Convert Cruise Ships Into Sustainable Seasteads

New Life for the Cruise Ship Industry to Create New Life on the Sea

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Summary: The Problem

The cruise ship industry has successfully painted itself green by first using scrubbers and then moving from heavy diesel fuel to Liquified Natural Gas (LNG). In this paper we will show that **these measures not only did not change the immense carbon footprint of the industry, it even exacerbated this real issue and other problems.**

Radical rethinking of the entire concept of the cruise ship industry is required to bring emissions to a sustainable level. Even the latest, most modern ships easily emit 2-3 times as much greenhouse gas per passenger as a typical western resident, even while at port or on anchor and fully booked. Propulsion accounts for about 40% to 70% of energy consumption and thus CO2 emissions when cruising. When cruising, CO2 emissions of an average European cruise ship passenger **emissions per capita are about six times higher** than at home for ship operation alone, not counting consumption and transportation to the vessel, e.g. by flying.

The extreme CO2 emissions even for an anchored vessel seems discouraging. A closer look shows that cruise operators accept many inefficiencies, mainly to cram more people into a given space, however. Lowering the density of people to about 60% and changing some expectations of residents will give engineers the freedom to reduce energy consumption by about 90% which then permits the use of photovoltaics to replace all diesel generators. Given that a lot of environmental damage has been done already by building the ships, finding an environmentally sound way of giving them a new life is paramount. Cruise ships can and should be built back better.

Ocean Builders' Plan of Action:

Cruise ships that are currently on the market will be **converted to zero emission seasteads**, by implementing the following steps:

1. Move to a location that makes a zero emission regime feasible. Mainly this means between +- 8 degrees latitude
2. Implement Thomas Gorreau's method of coral regrowth to encourage formation of corals on the walls of the ship. This will make toxic rust protection superfluous.
3. Remove all equipment for driving the vessel and make use of the gained space
4. Replace the wasteful part of the A/C system and replace is with efficient zero recirculation systems

5. Put solar panels on surfaces and provide sun protection on open deck areas using solar panel roofs
6. Reduce occupant density to about 60% of that of the cruise ship[1]
7. Remove typical North European interiors that require low humidity to prevent mold

With the case study of the *MS Satoshi,* we show a way towards carbon neutral conversion of ex-cruise ships into habitats at sea. We show that such habitats can be far more sustainable than any possible land habitat.

The Carbon Footprint of a Cruise Ship Passenger

We will focus on the greenhouse emission by the ship itself and ignore other pollutants such as oil, sulphur and CH. We also ignore other sources of greenhouse gases that are created as a side effect of operating a cruise ship, such as from the consumption of soda and beer cans, the flights to the cruise and back. These topics have been sufficiently covered elsewhere.

A common misconception is that the energy consumption of a cruise ship is overwhelmingly caused by the propulsion system. In normal operation, propulsion accounts for roughly 60% of the energy consumption of the ship and hence the CO2 emissions per passenger, however.

[1]Reducing occupant density makes it easier to change the cabin AC to 0% recirculation. Recirculation is strongly suspected to spread germs from cabin to cabin.

The 40% is used by the sum of a myriad of systems, but air conditioning and ventilation stand out.

Most cruise ships are made to meet the expectations of the Western customers, which means that the more different the climate is from the climate the Westerner is used to, the more energy is used to create that climate within the ship. Consequently, the energy consumption of the A/C in the ship can reach up to 2.5KW per passenger in a tropical climate, which means that each passenger produces about 60KG of CO2 per day, just to provide the simulacron of a dry, Northern climate. Nonetheless, the cruise ship industry awards itself “Environmental excellence prizes”, based solely on cosmetic improvements.

Using solar panels is pointless, because the energy consumption is so high that even covering the whole ship with solar panels would hardly ever yield 8% of the ship’s consumption.

The fuel consumption of the ship’s operation is the main part of the balance, but there are other factors that add to it, namely the construction and the maintenance of the ship. Ships require regular dry docking, during which the air conditioning is kept running. New paint is applied to the hull in large quantities, while old paint is removed and usually treated as toxic waste. The infrastructure of dry docking itself is a large source of CO2. Also, things like carpets and astroturf are regularly changed to match the latest fashion. All this must be added on the CO2 balance of a passenger.

Liquified Natural Gas (LNG) Is Worse Than Diesel

Converting a diesel engine into an LNG engine improves the CO2 footprint because LNG has more hydrogen and less carbon than heavier hydrocarbons. The drawback is that such engines emit substantial amounts of methane[2] which is an even worse greenhouse gas than CO2. The only technology that could avoid that is direct injection, as in modern automobiles.

Gas turbines burning LNG avoid the emission of methane, but they are much less efficient. This means the CO2 emissions are higher than a converted diesel engine or a traditional diesel engine and so are the CO2 emissions.

[2] Methane: The other important greenhouse gas, Environmental Defense Fund, Accessed: December 16, 2020

In addition, an LNG powered ship is an invitation for terrorists. So far, nothing has has happened, but it is clear that even a crude terrorist can unleash a disaster that kills everyone on board, while a sophisticated terrorist may turn such a ship into an aerosol bomb that can potentially achieve the power of a nuclear device similar to the ones deployed over Hiroshima and Nagasaki.

Scrubbers make the ship look cleaner, because it washes the soot and the sulphur emissions out and puts it into the sea directly, thereby avoiding the detour of emitting it through the funnel and have the rain wash it into the sea. But of course scrubbers must be operated using electrical energy from the ship's generators, thereby adding to the CO2 emissions. Scrubbers are worse than useless.

None of this is sustainable.

Energy Use And Emissions On A Cruise Ship

Even now, without serving customers, the CO2 emissions of the industry are about 32,000 metric tons per day. Since the beginning of the Covid-19 crisis, all cruise ships emitted about **6 million tons of CO2**. In addition, new, LNG driven ships emit more than 2 tons of methane each day, adding up to several thousand tons since the beginning of the Covid-19 crisis. We can expect the methane emissions to increase dramatically if the cruise industry is allowed to continue the conversion to LNG as planned.[3]

A cruise ship is designed to accommodate as many passengers on a given space as possible while at the same time providing as much luxury and entertainment as possible. Also, it has to be able to operate in all climate zones, from the arctic sea to tropical regions. This means the ship is not optimized for energy efficiency, but for flexibility and revenue per square meter. As little space as possible is provided for the machinery, because space occupied by machines is not generating revenue.

This optimization makes ventilation and air conditioning the biggest consumer of energy, potentially even bigger than propulsion as is the case during Covid.

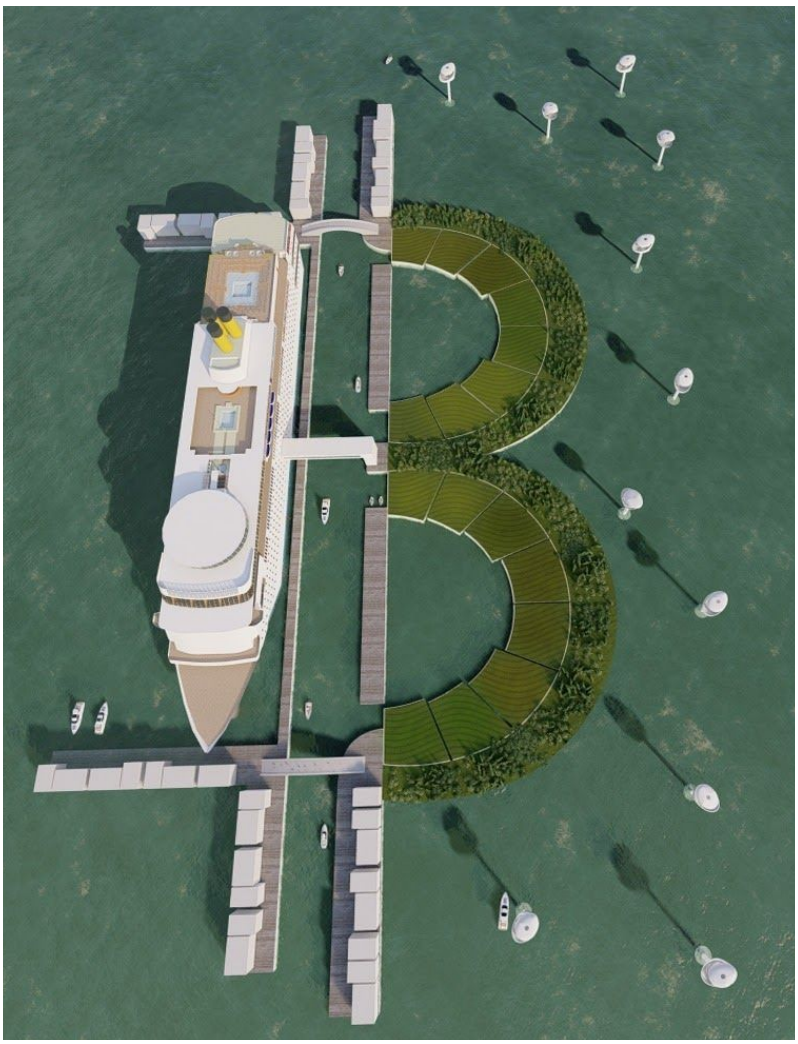
A cruise ship is generally designed to meet expectations of the target audience. For example the US, Northern European and Australian customers like thick carpets and thick blankets. In a hot and/or humid climate where a lot of cruising takes place, this requires extensive air conditioning for comfort and to avoid mold. In essence, the climate of Northern Europe must be simulated. This can be avoided by using wood floors or ceramics, and beds that are adapted to a tropical climate.

The future of cruise ships should be in a change of the design of such ships as well as the expectation of passengers. Ships should be much smaller, far more efficient vessels, powered

[3] See emissions for the Wärtsilä 46DF dual fuel engine. Copyright © 2019 Wärtsilä Corporation. Accessed December 18, 2020.

by solar panels, sails or solar active sails. Instead of a traditional hull, they should be highly efficient catamarans or SWATH with plenty of deck space and zero emissions. Passengers should be involved in the operations, as they are on many yachts. Indeed, the future of cruising should be very similar to yacht charter. The mega vessel cruise ship with thousands of passengers has turned out to be an error.

The Solution



Conversion to Seasteads

Once a cruise ship becomes a seastead, propulsion is no longer required. That alone lowers the CO2 footprint. Also, given that the conditions of the seastead are known, ventilation and air conditioning can be optimized to these conditions. Air conditioning can be privatized and metered, which can lower the energy consumption by 90% for the cabins because residents have an incentive to conserve energy if they must pay for it.

On a seastead, the density of residents would be lower than the density of guests on a cruise ship. This sounds counter productive at first, but it allows for further optimizations, such as reduced air flow in the ventilation system. Also, reduced density and private A/C helps greatly to prevent the spread of commutable diseases, such as Covid-19..

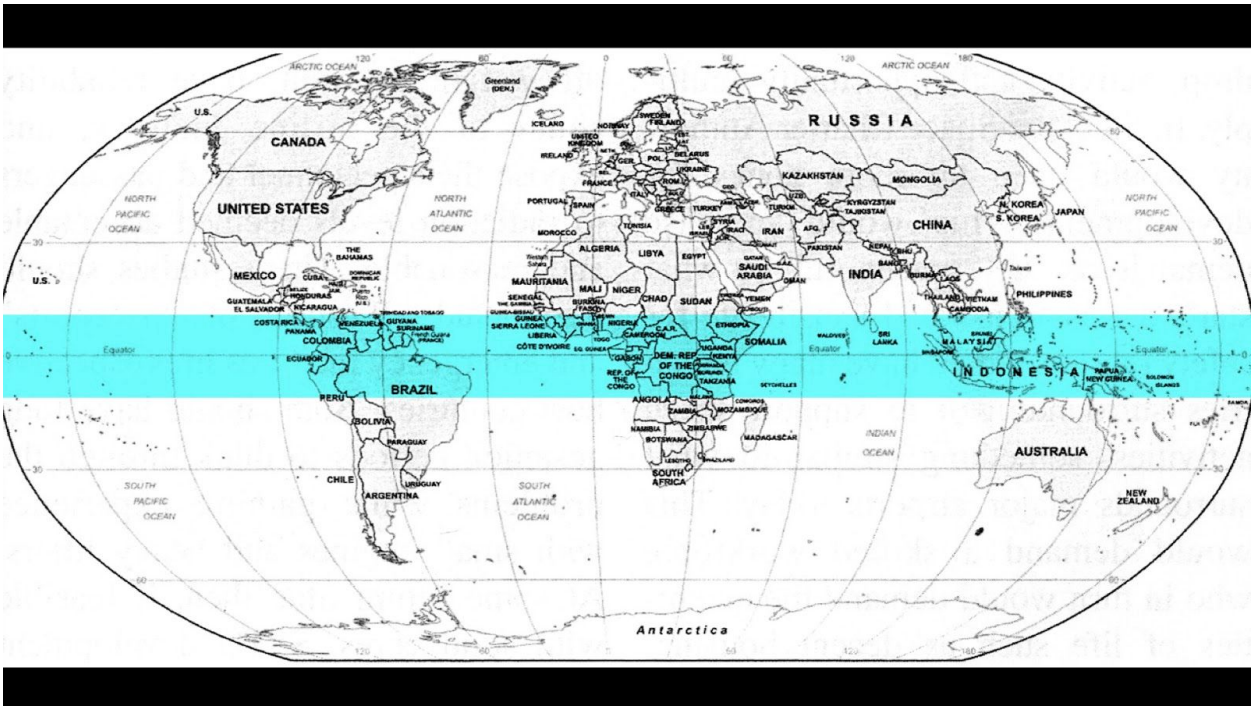
The need for other things goes away, too, such as the technical necessity for drydocking. It is possible to use impressed currents[4] much more effectively if the ship is stationary. Also, growth on the hull should be welcomed, not fought against. Such growth would greatly increase the resistance of a ship, but that is irrelevant for a seastead. So growth is not only beautiful, turning the ship into a wildlife refuge, it also protects against corrosion.

Land vs. Sea Habitats

The natural state of most land occupied by humans is a cover of green plants. The natural state state of most open sea is that of a desert. Building a house or a road turns productive land into desert. Any floating object at sea turns the desert into a marine garden. This strange effect gives such objects the unpoetic name “Fish Aggregation Device”. This effect can be enhanced by using Thomas Gorreau’s method of induced coral growth which also protects steel structures against corrosion. **In short, living on land is fundamentally wasteful while living at sea is beneficial.**

There is a belt of +- 8 degrees, or a thousand nautical miles, around the world that is free of cyclones and warm. At sea, there are none of the tropical insect borne diseases such as Malaria or Dengue. The sea has all the blessings of the tropics without the curses. This belt is about the same size as the total occupied fertile land. It is within our means to move a good part of humanity to this new frontier within a few decades, creating new opportunity societies and relieving the land of the heavy burden of which our presence there imposes upon it.

[4] Electrical Stimulation Greatly Increases Settlement, Growth, Survival, and Stress Resistance of Marine Organisms, Thomas J. Goreau, Global Coral Reef Alliance, Cambridge, USA, Copyright © 2014 by author and Scientific Research Publishing Inc. Accessed: December 18, 2020



A Case Study: *MS Satoshi*

When Ocean B Builders took over the *Pacific Dawn* from P&O, it was renamed to *Satoshi*. At the time of takeover, energy consumption was at 6.1MW and diesel fuel consumption was consequently at around 30 tons per day using heavy diesel. Fully operational with passengers, the consumption will go up to 8MW or more without propulsion. Propulsion at 15kn uses about 14MW, at “cruising speed” of 20 kn it uses 24 MW, putting the ship’s consumption at 160 tons/day, or **78 tons of carbon emissions per year per passenger.** For comparison: The average total emissions of a EU resident is about 8 tons per year[5], all inclusive, which includes energy intensive items such as heating and industry. Eight tons per capita is still far too high, however.

[5] • EU-28: GHG emissions per capita 2000-2018, Statista, Accessed: December 16, 2020

All indoor facilities, including cabins are closed and insulated as is common in the north. Almost all is carpet, about 50,000 square meter. This requires forced ventilation throughout the entire ship. Cabins below deck 7 have only small windows that cannot be opened at all. These windows are designed to withstand water pressure of extreme waves. Such waves do not exist in equatorial seas. The whole ship should be converted into a more open space with natural air flow. Air conditioning should be available, but mainly for the hot hours of the day when solar power is available in abundance.

Concrete steps include the removal of the main diesel generators and switching to the much smaller port generators. This requires some downscaling of the A/C because parts are running on 6600V which only the big diesel generators can provide. After downscaling, the efficiency needs to be improved massively by using heat exchangers.

With all these changes in place, the power requirement is low enough so adding solar panels make sense. In fact, for most of the day we will be able to run on the much smaller, 800 KW generator which is also available.

The last step to carbon neutrality will be achieved by adding solar roofs to the floating docks that will be installed around the *Satoshi*. At this point, the diesel generators will only serve as a last resort.

The antifouling paint will be removed and Biorock[6] will be grown on the walls of the *Satoshi*. This encourages the growth of corals so after a few years, the *Satoshi* will be a floating reef.[7]

The Way Forward

An important issue to consider is the miniscule size of the cruise ship industry. The total contribution to global GDP is about $40 Billion. Furthermore, a lot of this comes from gambling and a massive amount of alcohol. It is a well known fact in the industry that ticket prices barely cover the costs, if at all. From this, ethical questions arise about what is achieved by this industry and what the burden is.

Class 1 passenger ships benefit greatly from unfair advantages to other industries. **They should no longer be allowed to benefit from tax free fuel**. In addition, emission regulations should be introduced for diesel engines which compare to Euro-6, which is generally accepted for cars and trucks. LNG driven vessels should not be exempt from adhering to Euro-6, otherwise they will become a major driver of global warming. Furthermore, they should be required to insure the worst case scenario of an aerosol explosion of the LNG within harbor or dry dock.

This article focuses on greenhouse emissions, however. Consequently we suggest the reduction of per capita CO2 emission of cruise ships to a value comparable to a Western person

[6] The Biorock Process, Picturing reef building with electricity, by Ari Spenoff, Global Coral Reef Alliance and Sun & Sea e.V., April 2010
[7] Rigs to Reefs, Bureau of Safety and Environmental Enforcement, Accessed: December 16, 2020

at home. As CO2 certificates become mainstream, cruises should be required to purchase them.