RHO Resource Management:
Detroit-FC's Circular Economy Solution for Waste Pollution

Location

It is 2122 and Detroit-FC (Detroit Future City) has a population of 2,122,122. The city is in southeastern Michigan along the Detroit River, which connects Lake Erie with Lake St. Clair. Windsor, Ontario is directly across the 1.5-mile-wide river, and the RHO Bridge links Detroit-FC with Belle Isle State Park.

Founded in 1701, the city grew in the 1800's due to lumber and mining jobs. After the 1805 fire, Augustus Woodward designed the city's current honeycomb layout. The population exploded in the 1900's with growth of the auto industry. By 1950, it had 1.8 million residents, and the city was the fourth largest in the United States. The population decreased as the auto industry declined. By 2022, only one third of the residents remained in a city that still covered 139 square miles. Today, the city is thriving again. Detroit is Detroit-FC due to a strong economy and RHO Resource Management!

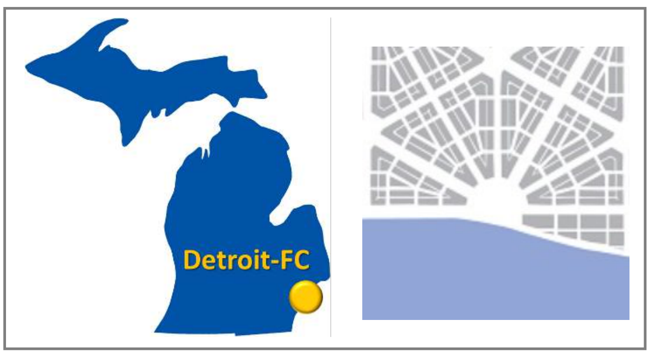

Figure 1
Detroit-FC: Location and Design

City Life

Detroit-FC has a diverse population of young and old and offers employment options to suit all backgrounds and interests. Job choices include tourism, engineering, medicine, agriculture, retail, recreation, skilled trades, and, of course, waste management. The historic district along the river, which includes museums and the restored Renaissance Center, honors the past while looking to the future.

Belle Isle has excellent beaches, and the river provides limitless recreational opportunities such as boating and kayaking. There are numerous parks and greenspaces, including acres of naturalized woodlands that contain hiking and horseback riding trails. The exciting, walkable commercial district features hotels, entertainment, shopping, and dining.

Infrastructure and Features

Housing options are available for all lifestyles and income levels. The residential zone's single-family homes and medium-density condos have great river views. High-density studio apartments are near the commercial district. Zones are interconnected with accessible transit options and all resources (waste, energy, and water) are conserved through advanced technologies.

Wireless vehicle charging systems are integrated into the infrastructure. Continuous induction roadways power both drivable and autonomous vehicles. Charge is delivered to the induction system through graphene supercapacitor batteries at each intersection.

Industrial zone infrastructure includes wind and solar renewable energy systems, and hydroelectric energy is harvested from the river. Advanced food production and water reuse systems provide sustainable nutrition and fresh water for everyone. The agricultural district includes vertical farms and orchards that supply farmer's markets throughout the city.

City Services

Delta-Link is an all-in-one communication system that connects residents to education, healthcare, safety, and transportation services. The voice or touch activated system is people-powered through piezo-beads in footwear that charge small graphene supercapacitor batteries. Movement creates energy, which encourages residents to stay active!

Detroit-FC offers students world-class educational opportunities through in-person or virtual-presence learning. Delta-Link dispenses medications, tracks vitals, and provides a direct connection with doctors for real-time health monitoring. The device detects smoke and heat, communicates with citywide decentralized fire and safety services, and interfaces with hover-drone rescue systems. Delta-Link provides universal accessibility to the elevated public transit system.

City Innovations

Innovative smart-pavement harvests energy, manages stormwater, and keeps roadways clear in the winter. Piezoelectric systems in roadways, walkways, and flooring harvest strain energy. Surplus energy is stored and shared with residents in need. Permeable pavement allows stormwater to filter down to catch basins at each intersection, and captured water is used for irrigation and fire safety. Finally, embedded thermal wires made from conductive metals harvested from landfill deconstruction keep surfaces snow and ice free.

Smart-architecture building exteriors provide off-the-grid living. The innovation links the exterior with the interior through an active membrane. Sunlight tracking solar cells collect and store energy. Water for bathroom use and cleaning is harvested through humidity condensation and rainwater collection. Natural light enhances interior lighting, carbon dioxide is filtered, and breezes provide natural air conditioning.

Before RHO

Before RHO Resource Management, Detroit's linear economy was based mainly on the automotive industry. As population declined, empty factories and vacant homes increased. By 2022, Detroit had over thirty-five square miles of abandoned land. Vacant property was a prime location for the disposal of solid waste and discarded household and industrial items.

Although glass, plastic, metal, and paper recycling took place through trash collection, less than 35% of solid waste was actually recycled. Sadly, only 9% of discarded plastic was recycled. Discarded trash piled up in landfills. In fact, nearly 25% of solid waste disposed in Michigan landfills was from other states and Canada.

Medical and other hazardous waste was disposed of through incineration or treatment with chemicals before being landfilled. Although methane was captured for energy at landfills, the hills of trash grew and grew with each year. Most yard and agricultural waste was collected and composted or processed, but energy harvesting from organic waste disposal was inefficient. The bottom line: waste was wasted.

The Transition

In 2051, engineers from SJL Industries presented a new concept at the Engineering Society of Detroit's 61st Annual Solid Waste Conference. That year's challenge was to design a waste-free city that uses the principles of a circular economy. SJL engineers used the Engineering Design Process to develop RHO Resource Management.

RHO stands for three types of waste: Reusable, Hazardous, and Organic. It is a total solution for garbage and waste pollution. Its closed-loop processes consider all city waste streams and turns them into energy and other useful products. The innovation received huge praise and sponsors provided funds to implement the concept, beginning with Detroit. Waste became a valuable resource, and soon Detroit became known as Detroit-FC.

Waste is a Resource

Each part of RHO meets some or all of the 3 Circular Economy Principles:

Principle 1: Designs Out Waste and Pollution
Principle 2: Keeps Products and Materials in Use
Principle 3: Regenerates Natural Systems

The "R" in RHO stands for Reusable. Instead of sending most solid waste to landfills as before, all solid waste is transported directly from homes and businesses to recycling centers in underground vacuum tubes. Metals are sorted with magnets. Ferrous materials are picked up, while non-ferrous metals are not. Recycling is a huge energy saver. For instance, recycling paper saves about 75% of the energy and carbon dioxide emissions versus making new paper, as shown in Table 1.

The “R” in RHO

1. Designs Out Waste and Pollution and
2. Keeps Products and Materials in Use.

With paper recycling, trees are saved, which

3. Regenerates Natural Systems.

Material (Recycled vs. New)	Energy Reduction	CO_2 Reduction
Aluminum	95%	85%
Steel	70%	81%
Paper	75%	74%
Plastic	65%	71%
Glass	38%	30%

Table 1
Recycling Benefits

The “H” in RHO stands for Hazardous. Hospitals produce non-recyclable medical waste. Chemical and other industrial waste is also in this category. In the past, disposal of toxic waste was a challenge. Today, this waste stream heads to plasma gasification systems using delivery pods. Gasifiers ionize this waste at 10,000 °F in the waste-to-energy process shown in Figure 2 (left side). The plasma glass byproduct is used to reinforce infrastructure.

The “H” in RHO

1. Designs Out Waste and Pollution and
2. Keeps Products and Materials in Use.

The “O” in RHO stands for Organic. This waste stream includes food, agricultural, and even human waste. Bioregeneration uses microbial composters to break down organic waste using anaerobic digesters in the waste-to-energy process shown in Figure 2 (right side). The compost byproduct is used to enhance soil in the agricultural district.

The “O” in RHO

1. Designs Out Waste and Pollution,
2. Keeps Products and Materials in Use, and
3. Regenerates Natural Systems.

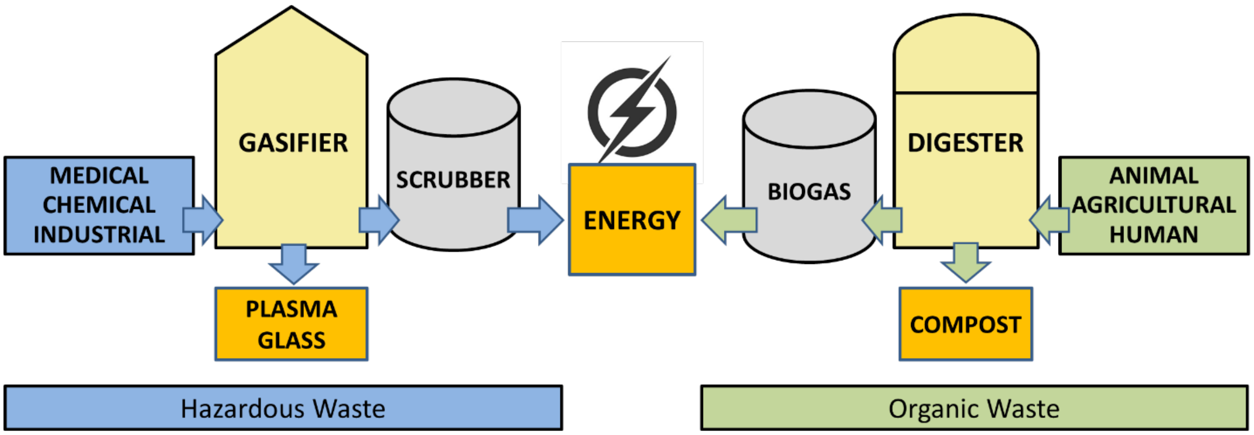

Figure 2
Waste-to-Energy Processes

Risks, Tradeoffs and Compromises

RHO's innovations provide the benefit of zero waste. Detroit-FC has a thriving circular economy from diverse industries and waste-to-energy systems. Residents enjoy an improved environment, increased property values, and lower taxes due to a strong tax base.

There were also risks and tradeoffs with RHO's implementation. A limitation was the cost to get things started, since residents wanted the benefits all at once. A compromise was implementing it over time using modular scalability principles: build a section, generate revenue, then reinvest the revenue to build another section. To address the risk of system malfunction, redundant controls and monitoring systems with closed-loop feedback were implemented across all zones. A tradeoff was added cost, but residents agreed that a price tag cannot be put on safety and dependability.

Engineers

Many engineers were and are involved in maintaining RHO Resource Management:

- Civil Engineers, who design and construct infrastructure, planned the implementation and layout of waste transport systems.
- Industrial Engineers, who optimize manufacturing processes, ensure limited impact on resident quality of life as RHO is expanded.
- Environmental Engineers, who improve environmental quality, maintain the water treatment and food production systems.
- Controls Engineers, who oversee electronic processes, implemented redundant monitoring systems in all zones.

Due to the work of amazing engineers, Detroit-FC is a vibrant, circular economy-based city that has turned waste into a resource!

Word Count without Title or References:
Text (1,451) + Figure 1 (1) + Table 1 (23) + Figure 2 (18) = <u>Total (1,493)</u>

References

Bartkowiak, Dave Jr. “How Much Trash Does Canada Send to Michigan Landfills?” Click on Detroit.com. 20 April 2021. Web. 14 Dec. 2021. <https://www.clickondetroit.com/features/2020/02/13/how-much-trash-does-canada-send-to-michigan-landfills/>.

Bird, Jane. “Graphene Filters Change the Economics of Clean Water.” Financial Times. Financial Times, 12 Oct. 2018. Web. 7 Dec. 2021. <https://www.ft.com/content/d768030e-d8ec-11e7-9504-59efdb70e12f>.

"Carbon Dioxide 'sponge' Could Ease Transition to Cleaner Energy." ACS Chemistry for Life. ACS., 10 Aug. 2014. Web. 7 Dec. 2021. <https://www.acs.org/content/acs/en/pressroom/newsreleases/2014/aug >.

Carmichael, Hayley. “Zero Waste in 5 easy steps.” Care without Carbon. Sussex Community NHS Foundation Trust 15 July 2021. Web. 7 Dec. 2021. <https://www.carewithoutcarbon.org/zero-waste-life-in-5-easy-steps/>.

de La Fuente, Jesus. "Graphene Supercapacitors - What Are They?" Graphenea. N.p., n.d. Web. 7 Dec. 2021. <http://www.graphenea.com/pages/graphene-supercapacitors#.Vk-U8NKrRkg>.

Dodge, Ed. "Plasma Gasification: Clean Renewable Fuel through Vaporization of Waste." Recycling: Waste Management World. N.p., 01 July 2009. Web. 7 Dec. 2021. <http://waste-management-world.com/a/plasma-gasification-clean-renewable-fuel-through-vaporization-of-waste>.

"Global Waste on Pace to Triple by 2100." The World Bank Group. N.p., 30 Oct. 2013. Web. 17 Nov. 2015. <http://www.worldbank.org/en/news/feature/2013/10/30/global-waste-on-pace-to-triple>.

Jozefek, Jakub. "Closing the Circle: Enhanced Landfill Mining." Waste Management World. N.p., 04 Apr. 2011. Web. 7 Dec. 2021. <http://waste-management-world.com/a/closing-the-circle-enhanced-landfill-mining>.

Kour, Ravjeet, and Ahmad Charif. “Piezoelectric Roads: Energy Harvesting Method Using Piezoelectric Technology.” OMICS International. OMISC International. 25 Mar. 2016. Web. 7 Dec. 2021. <https://www.omicsonline.org/open-access-pdfs/piezoelectric-roads-energy-harvesting-method-using-piezoelectrictechnology-ier-1000132.pdf>.

"Mining Landfills - Strategic Metals.” Mission 2016: The Future of Strategic Natural Resources. N.p., n.d. Web. 7 Dec. 2021. <http://web.mit.edu/12.000/www/m2016/finalwebsite/solutions/landfill.html>.

"New building hosts living skin concept." Biomimetic Architecture. N.p., 13 Jan. 2010. Web. 17 Nov. 2015. <http://www.biomimetic-architecture.com/2010/new-building-hosts-living-skin-concept/>.

Nutt, David. "Research paves way for wireless charging of electric vehicles." Cornell Chronicle. 28 Apr. 2021. Web. 7 Dec. 2021. <https://news.cornell.edu/stories/2021/04/research-paves-way-wireless-charging-electric-vehicles>.

"Recycling Facts & Tips." Waste Management, Inc. N.p., n.d. Web. 7 Dec. 2021. <http://www.wm.com/location/california/ventura-county/thousand-oaks/recycle/facts.jsp>.

Sims, Bryan. "Proving Out Plasma Gasification." Biomass Magazine. BBI International. 2021. Web. 7 Dec. 2021. <http://biomassmagazine.com/articles/2144/proving-out-plasma-gasification>.

Sorry Graphene – borophene is the new wonder material that's got everyone excited." MIT Technology Review. Orocobre Limited. 5 April 2019. Web. 7 Dec. 2021. <https://www.technologyreview.com/2019/04/05/239331/borophene-the-new-2d-material-taking-chemistry-by-storm/>.

"Sustainable Waste Management in a Circular Economy: A Policy Brief from the Policy Learning Platform on Environment and resource efficiency." Interreg Europe. European Regional Development Fund. Mar. 2020. Web. 7 Dec. 2021. <https://www.interregeurope.eu/fileadmin/user_upload/plp_uploads/policy_briefs/Policy_brief_on_waste_management.pdf>.

"Vacant Land Becomes Asset in Detroit." Detroit CBS Local. Associated Press. 28 Feb. 2019. Web. 14 Dec. 2021. <https://detroit.cbslocal.com/2019/04/29/vacant-land-becomes-asset-in-detroit/>.

"What is Anaerobic Digestion?" American Biogas Council. N.p., n.d. Web. 7 Dec. 2021. <https://www.americanbiogascouncil.org/biogas_what.asp>.

Yoneda, Yuka. "HABITAT 2020: Future Smart 'Living' Architecture." Inhabitat. N.p., 09 July 2008. Web. 7 Dec. 2021. <http://inhabitat.com/habitat-2020-off-the-grid-future-abode/>.

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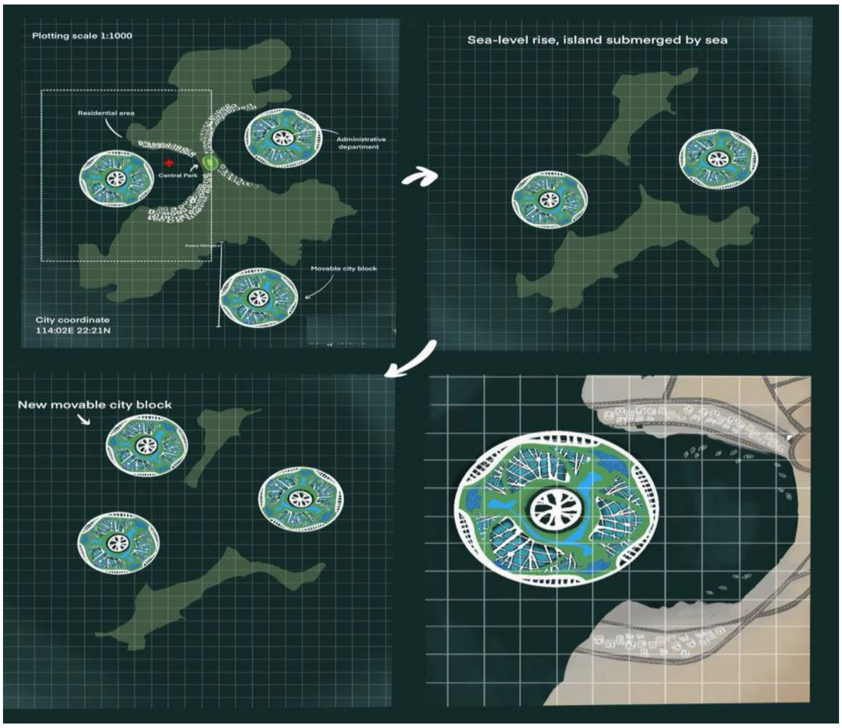
January 21, 22

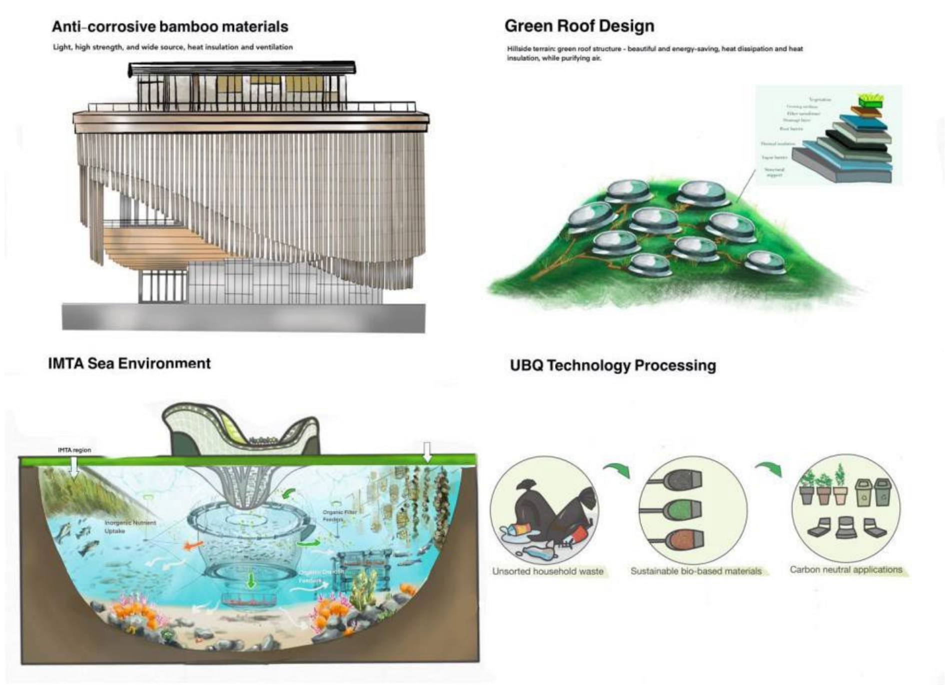
Oceanus City

A Brief Introduction to Oceanus City
If you were to visit the Pearl River Delta in 2122, you would find a strikingly pristine coastal metropolis by the name of Oceanus City. The city's humble population of 10,000, thanks to automation technology, works exclusively in engineering, research, and management. The island borders on the tropical zone, has a subtropical monsoonal climate, and offers little arable land and scarce mineral and oil reserves, but boasts thriving coastal ecosystems and volatile tides.

1. City Layout
Oceanus's most arresting feature is its two *sea-steads* - spinning, floating, and skyscraping constructions. It is the administrative center for all of Oceanus's marine industries and research activities including ocean cleanup operations and aquaculture, as well as an experimental area for novel sustainable technology.



The coastal and inland regions of the island are permeated by mixed residential-commercial high-rises, which merge semi-biomorphic architectural designs with organic-based structural elements such as anti-corrosion bamboo, and green hillside roofs.



2. City Services and Residential Life

The populace engages in a variety of jobs such as R&D, administration, and industrial maintenance. Job opportunities requiring less effort, such as bus driving, exist for physically challenged individuals. Residents receive public health care allowing access to Oceanus's biotechnology-based treatments and enjoy social benefits such as disability pay, social worker attention, and unemployment insurance. Education is public, age-independent, and AI-assisted.

Urban culture is diverse because people of different races and ages can settle here freely, making Oceanus a "rainbow" city.

Autonomous maglev trains and hyperlinks connect neighbouring districts and islands. Urban roads utilize the straddling bus design to coexist with automobiles. All transportation is fully electric or algae-biofuel-based. In addition, combinations of solar cells, wind sails, and turbines allow ships to sail fully on ambient power.

Endemic delicacies include seaweed-based dishes and seafood from the city's Integrated Multi-Trophic Aquaculture (IMTA) systems. Citizens' aquatic pastimes include technology-bolstered adaptations of yachting, diving, and water-skiing.

Oceanus City under the Circular Economy

The city started as an experimental base run by the neighbouring Chinese SAR of Hong Kong, which suffered a drastic decline in waste regulation quality following China's refusal to accept waste imports in 2017. The state saw its waste problem poison its marine environment, deplete its natural resources, and bury its countryside in the trash.

Lead pollution, smog, and particle pollution increased tumour growth and danger of heart and lung disease among its residents and forced them into masks. Maintenance costs and efforts for landfilling and incineration continued to skyrocket, and fewer and fewer people settled in Hong Kong. In 2057, Oceanus City was established in collaboration with internationally prominent architects, marine scientists, and engineers to solve the waste problem.

1. **From linear economy to circular economy**

Civil engineers were responsible for designing the framework of the circular economy, and mechanical, biochemical, and chemical engineers laid out the centralized, interconnected network of material recovery facilities (MRFs), collectively termed The Refinery, which they decided to concentrate underground. Electrical engineers designed the sustainable power grid, and biotechnical engineers constructed the IMTA and OMEGA systems making up Oceanus's agricultural sector. The initial infrastructure was designed to integrate then-existing technologies and natural resources of Cheung Chau Island. After implementation, it has remained in perpetual reformation concerning technology and framework.

The waste management system - Refinery - was designed with the auxiliary aim of recovering material value - turning waste into treasure to the city's commercial and fiscal advantage. It involved cargo ships importing large amounts of potentially valuable wastes – electronics, plastics, and metals – then recycling and re-exporting them. This has become one of Oceanus's major sources of revenue.

2. Reduce waste and pollution

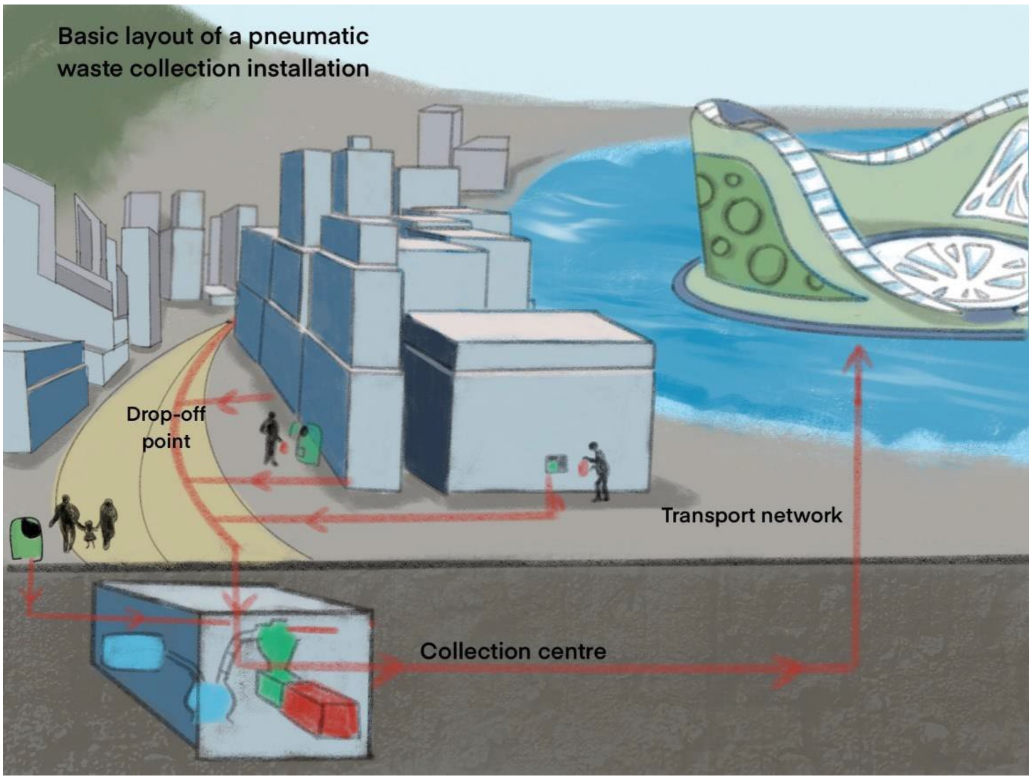
Waste reduction takes place on the administrative and production levels that are controlled by government-owned enterprises. To prevent the circulation of excessively unsustainable practices, Oceanus's government has implemented a customs net against imports that it deems unfeasible to process as waste, and enforced various producer responsibility policies to minimize greenhouse gas emissions and industrial waste output and to design products according to Cradle-to-Cradle standards.

An example of this is the city's algal bioplastics industry, which produces a plastic resin with an adjustable period of biodegradability. The basis of the technology comes from the British company Algopack, and the process relies entirely on polysaccharides from the city's abundant microalgal biomass yields. This product effectively supplants traditional plastics and even be used to manufacture automobile and train frames along with ship hulls.

2. **Reuse products and materials**

Various systems have been set up to ensure that products that have not yet lost their inherent value do not become waste. Products with longer life cycles are included in a "*Pfand*" system, meaning citizens receive a small refund for depositing them at renewal stations, where they are refurbished, upgraded, and redistributed through online shopping and exchange networks until their expiry. Machine-to-machine (M2M) location technology facilitates the transfer of electronic devices, and producers design components to be modular whenever possible.

Municipal waste, after being presorted by civilians based on standardized colour-labelled packaging, is deposited in garbage chutes present in every building into a pneumatic pipe conveyance system. Each MRF uses specific technology to remove a certain form of waste from the mix, and recover as much value as possible from them. These recovered materials are then amassed in the sea-steads to await redistribution. The process can be mostly automated.



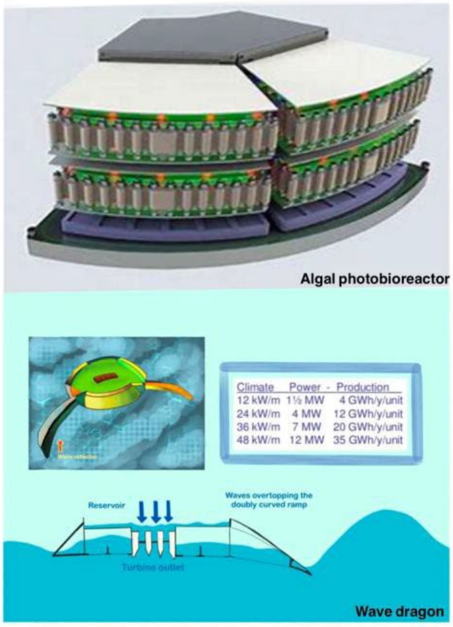
Waste stream	Separation method	Processing method	Product
Heavy metals		Electro-kinetics, plasma metallurgy	Raw component metals
Light metals	Eddy streams, air knives	Delamination mills	

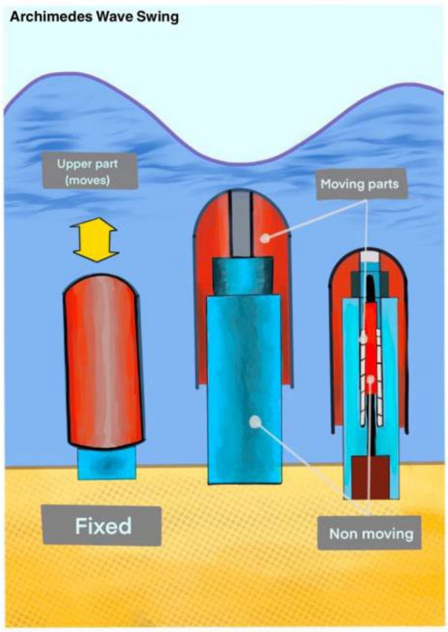
Waste stream	Separation method	Processing method	Product
Lithium-ion batteries		Pyrolysis	
Dry residual wastes	-	Combustion	Energy
Biowastes	-	In-vessel composting, photobioreactor feed	Food chain supplies
Oils	-	Sand filtration	
Sludges	-	Supercritical water oxidation	
Petroleum plastics	Optical sorting	Biodegradation, Plastcon	
White goods	-	Autoclave	
Wastewater	Semi-pneumatic sewage system	Anaerobic bacteria, algae biofilms,	Usable water at various grades of purity
Circuitry	Spectrometry	Shredding, microwaves	
Mixed cardboards, debris, and plastics	Excess waste	UBQ	Conventional structural materials
Fibre-based materials, textiles	-	Centrifugal shredding	Usable fibres

Notable approaches among these include the UBQ and Plastcon process, which breaks wastes down into their basic particle structure and then reconstitutes them into different types of structural products.

3. Regeneration of Natural Systems

Oceanus's power grid mainly utilizes blue technology as tidal lagoons, wave dragons, Archimedes Wave Swings (AWS) to harness tidal power in favour of fuel-based energy sources. Tidal energy not only is produced passively and requires no production costs but that of maintenance but is more efficient than traditional counterparts. Steadier underwater AWS and ball generators balance out diurnal tidal fluctuations. Furthermore, the island's coastline is covered with Offshore Membrane Enclosures for Growing Algae (OMEGA). These can cultivate large masses of intensely photosynthesizing microalgae, notably cyanobacteria and diatoms, using wastewater as a nutrient source. This makes Oceanus's carbon footprint negative, and also adds oxygen to the atmosphere.





-IMTA system

Oceanus implements IMTA, an aquaculture farming system that uses an ecosystem-based approach. It integrates the production of multi-trophic species, making the uneaten feed of one species into the food of another. This minimizes energy loss and environmental deterioration, creating a sustainable environment.

-Tradeoffs and Risks

The purpose behind concentrating heavy industrial activities underground was to prevent odours, dust microbes, bioaerosols, and smog from harming the populace, but this exacerbates the effects of exposure to maintenance personnel underground. Although hazmat suits and the subterranean shell completely insulate workers and the environment, the atmosphere of the area is nevertheless more toxic, albeit entirely closed off from its surroundings.

The refinement industry itself, although effective and profitable, is also not ideal: new MRFs must be designed and constructed to treat new waste streams, demanding extravagant funding, and existing MRFs undergo constant maintenance to remain state-of-the-art as well as functional. Renovations to reduce the maintenance work include reengineering the pneumatic pipe system has been redesigned into detachable segments, each equipped with rinsing and vibration mechanisms to expurgate dust buildups.

Empowering the Future

Despite this and many more, Oceanus is an international pioneer in circular economic development, and its citizens keep the city's infrastructure in perpetual development. That is our greatest asset - that we are prepared for the future.

Word count: 138 pictures +1339 text = 1477

References:

【1】 “The Process - UBQ Materials.” UBQ Materials | Waste to Sustainable
Thermoplastic Solution, UBQ, 3
Aug. 2021, https://www.ubqmaterials.com/the-process/.

【2】"Could Algae Help Us Fight the Plastic Problem?"
Institute for Molecular Bioscience, The University of Queensland, 16 Oct.
2019, https://imb.uq.edu.au/article/2019/09/could-algae-help-us-fight-plastic-problem.

【3】“The Benefits and Challenges of Green Roofs on Public and Commercial
Buildings.“ EPA, Environmental
Protection Agency, May 2011,
https://www.gsa.gov/cdnstatic/The_Benefits_and_Challenges_of_Green_Roofs_on_
Public_and_Commercial_Buildings.pdf

【4】Cao, Lilly. What Materials Keep Buildings Cool? 26Aug. 2019. ArchDaily.
https://www.archdaily.com/923445/what-materials-keep-buildings-cool

【5】Zhan, Lu, and Zhenming Xu. State-of-the-Art of Recycling
E-Wastes by Vacuum Metallurgy Separation. American Chemical Society, 2014.

【6】Sarswat, Gaurav, and Mohammad Arif Kamal. A Critical Appraisal of Off-Land
Structures: A Futuristic
Perspective. Civil Engineering and Architecture, 2014.

【7】Crystal Ward Kent , Bernhard Mueggler.The Future of Electronic Waste.Aug. 29, 2017. https://www.electronicdesign.com/industrial-automation/article/21805497/the-future-of-electronic-waste

【8】Wang, Jianmin, et al. “Hazardous Waste Treatment Technologies.”
Wiley Online Library, John Wiley & Sons, Ltd, 4 Sept. 2019,

https://onlinelibrary.wiley.com/doi/full/10.1002/wer.1213.

Rogoff, Marc J. *Solid Waste Recycling and Processing: Planning of Solid Waste Recycling Facilities and Programs*. Elsevier, 2014.

Cruz João. *Ocean Wave Energy: Current Status and Future Perspectives*O. Springer, 2008.

Richards, Tobias. Taherzadeh, Mohammed J. *Resource Recovery to Approach Zero Municipal Waste*. CRC Press, 2017.

Eaton, Kit. "Toyota's Seaweed Cars Take Green Design to a Whole New Level." *Fast Company*, Fast Company, 30 July 2012, https://www.fastcompany.com/1183909/toyotas-seaweed-cars-take-green-design-whole-new-level.

"Accueil." *Algopack*, 16 Aug. 2021, https://www.algopack.com/en/.

Jóhannsdóttir, Auður Elísabet. "Algal Bioplastics Are the Future - Here Is Why." *JONAA, Journal of the North Atlantic & Arctic*, JONAA, Journal of the North Atlantic & Arctic, 11 Apr. 2021, https://www.jonaa.org/content/2018/01/19/algaibioplastics.

【9】肖昌慧. 生活垃圾填埋场渗滤液处理工艺研究[J]. 科学与创新，2017

【10】张占仓. "无废城市"建设的科学内涵与探索方向[J]. 区域经济评论，2019.03

【11】杨敬增. 循环产业链 理念·模式·设计·案例[M]. 北京：化工业出版社 2018.11 【12】杨剑明. 从零废弃到闭环物料[M]. 北京：化学工业出版社 2020.7

【13】萧嘉欣. 无废：城市可持续设计探索[M]. 北京：中国建筑工业出版社 2019.11 【14】温宗国等.无废城市：理论、规划与实践[M]. 北京：科学出版社，2020.8

【15】【英】蓬莱（Peter Lacy）【瑞典】雅各布·鲁特奎斯特（Jakob Rutqvist）著，王景 丽、卜荣露译. 变废为宝：创造循环经济优势[M]. 上海：上海交通大学出版社 2015

Zale City

Word Count: 1491

In 2035, people and nations worldwide were united in the need to address pollution. Efforts were focused on transforming economies from a linear to a circular model, changing society's mindset accordingly, and educating younger generations. Zale City (ZC), along with PSI (Problem Solvers Incorporated) Labs, led the way in this revolution and continues to do so today.

As of 2143, ZC has a population of one million with various ethnic groups and a median age of 32. It is located at 33° N, 80° W on the east coast of the US and is situated on the estuaries of several rivers, giving it a unique and extensive coastline. ZC has a mean elevation of 19 feet and average highs of 92°F and lows of 39°F in the summer and winter, respectively. ZC receives around 52" of precipitation annually.

Many of ZC's citizens are employed at PSI Labs or run their own businesses. Others manage the power, agricultural, recycling, and regeneration facilities. ZC's citizens enjoy its numerous parks, playing and watching sports, and its many arts and food establishments. There are a variety of water activities like diving, sailing, and fishing. Outside the city is a reforested national park with hiking, biking, canoeing, and other outdoor activities.

ZC has a unique, two-district layout—one on land and one on water. The land-based district is composed of a mixture of residential, commercial, and industrial zones. It also houses the headquarters of PSI Labs. Plant-covered façades increase the city's aesthetics, boosts citizens' morale, and reduce the heat island effect. The on-the-water district has larger mixed residential/commercial centers surrounded by smaller residential sectors. Structural and civil engineers designed the city to be resilient against the occasional storm by utilizing a system of barriers, domes, and preventive structural designs.

ZC's roads and sidewalks are made of semi-permeable concrete, allowing water to pass through to the ground underneath. This minimizes the risk of flash floods and replenishes the water table. Geopolymer concrete (GPC) is used in building construction instead of traditional concrete. GPC has better physical properties, is more environmentally friendly, and utilizes industrial byproducts like reclaimed fly ash.

PSI Labs partnered with ZC and other cities to build the largest offshore power station in the world. It contains efficient wind turbines, solar panels, and wave energy converters (WECs) that provide power to the eastern part of the United States. Developed by mechanical and electrical engineers, WECs have a buoy that moves with the waves. The vertical movement of the buoy is translated into the rotational movement of the magnets within a generator. This process provides a near-continuous source of renewable electricity.

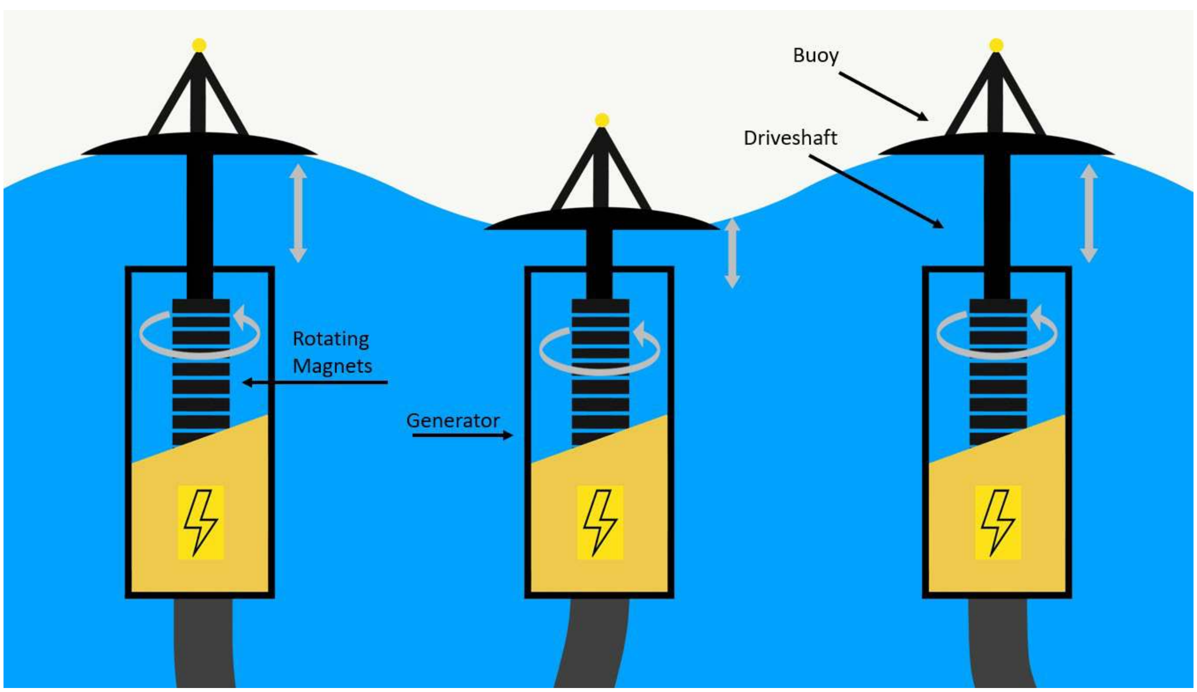


Fig. 1: Wave Energy Converter

Transportation in ZC is provided by a public-private partnership. The convenience and economics of this system make it largely unnecessary to own a vehicle (before the transition, cars sat idle 95% of the time on average). Known as AEVs (Autonomous Electric Vehicles), they can travel on land, air, and water. They are powered by long-lasting batteries developed by chemical and material engineers at PSI Labs. AEVs travel to the nearest hub when they run low on power and exchange their depleted battery for a full one.

K-12 schools in ZC are hybrid, mastery-based, and year-round (six weeks on, two weeks off). These models allow for better learning and less burnout. ZC also has a renowned university that attracts students from around the world and provides the city with many qualified candidates for the growing economy. PSI Labs and other companies partner with schools to expose students as early as middle schools to real-world jobs. The kids shadow engineers, project managers, and entrepreneurs to gain essential work skills.

Emergency service vehicles are equipped with enhanced batteries for increased life and speed. The fire and police departments have multiple stations located throughout the city. They can deploy autonomous drones from these locations to help fight fires and crime. Preventive healthcare is provided to every citizen of ZC. This promotes a healthy lifestyle. Numerous medical facilities are scattered throughout the city to ensure quick medical attention for all.

Prior to the shift to a circular economy, ZC's economy was based almost entirely on tourism. Transportation relied heavily on fossil fuels, and congestion during peak season worsened air quality. This affected the health of ZC's citizens and surrounding ecosystems. Restaurants used lots of single-use products and were a significant contributor to food waste in the city. Most visitors also purchased many single-use, travel-sized products adding to even more plastic waste and waste in general. Many local attractions were often littered with single-use products and trash. On average, food waste and plastics made up over 43% of landfills. The large number of visitors also resulted in more water usage and sewage; this was very taxing on ZC's systems. When pollution levels increased, tourists became uninterested in traveling to ZC, harming its economy.

Implementing a circular economy was a gradual process and required many key decisions on different fronts. ZC's citizens recognized the importance of implementing educational programs to help everyone embrace the change. This was accomplished at the school level through a variety of competitions and partnerships with corporate sponsors. The city also implemented education campaigns that highlighted the positive economic and environmental benefits of a circular economy. Other decisions were focused on infrastructure. Updated building codes required new construction and improvement projects to include regenerative design practices and smart water management strategies. ZC also addressed road congestion by partnering with pioneers in the transportation industry.

One of the biggest steps to becoming waste-free was to replace one-time-use plastics with biodegradable options. Bio-engineers developed a kelp-based alternative for the majority of single-use plastics. Scientists also developed enzymes to manipulate the biodegradation process. With these, the material can last up to two years and then break down within hours of being treated. Another benefit of this material was that even if the kelp plastic ended up in the environment, it would be safe for animals to eat. The kelp-based products have a high nutrient concentration and are often used as fertilizer. ZC produces enough kelp to provide raw materials for the plastic-alternative industry. The kelp farms are entirely automated. It grows on arms that move down at night to reach nutrient-rich waters and are raised during the day for sunlight. It also provides habitats for hundreds of marine species.

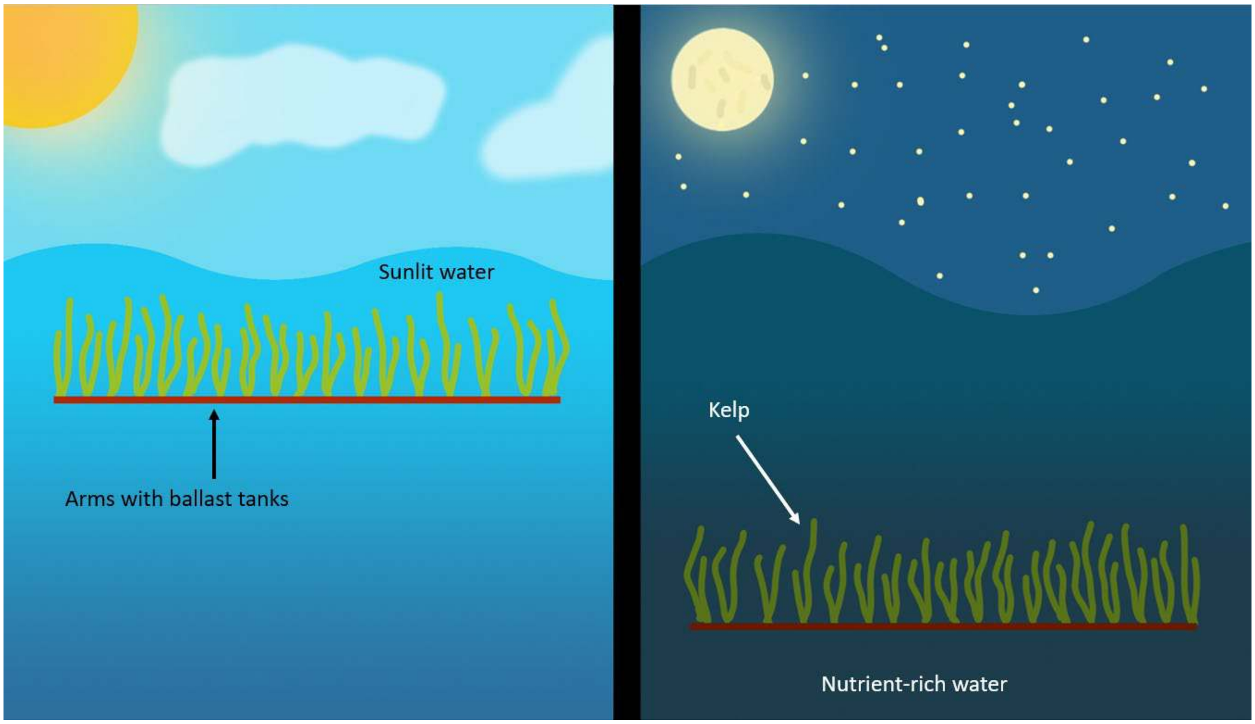


Fig. 2: Kelp Farms (Side View of Single Armature)

Recognizing that some plastics are still needed, chemical engineers at PSI Labs perfected an efficient recycling process that did not require the separation of different plastics. The plastics are fed through a grinder, compacted into pellets, and transferred into an oxygen-free chamber, which is brought to 600°C. This vaporizes the plastics without releasing any toxins. The gas is then pumped into another chamber where it is condensed into oil. This can then be turned back into plastics or other products right away. Many plastic components around ZC are made from recycled plastic, including the WECs.

Since food waste was one of the largest contributors to landfills, biochemical and environmental engineers at Zale City developed a solution to this problem. Advanced dehydrators that can process all types of foods are now standard throughout ZC. Within thirty minutes, the food is turned into a nutrient-rich base. The chemical compounds of the base are altered to change its properties and is then used in the preparation of new food. The base can also be used as animal feed or fertilizer, ensuring no food waste ever makes it to a landfill.

ZC is home to one of the largest clothing-recycling plants. Unusable clothing is put through a shredder; reinforcers are added before it is spun into new threads. This process is almost fully autonomous. These threads are then used to make new clothing.

Civil engineers and marine biologists designed the underside of ZC's floating district to regenerate marine habitats. The offshore power station was planned with a similar design in mind. Artificial reefs aided in the start of this process. Today, the thriving marine ecosystem is home to countless species and is popular among divers. ZC's plant-covered façades (one part of its regenerative design) provide homes to small mammals and birds. In addition, they improve air quality, building aesthetics, and also reduce the need for air-conditioning. Zale City also partnered with organizations to reforest a nearby national park.

The location of ZC is ideal for the mass production of kelp for plastic alternatives and provides access to sources of abundant renewable energy. ZC's floating district allows for better management of these offshore operations. However, being on the water meant that storms and high waves posed serious threats. Additional infrastructure was required to alleviate these threats. Funds were set up to protect ZC's water district using barriers, and more recently, the protective domes. The streamlined, retractable domes protect against winds and heavy storms.

Works Cited

Arafa, Salaheddin Abdulsalam, et al. “Optimum Mix for Pervious Geopolymer Concrete (GEOCRETE) Based on Water Permeability and Compressive Strength.” *EDP Sciences*, 2017, https://www.matec-conferences.org/articles/matecconf/pdf/2017/17/matecconf_iscee2017_01024.pdf. Accessed 30 Nov. 2021.

CNA Insider, “A World Without Waste: Circular Economy | Climate For Change: Closing The Loop | Ep. 1/2).” *YouTube*, uploaded by CNA Insider, 30 July 2021, https://www.youtube.com/watch?v=0EfsD7xNLIo. Accessed 30 Nov. 2021.

Ellen MacArthur Foundation, 2021, https://ellenmacarthurfoundation.org/. Accessed 30 Nov. 2021.

“Food: Material-Specific Data.” *United States Environmental Protection Agency*, 23 Nov. 2021, https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/food-material-specific-data. Accessed 30 Nov. 2021.

“Plastic: Material-Specific Data.” *United States Environmental Protection Agency* 30 Sept. 2021, https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/plastics-material-specific-data. Accessed 30 Nov. 2021.

“Waste.” *Community Action Works*, 2020, https://communityactionworks.org/issues/waste/. Accessed 30 Nov. 2021.

“Wave Energy.” *The Liquid Grid*, https://theliquidgrid.com/marine-clean-technology/wave-energy-converters/. Accessed 30 Nov. 2021.