia-creates-new-solar-powered-desalination-technology.

Precedents

Overview

The typology being created in this thesis is novel and thus requires a wide array of precedents from seemingly unconnected projects. Each precedent aims to diagram an idea that benefits this thesis in either a typological, programmatic, or formal way. In this chapter, the following precedents are meant to study an ideal sustainable development, an example of stacked program, a floating, self-contained community, an adaptive reuse project on the water, and an island community. The idea is to take the successful elements of each project and consider the tactics and impact of them in the context of this thesis.

Eco-City

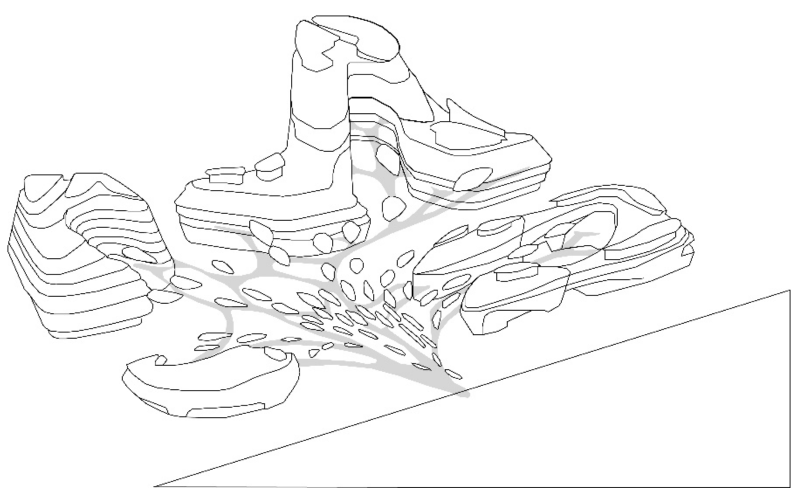

Figure 18: Eco-City by CAA Architects (source: author)

CAA Architects have a designed a new urban transport hub for the capitol city of Maldives (fig. 31). This hub introduces three types of transportation—plane, bus, and ferry—while appropriating a large portion of the program of the hub to tourism—with a hotel, convention center, shopping mall, and market. This project is an excellent precedent of how style and function of a project can be maintained despite a vastly different program. The project also utilizes photovoltaic panels in an interesting way by incorporating them into the wayfinding approach for pedestrians without sacrificing their purpose[42] (fig. 32). This practice of utilizing materials for more than one purpose is an important factor when aiming for sustainability. Any one-use item or material is essentially non-sustainable which further exemplifies why this project is a valid case study for this thesis.

Figure 19: Organization of Program and the Connection to Transportation of the Eco-City (source: author)

Another important aspect of this project that is useful to study is how this project deals with organization of buildings and the access to the buildings. The main axes are used to create a four-quadrant organization for the buildings. The pedestrian

[42] Eric Baldwin, "CAA Architects Reveals Futuristic Eco-City Design for the Maldives," *ArchDaily*, accessed March 29, 2019, https://www.archdaily.com/906503/caa-architects-reveals-futuristic-eco-city-design-for-the-maldives/.

bridges all feed into the courtyards of the buildings which are designed to accept the pedestrians (fig. 33).

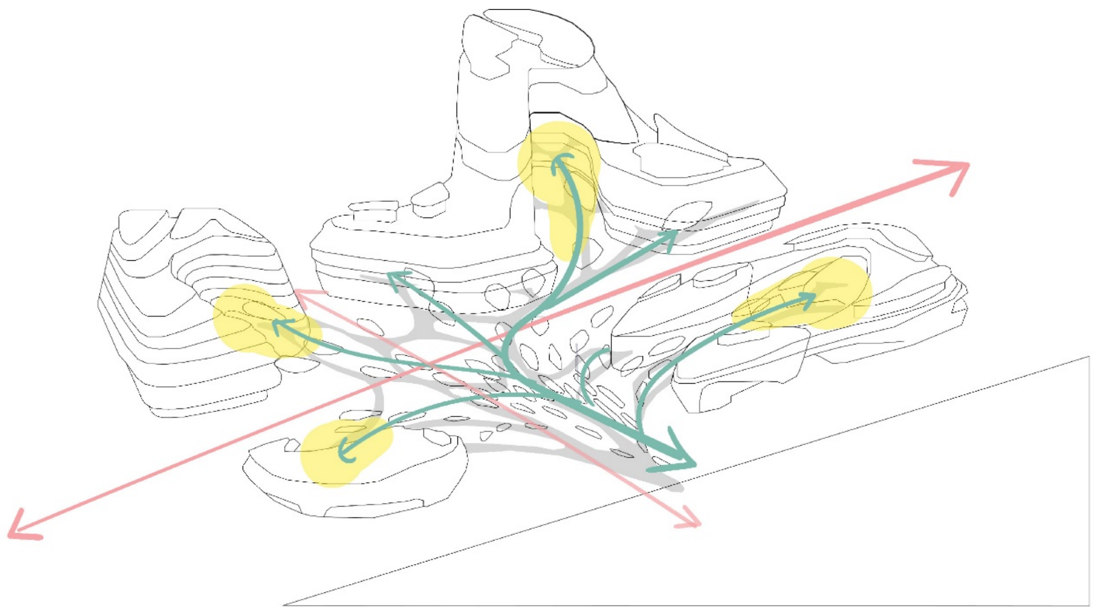

Figure 20: Pedestrian Access and the Greater Quadrants in which the Buildings are Organized (source: author)

Nanjing International Youth Cultural Center

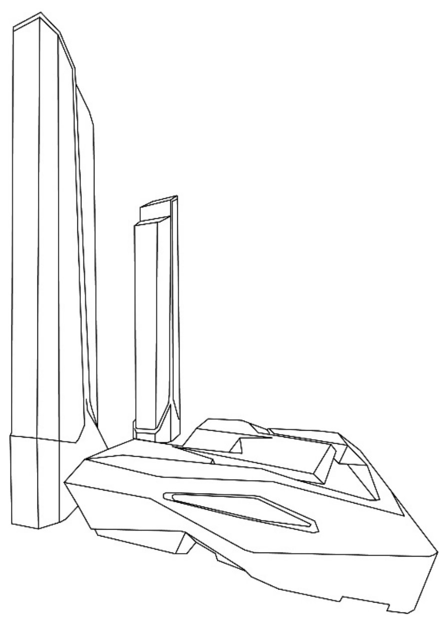

Figure 21: Nanjing International Youth Cultural Center by Zaha Hadid Architects (source: author)

The Nanjing International Youth Cultural Center by Zaha Hadid Architects is a cultural center meant to support the new business district in Nanjing, China (fig. 34). The concept of this project is to relate the context to two new towers. One of the most compelling aspects of this project as they relate to the thesis is the fluidity of the architecture that houses multiple semi-related programs. One tower has offices, a hotel, and support spaces that are separate from the other tower which only houses a hotel meant to support the main, activity space, the conference center that is a separate building[43] (fig 35).

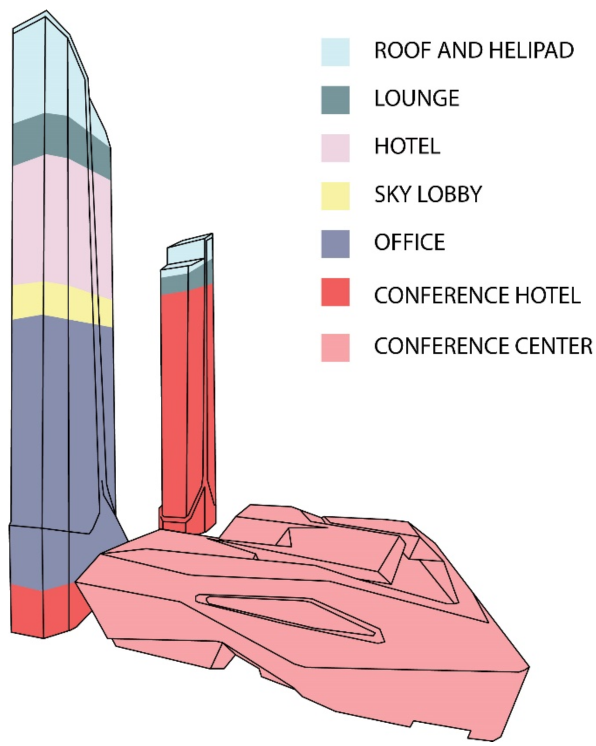

Figure 22: The Program of the Nanjing International youth Cultural Center is Stacked (source: author)

This project was chosen because the separation of program in a vertically stacked way is potentially compelling for this thesis. The separation of the dwelling areas

[43] "Nanjing International Youth Cultural Centre / Zaha Hadid Architects," *ArchDaily*, accessed March 29, 2019, https://www.archdaily.com/907145/nanjing-international-youth-cultural-centre-zaha-hadid-architects/%3E.

from high-energy, activity-centered program is also a smart tactic that allows for an area of retreat when the excitement gets to be too much. As seen below, the conference center is the main draw of the people and is therefore given multiple means of access, whereas access to the dwelling areas are less openly accessible (fig 36).

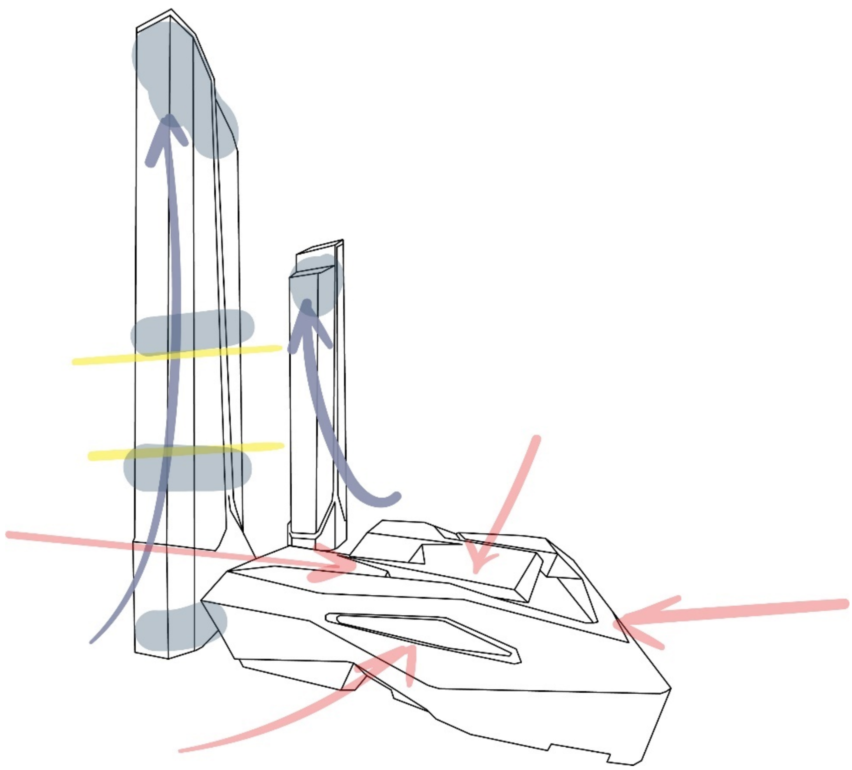

Figure 23: Diagram showing the Movement to the Conference Center and the Hotels (source: author)

Kraanspoor

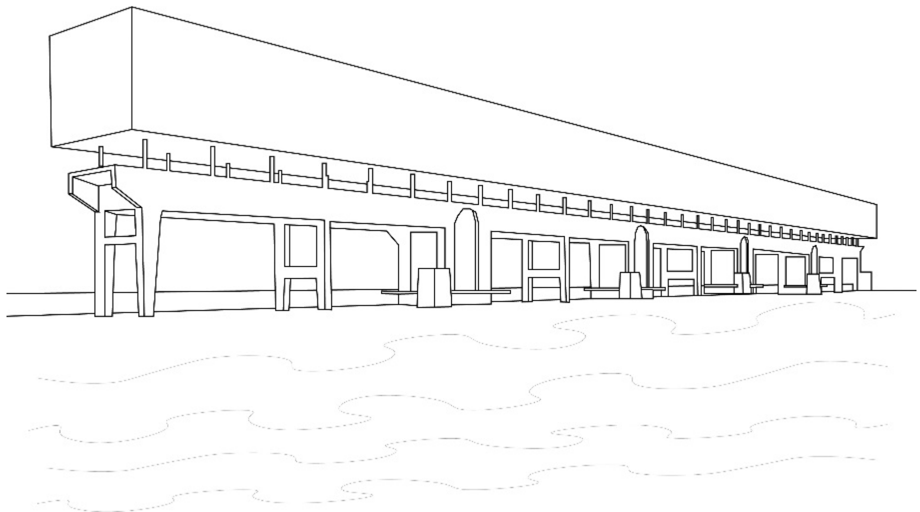

Figure 24: Kraanspoor by OTH Architecten (source: author)

Kraanspoor by OTH Architecten is an adaptive reuse project similar in concept to this thesis. The existing crane way structure was a relic of Amsterdam's shipping industry and was protected. To reactivate it, the architects placed a hovering, glass office complex on it to give it purpose and enrich the area again (fig. 40, 41).

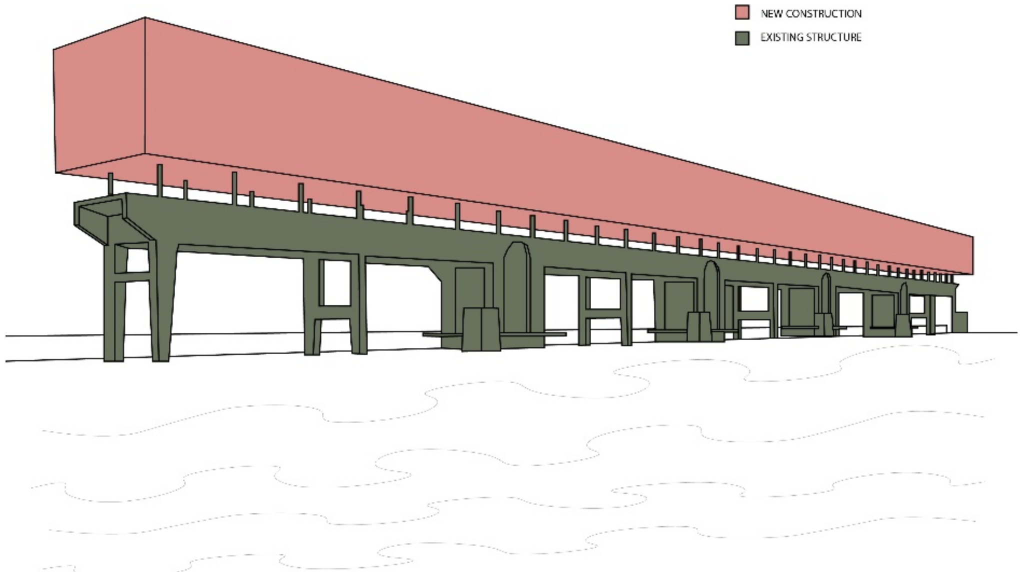

Figure 25: Pre-existing structure informs the abstracted form above it (Source: author)

Elements of the existing structure were taken into careful consideration as to the potential for the building. Alternating support cores were integrated into the vertical promenade one would take to reach the building. The hovering building highlights the part of the structure where cranes once rested and highlights this zone with panoramic views. This project also plays with the idea of extension and abstraction of form as the building itself gets most of its cues of design from the existing structure (fig. 42).

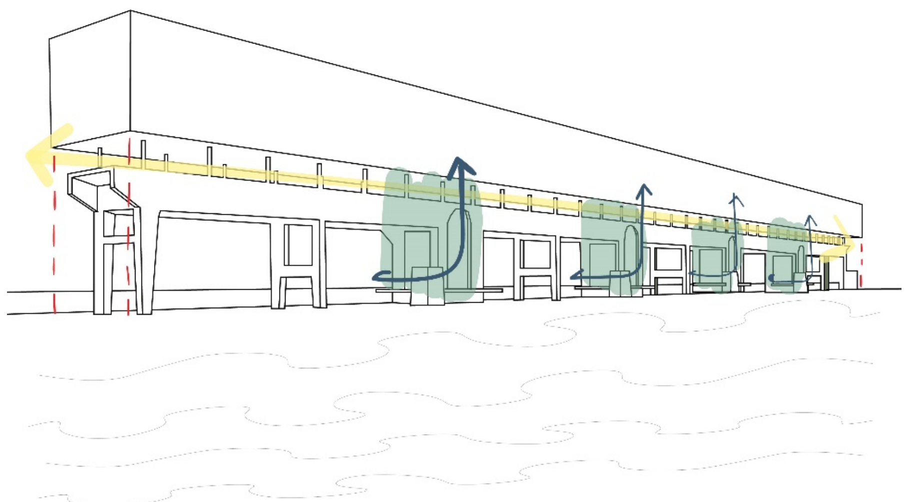

Figure 26: Elements of the Existing Structure are used to Inform the Design (source: author)

<u>*Blox*</u>

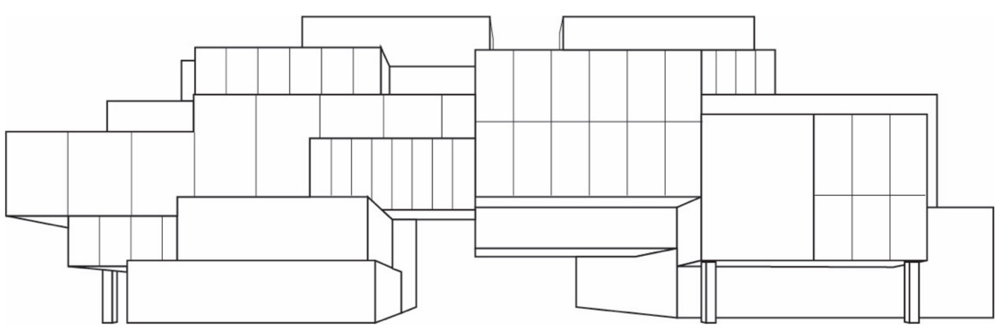

Figure 27: Blox by OMA (Source: author)

Blox by OMA is a project on the waterfront that deals with housing a variety of program (fig 27, 28). It was approached in a way that called for aggregation of similarly shaped boxes in a variety of ways while maintaining an interior organization that is clear.

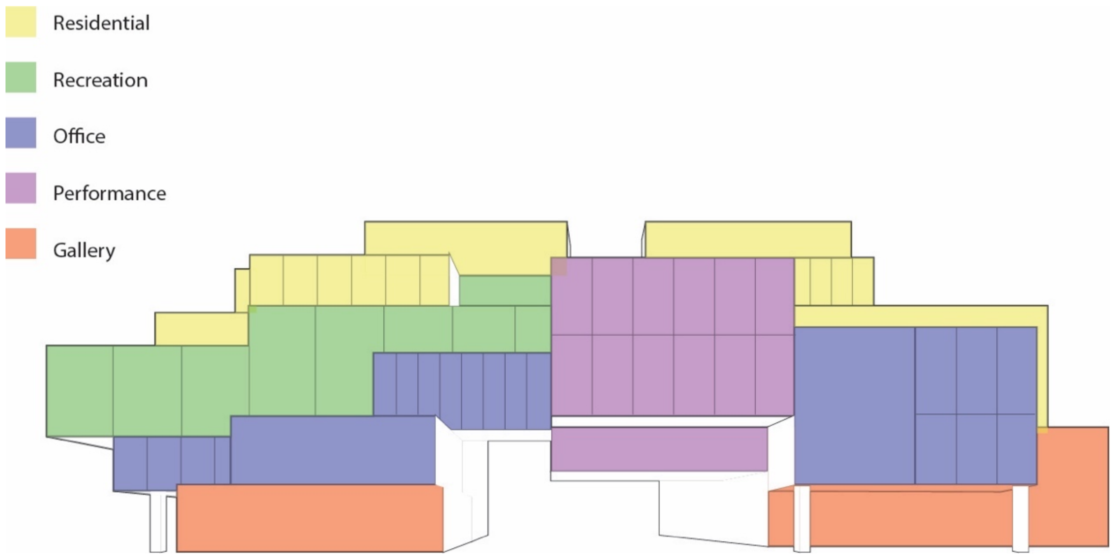

Figure 28: The program for Blox is discreetly distributed by boxes (Source: author)

This project also utilizes exterior facades as an approach to distinguishing the modules or separate boxes from one another (fig 29).

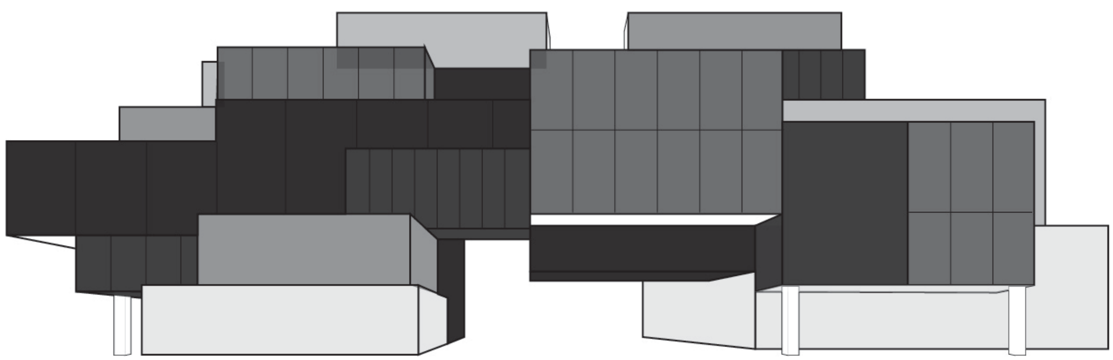

Figure 29: The facade treatment highlights the different boxes in this design. (Source: author)

Holmen Industrial Complex

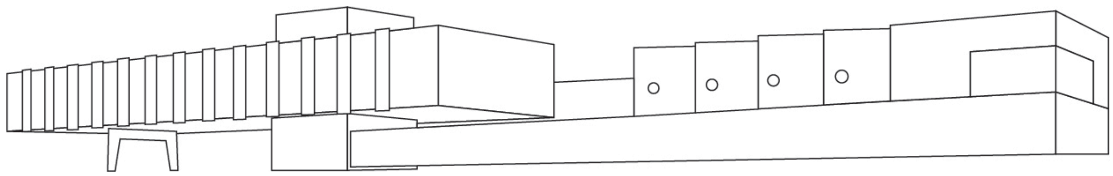

Figure 30: Holmen Industrial Area by Snohetta

The Holmen Industrial Complex by Snohetta is another waterfront project that deals with its site with a smart choice of materiality (fig 30). Similarly to the approach of materiality in this thesis, this project focused on materials that could easily withstand salt water: glass, painted steel, and wood (fig 31).

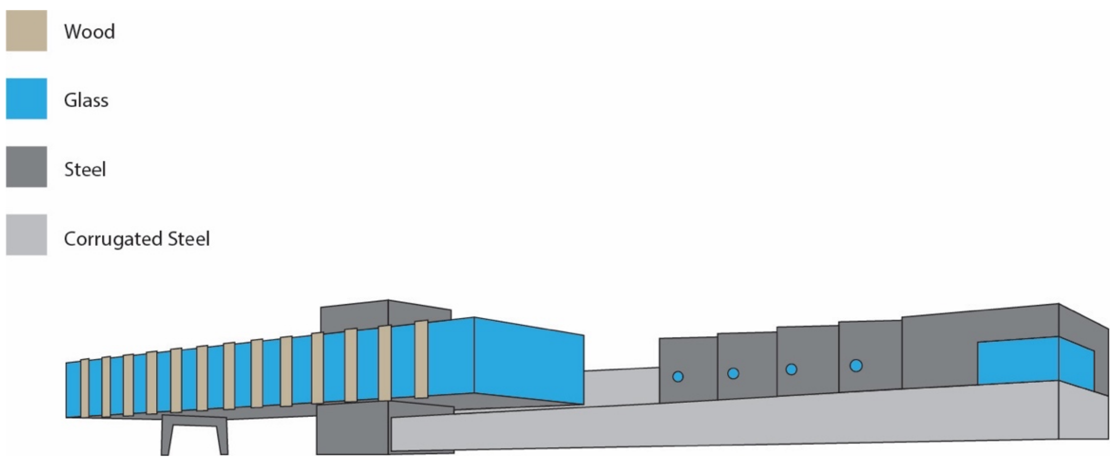

Figure 31: Materiality consists of sea water resistant materials. (Source: author)

Conclusion

Given the five precedent case studies mentioned above, aspects of their design, implementation, or planning are applicable and/or critiqued for the analysis in this thesis.

Something done well in the first project, the Eco-City is the continuity and connectivity of spaces and language in the design of the campus. However, this project's showiness is hindering of its potential to fully integrate sustainable building techniques. Any design meant to add to its sustainable nature is hidden by the parametric design of the buildings or disregarded because the style and language was given a priority.

The Nanjing International Youth Cultural Center is a good example of organizing program in an effective way, however, the site in this thesis behaves in a different manner. The platforms are inherently separated and despite the nature of lifting program from the ground plane which is a paralleled by the Cultural Center, the programmatic organization requires a small footprint whereas the overall footprint of the platforms will remain the same.

The Kraanspoor project is an interesting approach to an adaptive reuse of aquatic, obsolete infrastructure. Sadly, this project does not adequately incorporate a variety of interesting spaces into the new construction. This project had many constraints with its design which are not applicable to this thesis.

Blox has a similar design philosophy to the implemented approach. The collection of module-like boxes is stacked to create a conglomerate. This strategy is well adapted to a project that houses a lot of program elements, similarly to Blox.

Lastly, the Holmen Industrial Area was selected mainly as an approach to materiality. The project has brightly colored steel panels that create a livelihood in the project that wouldn’t be there otherwise. This fun and fresh feeling that comes from color was implemented for this project as well. Neither this project nor Blox stray from exposing structure as well, as both of them have highlighted their various trusses, columns, and beams in a way that would be beneficial to this thesis.

Design

Process and Early Approaches

The beginning of the design process brought about a few key factors that would be important considerations to keep in mind throughout the development: modular design, materiality, and sustainable systems.

There was an early concern of getting enough light into the center of the building because of the existing decking. This led to the perforation of the center of the platforms' decking in every iteration of design. Another early concern was how to deal with the modules, whether to make the modules just walls or to make a unit that is to be aggregated—and if the latter, what is the best way to aggregate the modules?

In the first iteration, there was an emphasis placed on the central punctures and the light it allowed for. This parti came about before the simplification of the program that reorganized the spaces from including exhibition spaces to being purely a campus. As seen in figure 32, the module would have been primarily used on Elly with a modular wall system used on Ellen instead. The approach here was in contrast with one another, as Elly's organization represented repetitions of the same form whereas Ellen's was more so one shape.

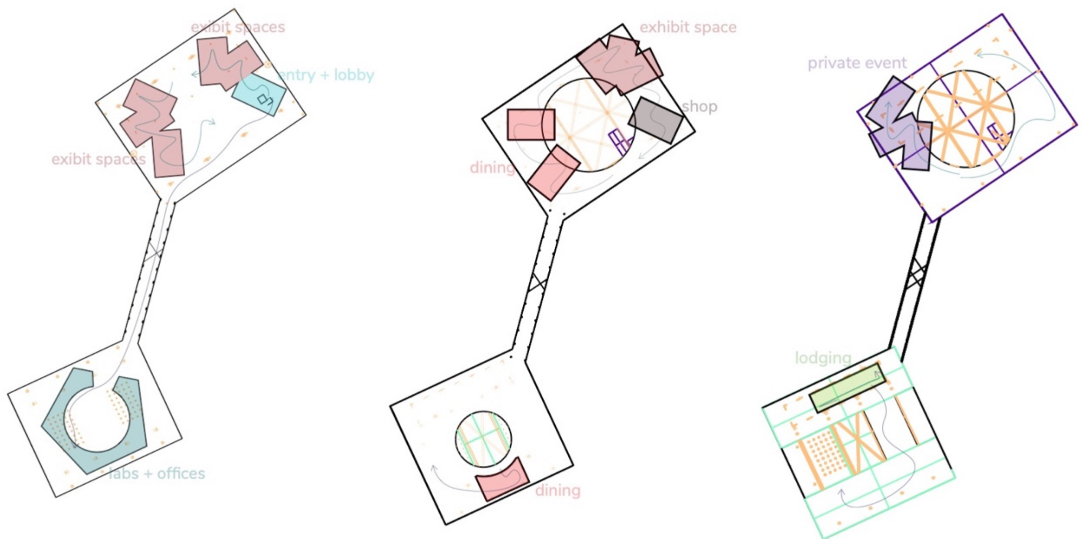

Figure 32: The first iteration, level 1 (left), level 2 (center), and level 3 (right). (Source: author)

This iteration was left behind because there was not enough building to warrant this configuration as well as a change in the building program that would call for an expanded series of spaces and sizes.

The second iteration of note involved a module wall system that would be used to discreetly highlight the separate spaces similarly to Blox. This design kept the central punctures from the first iteration but called for a much-expanded square footage for the building. This design also created a dialogue between round and orthogonal geometries with the central punctures still round and the building consisting of aggregated boxes that consisted of 90-degree angled walls. This iteration also began the thought process for the updated program, began to include some of the systems mentioned earlier, and began the process of thinking of arrival at the sea level (fig 33, 34, and 35).

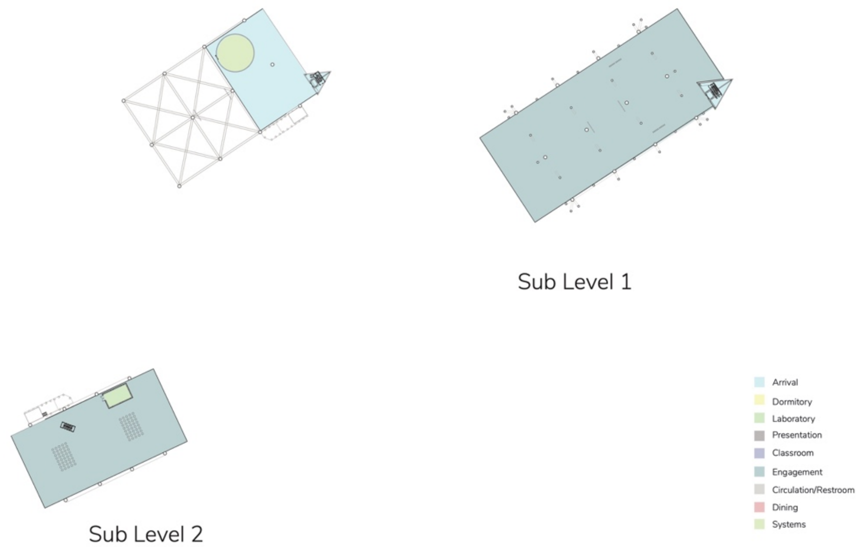

Figure 33: Sub levels of the second design iteration. (Source: author)

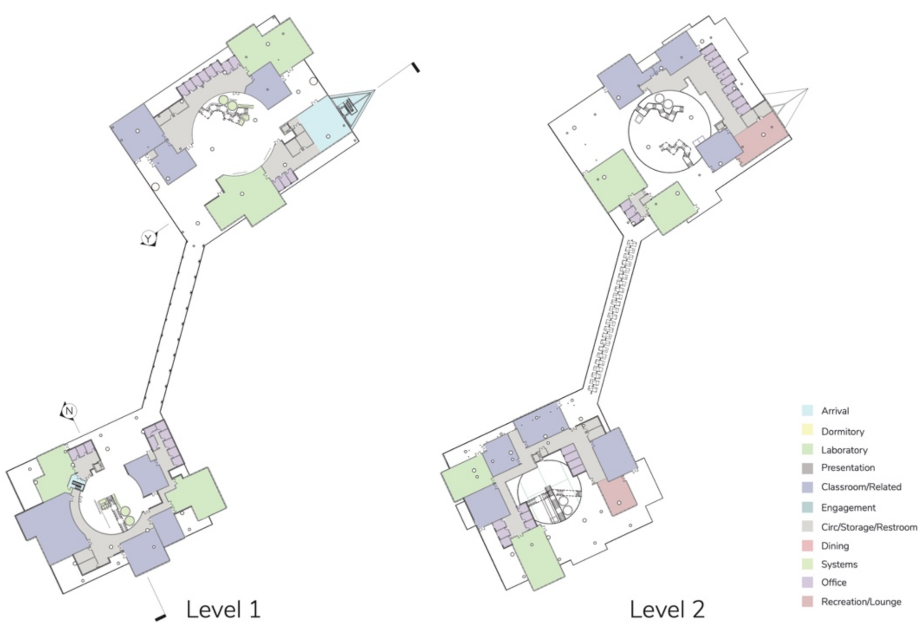

Figure 34: Levels 1 and 2 of the second design iteration. (Source: author)

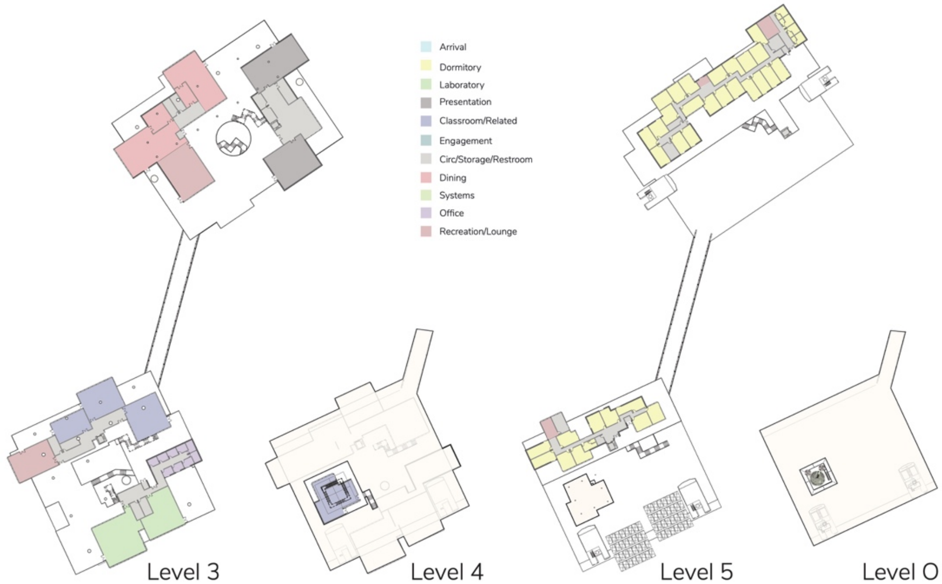

Figure 35: Levels 3, 4, 5 and O in the second iteration. (Source: author)

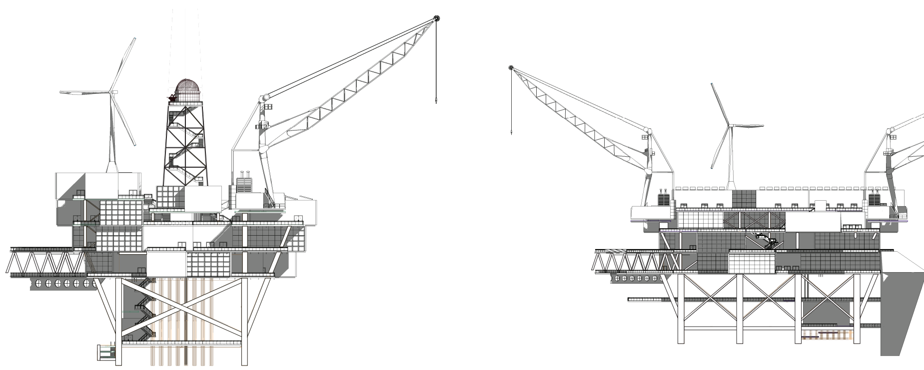

Figure 36: These elevations show the change in materiality of the facades to indicate modular differentiation. (Source: author)

This iteration's main flaw was in the connection of the new structure to the existing structure. For this design, there was a necessity for the building envelope to be punctured by the existing structure. While not impossible, the frequency at which that would have to take place as well as the somewhat arbitrary placement of the walls would make this close to not plausible. Additionally, while the assembly type would still be considered modular, the number of different elements that would need to be built in a custom way would reduce the benefit of the prefabrication. Thus, this iteration was left behind.

Final Design

The final design resulted in an amalgamation of the previous iterations as well as the insight gained from the design process. One of the elements that were carried through from the previous iterations is the use of a centralized perforation into the existing platforms to bring light into the platforms core—however the use of a circular perforation was abandoned because of feasibility and the geometry didn’t make sense with the module type that was chosen. Secondly, the use of exterior cladding as a means of indicating the distinct modules was carried through as well, however, in the final design the cladding was all stainless-steel panels with different colors showing the differentiation instead of façade type showcasing the it.

One of the new design ideas that was brought to the project for its final design w the use of the elevator as a wayfinding feature due to uniqueness of color and the panoramic views from the elevator as it functions in the open air. The stairs were located near the center of the platforms as well as a means of easy wayfinding. Also, it was concluded that nestling the modules into the existing structure was the best course of action for the maintained stability of the structure. This decision led to the orthogonal organization of spaces as well as the grouping of building modules by area of study, then by supplemental space use—like placing the dining hall and presentation halls on the same level with staff housing. The placement of the housing for students was always located at the top in every design iteration with the idea that the students could escape from the busy work and study life in the heart of the platforms and move upwards to relax and feel at home.

The systems, which were a main design feature in the second iteration as seen in the perspectives drawn at that time, have been more readily tied into the buildings so that they don’t detract from the study on site, but they can be seen if looked for. The conditioning would be supplied by central boilers and chillers on the main floor of each platform. They would each house 320-ton appliances for this load based on square footage. There is a total of 151 modules used in this 155,000 square foot project (gross interior square footage).

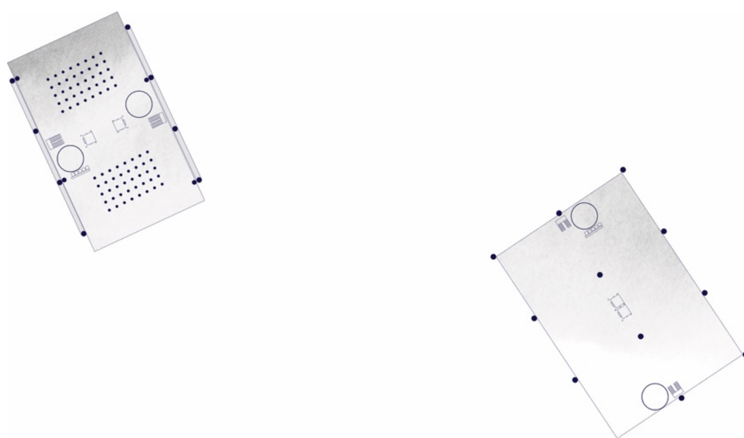

Figure 37: S level: ferry drop off and water storage and desalination take place here. (Source: author)

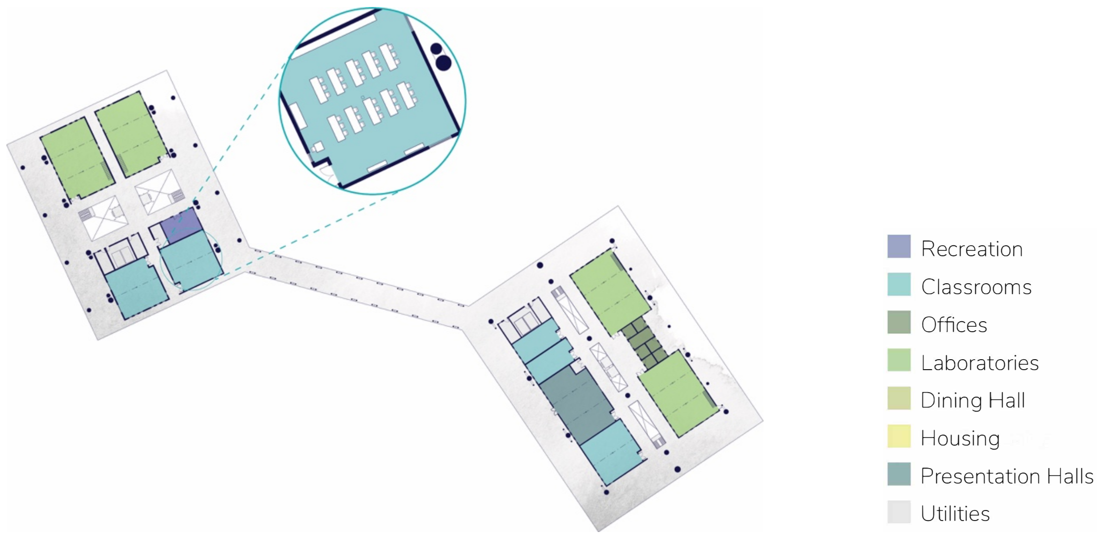

Figure 38: Level 1: hydrology and marine science labs are here as well as office space and classrooms. (Source: author)

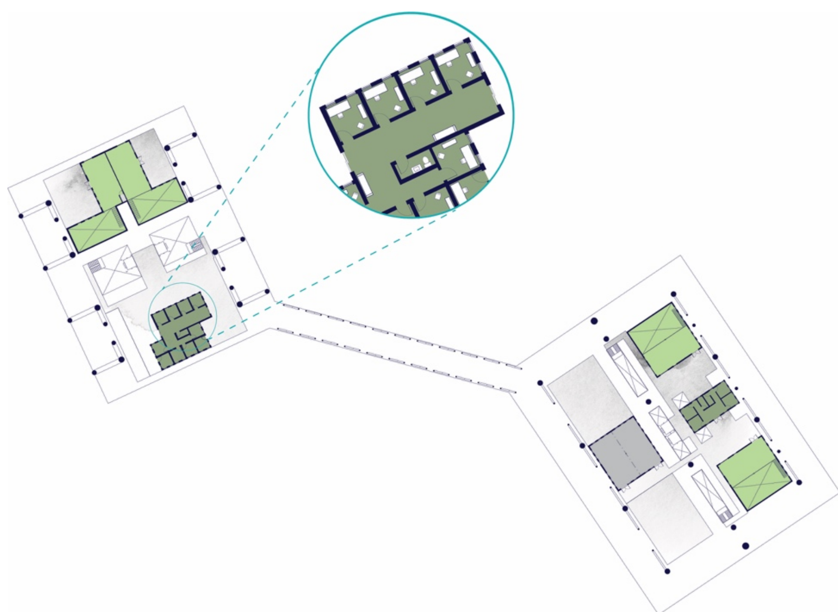

Figure 39: Level 1M: first mezzanine level with the remainder of offices and classrooms. (Source: author)

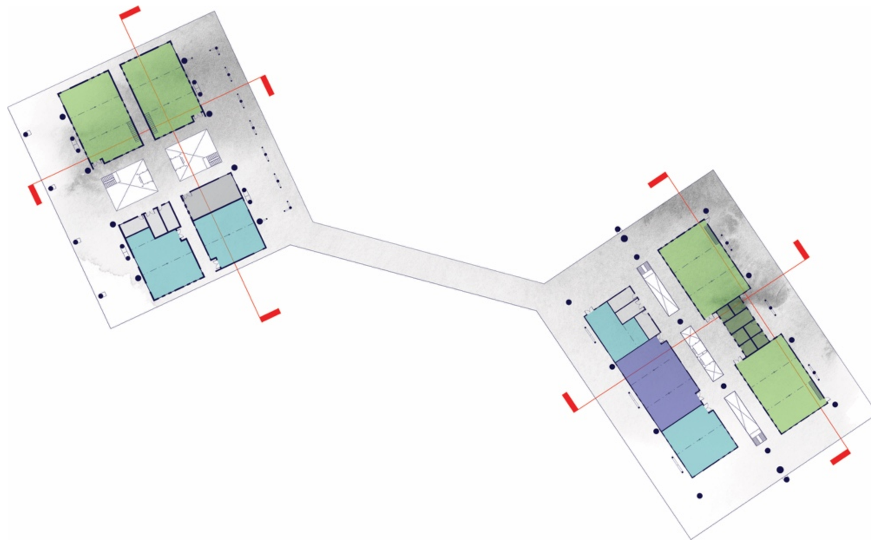

Figure 40: Level 2: Sustainable engineering and meteorology labs and offices are on this level with the main recreation space. (Source: author)

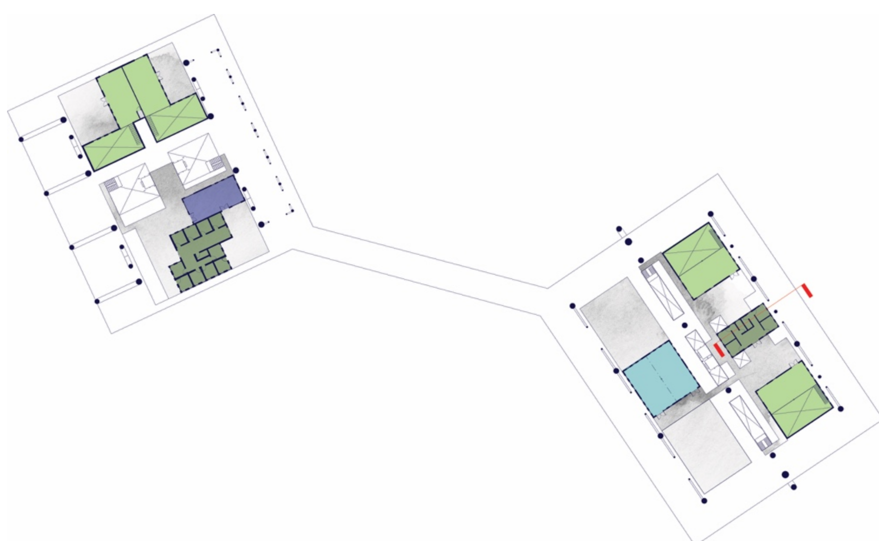

Figure 41: Level 2M: second mezzanine level housing the remaining spaces for sustainable engineering and meteorology. (Source: author)

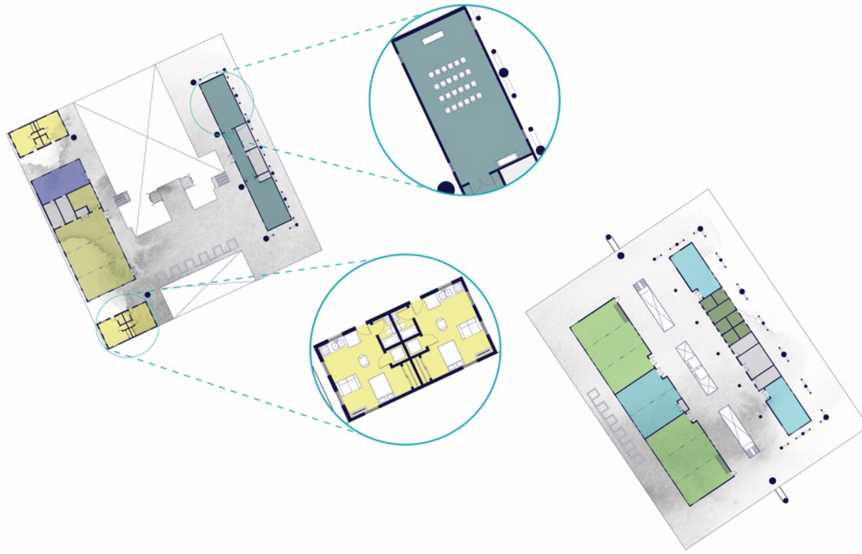

Figure 42: Level 3: Ellen houses the presentation halls, dining hall, and the staff housing while Elly houses the astronomy department. (Source: author)

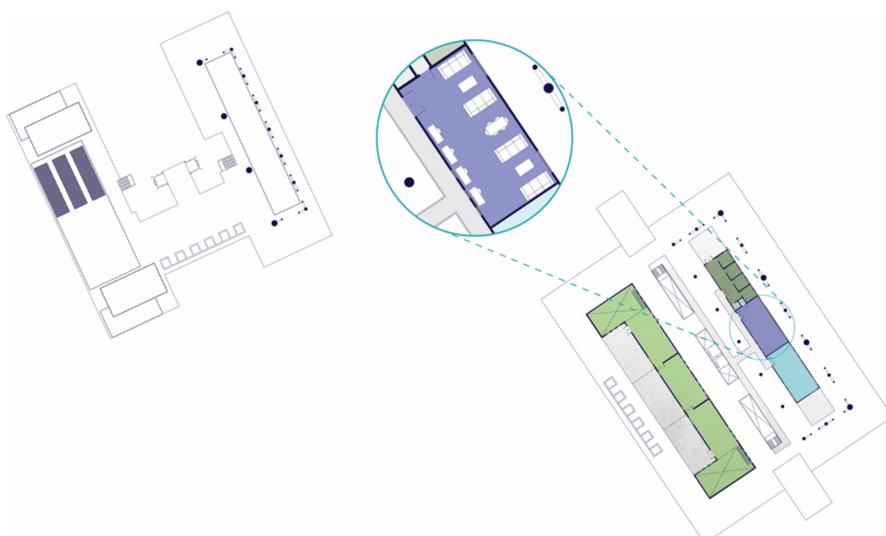

Figure 43: Level 3M: the last mezzanine level holds the remainder of the astronomy department and their shard observatory. (Source: author)

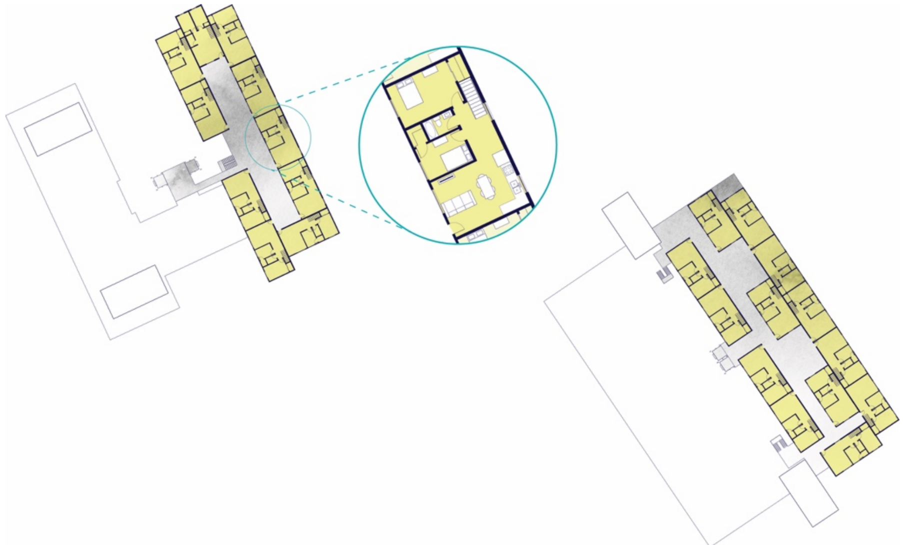

Figure 44: Level 4: the first level of the student housing with 6 bedrooms, 2 bathrooms, a living space, and a kitchen in each of the 23 houses. (Source: author)

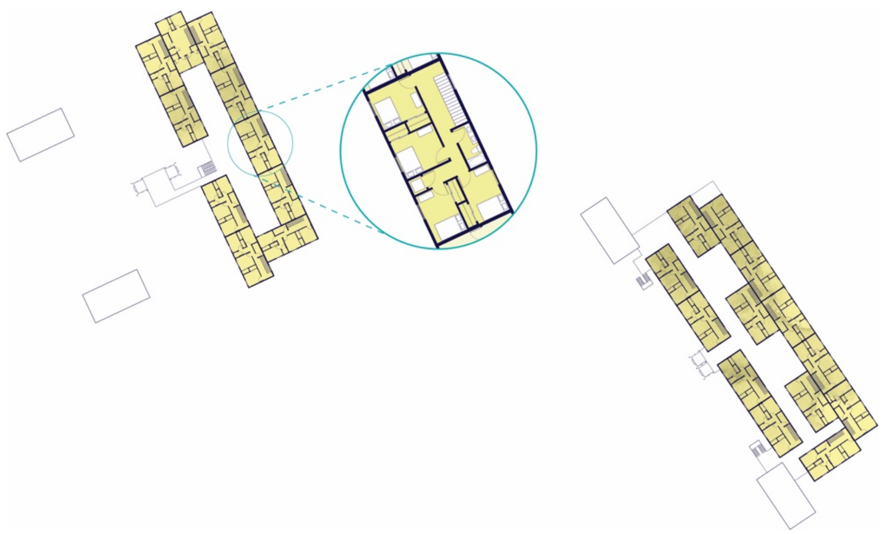

Figure 45: Level 4M: the upstairs of the student housing is here. (Source: author)

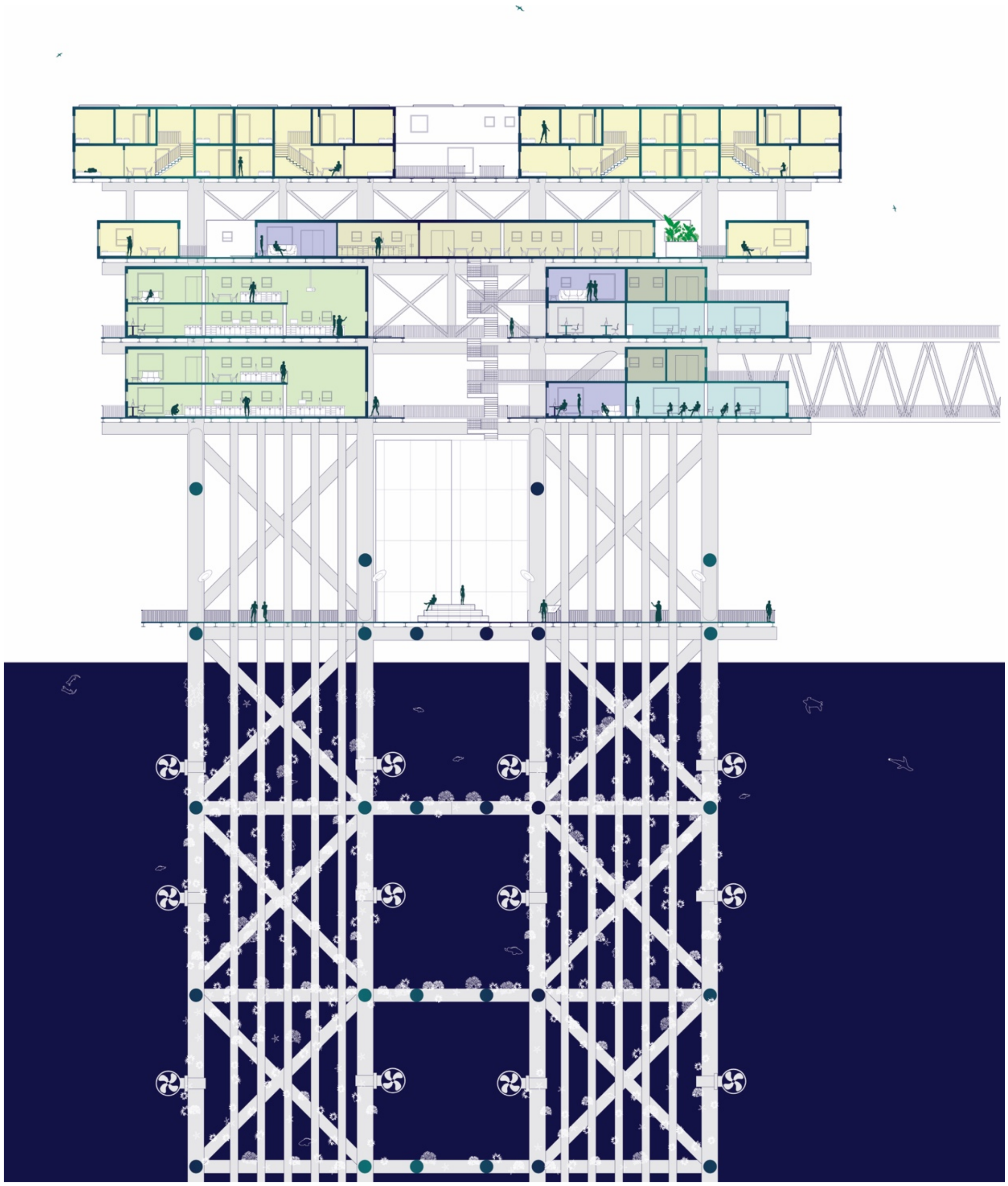

Figure 46: Section of Ellen. (Source: author)

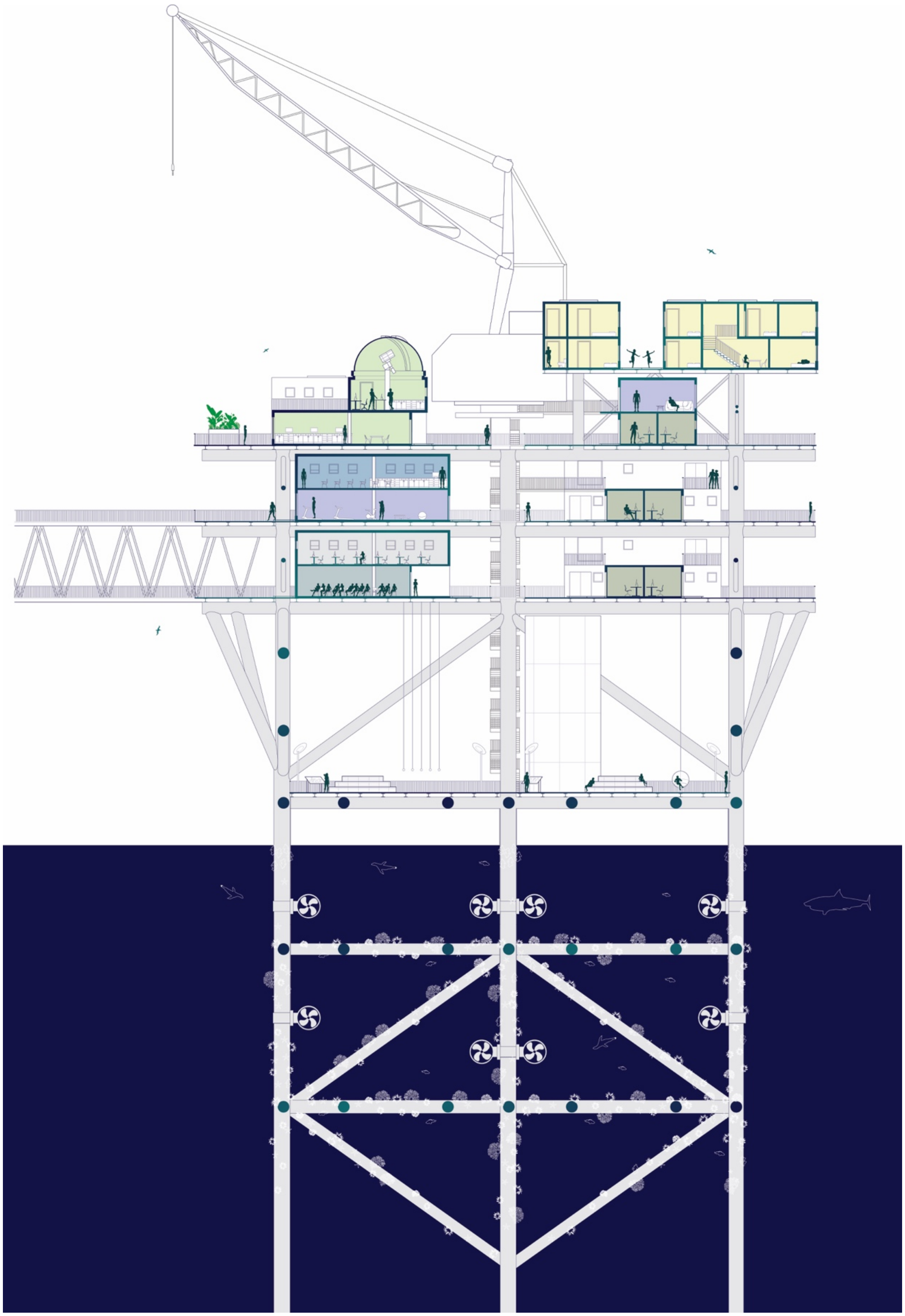

Figure 47: Section of Elly. (Source: author)

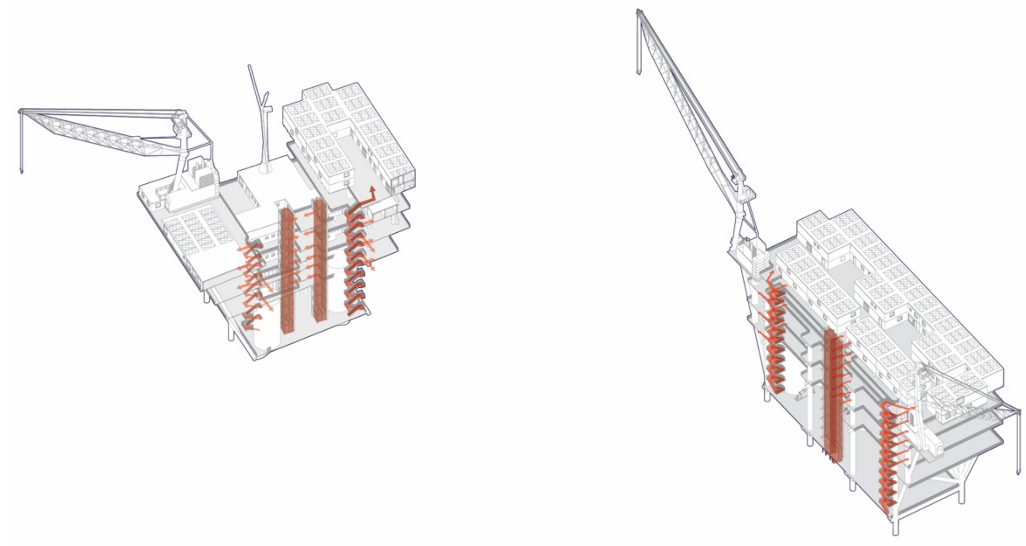

Figure 48: Diagram of vertical circulation in the center of the two platforms. (Source: author)

Figure 49: View upon arrival. (Source: author)

Figure 50: View of level S. (Source: author)

Figure 51: View of exterior corridor highlighting the vertical circulation. (Source: author)

Figure 52: View of the interior of a student laboratory. (Source: author)

Figure 53: View of the dining hall. (Source: author)

Figure 54: View of the exterior of the dining hall with the wastewater treatment system shown to the left. (Source: author)

Figure 55: View of a courtyard outside the student houses. (Source: author)

Figure 56: View of a living and kitchen space in a student house. (Source: author)

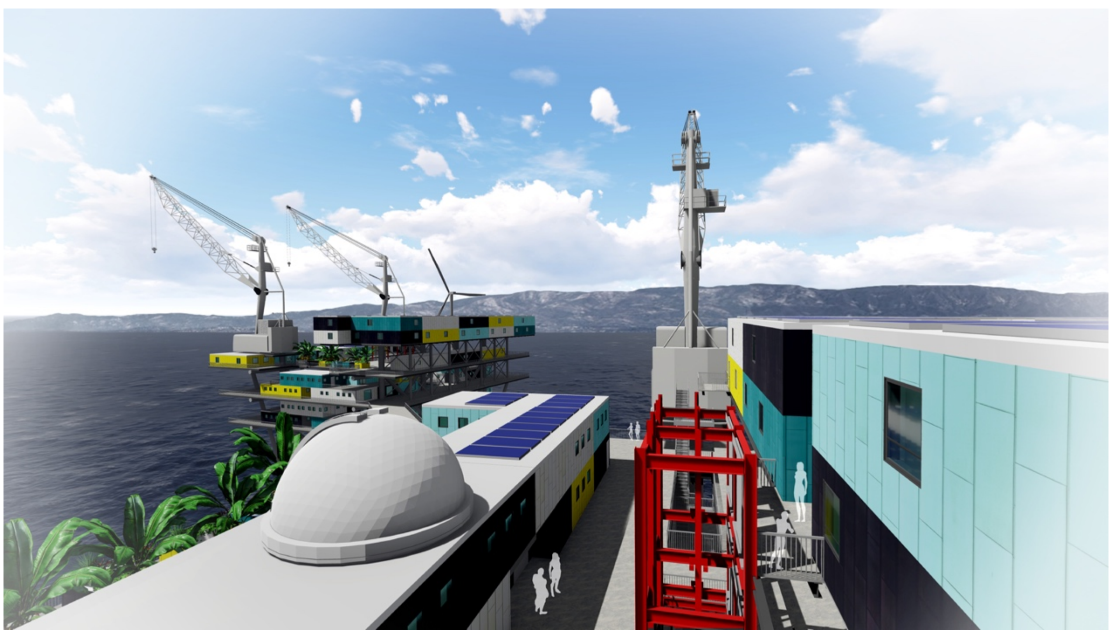

Figure 57: View of observatory and of Ellen from the top of Elly. (Source: author)

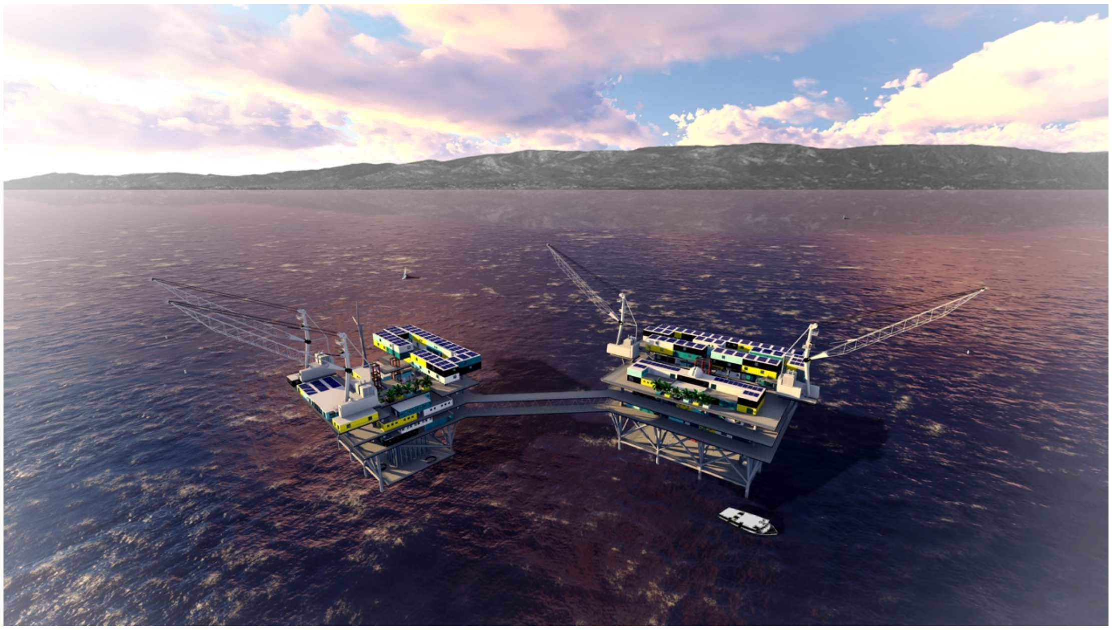

Figure 58: Aerial view. (Source: author)

Conclusion

At the final review, the following comments were made: that there was a desire for more plants allowing for a greater tie to the earth, there is a need of more fantasy and whimsy in the project—the project seemed too engineered, and that the two platforms could have a duality instead of a complete likeness to one another.

The response of the author are as follows. To the desire for plants: it was considered. Originally the idea was that the platform would house many plants, however, there were major flaws in that concept. Firstly, the water needs of the plants placed on site would greatly increase the demand and call for an abundance of additional storage tanks and treatment machinery. Secondly, there were concerns for the soil needs of the plants. Many plants that grow in the Southern California region have tap roots that extend deep into the soil to reach the low water table as this region is not known for heavy amounts of rain. These reasons led to the lack of foliage on site.

The next critique of being too engineered was something struggled with often in this design process. Critique early on was placed on the feasibility and the idea that this was to be treated as a real project. Walking a thin line between what is realistic and what is fun is a challenge and the most common practice is to err on the side of functionality which was done in this project as well. This is one design choice that could have been pushed back on harder.

The last critique was the similarity of the designs on the two platforms and a lack of individual personality for each. This was an idea early on as well in a diagram that one would house the areas of study that look down to the earth or the sea and the other would house the areas of study that would look to the sky and space. This was a concept forgotten in the process of creating the modular rules and tactics for implementation.

Ultimately, the goal of this thesis is to highlight an untapped opportunity that exists all over the world that could help to foster a multifaceted and positive transition of an existing icon of the fossil fuel industry to an icon of a more sustainable and thoughtful future.

Bibliography

American Bureau of Shipping. *Rules for Building and Classing Facilities on Offshore Installations*. Houston, United States, 2013. https://ww2.eagle.org/content/dam/eagle/rules-and-guides/archives/offshore/63_facilitiesonoffshoreinstallations_2014/fac_rules_e-feb14.pdf.

———. *Rules for Building and Classing Facilities on Offshore Installations*. Houston, United States, 2013.

Baldwin, Eric. "CAA Architects Reveals Futuristic Eco-City Design for the Maldives." *ArchDaily*. Accessed March 29, 2019. https://www.archdaily.com/906503/caa-architects-reveals-futuristic-eco-city-design-for-the-maldives/.

Banerjee, Chirantan. "Up, Up and Away! The Economics of Vertical Farming." *Journal of Agricultural Studies* 2, no. 1 (2014): 40–60. http://large.stanford.edu/courses/2016/ph240/swafford2/docs/banerjee.pdf.

Callebaut, Vincent. "Lilypad." Last modified 2017. Accessed March 29, 2019. http://www.vincent.callebaut.org/object/080523_lilypad/lilypad/projects/user.

FitzGerald, Emmett. "Crude Habitat." *99% Invisible*. Accessed April 25, 2019. https://99percentinvisible.org/episode/crude-habitat/.

Foundation, Great Barrier Reef. "Great Barrier Reef Foundation."

Haritos, Nicholas. "Structural Capability Interview," n.d.

Harrington, Kent. "Saudi Arabia Creates New Solar-Powered Desalination Technology." *AIChE*. Accessed April 25, 2019.

https://www.aiche.org/chenected/2015/10/saudi-arabia-creates-new-solar-powered-desalination-technology.

Hu, Ming. "Structural Capability Interview," n.d.

Kibert, Charles J. *Sustainable Construction: Green Building Design and Delivery*. New York: John Wiley & Sons Incorporated, 2016.

Marshall, John, and R. Alan Plumb. *Atmosphere, Ocean, and Climate Dynamics*. *Academic Press*, 2008.

Mayhead, Gareth J. "Biomass to Electricity." Berkeley, Ca: University of California Berkeley, n.d. https://ucanr.edu/sites/WoodyBiomass/files/78993.pdf.

Midwestern Regional Climate Center. "Cli-MATE." Last modified 2019. Accessed March 27, 2019. https://mrcc.illinois.edu/CLIMATE/welcome.jsp.

National Oceanic and Atmospheric Administration. "Ocean Currents." Accessed March 27, 2019. https://www.noaa.gov/education/resource-collections/ocean-coasts-education-resources/ocean-currents.

National Research Council (U.S.). *Adapting to the Impacts of Climate Change: America's Climate Choices*. Washington D.C.: National Academies Press, 2010.

Roche, Pablo La. *Carbon-Neutral Architecetural Design*. Portland: CRC Press LLC, 2017.

Rogers, Paul. "California Water: Desalination Projects Move Forward with New State Funding." *The Mercury News*. Accessed April 25, 2019. https://www.mercurynews.com/2018/01/29/california-water-desalination-projects-move-forward-with-new-state-funding/.

Samie, Naeim Nouri. "Introduction to Offshore Platforms." In *Practical Engineering*

Management of Offshore Oil and Gas Platforms, 2016.

Shell Oil Company. *Beta Unit Plan of Development*. Los Angeles, 1977. https://www.boem.gov/1977_Platform_Elly_Ellen_Eureka_DPPs/.

———. *Beta Unit Plan of Development*. Los Angeles, 1977.

United States. National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling. *A Brief History of Offshore Oil Drilling*. Washington D.C., 2010.

Wolfson, A., G. Van Blaricom, N. Davis, and G. S. Lewbel. "The Marine Life of an Offshore Oil Platform." *Marine Ecology - Progress Series* 1 (1979): 81–89.

Beta Unit Complex: Oil Spill Prevention and Response Plan, n.d. https://www.bsee.gov/sites/bsee.gov/files/oil-spill-response-plan-osrp/inspection-and-enforcement/beta-operating-company-osrp-april-2012.pdf.

"Bioprocess Innovation Center / Clark Nexsen." *ArchDaily*.

"Crop Yield Verification." Accessed April 25, 2019. http://www.gardensofeden.org/04 Crop Yield Verification.htm.

"Energy Portfolio." *Energy Portfolio*. Accessed April 25, 2019. http://nelha.hawaii.gov/energy-portfolio/.

"Escape With Catalina Express." *Catalina Express*. Last modified 2019. Accessed March 29, 2019. https://www.catalinaexpress.com/.

"Food Consumption and Nutrient Intakes." *USDA ERS - Food Consumption and Nutrient Intakes*. Accessed April 25, 2019. https://www.ers.usda.gov/data-products/food-consumption-and-nutrient-intakes/food-consumption-and-nutrient-intakes/#Food Consumption Estimates.

“Greenhouse as a Home / BIAS Architects.” *ArchDaily*.

“Healthy Habitat, Healthy Oceans.” *Oceana - Protecting the World’s Oceans*.

“Leixões Cruise Terminal / Luís Pedro Silva Arquitecto.” *ArchDaily*.

“Lights On Solar.” Accessed April 25, 2019. http://www.lightsonsolar.com/solar-basics-kw-and-kwh/.

“Los Angeles, California Population 2019.” *Los Angeles, California Populatiuon (Demographics, Maps, Graphs)*. Last modified 2019. Accessed March 29, 2019. http://worldpopulationreview.com/us-cities/los-angeles-population/.

“Mist-Hot Spring Hotel.” *ArchDaily*.

“Nanjing International Youth Cultural Centre / Zaha Hadid Architects.” *ArchDaily*. Accessed March 29, 2019. https://www.archdaily.com/907145/nanjing-international-youth-cultural-centre-zaha-hadid-architects/%3E.

“Niagara Falls USA.”

“Nightingale 1 / Breathe Architecture.” *ArchDaily*.

“Number of Offshore Rigs Worldwide as of January 2018 by Region.” Last modified 2019. Accessed March 26, 2019. http://www.statista.com/statistics/279100/number-of-offshore-rigs-worldwide-by-region.

“Ocean Thermal Energy Conversion.” *Ocean Thermal Energy Conversion - Energy Explained, Your Guide To Understanding Energy - Energy Information Administration*. Accessed April 25, 2019. https://www.eia.gov/energyexplained/index.php?page=hydropower_ocean_thermal_energy_conversion.

“Phillip and Patricia Frost Museum of Science / Grimshaw Architects.” *ArchDaily*.

“Plant Species.” *Catalina Island Conservancy*.

“Stanford University Central Energy Facility / ZGF Architects.” *ArchDaily*.

“The Village / Gianni Ranaulo Design.” *ArchDaily*.

“Tidal Power.” *Tidal Power - Energy Explained, Your Guide To Understanding Energy - Energy Information Administration*. Accessed April 25, 2019. https://www.eia.gov/energyexplained/index.php?page=hydropower_tidal.

“Top Five Must-See Migrations in California.” *The Nature Conservacy*.

“Waste-to-Energy (Municipal Solid Waste).” *Waste-to-Energy (Municipal Solid Waste) - Energy Explained, Your Guide To Understanding Energy - Energy Information Administration*. Accessed April 25, 2019. https://www.eia.gov/energyexplained/index.php?page=biomass_waste_to_energ y.

“Wave Power.” *Wave Power - Energy Explained, Your Guide To Understanding Energy - Energy Information Administration*. Accessed April 25, 2019. https://www.eia.gov/energyexplained/index.php?page=hydropower_wave.

“Wind Energy Frequently Asked Questions | EWEA.” *EWEA RSS*. Accessed April 25, 2019. http://www.ewea.org/wind-energy-basics/faq/.