BLUE FRONTIERS

State of the Art Report: Energy & Water

Final input and recommendations for Phase 1

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***Note about redacted sections: Any sections blacked out have been redacted to protect the intellectual property of Blue Frontiers' staff and volunteer team.**

1. Introduction

The Energy and Water Group's State-of-the-Art report will summarize the major findings of the past months, including findings within the working group and from interacting with the other teams. The Energy and Water team is dedicated to making the most green choices from available technologies, as we strive to engineer sustainable solutions into our first Floating Island Platform.

Over the past several months we have found many promising, available technologies that will allow us to produce zero emission energy, reuse water and recycle waste. At the same time, we need to stress the enormity of the task ahead: in order to achieve the promised objectives of zero waste discharge and zero emissions, we will have to push the limits of available technology. Even more challenging than finding reliable technologies will be integrating them all together in a system that is safe and reliable. As far as we can tell, no one has ever built a floating structure of any kind that did not produce any kind of pollution or waste.

This challenge becomes more apparent when one takes time to consider what it means to be truly zero waste. We can filter waste water to the point where it becomes potable again, but what happens to the filters once they are full of waste material and need to be changed? How do we remove more elusive contaminants like pharmaceutical, heavy metals or cleaning chemicals, and what becomes of these contaminants once they are removed? How do we prevent any of these pollutants from being accidentally washed overboard during a storm? Thanks to the depth of knowledge of our volunteer team, we have come up with some working solutions to some of these challenges, but some remain unsolved.

The Energy & Water Group has considered both established and developing technologies. The group developed a reasonable bias towards technologies that have proven themselves to be implementable, reliable, and affordable. Nevertheless, many technologies seem to be on the cusp of being able to check these boxes, and are included here, but are marked accordingly.

Starting with solar cell energy as our prime source of power, given its proven reliability and known cost, we will also venture into new and emerging technologies that we can first use as supplemental and backup energy during the initial phase and then include them to a greater degree in future platforms.[8]

The following factors were considered in the evaluation of technologies:

- What is the tech readiness level? Is it proven tech?
- Who is the vendor? How much does it cost?
- Is it something we can make money from or have a usable surplus from?
- What kind of maintenance will it require and will it be possible on the floating platform?
- How durable is it? How long will it last?
- How much energy will it use?
- How does it fit into land planning/layout?
- How sustainable is it? What's the environmental impact?
- How appealing are the aesthetics? Does it make noise or bad odors? What will it look like?

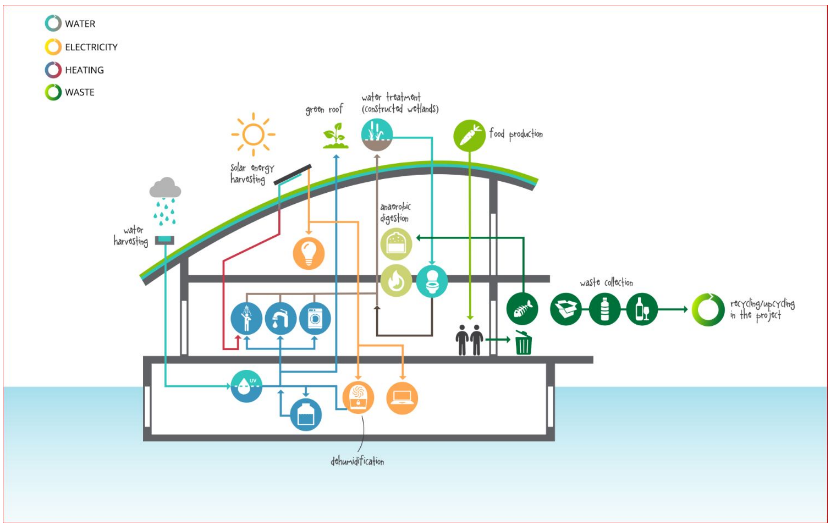
[8] https://docs.google.com/document/edit?hgd=1&id=1ri_Iyg8hX5EGo8RWeHNKQx_WQq-oghK_GDSdIdveeFA

Not all of these questions have been answered for every technology considered. But these are the general guidelines we are using as we continue our research.

What follows are only some of the technological solutions available to us. We hope to design a platform that can remain flexible and integrate new technologies as they become known to us, or as they become more available and reliable.

2. Blue21 Utilities Overview[9]

The Utilities Overview from Blue21 is shown in the figure below. The figure shows solar energy harvesting of electricity and water heating, rainwater harvesting, water treatment, electrical and water cycles, waste systems and wetlands, green roofs, and food production.



The group acknowledges that this conceptualization was created with great care and thought, and we agree with many of the concepts that it embodies. At the same time, we suggest some revisions. One of the most common has been the suggestion that the green roof should include food plants. Others suggest that we should use the surface to capture rainwater, and that a green roof is not the most effective way to do this. It may be that we do not have enough space on the roof both for the amount of solar panels and rainwater collection needed. The group is committed to working with Blue21 to continue refining these concepts, and this is clearly a good start.

3. A Unified Seasteading Model [10]

The following is a series of questions and answers that were included in a document intended to clarify some basic points for everyone at Blue Frontiers about what the first Floating Island would look like. Note that the answers given come from individuals, and do not necessarily reflect a consensus view of the entire Energy and Water Group.

Are we assuming air-conditioning for most spaces (or only specific spaces)?

People may choose A/C for their residences. Most public open spaces should also be open-air with a few small exceptions. Green roofs (with or without greenhouses above them) can also contribute to more comfortable temperatures inside, plus vegetation can clean and cool incoming air.

Is the island going to be connected to shore and/or will it have a backup generator?

9

10 https://docs.google.com/document/d/1q8M83VfsSzq81FG4ZAWYfuRc-BGOdwLgn9RzGkyZBXg/edit?ts=5a15c0d7#heading=h.4zdbj0dgetqr

We’ve discussed both options, but the backup generator cannot be diesel as it’s too polluting. It could be powered by biogas from the digester - but ultimately, we will need someone skilled at designing microgrids to determine whether this would be enough to ensure power stays on 24/7. ~Daniel

The main challenge of depending on solar energy is that the amount of sun is variable and we cannot conjure up more when we need it. Batteries are an option for nighttime and other short-term variabilities, but could not cover the extremes, unless a huge number of batteries are bought that are only used once a year.

How about communications? Is wireless going to cut it?

If connected, does that mean that SZ residents could opt for public utilities, or are we restricting the SZ to be limited to only consume power (etc.) through BF? What protections do SZ residents have against monopolistic BF pricing in the future?

This also depends on the claims BF is making (or agreements it is bound to) with regard to 100% renewables/self-supporting. I guess people can opt out, but have to come up with alternative measures that are within the common aims/constraints of the community. Rates can be determined by an elected board.

BF has a very strong disincentive against overcharging people for electricity - the Seasteading principle of “vote with your house” applies here. If people think they are being cheated, they will just leave and go back to where ever they came from. Monopolies only abuse their power when they are really big and socially disconnected from their customers, and BF is very far from that. We’ve been treating self sufficiency of the SZ as the priority. ~Daniel

How many people are we designing the utilities for? And what is the average consumption pattern?

Current assumption is 200 people. If there will be more villas, more commercial functions or higher individual space requirements the density (and number of people) will go down.

What systems will be used for wastewater treatment and what effluent quality level needs to met?

Wastewater will be productively and hygienically recycled, especially in agriculture. No wastewater should go into the ocean, treated or not, especially in terms of blackwater that carries human excrement. Biodigesters may treat some wastes, Urine-diverting Dry Toilets can avoid the production of blackwater, and flush toilet with closed-loop flush water recycling may also be applied. Clean drinking water will come from rain, distillation or desalinization and water will leave the system mainly via evapotranspiration of plants, animals, and humans. Excess runoff from rain can be filtered as needed in constructed wetlands, before its discharge into the ocean. Effluent quality needs to be close to 100% treated or at levels that are very close to natural levels in the lagoon water, in order to minimize environmental impact. (See the Food Systems Report.)

Cleaning the platforms and what to do with the cleaning water?

Platforms can be cleaned with rain runoff from the platforms themselves that is collected via a peripheral gutter and cleansed in a constructed wetland, to remove soil and other contaminants that may be present. Treated grey water may also be used when needed. As mentioned above, excess rainfall can be discharged after filtering through constructed wetlands.

Is there going to be a separate utilities platform? What are the pros and cons?

Pros:

- Central point of connection for power and communication lines coming from shore or sea cables. Power and data can then be stepped down and fed to the platforms.
- Efficiencies gained in processing wastewater and making freshwater.
- Efficiencies gained in processing waste via anaerobic digesters.
- Could be a separate product line that could be sold to a variety of customers from floating communities, offshore oil rigs, remote communities and work sites, island municipalities, etc.

Cons:

- Duplicates resources, each villa is meant to be a standalone unit, a utility platform would have some redundancies.
- Expensive, a platform of this type especially early versions would be costly

4. Toward Net Zero Design

Designing the first super sustainable floating island will largely be an exercise in Zero Net Energy (ZNE) and Zero Waste building design. The Floating Island Project and its successors are essentially mixed-use real estate development projects, that happen to also be boats. Therefore, design of the Floating Island Project can draw largely from the world of Zero Net Energy and Living Building design.

ZNE buildings are no longer in the demonstration phase, but are in fact starting to become a segment of the mainstream real estate development market.[11] In 2015, the California Energy Commission mades updates to the building code as it relates to energy, known as Title 24, which mandate that by 2020 all new residential buildings in California will be ZNE, and by 2030 all new commercial buildings will also meet this standard. Since California is such a large market, these new regulations will likely reshape the entire US construction industry[12]. While some may disdain such a heavy-handed approach by the government to move the market, no one can deny the impact this will have. It also will have the effect of pushing ZNE buildings further into the mainstream in the coming years. All this bodes well for the first Floating Island Project, as a greater supply of technologies and firms that specialize in this kind of design will mean a more competitive market for such technologies and services.

Below is a sample list of buildings in the United States that have achieved Zero Net Energy certification. This is just a small sample of a much larger list of buildings that includes buildings that have nearly achieved Zero Net Energy, or were designed with the goal of being ultra-low energy usage (but not producing any of their own energy, so they couldn't quite achieve net zero).

[11] 2016 List of Zero Net Energy Buildings, New Buildings Institute, https://newbuildings.org/wp-content/uploads/2016/10/GTZ_2016_List.pdf

[12] https://cleantechnica.com/2014/04/15/californias-net-zero-energy-building-will-reshape-us-construction-industry/

2016 List of Zero Energy Buildings

ZNE Verified Buildings

Zero Net Energy Verified Buildings have achieved ZNE for at least one full year. The total consumption of energy, from all sources, has been fully balanced by onsite renewable energy generation on an annual basis. NBI has verified performance data.

Year	Project Name	City	State	Building Type	Size (sq ft)	Base (Gross) Energy Use (kBtu/sf/yr)		Onsite Renewable Production (kBtu/sf/yr)		Net Grid Energy Use (kBtu/sf/yr)		zEPI Score
						Site	Source	Site	Source	Site	Source	
2000	Oberlin College Lewis Center	Oberlin	OH	Education	13,600	31.4	98.8	36.9	116.2	-5.5	-17.4	-5
2001	Environmental Tech. Center Sonoma State	Rohnert Park	CA	Education	2,200	2.3	7.3	3.8	11.9	-1.5	-4.6	-2
2003	Audubon Center at Debs Park (off grid)	Los Angeles	CA	Other	5,020	17.1	53.9	17.1	53.9	0.0	0	0
	Science House	St. Paul	MN	Other	1,532	18.0	56.7	18.0	56.7	0.0	0	0
2004	Challengers Tennis Club	Los Angeles	CA	Other	3,500	9.0	28.4	9.0	28.4	0.0	0	0
2005	Hawaii Gateway Energy Center	Kailua-Kona	HI	Other	5,600	28.0	88.2	31.0	97.7	-3.0	-9.5	-4
2007	Aldo Leopold Legacy Center	Baraboo	WI	Office	11,900	16.0	50.4	18.0	56.7	-2.0	-6.3	-2
	IDeAs Z2 Design Facility [L]	San Jose	CA	Office [R]	6,557	22.6	71.2	23.2	73	-0.6	-1.8	-1
2008	Camden Friends Meeting Social Hall	Camden	DE	Public Assembly	3,121	17.9	56.3	19.7	62	-1.8	-5.7	-2
	Environmental Nature Center	Newport Beach	CA	Public Assembly	8,535	17.6	55.4	27.7	87.3	-10.1	-31.9	-12
	Hudson Valley Clean Energy HQ	Rhinebeck	NY	Other	5,470	9.8	30.7	10.4	32.6	-0.6	-1.9	-1
2009	Bacon St. Offices	San Diego	CA	Office [R]	4,500	12.7	40	22.2	69.9	-9.5	-29.9	-13
	Chrisney Library	Chrisney	IN	Public Assembly	2,413	16.7	52.6	17.4	55	-0.8	-2.4	-1
	Living Learning Center at Tyson Research Center [L]	Eureka	MO	Education	2,968	24.5	77.1	26.4	83.2	-1.9	-6.1	-2
	Omega Center for Sustainable Living	Rhinebeck	NY	Other	6,200	13.2	41.6	21.5	67.6	-8.3	-26	-7
	Pringle Creek Painter's Hall	Salem	OR	Public Assembly [R]	3,595	11.1	35	15.4	48.4	-4.3	-13.4	-5
	Putney Field House	Putney	VT	Education	16,800	9.7	30.6	10.4	32.9	-0.7	-2.3	-1
	Watsonville Water Resources Center Admin Building	Watsonville	CA	Office	16,000	51.4	161.9	117.8	371.1	-66.4	-209.2	-101

2010	Bertschi School Science Wing	Seattle	WA	Education	1,425	48.0	151.2	48.4	152.5	-0.4	-1.3	0
	Dovetail Construction HQ Barn	Richmond	VA	Office [R]	6,800	UA	UA	UA	UA	0.0	0.0	0
	DPR Construction San Diego Net Zero Office	San Diego	CA	Office [R]	24,000	14.8	46.1	17.1	53.9	-2.4	-7.8	-3
	Energy Lab at Hawaii Preparatory Academy [L]	Kamuela	HI	Education	5,902	11.0	34.8	28.0	88.2	-17.0	-53.4	-15
	Hood River Middle School Net-Zero Addition [L]	Hood River	OR	Education	5,331	26.8	84.3	27.1	85.4	-0.4	-1.1	0
	NREL Research Support Facility	Golden	CO	Office	222,000	46.1	145.2	46.1	145.2	0.0	0.0	0
	Richardsville Elementary School	Bowling Green	KY	Education	72,285	19.0	59.9	21.6	68	-2.6	-8.1	-3
	Anna Maria Historic Green Village	Anna Maria	FL	Mixed Use [R]	District	28.2	88.8	34.8	109.6	-6.6	-20.8	-7
	Coastal Maine Botanical Gardens Bosarge Family Education Center	Boothbay	ME	Education	8,200	19.2	60.3	23.5	73.9	-4.3	-13.6	-4

L- Building is either Living Building Certified or Net Zero Energy Certified by the International Living Future Institute

R-Indicates a retrofit project

Buildings in ***Bold Italics*** are new to the list

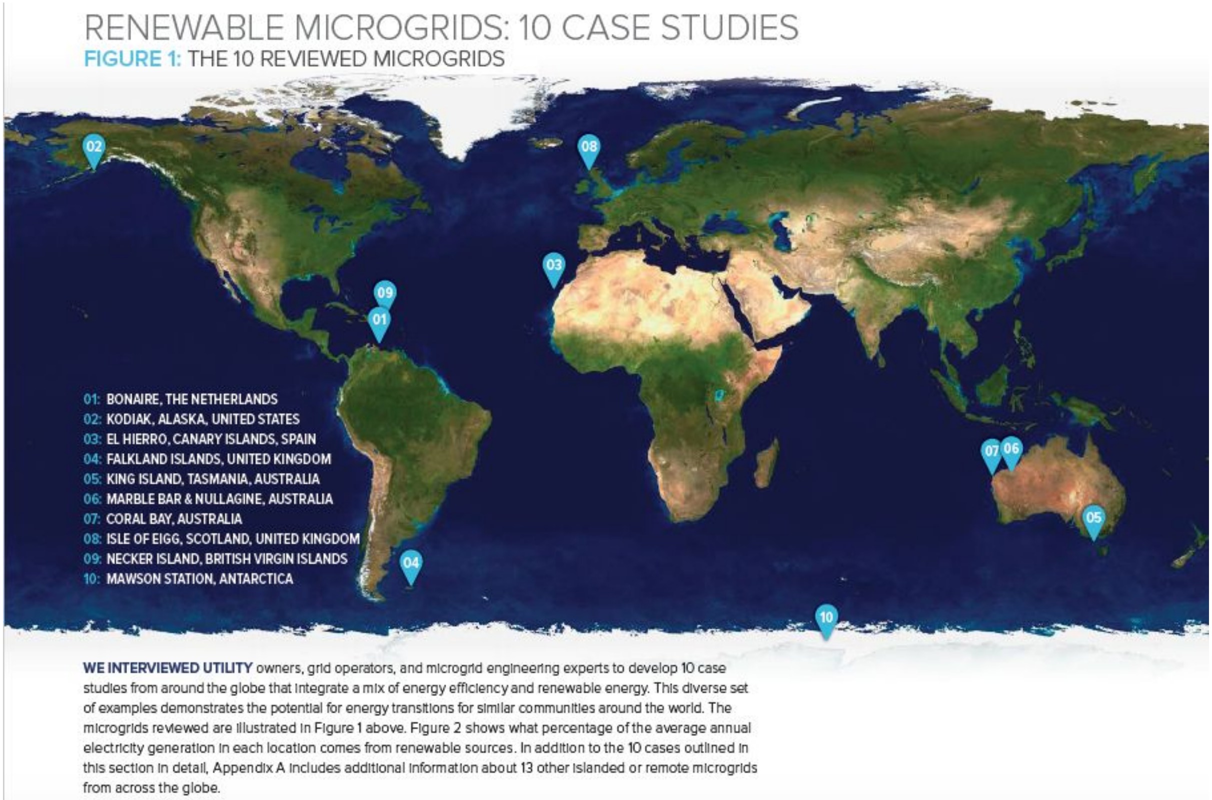
Year	Project Name	City	State	Building Type	Size (sq ft)	Base (Gross) Energy Use (kBtu/sf/yr)		Onsite Renewable Production (kBtu/sf/yr)		Net Grid Energy Use (kBtu/sf/yr)		zEPI Score
						Site	Source	Site	Source	Site	Source	
2011	***Diamond X Ranch Student Intern Center-Malibu***	Calabasas	CA	Other	3,500	31.5	99.3	35.1	110.5	-3.6	-11.2	-4
	EcoCenter at Heron's Head Park (off grid)	San Francisco	CA	Education	2,400	UA	UA	UA	UA	0.0	0.0	0
	Locust Trace AgriScience Campus (High School)	Lexington	KY	Education	70,000	9.9	31	10.6	33.3	-0.7	-2.3	-1
	TD Bank Branch	Fort Lauderdale	FL	Office	3,970	91.8	289.3	95.6	301.1	-3.8	-11.8	-4
	zHome - Issaquah [L]	Issaquah	WA	Multifamily	5,813	21.0	66.2	22.0	69.3	-1.0	-3.1	-2
2012	Bullitt Foundation Cascadia Center for Sustainable Design and Construction [L]	Seattle	WA	Office	51,800	9.7	30.6	16.6	52.4	-6.9	-21.8	-10
	David and Lucile Packard Foundation	Los Altos	CA	Office	49,161	24.4	76.8	29.0	91.4	-4.6	-14.6	-7
	DPR Construction Phoenix Net Zero Office [L]	Phoenix	AZ	Office [R]	16,533	26.8	84.3	29.5	92.9	-2.7	-8.6	-3
	Leon County Cooperative Extension	Tallahassee	FL	Office [R]	13,000	19.4	61.1	19.6	61.7	-0.2	-0.6	0
	Phipps Center for Sustainable Landscapes [L]	Pittsburgh	PA	Public Assembly	24,350	18.2	57.3	18.7	58.8	-0.5	-1.5	0
	Sacred Heart Schools Stevens Family Library [L]	Atherton	CA	Education	6,300	16.9	53.2	29.1	91.7	-12.2	-38.5	-15
2013	***IBEW Local 595 Zero Net Energy Center***	San Leandro	CA	Education	45,001	15.0	47.3	21.0	66.2	-6.0	-18.9	-7
	Lenawee Intermediate School District Center for a Sustainable Future	Adrian Township	MI	Education	8,750	7.7	24.3	10.1	31.8	-2.4	-7.5	-2
	PNC Net-Zero Branch [L]	Ft Lauderdale	FL	Mercantile (Enclosed and Strip Malls)	4,900	59.1	186.0	64.4	203.0	-5.4	-16.9	-5
	Sandy Grove Middle School	Lumber Bridge	NC	Education	74,000	20.6	64.9	35.7	112.6	-15.1	-47.7	-15
	West Berkeley Public Library	Berkeley	CA	Public Assembly	9,399	21.7	68.3	25.5	80.4	-3.8	-12.1	-5
2014	***Brock Environmental Center*** [L]	Virginia Beach	VA	Education	10,500	14.6	45.9	28.6	90.1	-14.0	-44.2	-14
	DPR San Francisco Office [L]	San Francisco	CA	Office [R]	24,010	144.1	453.9	147.5	464.7	-3.4	-10.8	-5
	Jess Jackson Sustainable Winery Building	Davis	CA	Warehouse and Storage	8,500	1.4	4.4	2.7	8.5	-1.3	-4.1	-5
	Pahranagat National Wildlife Refuge Administrative Office and Visitor Contact Station	Alamo	NV	Public Assembly	5,000	27.8	87.7	39.9	125.5	-12.0	-37.8	-12
	Willow School	Gladstone	NJ	Education	20,000	21.8	68.8	35.0	110.2	-13.1	-41.4	-12
2015	***231 Main Street***	New Paltz	NY	Office	5,400	45.2	142.3	52.6	165.8	-7.5	-23.5	-9
	AP+I Design	Mountain View	CA	Office	14,300	17.9	56.3	18.4	57.8	-0.5	-1.5	-1
	DMV Fresno Field Office	Fresno	CA	Public Assembly	19,908	12.4	39	19.9	62.7	-7.5	-23.7	-9
	Maclay Architects' Office	Waitsfield	VT	Office	2,568	22.1	69.5	25.0	78.6	-2.9	-9.1	-3
	Suncoast Credit Union	Bushnell	FL	Office	3,743	6.8	21.4	8.4	26.5	-1.6	-5.1	-2

5. Designing Microgrids

A microgrid can be defined as any combination of electricity production and storage resources that are connected together, but operate independently from a larger regional or national grid. They can be as small as a solar PV system and battery on an individual home, and as large as an entire city. While microgrids can use any type of electrical generating resource, they tend to utilize a lot of distributed, renewable energy resource, because of the small-scale generating capabilities of these resources, as compared to most fossil fuel generating plants.

Because the Floating Island Project will essentially be relying on a renewable microgrid, there is a lot we can learn from other renewable-heavy microgrids around the world. Encouragingly, there are many island nations around the world that have developed largely renewable microgrids. The bad news is that just about all of them use either diesel generators or hydro resources for a large percentage of their energy (typically paired with solar and/ or wind). Diesel is polluting and most of these islands have to import the diesel fuel, making them less self reliant (using locally produced biodiesel would be a potentially advantageous substitute). Hydro relies on specific land formations that will not be available to the floating island project. As a result, we will have to get creative in figuring out how to build and operate a 100% renewable and sustainable microgrid.

Below is a list of 10 case studies conducted by the Rocky Mountain Institute and the Carbon War Room of island-based microgrids around the world. Notably missing from these, because it is so recent, is the Tesla solar-battery microgrid on American Samoa. While this microgrid has a diesel generator, reports have suggested that diesel is only supplying a few percentage points of the total power production, and the rest is coming from solar. This suggests that is may be possible to build a microgrid without utilizing diesel.

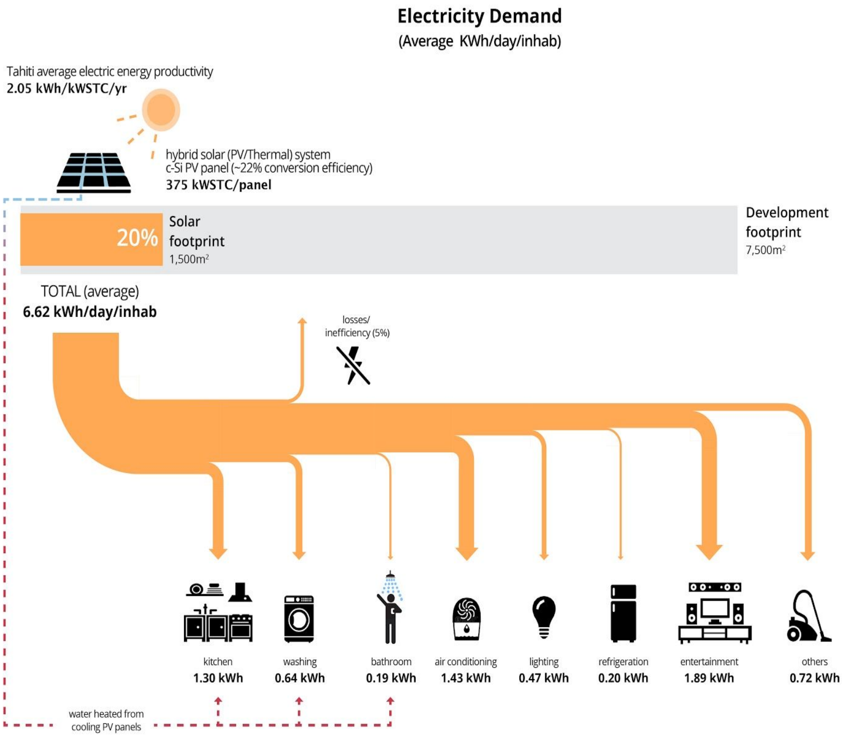


6. Energy Systems

6.1 Energy Demand on the FIP

Among its three subsets, the group has made perhaps the greatest progress in the realm of energy. To develop an understanding of how the first floating islands can be powered, the group began by estimating what typical demand might look like. This was calculated by multiplying power requirements of all necessary applications and appliances [Watts] by approximate usage [hrs/day] to yield an energy usage on a per-person, per-day basis (kWh/p.d). Initially, this estimate came out to around 18.5 kWh/person-day before HVAC [EnergyandWaterSystemsData, Energy Usage, Cell J42]. Put in context, this is perhaps a high estimate compared to estimates for the average American needing 15 kWh/day [source?]. Blue21's demand estimates have also been taken into consideration, but still remain much lower than our group. They currently estimate a low scenario (LS) of 4.73 kWh/p-d and a high scenario (HS) of 11.73 kWh/p-d [Blue21's [CURRENT] Utility calculation V2, Energy Demand, cells G52 & K52] . The disparity between the two group's energy estimates have perhaps led to different conclusions regarding supply.

Electrical demand has been estimated to range between and 4.73[13] and 16.67[14] kWh/day per person. In order to produce this much electricity, 20 to 40% should be covered with solar panels. The first platforms built should have the larger coverage area and then later platforms can be built with great knowledge of user demand.



6.2 Solar

6.2.2 Choosing the Right Solar Technology

As the group has investigated different solar technologies and learned more about how solar works, we've begun to develop some rough criteria that will help to determine which solar technology we ultimately use. These include:

1. Are they salt resistant?
2. How much lead do the panels contain, and will this lead contaminate any water running off them?
3. Can the panels produce thermal, as well as electrical energy?
4. What is the overall efficiency of the panel? What is the energy yield per square foot/ meter?

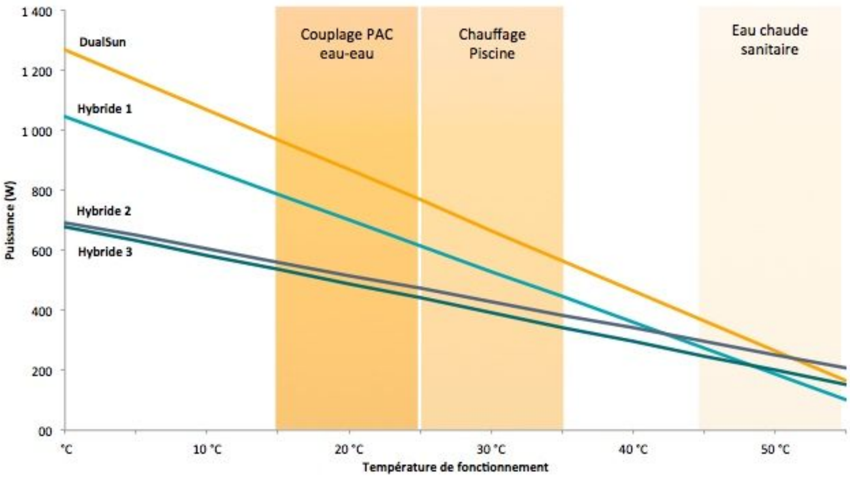
13 https://docs.google.com/spreadsheets/d/1rbAh8SZXUcgk0lNDOIcmLBxRLmE6TxQIaxqE9-DTSaE/edit#gid=972928314

14 https://docs.google.com/spreadsheets/d/10frICKr7SSBaacs8W69Nbz0CvQNq31549_TcR8Duj3s/edit?ts=59662abf#gid=408285885

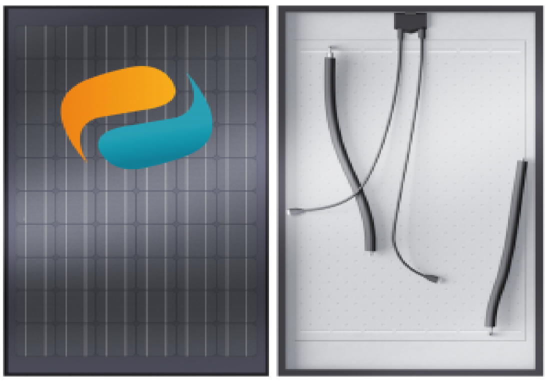
6.2.3 DualSun:

The DualSun is an advanced hybrid solar (PV/T) panel that produces simultaneously electricity (photovoltaic) and hot water (solar thermal) for homes and buildings. The patented system intelligently integrates a photovoltaic panel with a heat exchanger on the backsheet, to produce up to 4 times more energy than a traditional photovoltaic panel. The DualSun solution is designed to transform our homes and offices into positive-energy buildings. [15]

Among other PV/T technologies, DualSun seems promising. They claim that in a study by National Institute of Solar Energy (INES), their panels thermally outcompeted 3 comparable PV/T panel technologies on the market.



DualSun has actually commissioned the study. It can be found here:
http://pro.dualsun.fr/wp-content/uploads/DualSun-FR-Rapport-INES-mesures-panneaux-PVT-v1.0-Octobre-2015.pdf



Further information can be found here:

http://pro.dualsun.fr/wp-content/uploads/DualSun-FR-Fiche-Technique-Wave.pdf

https://dualsun.fr/2017/10/meilleure-performances-thermiques-panneaux-solaires-hybrides/

https://dualsun.fr/2017/10/calcul-performances-thermiques-capteurs-pvt/

6.2.4 SunPower

SunPower: the unique design of SunPower solar cells eliminates 85% of the reasons conventional cells fail.[16] SunPower panels have consistently achieved the highest efficiency in the solar industry for decades, with their record-setting highest-efficiency commercial panel coming in around 21% (industry standard for commercial panels is about 16%). Sunpower also provides the longest warranty of any solar manufacturer in the industry: a 20 year warranty. Finally, Sunpower panels are specifically designed to be salt-resistant. This means they will do well in

[15] https://dualsun.fr/en/product/2-in-1-solar/
[16] https://us.sunpower.com/why-sunpower/maxeon-solar-cells/

environments with salty myst close to the coast, however it is unclear and untested whether they will consistently performed if located directly on the ocean.

6.2.5 Smartflower

Smartflower is a fully integrated, plug-and-play solar system that powers your world with clean energy. Simply set up, connect and start producing clean energy. Smartflower is a fully integrated, all-in-one solar system that can live anywhere. Designed to be a plug-and-play system, smartflower makes solar simple. All it takes is a quick setup by one of our installers and you'll be producing clean energy for your home or business. And if you ever have to move it, smartflower can be easily packed up and moved to a new site. [17]

6.2.6 Combined PV/T Solar Concentrators

Combined PV/T solar Concentrators - These systems utilize three technologies in tandem in order to best extract the incoming sunlight. Sunlight is concentrated (between 2x~200x concentration) onto a set of PV panels to increase energy density. This concentration tends to increase the overheating issues normally associated with PV solar panels. To combat and utilize this waste heat, a working fluid can be piped behind the panels and then utilized in an organic rankine cycle. Efficiency numbers are promising and such a system could capture up to 3x as much energy as similarly sized PV arrays. From a cost standpoint, mirrors are cheaper than PV panels which may offset some of the additional R&D costs. Here's a brief overview of PVT systems and Xi'an Jiaotong University's attempt at creating such a system. [18]

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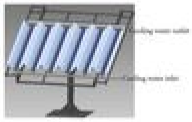
[17] http://smartflowersolar.com/

[18] https://www.hindawi.com/journals/ijp/2012/869753/

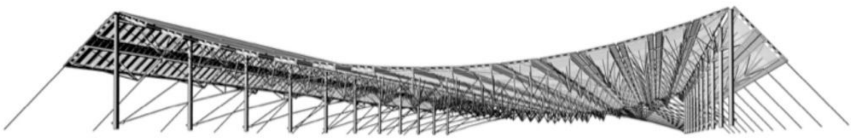
While these systems seem promising, companies have been trying to make cost effective concentrating PV for over a decade, and so far the technology has not been able to compete with conventional PV. This may change in the future, and so this is a technology to watch.

Some other concentrating PV technologies to watch include:

- Belgium company (Kaneka) that seems to have developed some next-gen TPV. http://www.renewableenergyfocus.com/view/22658/kaneka-and-imec-develop-silver-free-heterojunction-silicon-solar-cell/
- There has been significant cost reductions and efficiencies with multilayer tungsten-alumina-based broadband light absorbers for high-temperature applications. Maybe we can develop a hybrid a panel in the future.
  https://www.osapublishing.org/ome/abstract.cfm?uri=ome-6-8-2704
- Additional References:
  https://pdfs.semanticscholar.org/ae95/408cba43f967d954fec3c071e3330183941d.pdf
  http://www.alternative-energy-news.info/thermo-photovoltaic-cells/
  https://www.sciencedirect.com/science/article/pii/S1473832503006175

6.2.7 Solar Tensile Structures

Solar Tensile Structures P4P's patented, PV panel suspension system utilizes tensioned steel cable technology to reduce cost and bring about entirely new solar applications. P4P's solution incorporates the same tensile structure principles used in thousands of suspension bridges around the world, to suspend solar panels. This approach allows unparalleled versatility, enabling PV arrays to be supported at virtually any height on free spans of up to 100 meters. P4P's system is ultralight yet designed to withstand hurricane force winds. [19]



6.2.8 Atlantis Solar Air Conditioner

Atlantis Solar Air Conditioner Triple Thermal Heat Transfer Processing. Air-Conditioner absorbs solar energy to heat the inside medium by using a vacuum solar collector. The refrigerant from the compressor goes through the copper coil inside the collector and undertake a heat exchange. The refrigerant heated by the medium inside the solar collector will go through a cycle inside the system cooling and heating. [20]

Further research into this technology is required to determine whether it is currently viable.

6.2.9 GlassPoint Solar Steam Generators

GlassPoint solar steam generators are designed to meet the unique needs of industries. The company's enclosed trough technology houses thin curved mirrors inside a greenhouse. The mirrors track the sun throughout the day, focusing heat on pipes containing water. The concentrated sunlight boils the water to generate steam. [21]

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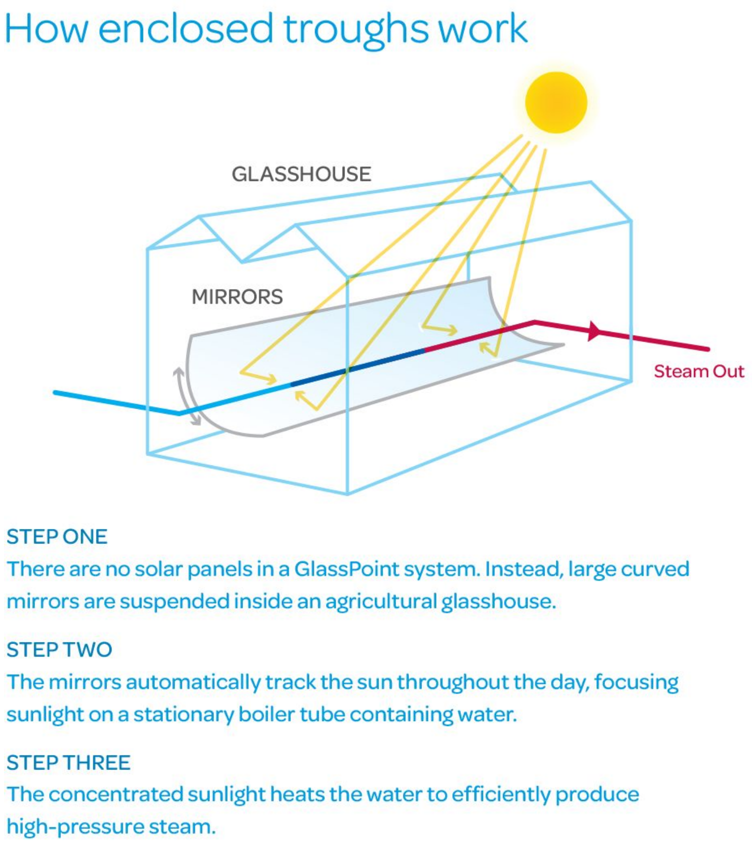
[19] http://p4penergy.com/technology/

[20] http://www.atlantissolar.com/ac_details.html

[21] https://www.glasspoint.com/technology/



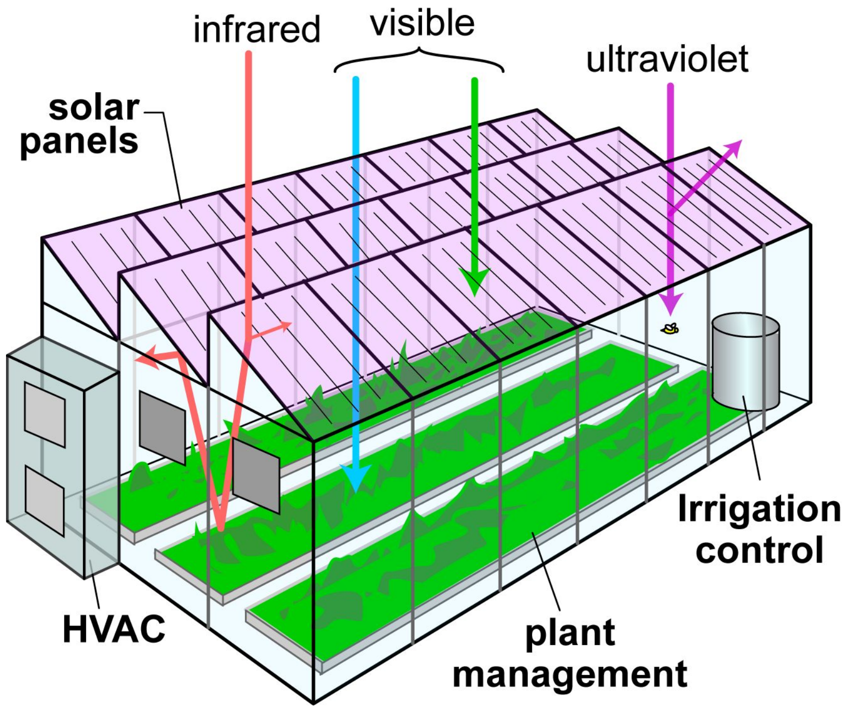
There are likely some additional Pros and Cons to think about with concentrator type solar systems, but the team has not yet had time to fully consider them. [22]

Further research into this technology is required to determine whether it is currently viable.

6.2.10 Solar Greenhouses and Transparent Solar Cells

Organic transparent PV solar cells are one way researchers hope to meet the high energy demand of modern greenhouses. Essentially, the roofs and/or walls of a greenhouse can be made up of organic PV solar cells which are transparent to the colors the plants need and can actively capture other parts of the spectrum. See picture below.

[22] https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/cpv-report-ise-nrel.pdf



Examples of this technology are being worked on by researchers at North Carolina State University and University of California, Santa Cruz. The latter of which has been spun off into a startup by the name of Soliculture. If the magenta panels seem off putting, the company Polysolar is offering a softer orange version of the technology. Transparent solar cells can offer around 8%-10% efficiency compared to around 15% for their traditional inorganic counterparts. Surely Seasteaders will eventually have greenhouses and aquahouses out at sea. A traditional greenhouse would potentially hit our energy demand books twice, as both an energy hog and by taking up roof space that could otherwise be allocated to energy generation. With these systems, this compromise need not be made.

In contrast to the pink/magenta panels those researchers have developed, BMW claims to have a completely transparent cell (full visible spectrum) that generates energy from the UV and infrared bands. This technology could be useful on the Seasteads to reduce the amount of infrared (heat) that enters the building while simultaneously generating useful electricity. If it proves to be economical, this sort of technology could quickly become the standard for smart buildings/skyscrapers, especially in warm climates.

- https://news.ucsc.edu/2016/05/solar-greenhouse.html
- http://www.soliculture.com/
- http://www.polysolar.co.uk/
- https://www.youtube.com/watch?v=5Vx59VLc98E

We have been told that this technology is commercially available at a reasonable price, which, although higher than regular solar panels, provides additional advantages.

6.2.11 Kalina Cycle

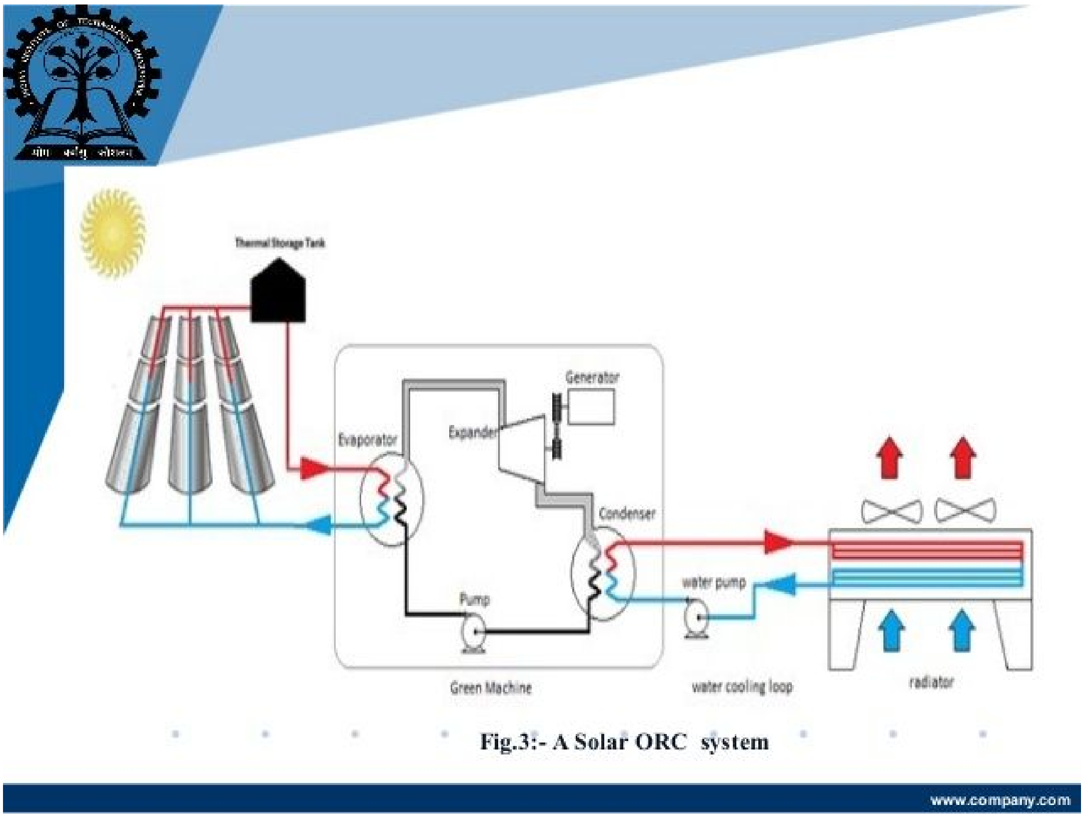


Fig.3:- A Solar ORC system

Kalina cycle is used in OTEC power plants and has the advantage of using lower temperature heat sources to produce electricity. Kalina Cycle is a type of Organic Rankine Cycle power plant where the working fluid is an ammonia water mixture that has a much lower boiling point.

Because of this ability to take full advantage of the temperature difference between the particular heat source and sink available, it finds applications in reuse of industrial process heat, geothermal energy, solar energy, OTEC and use of waste heat from power plants.

A potential use of this technology would be to couple a solar trough heater with a Kalina cycle system and a molten salt heat storage system. This would offer the advantage of learning how to build, operate, and maintain Kalina cycle plants, so that later it would be a smooth transition to building and operating OTEC Power Plants. Molten salt storage would also allow the plant to operate at night without battery storage. The company Kalina builds custom Kalina cycle power plants and would be a good resource should we decide to go this route.

Another potential hybrid system could combine this technology with water from PV/T panels which are discussed above. One complication is that thermal solar panels often run on antifreeze, while a Kalina cycle desires fluid with a lower boiling point. Note: We are waiting for a response from DualSun if this is feasible or has been tried.

Pros:

- 100% renewable
- Zero CO_2 emissions
- Knowledge of Kalina Cycle will provide a smooth transition to OTEC plants
- Provide electricity at night without battery backup

Cons:

- Likely will be more expensive than solar panels although cost is unknown
- This would require a custom built plant so parts would not be off the shelf

Further research into this technology is required to determine whether it is currently viable.

6.2.12 Gallium Arsenide (GaAs)-based photovoltaics

The high efficiency of GaAs cells (measured at more than 40% peak power conversion efficiency by the National Renewable Energy Laboratory) makes them ideal solutions for utility scale solar, if it can be deployed at a reasonable cost.[23]

However this type of PV is not yet commercially available.

6.2.13 Surface Water OTEC + Solar Concentrator

These appear to achieve thermal differential with super heated material from a solar concentrator and use subsurface water for cooling. As opposed to the traditional surface water and deep water differential of OTEC, this technology creates the differential with solar concentrators. "The advantage of using a CPV dense array module compared to fresnel cpv systems is that it is compact, low cost, and low maintenance."[24]

Further research into this technology is required to determine whether it is currently viable.

6.2.16 Solar-Produced Hydrogen

This is Nanotechnology for making renewable hydrogen from sunlight[25]. Extraction of hydrogen has been found to be more efficient if the raw material is urine, instead of water[26]. There will be abundant pure urine from Urine-diverting Dry Toilets and Waterless Urinals (see Food Systems), but the disadvantage is that the valuable nitrogen would be lost to the air as N2, so the resulting liquid would no longer be an excellent nitrogenous fertilizer for the gardens.

Further research into this technology is required to determine whether it is currently viable.

6.3 Biofuels[27] [28] [29]

6.3.1 Bio-Alcohol

The bioconversion of biomass to mixed alcohol fuels can be accomplished using the MixAlco process. Through bioconversion of biomass to a mixed alcohol fuel, more energy from the biomass will end up as liquid fuels than in converting biomass to ethanol by yeast fermentation.

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[23] http://www.nanoflexpower.com/utility

[24] http://www.solartronenergy.com/solar-concentrator/how-does-a-solar-concentrator-work/

[25] http://www.hypersolar.com/technology.php

[26] https://www.chemistryworld.com/news/urine-turned-into-hydrogen-fuel-/3004176.article

[27] https://docs.google.com/spreadsheets/d/1_3YOUrypo04QnJPc-nMYH-xa-S9cpCELft3yh_xXngM/edit#gid=101262602

[28] https://www.wikiwand.com/en/Bioconversion_of_biomass_to_mixed_alcohol_fuels

[29] https://docs.google.com/spreadsheets/d/1_3YOUrypo04QnJPc-nMYH-xa-S9cpCELft3yh_xXngM/edit#gid=101262602, https://phys.org/news/2017-02-eco-battery-seawater.html#jCp, https://www.youtube.com/watch?v=NWEXNjFJNmI&feature=youtu.be

Further research into this technology is required to determine whether it is currently viable.

6.3.2 Biogas/ Anaerobic Digestion

Anaerobic digestion provides an efficient, proven way to convert almost any kind of biomass into energy and organic fertilizer. Soft, wet biomass is the most digestible, and will on average require 30 days of retention time, although that time can vary widely based on the specific parameters of the digester, and desired goals of the operators. Waste water and manure, as well as food and even green and some types of paper waste will digest readily, while hard, woody biomass will take longer and may not ever fully digest. *Feedstocks like food waste are ideal, because they are very high in embodied energy and will produce the most gas. Manure/ wastewater by contrast, is very low in energy and will not produce much gas.*[30]

The most important parameters for a digester are temperature and pH. The optimal digester temperature is usually either 35 or 55 degrees C, depending on whether the digester is classified as mesophilic or thermophilic. A higher temperature digester will digest faster, but the reaction is more unstable and susceptible to upset from small changes in temperature or pH. Keeping the right Carbon: Nitrogen ratio will also help the digester work more efficiently and allow it to produce more gas.[31]

The biogas produced by an anaerobic digester is about 60-70% methane (chemically identical to natural gas) and 30-40% Carbon Dioxide. Biogas is considered “carbon neutral” because the carbon dioxide that is emitted is part of the natural carbon cycle, and is not a fossil fuel that is extracted from the Earth (added to the carbon cycle). The fact that biogas is largely similar to natural gas makes it an diverse fuel that can be used in almost any appliance that runs on natural gas. At 600-700 BTUs per cubic foot (methane has roughly 1,000 BTUs per cubic foot), it is far more energy dense than syngas - the byproduct of waste gasification - which only contains 67-131 BTUs per cubic foot,[32] and is made of 30-60% carbon monoxide, 5-15% carbon dioxide, 25-30% hydrogen, and only 0-5% methane.[33]

There are hundreds of turn-key anaerobic digester systems on the market all over the world, but only a few that are small enough for the purposes of the first FIP. If the digester is used just to process food waste, in order to maximize energy yield per volume of digester space, and each adult human produces about 1 pound per day of food waste, then we can expect about 200 pounds per day, or 0.75 tons per week.

While not very energy dense compared to liquid fuels, methane can be easily stored in large PVC-reinforced inflatable bags - a common practice all over the world. Such a bag could be floated off the side of the FIP platform, where it could safely store energy for electricity production when needed. We estimate that anywhere from 5-10 hours worth of power could be stored in this way (SWAG by Daniel).

The HORSE (High-solids Organic-waste Recycling System with Energy output), made by Impact Bioenergy and distributed by Everflux Technologies (in California) is the only commercial biogas unit that is design for a weekly input this small, with systems ranging from 0.5 tons per week to 16 tons per week. This system provides on-site generation of energy from food waste and similar organic materials, avoiding expensive offsite trucking and turning waste into value.[34]

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[30] David House, The Complete Biogas Handbook.
[31] David House, The Complete Biogas Handbook.
[32] http://www.cleangreenengines.com/banners-view/renewableenerg/
[33] https://www.netl.doe.gov/research/coal/energy-systems/gasification/gasifipedia/syngas-composition
[34] http://www.everfluxtechnologies.com/commercial-kitchens.html
http://www.everfluxtechnologies.com/uploads/7/6/7/4/76741299/horse-ad-25-series-fact-sheet-2017.pdf

An alternative model for the first FIP might be to have an individual food waste anaerobic digester for every household. In this case, it would be technically and logistically challenging to collect all that biogas to produce electricity, however individual households could use it for cooking gas. **HomeBiogas** makes a household biogas unit at a very reasonable price.

6.3.3 Algae Biodiesel

While the cost of producing algae-based biofuel was as high as $30 a gallon about a decade ago - when a short-lived venture capital craze around algae biofuel resulted in several bankruptcies - steady research has lead to a cost decline that has reached $7.50 per gallon. At this price, algae biodiesel is nearly competitive with the price of conventional diesel on island nations. A more extensive summary of the (somewhat) current (2014) state of the art in algae biofuel can be found here:

http://www.biofuelsdigest.com/bdigest/2014/10/13/where-are-we-with-algae-biofuels/

According to a post on an online forum[35] (take this with a grain of salt), the price of refining crude oil into gasoline is about $0.70 cents (although this might only be at a very large scale). Based on this information, it would be reasonable to estimate the price of algae-based gasoline at about $8.20.

6.3.4 Algae Disk Reactor

This is still a highly experimental, but promising project to build a highly efficient reactor to capture CO2 from industrial processes and convert it into algae biodiesel[36].

SwRI is a leading provider of technical solutions that improve the efficiency, performance, and safety of energy across fuel cycles and supply chains. As part of our work in energy, we provide comprehensive environmental services that complement our work in improving efficiency and lowering emissions[37].

6.4 Wind

Wind would be a good compliment to solar, because the wind will often blow during times when there is reduced or no solar: at night, and during storms. While large wind turbines would created a significant eyesore and would likely be unwelcome, small or micro wind turbines are an ideal renewable energy source for small islands[38]. At $3-$7 per watt installed[39], costs for a 2-6 kW turbine (which would produce enough energy for a single family home) are not

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35 https://www.researchgate.net/post/How_does_the_price_of_crude_oil_compare_to_the_cost_of_processing_it_into_petrol_and_or_diesel

36 http://algadisk.eu/

37 https://www.swri.org/industry/energy-environment

38 https://www.iucn.org/content/wind-energy-production-low-pacific-islands

39 https://cleantechnica.com/2014/10/27/small-wind-turbine-myths/, http://prdrse4all.spc.int/sites/default/files/MR0559_0.pdf "Wind Energy Economics", http://www.renewablegreenenergypower.com/how-much-wind-turbines-cost/

unreasonable, and range anywhere from the same, to a little more than double the cost of a similar sized solar system. Furthermore, the use of wind could significantly reduce the amount, and therefore cost of batteries required on the FIP, by balancing solar energy production.

One important fact about wind to keep in mind: *wind generally blows much more constantly and typically harder off the coast, compared to on land*. This means that while data about wind on shore may not seem to make wind a suitable option, the reality could be very different in the lagoon. This is something that would be best to assess with a wind measurement device placed in the lagoon.

6.4.1 Helix Wind Turbine

The specially developed power converter for wind turbine converts kinetic energy into electricity for the household. The electricity is fed 3-phase with 400 VAC into the power converter, which switches the power to 600 VDC, which then flows into an intermediate voltage circuit, where it is transformed into 400 VAC / 50 Hz / 16 A by the power converter and can therefore be fed as 3-phase into the household consumer unit. Communication interfaces enable the connection and transfer of the data to PC via Ethernet and remote system access via the Internet. At a wind speed of 6 m/h, this turbine will produce 2 kWh/d, at an initial cost of 8,100 euros.[40] Another page of their website says 1.9 kWh/day at avg wind speed of 3.4 m/s.[41]

Helix →

← SkyStream

6.4.2 SkyStream 3.7

The SkyStream brand of wind turbines, from Southwest Wind, is one of the most enduring, and cost effective, small-scale wind turbines on the market. The shape is unlikely to be considered an eyesore, and just two of these turbines can power a single family home.[42]

6.5 Wave/ Tidal Energy

Buoys need to be placed in and near the platform locations. Further research into Wave and Tidal Energy technologies is needed, but most of them are still in the demonstration phase.

6.6 Water-Source Heat Pumps

A heat pump is, technically speaking, any device that moves heat from one area to another (i.e. inside to outside a building, or visa versa), and usually concentrates or disperses that heat. Refrigerators and Air Conditioners work according to this principle. Heat pumps can also be used in reverse in order to “extract” and concentrate heat from the outside air to heat water or the air inside a room.

Water source heat pumps refer to heat pumps that use a water loop as their source for heating or cooling. Since the FIP will be floating on a body of water that we assume will generally be cooler than the air, ocean water can act as a source of air conditioning for the FIP.

[40] http://www.wind-of-change.org/index.php/technology.html#specs

[41] http://wind-of-change.org/index.php/income.html
[42] http://www.windenergy.com/products/skystream

Note that heat pumps are **not** used as a source of electricity, but rather of heating and cooling, two activities which typically constitute the largest portion of energy usage for a commercial or residential building.

6.6.1 Sea Tubes for Passive Cooling/Fresh Water

If we were to take the method of Earth Tubes (ground coupled heat exchanger systems) and apply it to subsea thermal transfer. The water temperature could be brought up into the living spaces for passive cooling. If the deeper lagoon water is 24 celsius and we pipe that cool air up to our living spaces, that'd be really comfortable.[43]

Added feature, water from condensation. "In a humid climate, (ie anything with more than a 50% relative humidity) the air coming in will drop so much condensation inside the tube that it would serve practically as a passive water source."[44]

6.7 Energy Storage and Backup Systems

An important point should be recognized about energy storage and backup systems: If the FIP is relying on solar to provide the majority of its energy, then the FIP should never be in need of a "backup" system, any more than a regular commercial building would be - only a system to reliability supplement solar energy when the sun is not shining is needed. This is because 1) Solar never completely goes away - even on rainy days, some solar energy still gets through the clouds (solar thermal is more effective at capturing this energy than PV is), and 2) power outages due to equipment failure should theoretically be even less frequent, and of shorter duration than on land, because we aren't dealing with power lines (usually the point of failure in a power grid).

6.7.1 Lithium Ion Batteries

Tesla Powerwall and Powerpack. Powerwall provides backup power during utility outages, natural disasters and even the Zombie Apocalypse (you know it's coming). Compact, stackable and with a built-in inverter, Powerwall also comes ready to integrate seamlessly with Tesla solar, enabling you to self-power your home and even go off-grid, if you like. [45]

Tesla's Closed Loop Battery Recycling Program. As we work to lessen global dependence on petroleum-based transportation and drive down the cost of electric vehicles, we are committed to instituting a closed loop battery recycling system. A closed loop of material use involves manufacturing of battery cells, assembly into battery packs, then vehicles, and finally, recycling into raw materials for future use. [46]

6.7.2 NanoFlowcell

This is power storage that works with salt water. The efficiency of the nanoFlowcell® stands at more than 90 percent. When used in electric mobility applications, the operating temperature is between just 90 °C and 130 °C. The entire nanoFlowcell® system is also incredibly reliable and low-maintenance as it has no moving parts aside from the electrolyte pumps.[47]

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[43] https://www.thenaturalhome.com/earthtube.htm
[44] https://permaculturenews.org/2017/07/10/earth-tubes-natural-way-air-condition-home/

[45] https://www.wikiwand.com/en/Tesla_Powerwall

http://www.solarcity.com/residential/powerwall

https://www.tesla.com/powerwall

[46] https://www.tesla.com/blog/teslas-closed-loop-battery-recycling-program

[47] http://nanoflowcell.com/en/what-we-do/application-research/stationary-energy/

As far as we can tell, this technology is still in prototyping stage, and may not be ready for commercial deployment, nor have it's claims fully tested. Further research is required.

6.7.3 Air-breathing Batteries

"This battery literally inhales and exhales air, but it doesn't exhale carbon dioxide, like humans — it exhales oxygen,"

"The battery's total chemical cost — the combined price of the cathode, anode, and electrolyte materials — is about 1/30th the cost of competing batteries, such as lithium-ion batteries. Scaled-up systems could be used to store electricity from wind or solar power, for multiple days to entire seasons, for about $20 to $30 per kilowatt hour."[48]

6.7.4 Molten Salt Energy Storage

SolarReserve is the industry leader in advanced solar thermal energy storage technology. Molten salt is used both as a heat transfer fluid (HTF) as well as a thermal energy storage medium. The molten salt mixture is both non-toxic and inert. Together with the SolarReserve technology design, the use of molten salt represents the most flexible, efficient and cost-effective form of large scale energy storage system deployed today. This storage feature enables stable and dispatchable power delivery without the need for any backup fossil fuel such as the natural gas needed for many other CSP technologies. SolarReserve's experience with molten salt includes salt specifications, equipment metallurgy, tank foundation design and engineering, as well as initial salt melting and commissioning processes.

Molten salt is circulated through highly specialized piping in the receiver (heat exchanger) during the day, and held in storage tanks at night – requiring no fossil fuels. The tanks store the salt at atmospheric pressure. Use of molten salt for both heat transfer and thermal energy storage minimizes number of storage tanks and salt volumes needed. Molten salt is stored at 1050°F (566°C) until electricity is needed – day or night, whether or not the sun is shining. As electricity is needed, molten salt is dispatched from the hot tank through a heat exchanger to create superheated steam which then powers a conventional steam turbine. The molten salt never needs replacing or topping up for the entire 30+ year life of the plant. Heat loss is only 1°F per day. The salt, an environmentally friendly mixture of sodium nitrate and potassium nitrate, is able to be utilized as high grade fertilizer when the plant is eventually decommissioned.

Storage enables solar thermal power plants to operate just like a conventional fossil fuel or nuclear power plant, reliably generating electricity when it's needed most - but without the associated harmful emissions and without any fuel costs. Solar thermal power plants with integrated molten salt energy storage can operate 24/7, proving baseload power for both on-grid and off-grid applications. Integrated energy storage provides the ability to shift electricity generation to meet different profile needs and deliver firm, reliable power at high capacity value. Molten salt thermal energy storage is the lowest capital cost energy storage system. Solar thermal power plants with integrated energy storage are cost-competitive with any new build coal, natural gas, or nuclear technology
Storage allows the facility to produce more than twice as much net annual output (megawatt hours) than any other solar technology. Firm output ensures a more stable and secure transmission system
KEY VALUE By turning the sun into a 24/7 energy source, SolarReserve offers a realistic solution that can meet the global need for reliable, emissions-free electric power that is available around the clock and is a viable alternative to baseload coal, nuclear or natural gas burning electricity generation facilities.[49] [50] [51]

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[48] http://news.mit.edu/2017/air-breathing-battery-making-renewable-power-more-viable-grid-1011
[49] http://www.solarreserve.com/en/technology/molten-salt-energy-storage

[50] https://youtu.be/EfUZofkc0Mw
[51] https://en.wikipedia.org/wiki/Molten_salt_reactor

6.7.5 Saltwater batteries

"Per kilowatt-hour of storage, salt water batteries are the heaviest batteries on the market. They are more than twice as heavy as lead-acid batteries." [52] Still, this may be a viable option for energy storage, especially if we can find novel solutions that only a Seastead could take advantage of.

Advantages

- Nearly endless supply of seawater available
- With energy density of 17 to 90 Wh/kg, and assuming the floating island needs 2 million Wh storage, the weight would be 20 to 120 tonnes. If placed on a single platform it would only increase draft by 3 to 18 cm.

Disadvantages

- This system has a very large "footprint" the area required to supply the amount of energy required for a floating island would likely be much larger than other types of storage.
- This technology is still largely experimental

6.7.6 Flow Batteries

"A flow battery, or redox flow battery (after *reduction–oxidation*), is a type of electrochemical cell where chemical energy is provided by two chemical components dissolved in liquids contained within the system and separated by a membrane.[2][3] Ion exchange (accompanied by flow of electric current) occurs through the membrane while both liquids circulate in their own respective space. Cell voltage is chemically determined by the Nernst equation and ranges, in practical applications, from 1.0 to 2.2 volts.

A flow battery may be used like a fuel cell (where the spent fuel is extracted and new fuel is added to the system) or like a rechargeable battery (where an electric power source drives regeneration of the fuel). While it has technical advantages over conventional rechargeables, such as potentially separable liquid tanks and near unlimited longevity, current implementations are comparatively less powerful and require more sophisticated electronics." [66]

The energy capacity is a function of the electrolyte volume (amount of liquid electrolyte) and the power a function of the surface area of the electrodes.

"Redox flow batteries offer an economical, low vulnerability means to store electrical energy at grid scale. Redox flow batteries also offer greater flexibility to independently tailor power rating and energy rating for a given application than other electrochemical means for storing electrical energy. Redox flow batteries are suitable for energy storage applications with power ratings from 10's of kW to 10's of MW and storage durations of 2 to 10 hours." [67]

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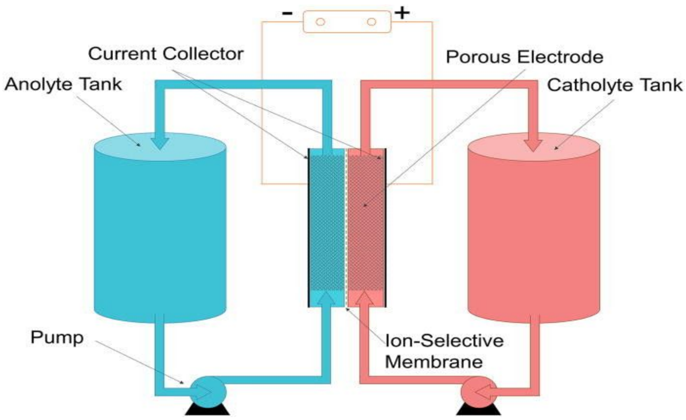
[52] https://www.solarquotes.com.au/blog/aquion-salt-water-battery/

[66] https://en.wikipedia.org/wiki/Flow_battery

[67] http://energystorage.org/energy-storage/technologies/redox-flow-batteries



6.8 Diesel Generators

Diesel generators are one of the most prominent sources of energy on island nations today. However diesel generators have some significant drawbacks. Burning diesel is dirty, creating localized air pollution in the form of NOx and fine particulate matter that can penetrate deep into the lungs and lead to asthma and other cardiovascular problems, as well as premature death[53]. Diesel is also a fossil fuel and burning it contributes to greenhouse gas emissions. However, powering such an engine with biodiesel would be less polluting, would not contribute to greenhouse gas emissions, and may be feasible.

A company from Finland makes one of a few available engines that can run on 100% biodiesel[54].

6.9 Microturbines

Microturbines are versatile technical solutions for the production of electrical and thermal power. This term is applied to a new group of small gas turbines being used to provide on-site power and becoming an attractive option to feed the load of small users, especially when cogeneration can be exploited.

Most microturbines with a power range from 20 kW to 250 kW are based on technologies that were originally developed for the use in auxiliary power systems, aircrafts or automotive turbochargers.

The major advantages of microturbine systems include:

1. Simple, compact systems – directly connected to high-speed turbo generators
2. Low emissions
3. Low investment costs
4. Reduced maintenance costs
5. Potential application for base load/ peak shaving and for delivering reliable electricity both for stand-alone and grid-connected systems
6. Potential operation on a variety of fuels (e.g. natural gas, biogas, diesel, gasoline, methane, liquid biofuels)[55]

[53] https://www.ucsusa.org/clean-vehicles/vehicles-air-pollution-and-human-health/diesel-engines#.Wi-KnVQ-do4

[54] http://www.maritimejournal.com/news101/power-and-propulsion/biodiesel-engine-launched

[55] http://www.bioturbine.org/

6.10 Other Generators

6.10.1 Cyclone Engine

Cyclone Engine – an all fuel, eco-friendly thermal engine with the power and versatility to run everything from power generators fueled by biomass, waste fuels, solar thermal or engine exhaust, to cars, trucks and locomotives.[56]

6.10.2 CO2 Turbine

CO2 squeezed and heated so much that it becomes a supercritical fluid, which behaves like a gas and a liquid at the same time[57]. This is another type of Organic Rankine Cycle System, it uses CO2 as the working fluid instead of ammonia, R-134a, or isobutane

Advantages

- Non toxic working fluid
- Low boiling point making it an option for low heat energy sources
- Non flammable

Disadvantages

- New technology not widely adopted

6.11 Electrical connection to Land Zone

Having an electrical connection to the Land Zone will greatly reduce the required solar panels and battery backup needed for Peak Demand Times and long periods without sunshine. Connection to shore also adds to safety. While we don't intend to use it as a crutch, it would allow us some extra backup capability, to sell power back to local communities when we have access, to put battery storage on land instead of on the water, and as a connection to other deep sea energy systems in the future.

7. Water Systems

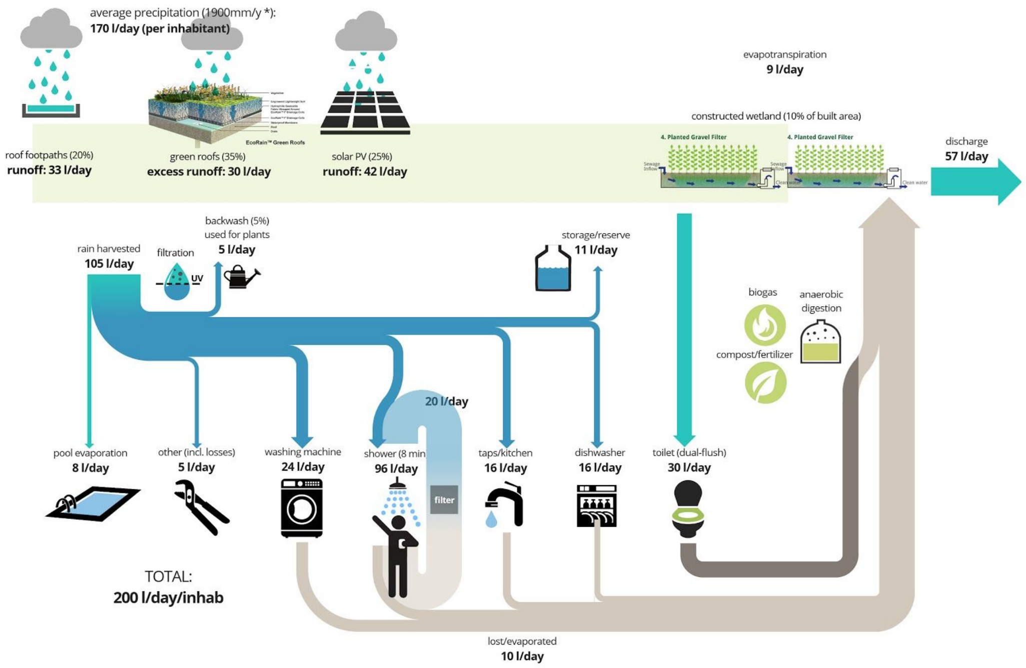
7.1 Water Demand

Water demand is estimated to average 200 liters per person per day (l/p/d).[58] Nonetheless, the following diagram represents a first approximation and we should eliminate any discharge of even treated wastewater into the ocean. This can be achieved as explained in the Food Systems Report.

[56] http://cyclonepower.com/how-it-works-2/

[57] http://www.ge.com/reports/call-ecomagination-ge-building-co2-powered-turbine-generates-10-megawatts-fits-table/

[58] https://drive.google.com/drive/u/2/folders/0B5asttOq9VibRkw1VjRjYU15S3c



7.2 Water Supply Systems

"New" water will come from a combination of rain water and desalination. Other sources of water include distillation, filtration and recycling of greywater.

7.2.1 Rainwater Harvesting[59]

A first flush diverter can be sized by surface area to clean surfaces for the first 5-10 minutes of rainfall. However those first 5-10 minutes will have high TDS (2000-5000+) and will need to be treated much like seawater. The level of treatment from the first few minutes of rain is significantly more work, it can alternatively be used for irrigation and toilet flushing.

Green roofs have been suggested as a way to add a number of ecological benefits to the FIP, including capturing rainwater. Green roofs are popular in cities to mitigate stormwater, where new legislation in some states now mandate zero rainwater/stormwater discharge from buildings over a certain size. However green roofs pose a challenge for the rain water harvesting and treatment side, as excess water must be treated differently than standard rainwater due to solids, turbidity, tannins, etc, that will get into the water once it lands on the green roof. Different types of vegetation can be treated differently.

Another suggested way to capture rainwater has been from solar panel runoff. However solar panels contain some amount of lead, and so lead contamination poses its own unique filtration challenges. A study done by the University of Washington found that 90% of solar panels have lead in them which showed up in rainwater harvesting. If we are to use solar panel surfaces for rainwater harvesting we'll need to source low-lead panels. Lead is the only heavy metal found in rainwater and the hardest one to treat in point of entry (POE) filtration. The same would apply if the water is used for greenhouse irrigation.

A floating scissored membrane could be deployed temporarily before a rain to collect additional rainfall without a detrimental appearance.

7.2.2 Atlantis Solar Atmospheric Water Generator
Atlantis Solar - Atlantis H2O Newest Technology in Pure Drinking Water Production Atlantis H2O Elite Atmospheric Water Generators producing 100L to 100,000L Per Day: [60]

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59 https://docs.google.com/spreadsheets/d/1rbAh8SZXUcgk0lNDOIcmLBxRLmE6TxQIaxqE9-DTSaE/edit#gid=2053619965

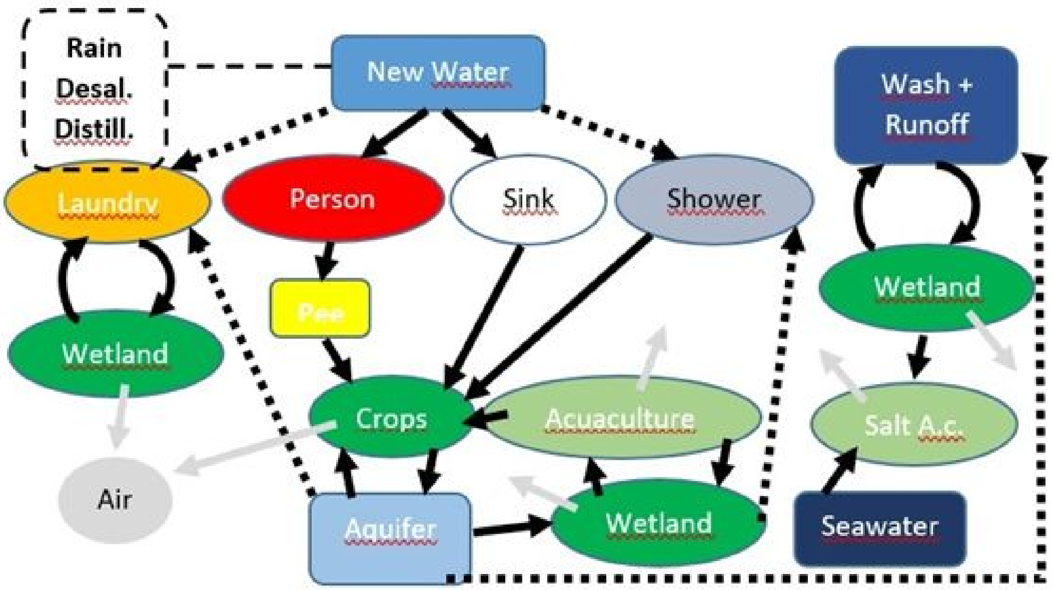
60 http://www.atlantissolar.com/atlantis_h2o_elite.html

7.3 Water Treatment Systems

One of our overarching goals is to not discharge any wastewater, treated or not, into the ocean, so it should all be purified as needed and put back to use productively. By maintaining different types of greywater separate, each may receive proper treatment and productive reuse. In many cases, this is very simple. For example, greywater from kitchens can go straight to our gardens, where the particles of food will fertilize the soil, especially if toxic chemicals are not used. Each liter of water that we recycle is a liter less that we need to take from nature and one liter less that is given back to nature with some degree of contamination.

In many cases, the same exact water can fulfill a function, receive proper treatment, and then go back to doing the same task, without needing to constantly use new water. For example, in laundries, it is feasible to install grease traps and artificial wetlands (as described in the section on Closed-loop Flush Water Recycling, in the Food Systems Report) to clean the water and then use it again various times or indefinitely, taking into account that it is not necessary to use potable water. Even the same non-biodegradable detergents could continue to do their same task time and time again. The rinse cycle could be done with ‘new water’, which may compensate for the water lost via the evapotranspiration of the plants, especially if rainwater is kept out by putting the artificial wetlands in greenhouses. This would have the added advantage that clean rainwater could be collected from the top of the roof and distilled water evapotranspired by the plants from the bottom of it.

Distillation can include having saltwater fish ponds inside greenhouses and collecting the condensation. Note that the only water that leaves the system is that of evapotranspiration and no arrows lead to the ocean, since the goal is to not contaminate the sea at all. The term, “Aquifer”, refers to an artificial structure in the basement of each platform, where water will accumulate after filtering through the soil of gardens. “Wash + Runoff” refers to water used to clean the Seasteads, together with stormwater. Crops receive nutrients from diverse sources and constructed wetlands (or algal culture) strategically clean the water sufficiently. Dotted arrows indicate alternate sources of water for those uses. (Urine-diverting Dry Toilets do not use water, and the Toilets with Closed-loop Flush Water Recycling will continually reuse the same water, so these are omitted from this graph. See the Food Systems Report.)



7.3.1 WOTA

This is a company aiming to realize better life and society through personal water circulation system . Until now, water depended on huge infrastructure centered on water supply and sewerage. WOTA shifts the water infrastructure to a compact one that individuals can carry. By doing so, we will change our lifestyle into something more convenient, environmental conscious, more free and enjoyable Personal water circulation system RAINBOX is a future water system that can continue to use water by attaching RAINBOX around various water. On the spot, we will purify over 95% of the waste water used to clean water and recycle it. By using our own sensing system and algorithm, we use the built-in filters properly, and we will predict the replacement timing. Shower, washstand, dishwashing, washing and so on are deployed sequentially around the water, aiming to make the water of the household off-grid.[61]

7.3.2 Biochar

Biochar has the potential to remove pharmaceuticals from the urine stream.[68]

7.3.3 Anaerobic Biodigesters

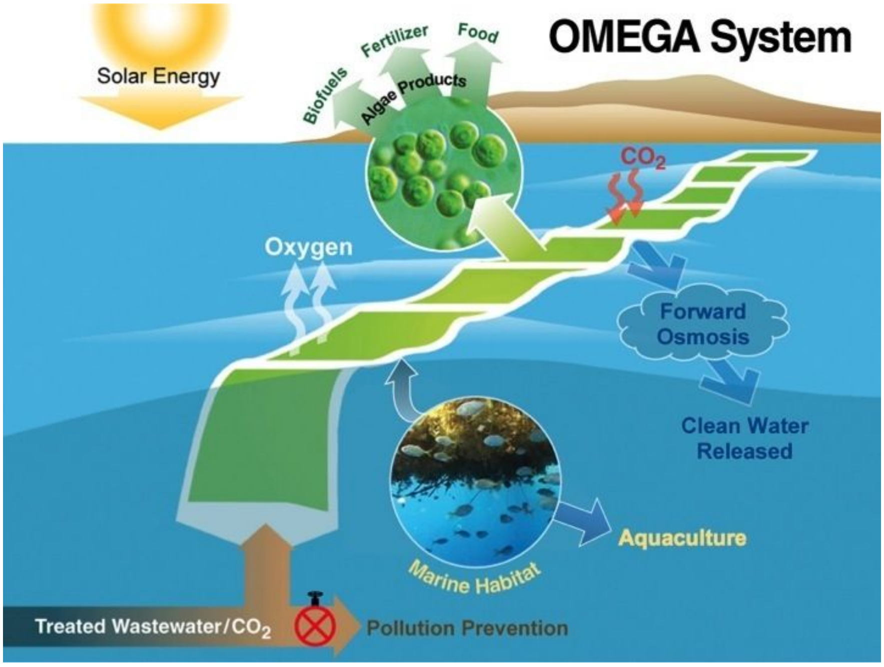
These are discussed in the Food Systems Report, as part of nutrient recycling, and also earlier in this document under Biogas/ Anaerobic Digestion.

7.3.4 Vapor Compression [62]

Further research is needed into the feasibility of this technology.

7.3.5 OMEGA

Offshore Membrane Enclosures for Growing Algae (OMEGA) is an innovative method to grow algae, clean wastewater, capture carbon dioxide and to ultimately produce biofuel without competing with agriculture for water, fertilizer or land. [32]



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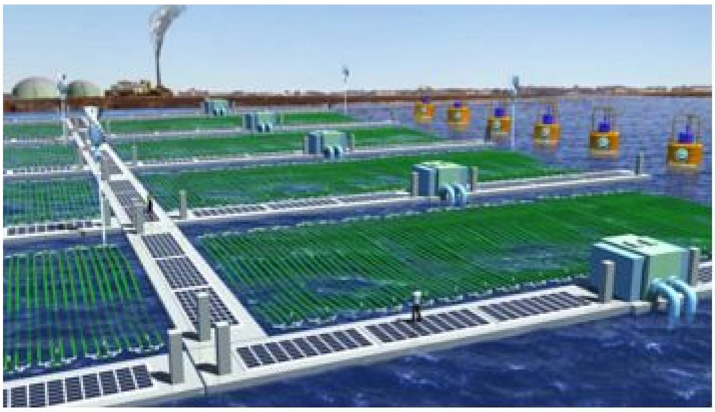
[61] http://wota.co.jp/product/

[68] https://www.chemistryworld.com/news/biochar-takes-the-pharmaceuticals-out-of-urine/2500487.article

[62] https://drive.google.com/drive/u/2/folders/0AEofDjjZBjx6Uk9PVA

[32] https://www.nasa.gov/centers/ames/research/OMEGA/index.html

[33] https://www.nasa.gov/centers/ames/pdf/637997main_omega_brochure.pdf



“By treating wastewater, sequestering CO2, and providing a marine habitat”, this technology has the potential to feed a few birds with one system. Additionally, it has the potential to produce algae biofuels, a carbon neutral source of fuel. The PDF brochure [33] , explains the technology well. This technology certainly fits in the ‘developing’ category, and is likely not feasible for the scope of the pilot project. NASA explains its limitations quite well by saying, “Large-scale algae farms (millions of acres) require huge pipelines for wastewater and CO2, the farm infrastructure, and a transportation network for the diverse products. On land, neither the required energy nor the economic returns on investment can be met. It is not known if OMEGA, using existing offshore wastewater outfalls, coastal CO2 sources, ships, and local energy sources (solar, wave, and wind), can meet the required returns, but the results of the OMEGA team show promise, a lot is at stake, and at this stage OMEGA warrants further investigations.” [33]

The OMEGA system, with cultivation of algae in floating plastic containers, has great potential for treating greywater that includes chemical contamination that we want to keep away from our food chain (e.g., industrial wastewater), together with motor exhaust (as a source of CO_2), to form biodiesel and/or other products. The treated water could return to the same uses and the remaining algal solids could be placed in a dedicated biodigester (possibly an Anaerobic Baffled Reactor with recycling water) for biogas production, and the small amount of resulting sludge could be composted for agricultural use, buried in the forest reserve, or land-filled, depending on the final degree of contamination. One disadvantage with respect to certain sites is that this may shade the underlying coral reef excessively, although in the middle of the ocean this should not be a problem. Another disadvantage would be the risk of the plastic containers breaking opening in the ocean (and, to reduce this risk, the containers could consist of rugged post-consumer beverage bottles). It may be more prudent to install vertical algal reactors on the sides of buildings on the platforms, especially if the volumes to be treated are not too great.

The OMEGA uses secondary treated wastewater, further improving the effluent quality before discharge. After secondary treatment some nutrients are left and could be recovered by algae. The system consists of plastic bladders filled up with water and air. CO2 is pumped into the system to enhance algae growth. Clean water is released into the marine environment by diffusion through patches of forward osmosis (FO) membranes. Bacteria, virus and pollutants do not pass the membranes. The surrounding saltwater prevents freshwater algae species growing inside the system from becoming invasive species in the marine environment if bags break.[63]

This can be done with open-source technology, managed by seasteaders themselves, without dependence on patented intellectual property. Further concepts on sanitation and water recycling are discussed here (see citation)[64].

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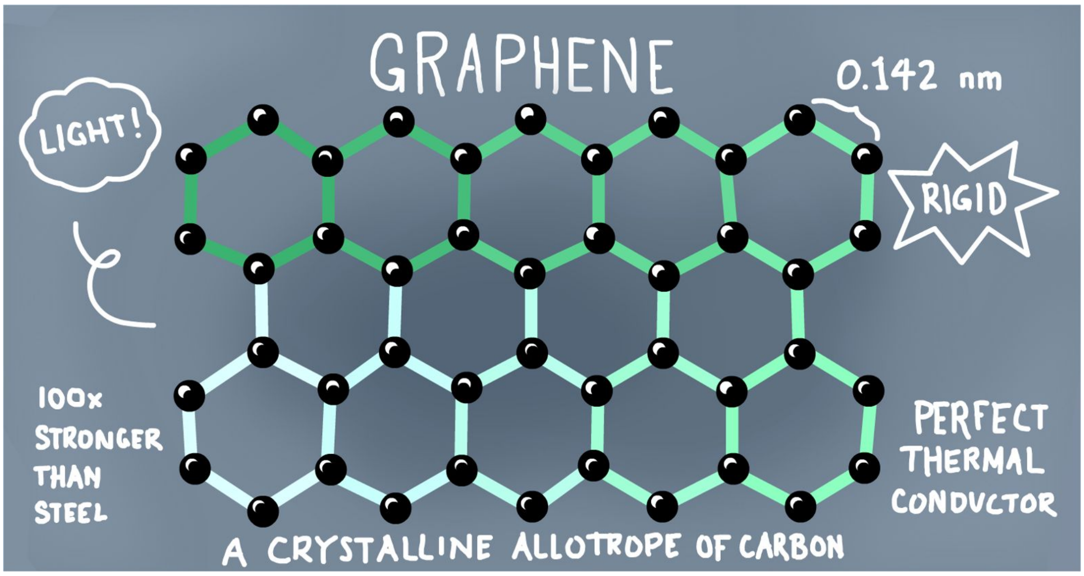
[63] https://www.researchgate.net/publication/235987654_Microalgae_Cultivation_Using_Offshore_Membrane_Enclosures_for_Growing_Algae_OMEGA; https://ia601209.us.archive.org/26/items/NASA_NTRS_Archive_20100039342/NASA_NTRS_Archive_20100039342.pdf)

[64] https://issuu.com/chriscana/docs/suggestions_for_sustainable_sanitat

7.3.6 Graphene Filters



Graphene Filters are an emerging technology that filter out salt from seawater. They use a Graphene membrane which is able to filter water at the molecular level. The advantage is we would no longer have to worry about discharging a heavy brine into the lagoon as we would with a traditional reverse osmosis plant. Other advantage of a Graphene filter would be a significantly smaller footprint than rain water collection, or solar stills, and less energy usage than distillation and possibly even less energy usage than reverse osmosis. The technology is in the prototype phase right now but is being developed concurrently by:

- Shinshu University and Pennsylvania State University
- Monash University and the University of Kentucky
- University of Manchester
- A Startup Company called G2O
- Lockheed Martin

7.4 Potable Water Storage

The Design Team Blue 21 has allocated a maximum rain water storage volume of 700 mm/m^2 times 7,500 m^2 platform area or 5,250 m^3 which works out to 437.5 m^3 per platform assuming twelve platforms.[65] This is a height of .7 m of the 625 platform footprint.

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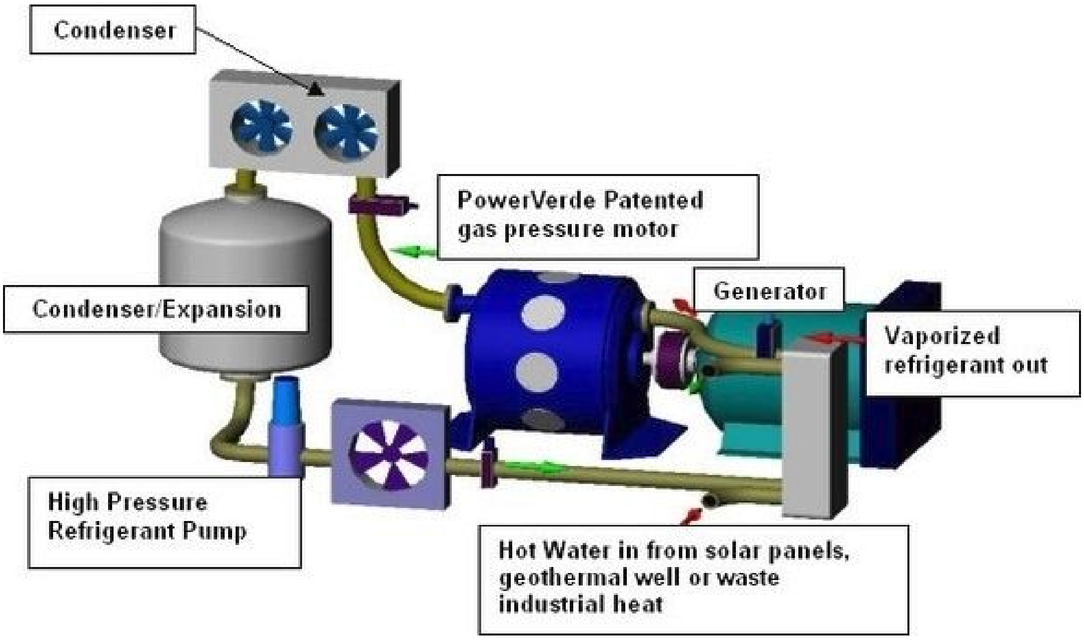
65 https://docs.google.com/spreadsheets/d/1rbAh8SZXUcgk0lNDOIcmLBxRLmE6TxQIaxqE9-DTSaE/edit#gid=2053619965

8. Energy and Water Saving Opportunities

8.1 Energy Savings

8.1.1 Waste Heat Recovery



Waste Heat recovery captures heat from an existing industrial process, examples include:

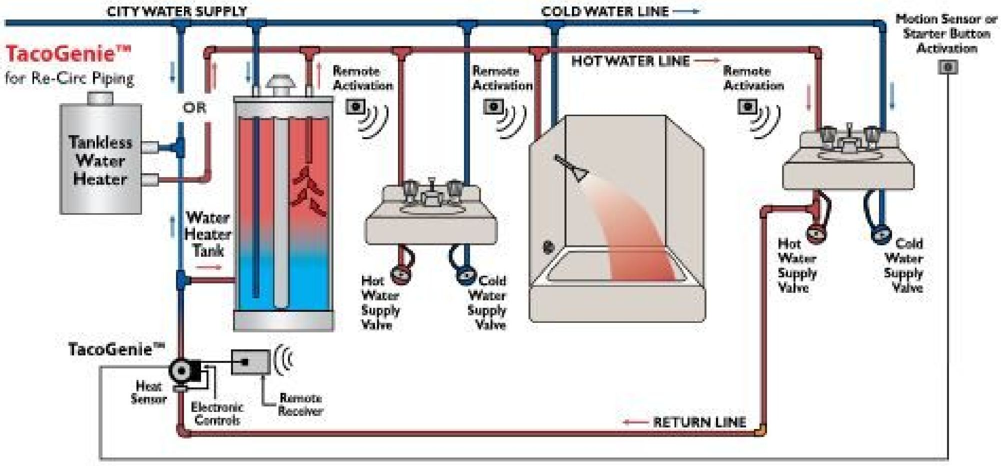
- Heat from computer servers
- Heat from engines
- Heat from blast furnaces
- Heat from concrete plants

Many companies offer custom or turn key solutions that utilize this heat via an Organic Rankine Cycle System and turn it into electricity. One option would be to partner with a company that has a lot of waste heat and sell carbon free electricity back to the grid or as credits in exchange for our own electrical consumption.

Examples of Organic rankine Cycle Waste Heat Recovery Companies

8.1.2 Hot Water Recirculating

This is a system whereby hot water can be present on demand right at the faucet or appliance so as to cut down on the cost of hot water storage and the water wasted while waiting on hot water to make it to the faucet or appliance. Through careful design and programming, the system should be able to be efficient and cost effective. Solar-heated water could also be injected instead of cold water at the input to the heater.



8.1.3 Dehumidifying Plants

Dehumidification is one of the highest power draws just below air-conditioning. Utilizing dehumidifying plants within the buildings will help cut down the energy costs of dehumidifying as well as purifying construction contaminants from the air. Research is in progress on using dehumidifying plants on a window shutter for processing breeze air.

8.2 Water Savings

The use of single handle faucets should help to eliminate hunting for the right temperature when combined with a recirculating hot water system, thereby saving on water usage.

The use of single handle faucets in the shower would help with the shower technique of getting the body wet, soaping with the water turned off, and then rinsing.

Further research is needed into the different technologies available for water saving.

9. Waste

9.1 Solid Waste Handling Systems

9.1.1 Blackwater

Water that carries human feces is called blackwater. Due to space and weight limits on the FIP, systems that treat human (and perhaps animal) feces without adding a lot of extra water, such as composting or dry toilets, have significant advantages.

If Urine-diverting Dry Toilets and Waterless Urinals (UDDT)[66] are implemented, these will not produce any blackwater. It is also feasible to install Flush Toilets with Closed-loop Flush Water Recycling, such that the same water is cleaned up and put back into the same toilets, so there will still not be any blackwater going toward the ocean. It is not necessary to use potable water in a toilet and no conventional treatment can remove all of the pharmaceutical chemicals that people consume. These options are explained in the Food Systems State of the Art Report, since the nutrients (especially those found in the urine) can be recycled back into the soil to produce more crops.

9.1.2 Food & Plant Waste

This is treated in much more depth in the Food Systems Report. See also the section on Biogas/ Anaerobic Digestion. Almost all organic waste can be treated with this type of system.

9.1.3 Metal

Further research is needed into types of small scale metal recycling technologies. However this is not a high priority, as there is likely to be little waste metal on the FIP.

9.1.4 Paper

Anecdotally, there are many ways to recycle paper, and at least some of them can be used on a small scale. It may also be possible to add paper waste to the anaerobic digester. Further research is needed to specific options for small scale paper recycling.

9.1.5 Plastic

If plastic is properly sorted into different types, and care is taken only to use limited types of plastic on the FIP, plastic recycling on a small scale is relatively easy. A website called Precious Plastics (https://preciousplastic.com/en/) instructs people on how to make small, DIY plastic recycling devices.

9.1.6 Glass

Further research is needed into types of small scale glass recycling technologies.

9.1.7 Mixed-waste processing

The primary method by which mixed waste can be recycled is through a chemical treatment process known as pyrolysis or gasification. It consists of a high-temperature continuous feed process and transforms mixed municipal waste that comes unsorted to the landfills into 90-98% of combustible syngas and 2-10% of solid carbon char which has further use.[67]

Syngas - the byproduct of pyrolysis - is a source of energy, but it only contains 67-131 BTUs per cubic foot,[68] and is made of 30-60% carbon monoxide, 5-15% carbon dioxide, 25-30% hydrogen, and only 0-5% methane.[69] This is in contrast to other gaseous fuels like biogas, which contains 600-700 BTUs per cubic foot (methane has roughly 1,000 BTUs per cubic foot).

[66] inodoroseco.blogspot.com, www.ecosanres.org
[67] http://www.glescorp.com/en/energy_dep/technology_1.html
[68] http://www.cleangreenengines.com/banners-view/renewableenerg/
[69] https://www.netl.doe.gov/research/coal/energy-systems/gasification/gasifipedia/syngas-composition

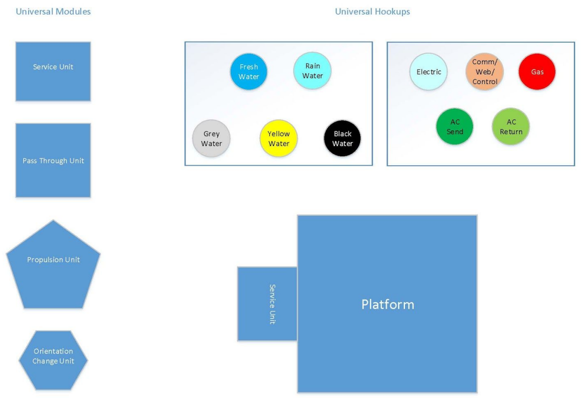
9.2 Methods for Reducing Waste

Putting the right systems in place to ensure that all "waste" is recyclable will be key to making a truly zero waste system. An example of such systems is having a **bulk-only grocery store** on the FIP where food items have no individual wrappings. In this scenario, people would bring their own glass jars or canvas bags to the grocery store and fill those up with food. Compostable packaging is also becoming more widely available, and may be a cost effective solution by the time the FIP is up and running.

10. Platform Interconnections

10.1 Universal Hookup

Some discussion was made on having a universal hookup system, something similar to a docking area on a spacecraft, where the platforms could be easily connected either to a central utilities platform or to individual utilities modules that would contain either/or all of energy, water, or waste treatment systems. Another module could even contain a propulsion system with controls, for platform movement. There would be assorted standardized sizes per capacities of the systems on the platforms. The goal was to be able to take some of the engineering off of the platforms to the modules for easier prototyping and repair.



10.2 Dry Dock

The recommended docking method is an excavated (basin) dock with a floating gate. This appears to be one of the more economical methods with the added bonuses of a less obtrusive appearance, boat ramp when not in use, could also be used as a ferry station in between uses. My biggest concern against using a balloon system is the possibility of unequal stressing causing a breakup of the platform (I don't know for sure that this is a valid concern or not).

http://www.hegerdrydock.com/dockmaster_training_manual.pdf

11. Land Zone

The Land Zone has not been address separately in this report, as it is believed that the above technologies will apply in mostly the same ways to both the Sea Zone and the Land Zone. Also, the challenge of designing energy, waste and water systems that will be entirely self contained on a floating island is much more daunting - as it has never been done before - than designing such systems for land use.

12. Conclusions & Recommendations

Over the course of the last several months, the Energy & Water group has researched and assessed dozens of technologies for producing and storing both energy and water, as well as some technologies that will help the FIP deal with waste (especially wastewater). Throughout this process, one key realization we have come to is that the energy, water, food and waste systems we employ on the FIP will all be interconnected, and thus it's very difficult and probably unadvisable to consider each category in a vacuum; the best approach for choosing technologies to meet these needs is with a full systems approach that considers how different technologies will complement, oppose, and interact with each other.

While the group has not yet come to a consensus choice on which technologies will ultimately fill our needs for the FIP, we have settled on some general conclusions, which are as follows:

1. Solar PV combined with storage is the most suitable option to meet the majority of the FIP's electricity needs. However, we have not been able to find any real life examples of a large scale floating solar farm on *seawater*, and are still unsure of the long-term durability of such a solar farm, due to the dangers of salt water corrosion.
2. Wind energy may be able to complement solar's variability by producing more energy when the sun isn't shining.
3. A generator powered by some sort of clean, renewable fuel will likely be needed to supply "peak load" power during times of unexpectedly high demand or low solar and wind production. The best candidate fuels are biodiesel and biogas. Regular diesel should be a last resort, as this is neither renewable nor sustainable.
4. The group agrees that supplying all fresh water from rainwater and avoiding desalinization would be preferable, however it is yet unclear whether this will be possible. Further study needs to be done on how much rain and recycled water can be retained and stored on the FIP, as well as how much water demand can be reduced through various efficiency measures.
5. There are many commercially available technologies for water recycling, and it is technically possible with existing technologies to recycle used water back to potable levels. It is still unclear whether or not this is more expensive than desalination
6. Treating different waste systems separately will allow the highest level of recycling and efficiency. This includes treating "blackwater" (i.e., including human feces), urine, and "graywater" (i.e. non-human wastewater) separately.
7. There are many advantages and disadvantages to employing centralized versus decentralized systems for energy, water and waste on the FIP. The group is undecided as to which will work better. A hybrid approach is also possible.
8. In general, the first FIP will need to use commercially available and "proven" (i.e., there are existing installations that have been operating *at scale* for at least a year) technologies. More experimental technologies that have not yet been proven will be considered for future floating islands. The group is in the process of developing a matrix to evaluate technologies on this basis.
9. Ultimately, some systems for treating and recycling waste will be new to the majority of residents, and may require some users to overcome psychological aversion to using them. This may also require users to have some knowledge of how the systems work and their importance, so that they can be active participants in correct use of the systems. This may present the most challenging aspect of designing a 100% closed-loop, "sustainable" seastead.

The Energy and Water group plans to get together with the Food Systems group in January to come up with a rough consensus on which of the available technologies we think will work best together, and to work out solutions for most, if not all of the dilemmas presented above.