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### **THE OCEAN EMPIRE LIFE SUPPORT SUPERYACHT**

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### **THE WAVE OF THE FUTURE**

The Ocean Empire LSV (life support vessel) points to the innovative use of existing technology that will transform Super & Megayacht vessels into self sufficient ocean going platforms. We look at how combining advanced aero and hydrodynamic principles with Emax Solar Hybrid technology enables Superyachts to achieve a 50% to 100% reduction in GHG emissions by harnessing the collective maritime resources derived from the sun, wind, waves, currents and life in the sea.



Figure 1: The Ocean Empire LSV

### **1. ENERGY, EFFICIENCY, ECONOMY & ECOLOGY**

An Emax Life Support Superyacht maximizes the potential energy, efficiency, economy and ecological benefits related to the design and construction of luxury vessels, to arrive at ultra green alternatives to the increasing number of larger than ever Superyachts that are destined to produce needlessly high levels of GHG emissions over their entire service life.

## 1.1 ZERO EMISSIONS ZERO COST

The needless proliferation of global warming pollutants is exacerbated by the fact that, even without trying to predict just how far and how fast fuel prices will rise, we know enough to postulate that the cost savings in fuel, over the service life of Emax Superyachts will more than pay for the solar hybrid innovations that can reduce their fuel consumption and GHG emissions by on average 75%.

To be sure, the initial investment in building Emax Solar Hybrid Superyachts will be 3 to 15 % higher, depending on their size. 3% higher for a 150 meter Gigayachts, reaching 15% higher, for vessels around 40 meters in length. None the less, we can expect the level of return on this initial expense to steadily increase as fuel prices rise and in relation to the type of use and the number of voyages the vessel makes over what could easily be 50 years of service.

## 2. A COST EFFECTIVE GUIDE TO LIVING FREE

The principle objective of this paper is to identify the cost effective, currently available OEM technologies that will elevate high profile Superyachts to exemplar Carbon Offset Vessels that will establish a foundation on which the movement towards responsible yachting can build.

In reaching this goal, theoretical arguments that might favour one type of design over another are avoided by identifying the empirical evidence that establishes the practical superiority of one design feature over another.

With that in mind the Ocean Empire LSV utilizes existing maritime, aerospace, automobile and industrial technologies that can provide present day hi-performance Superyachts with every accustomed luxury within their full range of operation, which extends from a 50%, reduction in consumption and GHG emissions to Carbon Neutral and unlimited Zero Carbon cruising.

### 2.1 EXISTING TECHNOLOGY PRESENT IN THE OCEAN EMPIRE LSV;

- Turbo Compound DD16 Electric Power Generation by Daimler/Interpower
- Automated Traction Kite by SkySail
- Photo-Voltaic exoskeleton by SunPower
- OEM Electronic Controller (KER) (Kinetic energy regeneration)
- Motion Damping Regeneration (MDR) Maurer Sohnes /Advanced Motion Technologies
- Electric Propulsion Surface Drives by Voith
- Carbon/Kevlar Composite Wave Piercing Hi-efficiency displacement hulls by NedShip/SCOD
- Aerodynamic Radar Canopy with PV Wing Spoilers by SunPower/SCOD
- OEM Energy Efficient Equipment and Lighting
- OEM AC & Refrigeration with Waste Heat Recovery
- OEM Computerized Energy Management, Maintenance & Guidance
- OEM Plug-in Lithium ion Battery Storage UPS rated at 2,000KWh

## 3. THE EMAX SUPERYACHT AS A CARBON OFFSET PROJECT

The opportunity is there for ship builders to address the provisions of the Kyoto Protocol by creating what amounts to a Carbon Offset Project based on cutting edge Solar Hybrid Superyachts able to offset from 1 to 8,000 tons of GHG emissions every year. This is more than many Certified Carbon Offset Projects in developing countries can achieve.

With the Monaco Boat Show going Carbon Neutral, we see carbon credits moving to the centre stage of the Superyacht world. Even so, existing offset schemes for Superyachts, though having merit, do not address the enormous carbon footprint that is left in their wake.

Purchasing carbon offset credits does not reduce GHG emissions in Superyachts, let alone in Mega or Gigayachts. In reality, because of their increasing numbers, this practice is causing GHG emissions to rise in this sector. What's needed whether certified or not, are high profile Superyachts that match or even surpass their counterparts, while meeting the IMO's achievable target of a 75% reduction in GHG emissions.

The Ocean Empire Life Support Superyacht goes a step beyond, by providing an unlimited zero cruising range at 14 knots and by harnessing enough energy to allow for up to 5,000nm of Carbon Neutral Cruises at speeds of up to 22 knots.

### 3.1 SUPERYACHTS AS POWER STATIONS

As a Power Generating Carbon Offset Vessel, the Ocean Empire LSV stands in readiness to return to the grid, the renewable energy she generates at moorings. Plugged-in, up to 450 MWhs of energy harnessed from her PV exoskeleton, turbine props and motion damping regeneration may be stored in her 2MWhs UPS, or returned to the grid via V2G (vessel to grid) systems already in use and planned for mass produced plug-in vehicles in the next few years.

## 4. CAPITALIZING ON THE SUN, WIND, WAVES, CURRENTS AND LIFE AT SEA



Figure 2: The Ocean Empire LSV

Today we find that the very same marine environment that challenges the design elements of ocean going vessels is also capable of generously rewarding voyagers with an unlimited supply of clean energy.

The existing technology that makes this possible is there for the taking. The apparent inertia associated with maritime advances in Eco Conscious Superyachts is not due to buyers having a lack of interest, but to buyers having a lack of choice.

### 4.1 SUN POWER

Energy from the Sun not only lights and heats our planet, it sustains life and powers the winds which along with The moon are constantly reshaping the 7 seas. The Ocean Empire LSV employs readily available systems that capture the rays of the sun to power her PV (Photo Voltaic) exoskeleton and illuminates her two hydroponic farms.

Taking full advantage of the increased luminosity coming from the reflective surface of the water, her state of the art Photo Voltaic exoskeleton covers all sides of the vessel, not just the top. The exposed aerodynamically contoured PV surfaces are imbedded with SunPower Solbianflex panels producing 190 Watts per square meter with an efficiency greater than 22, 5%.

Made with crystalline cells embedded in polymers with high- resilience technology, the panels can be walked on and

Are highly resistant to the marine environment. Flexible and about 1/8th the weight compared to traditional glass panels, they are ideally suited for covering the contoured aerodynamic surfaces of hi-performance yachts.

#### 4.1a Sun Power Carbon Offset Cost Benefits

This PV exoskeleton generates up to 350 MWhs of energy per year, reducing diesel consumption by 90 tons and its related GHG footprint by up to 300 tons per year. Over their 25 year warranty, these PV panels will prevent over 7,000 tons of GHG emissions from polluting the environment. The cost savings in fuel over that same period of time outrageously exceeds the initial cost of the system.

#### 4.1b Fish and Two Veg

The Ocean Empire Life Support Superyacht incorporates fishing stations and two greenhouses employing automated hydroponic growing facilities, from which organic produce can be harvested, preserved and stored. Sunlight for photo-synthesis pours into these greenhouses glazed with polycarbonate set into the bow. This onboard farm grows enough plant life in the form of fruit and vegetables to balance the high protein fresh catches available every day. Fishing is done with trawling lines never with nets.

#### 4.2 MOTION DAMPING REGENERATION (MDR)

The Ocean Empire's MDR (motion damping regeneration) is basically an ATMD (Adjustable Tuned Mass Damper), utilized in skyscrapers such as Taipei 101 to reduce their swaying motion. In this application 16 tons of Lithium-ion batteries are the Mass, while linear generators produce up to 50 kW of electricity as they dampen the motion of the vessel.

Active Regenerative Suspension Systems developed by Bose, Advanced Motion Technology and others are the most important component in the MDR system. They are the key to harnessing the powers of the commonly used ATMD.

In this application the regenerative dampers are travelling up to 20 cm in either direction at variable rates between 10 to 30 cycles per minute. The Lithium-ion battery mass is rated at 2 MWhs and weighing 16 tons is approximately 1/6<sup>th</sup> the weight of the vessel, a weight with enough of a counter-acting force to reduce yacht motion appreciably.

#### 4.2a Lithium-ion UPS with Extended Life

Lithium-ion batteries probably power your laptop. They are the most efficient batteries to date. Cooling them and keeping them from running down extends their life. At sea, as one might imagine, cooling is made easy. A constant charge from MDR in conjunction with capacitors, KER (Kinetic Energy Regeneration) and PV sources of energy reduces the number of battery cycles the Ocean Empire LSV will encounter in daily operation, particularly when cruising.

#### 4.2b Cost Effective Mass Produced Products

The expected life of the MDR Lithium-ion batteries is 10 years. The energy generated by MDR more than covers the cost of replacing the batteries at those intervals. While the cost of diesel is expected to rise dramatically over the next 10 years, the cost of hi-tech batteries is expected to drop, largely due to their much wider use in the automotive industry.

#### 4.2c MDR Carbon Offset.

The amount of electricity generated by MDR is estimated at up to 400 MWhs per year. This is equivalent to reducing diesel consumption by 100 tons and GHG emissions by around 300 tons per year. Over 50 years, MDR can prevent up to 15,000 tons of global warming pollutants from entering the atmosphere.

#### 4.3 POWER FROM CURRENTS & KER

When employing prop driven electric propulsion, under the following conditions, electronic controllers will convert the props to Power Generating Turbines.

- While the boat is moored where currents are strong .
- While powersailing if the speed of the Ocean Empire exceeds a fixed point due to favourable currents, gusts of wind or accelerating off the crest of wave. This form of energy capture is often referred to as kinetic energy regeneration or KER

#### 4.3a Turbine Energy Carbon Offset

There is no way to accurately estimate the amount of electricity generated by props acting as turbines when conditions warrant it. Examples of Motorsailing Regeneration Systems produced by Solomon Technologies indicate that 10% of the kW energy from the sails can be fed to the UPS or capacitors for immediate reuse at the props. This process would give up to 20kW of free energy when powersailing. When moored, examples in Manhattans East River are showing that the Ocean Empire LSV might produce up to 10kW of electricity from the props acting as turbines.

Based on these estimates, the Ocean Empire LSV moored in the East River beside the UN, would generate up to 90 MWh of energy a year from her turbines, saving 25 tons of diesel and reducing GHG emissions by up to 75 tons. At sea, let's assume that her turbines would generate another 50MWh of energy per year. From harnessing currents and KER, this would bring the total reduction in GHG emissions over her service life to more than 6,000 tons.

#### 4.4 WIND POWER

Employing an automated launch and recovery traction kite can push the Zero Carbon cruising speed of the Ocean Empire LSV to 18+knots along with charging her Lithium UPS as it attenuates the speed surges related to KER.

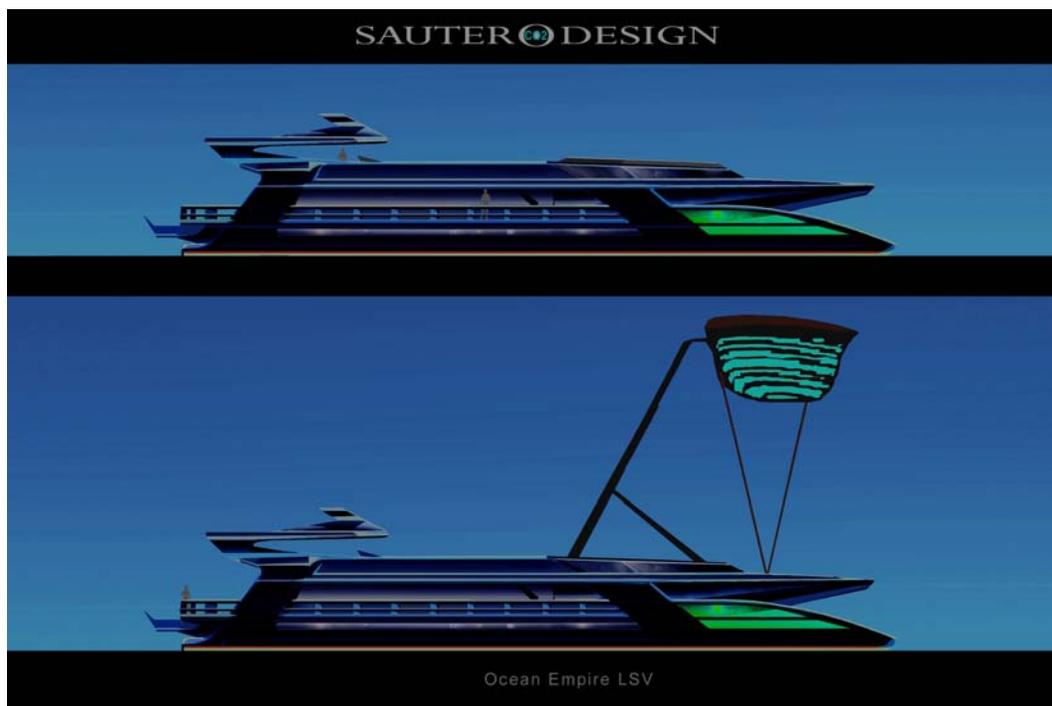


Figure 3: The Ocean Empire LSV

The auxiliary SkySail on the Ocean Empire LSV is the most efficient sail in existence. It is capable of generating more than 2kW of power per square meter. Being inflatable, the kite's deployment is made quite simple by inflating it with Hydrogen generated on board.

An 80 square meter SkySail will, according to wind conditions generate between 100 and 200 kW of power. Add to this, the 350kW of power generated by Emax D/E Propulsion, and speeds of 22+ knots are achievable. With the aid of the SkySail, at maximum speed under full D/E Solar Hybrid Power, fuel consumption and GHG emissions are reduced by more than 50%.

#### 4.1 Wind Power Carbon Offset

Cruising with Zero Emissions at an average speed of 16 knots, the amount of energy generated by the SkySail with KER is approximately 4 MWs per day. At this speed a Zero Carbon circumnavigation of the globe could take around 60 days. The amount of wind power a SkySail will harness on this journey is around 250 MWs, which reduces diesel consumption by up to 85 tons. On this one voyage alone, a minimum of 250 tons of GHG emissions are prevented from polluting the planet, over 50 years this figure could conceivably reach 15,000 tons.

## 5. CAPITALIZING ON FLUID DYNAMIC EFFICIENCY

We have seen the part that the generation of green energy can play in reducing consumption and its related GHG emissions by 50% to 100% in the Ocean Empire LSV. The following sections look at the part efficiency plays in this process, starting with the application of aero and hydrodynamic principles that we see work, and for the most part, see ignored.

### 5.1 FORM FOLLOWS EFFICIENT FUNCTION

Advanced design features that optimise a vessels' performance below and above the waterline have a direct effect on the performance of vessels, not just in terms of speed, but in terms of the power requirement necessary to attain a given speed. The best and most cost effective way to reduce the power consumption in propelling a Superyacht, is to arrive at a 'form' that delivers the highest level of fluid dynamic efficiency.

### 5.2 Aerodynamics

Above the waterline the application of the fundamental aerodynamic principles seen in every form of modern transport, is for the most part ignored in Superyachts. This disregard for the ill effects of 'drag' has increased the fuel consumption and related GHG emissions by up to 20% in just about every yacht ever built, and will continue to do so until they have all been replaced with aerodynamic models that reflect the knowledge and conscience of our age.

The Aerodynamic cowling that encloses the electronic guidance and communication systems on the Ocean Empire LSV, reduces her drag and with it her related carbon footprint. The same is true of the rear PV spoilers employed on the upper deck, and spoilers at the rear of the demi-hull.

The optimization of every aspect of the Ocean Empire's aerodynamics was given top priority because as a passive design solution, it constitutes one of the most cost effective ways to lower fuel consumption and GHG emissions in vessels of all types and sizes.

### 5.3 Hydrodynamics

Whether one is willing to admit that the Froude law only applies to poorly designed displacement hulls, there is no denying that fast displacement hulls are far more efficient than their semi-planing counterparts. Looking at their use in high speed catamarans they require half the power of hi-performance semi-planing yachts to reach speeds of 45+knots.

For those that think that high efficiency displacement hulls don't apply to lower aspect ratio mono-hulls, there are the 55 knot, 16 and 22 meter SBS vessels that successfully challenge that notion.



Figure 4: The Ark Angel LSV

Superyacht designs that ignore the superior efficiency clearly shown in hi-speed wave piercing displacement hulls throw away the opportunity to dramatically reduce their carbon footprint. As with the application of well established aerodynamic principles, the benefits derived from passive hydrodynamic innovations, are one of the most cost effective ways to reduce fuel consumption and GHG emissions, in the worst cases by up to 50%.

## **6. EMAX DIESEL ELECTRIC POWER GENERATION**

The Emax Power Generating System on the Ocean Empire LSV features the only compound engine other than the Curtiss Wright Cyclone to ever go into production; the Daimler Bluetec Turbo Compound DD 16. It is a in-line six cylinder diesel engine that features a Turbo Compound System whereby exhaust gases drive a velocity turbine to recover energy that would otherwise be lost.

Employing an EPA (Environmental Protection Agency) regulated “on road” Turbo Compound Genset provides the aero and hydro-dynamically advanced Ocean Empire LSV with the cleanest marine propulsion system in the world. At 22 knots her fuel consumption and GHG emissions are reduced by 50%. Cruising at 18 knots by up to 75% and at 14 knots by up to 85%

Bluetec emission technology is a fully automatic system used for automotive applications to comply with the far more stringent automobile emission regulations. It utilizes a compilation of technologies to keep emissions to a minimum. These include; exhaust gas recirculation (EGR), diesel particulate filter (DPF), diesel oxidation catalyst (DOC) and selective catalytic reduction (SCR). The SCR requires urea as an activation fluid; the approximate dosage of 2 per cent of fuel consumption is metered and supplied from a separate tank.

There is no reason why Gensets, marine or otherwise couldn't be powered by the far greener state of the art turbo compound engines. Companies like Interpower in the UK will provide a marine certified Daimler Bluetec turbo DD 16 Genset on request.

### **6.1 EMAX SUPERYACHT CARBON OFFSET**

When matched against comparable Superyachts, cruising at 18 knots the Daimler Emax Genset saves the Ocean Empire up to 2.5 tons of diesel per day. One 4,500nm cruise will reduce her GHG emissions by up to 80 tons. As a chartered Superyacht this reduction could easily come to 200 tons per year. Over her entire service life, one might expect Emax D/E power generation to stop more than 5,000 tons of GHG emissions from polluting the air.

## **7. POWER FROM THE GRID VS POWER FROM THE PUMP**

While the capacity to sell green energy via a V2G system won't be seen for a few years, the benefits to being plugged-in are presently real. The energy supplied from the grid has a much smaller carbon footprint associated with its production. Where available, hydroelectric, wind, and solar power generation is virtually green. Even the Power generated from Coal fired plants is cleaner than the diesel utilized on Superyachts, and far cleaner than bunker fuel.

To have some idea of the harmful effects directly related to Bunker fuel, there is this news to reflect on; The IMO now allows the US EPA to require that large ships entering American waters burn only the new- low sulphur, relatively clean fuels, instead of the staggeringly dirty “bunker fuel” that most of today's commercial vessels use. The EPA estimates that this agreement will prevent as many as 14,000 premature deaths and 5 million cases of acute respiratory illness every year.

## **8. TOTAL AMOUNT OF CARBON OFFSET**

When the Ocean Empire LSV is viewed as a Carbon Offset Superyacht, we see that the potential is there to save up to 400 tons of diesel, thereby eliminating the proliferation of up to 1,200 tons of GHG emissions per year. Given that the service-life of a carbon composite LSV is well over 50 years, it's safe to say that this one vessel can prevent at least 50,000 tons of global warming emissions from needlessly polluting our planet.

## **9. CONCLUSION**

If we are to take some responsibility for preserving our world for future generations to enjoy, we need to consider the two fundamental ways to transform Superyachts into what might be considered Paradigm Carbon Offset Vessels.

- a. Design Superyachts that adopt, optimize and apply existing technology to harness as much green energy as possible
- b. Design Superyachts that adopt, optimize and apply existing technology to reduce the size of their carbon foot print as much as possible.

The Ocean Empire LSV is evidence that the adoption, optimization and application of existing technology to achieve a 50 to 100% reduction in the carbon footprint of Superyachts is indeed possible.

## 10. OCEAN EMPIRE LSV SUPERCAT SPECIFICATIONS

- Length overall 44m
- Beam: 15.5 m
- Draft: 0.8 m (50% load)
- Hull & decks: Carbon/Kevlar Composite
- Displacement: <100 t
- Auxiliary sky sail; 80+sq. m
- PV exoskeleton; 70kW
- MDR; 50kW
- Turbine with KER; 20kW
- D/E engine: 350kW Emax Turbo Compound DD16 D/E power generation
- Electric power: 600kW divided into 4 x 1.5m electric surface drives
- Battery: Lithium-ion 2MWh. 16t
- Fuel Capacity: 25,000 l
- Fresh water: 5,000 l
- Berths: 10 Guest/8 Crew
- 2 Hydroponic Farms & Fishery
- Tenders: 2 x Solar Hybrid Guardian S Class 9.5m Tenders
- Carbon Neutral cruising range at 22 knots up to 5,000nm.
- Carbon Neutral cruising range at 18 knots up to 12,000nm.
- Zero Carbon Powersailing range at an average of 16 knots unlimited
- Zero Carbon motoring range at an average of 12 knots unlimited

## 11. ACKNOWLEDGEMENTS

We thank the organizations and companies listed here for their pioneering achievements:

Daimler, SunPower, Solbianflex , Maura Sohnes, Advanced Motion Technology, Solomon Technologies, Incat, Knierim, Vosper Thornycroft, Interpower, IMO, Tesla, SkySail, Voith, Wartsila, Kyoto Protocol, Siemens, Verdant Power, Energy Star, Sistemar, GM Allison, Delco Remy, Stadt, Ulstien, Scaled Composites, Multimarine, Atlantic Motor Yachts, EPA and DOE.

## 12. DISCLAIMER

Estimates on fuel consumption and GHG emissions are based on averages that might vary by + or -10% depending on the age, condition and make or model of an engine.

Estimates on levels of efficiency for an item are based on averages that can vary by + or - 10%, depending on the age, condition, make or model and from one design to another.

## 13. BIOGRAPHY

**Richard Sauter** is the founder of Sauter Carbon Offset Design. His origins stem from R&D related to designing safer hi-performance alternatives for the automobile industry, which ultimately led to exhibiting advanced concept cars at The Geneva Palexpo, Frankfurt and Earls Court Motor Shows.

Innovative firsts in his designs include; the lowest CD (.026) ever recorded at the MIRA wind tunnel for a full size 4 door passenger car, a safe at any speed Kevlar bodied car, an explosion- proof fuel tank in a production car, a supercharged V8 production car and a production car with a built- in solar powered generating system.

In 1992 Richard Sauter received a British Patent for an automotive Supercharger. UK Patent GB 2209802.

R&D Supercharged prototypes for manufacturers include; A supercharged Aston Martin Lagonda, a Supercharged V6 Volvo, a supercharged Peugeot 205, a Supercharged Fireball Rover V8 engine for British Leyland.

Sauter Carbon Offset Design offers the maritime industry designs and consultations specializing in Ultra Green Hi-Performance Superyachts, and smaller pleasure craft.

Sauter Carbon Offset Design Portfolio includes;

The 44m Formula Zero, the 50m Transcendence, the 60m Super Nova and the 60m Ocean Empire LSV and The 78m Ark Angel LSV.

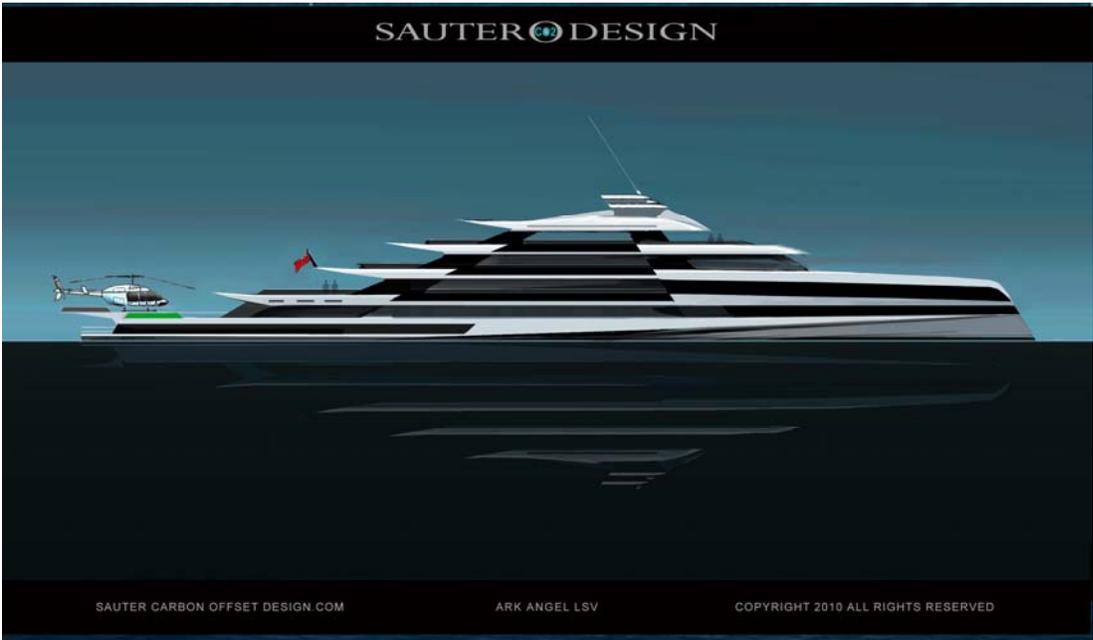


Figure 5: The Ark Angel LSV