

Perpetual motion machine



Chris Beeson goes sailing with a genius, aboard a boat packed with radical technology. She generates all her own power and fresh water, never needs refuelling – and she will change the way we sail

WORLD EXCLUSIVE

Gideon Goudsmit, 58, has spent seven years of his life and over £1.6 million developing an ocean-going yacht that needs no fossil fuels and generates all the power she needs. It's the future, it's here and it works. His obsession with capturing natural energy has crossed over from home life to sailing life.

We were motoring through Amsterdam in his revolutionary 44ft catamaran, *Green eMotion*, when Gideon got a phone call from the electricity company. Their records showed that the national grid had received 4,000kW from his house in the last four months. They didn't believe it. 'I told them that's the spare energy I've produced. They must pay me the same rate I pay them.'

By the time you read this, Gideon's home



The motorgen saildrives lift, reducing drag while sailing and galvanic corrosion while moored



will be totally energy self-sufficient, thanks to solar, wind and geothermal energy. 'I could power half the houses on the street, but it's cost me £333,000 to go fossil-free,' he said.

She never needs to refuel

Green eMotion is a comfortable, fast cruiser. Because she's so light, she has logged 109 miles in five hours, attaining a top speed of 30 knots. 'Never again!' said Gideon, 'The boat can take it, my heart can't.' She'll average 8 knots on passage. She is packed with cutting-edge technology. The marine industry has much to learn from her.

The heart of the set-up is Green Motion: two electric 'motogens' (motor-generators), built into lifting saildrives. When there's no wind, these can power her at 6 knots for three hours, or 5 knots for seven hours. When the wind returns, they generate electricity or lift clear of the water to reduce drag.

It sounds simple, and it is, but making it work has so far evaded all the major boatbuilders. Many have tried – and failed. Gideon founded African Cats in Durban, South Africa, to turn his hi-tech vision into reality and now he's building boats to fulfil other people's dreams.

The first boat, *African Innovation*, was launched in 2004. The basic African Cats 445 costs £416,600 and the 10kW Green Motion system adds £41,600. The fully-equipped boat seen here costs £583,210. There are also 20, 30 and 40kW Green Motion systems.

The tenth African Cat on order is a 61ft carbon fibre cat built for a surgeon who works with Médecins sans Frontières, and it has a fully equipped operating theatre in the starboard bow. The doctors will sail to remote South Pacific islands to provide much-needed medical care. Designed by South African duo Simonis-Voogd, she will run on Green Motion, with two back-up diesel gensets to guarantee power during surgery.

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MAIN PHOTO: CHRIS BEESON, THIS PAGE: AFRICAN CATS



Not having to worry about refuelling opens up a wealth of cruising possibilities



'Gideon Goudsmit has spent over £1.6 million developing a yacht that needs no fossil fuels and generates all the power she needs'



The wind generator is mounted at the masthead to ensure it gets a smooth, unimpeded airflow

Green eMotion is the product of one man's obsession with saving weight and crossing oceans without using fossil fuels

Carbon fibre mast weighs just 92kg

Laminate sails made from Spectra and carbon fibre are lighter and hold their shape for longer

PBO fibre rigging: ultra-light and super-strong

Four heavy-duty solar panels on the bimini and two on the cabin top generate most of the electricity the boat needs

Lifelines are Dyneema rope instead of wire. Stanchions are carbon ski poles

These polycarbonate windows are 250 times as strong as glass and 100kg (220 lb) lighter

Propellers generate electricity while you sail

Dyneema trampoline: quick draining, comfortable to lie on, ultra-light and immensely strong

A brand-new boatbuilding material – basalt fibre!

Carbon/kevlar keel stubs make for safe grounding and allow her to be beached

Revolutionary construction

The lighter a boat, the less her wetted surface area and the less power is needed to drive her through the water. Gideon removed 200kg (440 lb) to reduce draught by 1cm (0.4in)

Mast and rigging

Green eMotion's carbon fibre mast, built by Southern Spars, weighs just 92kg. The forestay is Dyform wire, the mast's jumpers are solid rods but the stays are PBO, a super-strong, lightweight fibre, with wire rigging on the bottom metre, which makes it easier to adjust the fixed-length PBO stays.



Sails The sails are Spectra and carbon fibre cruising laminates, made by North. Gideon says these offered the best combination of light weight, longevity and shape retention, which is essential for efficient sailing.



Steering wheel

African Cats makes carbon wheels for itself and other boatbuilders. A stainless steel wheel weighs 14kg (31 lb), whereas a carbon one weighs 0.9kg (2 lb).

Throttle

Green eMotion's hydraulic, bronze twin-throttle unit weighs 10kg (22 lb). Gideon commissioned a new design from a Slovenian company, which weighs 1.4kg (3 lb 2oz).

Trampoline

The trampoline didn't drain fast enough. Once, it took a wave and collapsed under the weight, almost taking Gideon's wife, Elske, with it. He designed the perfect tramp – quick draining, comfy to lie on, strong, light and UV-stable. His Dyneema net weighs 20kg (44 lb) less than a regular tramp. It's now being used by other builders.



Keels and rudders

Green eMotion can be beached. Each hull has a keel stub, like a small daggerboard, to limit leeway. The edges are carbon fibre and Kevlar to cope with the abrasion of grounding. The core is made of Coosa composite rather than marine ply, a saving of 35kg (77 lb). The rudders are foam-cored basalt fibre and Kevlar, on aluminium stocks. Gideon experimented with carbon fibre but found electrolysis where the carbon rudder skin and aluminium stock were in contact.



African Cats are designed to dry out on keel stub and rudders

Compression beam

Many boatbuilders use a boom section for the compression beam, which runs between the forward beam and the mast. Gideon designed his own to save weight and improve performance. The section has a V-form below to reduce wave impact, tracks either side for the slides holding the trampoline fastenings and a flat section on top to walk on. It's now used by several boatbuilders.

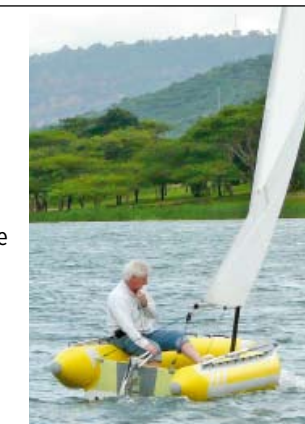
Cork sole

Instead of the usual teak-and-holly veneered marine plywood, Gideon chose cork. It's lightweight, an excellent insulator, feels good underfoot and if a slippery plate evades you while washing up, it doesn't break when it lands.



Tenders

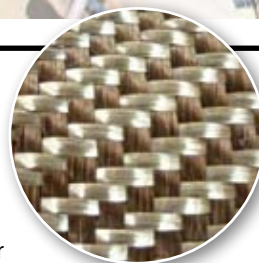
Gideon has designed a pair of 3.6m (12ft) RIBs, dubbed 'Catalites', with vee bow sections and concave after sections, weighing in at 29kg (64 lb) each. One has a 15hp outboard – it planes easily and corners well – while the other is rigged for sailing. Each hull has a shaped-foam core, epoxy-infused, then coated in carbon and Kevlar and painted. Inflatable tubes made from tough, long-life Hypalon add buoyancy and stability.



Hulls

A camera tripod made from basalt fibre was the inspiration for Gideon's remarkable choice of construction material. It's lightweight and strong. 'The Russians call it poor-man's carbon fibre,' he says. 'It's 2% heavier than GRP but 26% stronger, so you can use less of it, and much safer to work with – you don't need to spend an hour in the shower after using it. And it's natural – the earth produces 1km³ of basalt every year.'

Gideon commissioned the Universities of Durban and Leuven to assess its suitability for boatbuilding and in 2008 basalt fibre was CE-approved for yacht construction. It's expensive – £8.54/kg compared to



After using a tripod made of basalt fibre, Gideon commissioned scientific studies that resulted in the CE approval of basalt fibre in boat construction

£2.14/kg for GRP – but cheaper than carbon at £42.70/kg. The hulls and bridgedeck are one-piece mouldings to keep down weight. African Cats uses vacuum infusion, which is much more efficient than hand lamination – reducing the lay-up ratio from 30% mat : 70% resin, to 70% mat : 30% resin – and saves a whole tonne of weight in a 40ft catamaran.

Uniquely, African Cats establishes the vacuum 48 hours before infusing the epoxy resin, to expel air and compress the basalt and foam, saving a further 100kg (220 lb) of resin. The vacuum is released 24 hours

after infusion is complete. The deck is also one-piece, built from foam-cored carbon fibre. Gelcoat weighs 0.4kg/m² (0.08 lb/sq ft), so Gideon uses two-part spray paint, which is 95% lighter.

Finished GRP, with gelcoat inside and out, weighs 12.5kg/m² (2.56 lb/sq ft). Foam-cored basalt fibre, vacuum-infused with epoxy resin and painted, weighs 5.5kg/m² (1.13lb/sq ft). Using carbon fibre reduces that to 4.8kg/m² (0.98lb/sq ft), nearly a third the weight of GRP.



Using vacuum infusion more than halves the amount of resin required, saving almost one tonne on a 45ft catamaran



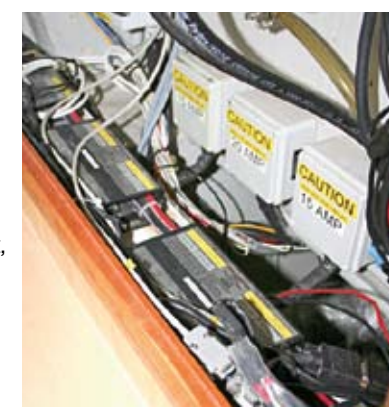
PHOTOS: CHRIS BESON

Windows

The large windows are Lexan Margard, a polycarbonate sheet that has 250 times the impact resistance of glass. It's also abrasion-resistant, UV-stable and lightweight, saving 100kg (220lb) over the glass alternative.

Wiring

By using a Capi2 power distribution system – an electronic spine through which power is supplied and data exchanged by the boat's various systems – Gideon saved 120kg (265 lb) of weight, primarily copper wiring.



Revolutionary power

Gideon has cracked the thorny issue of generating enough power to keep all systems running at sea



Sailing at 7-8 knots with both motorgens deployed, we generated 4kW in an hour

Generation

We were making nearly 8 knots when the picture above was taken. Each saildrive was generating 13.5A at 150v – a total of 4kW. An hour's cooking uses about 2kW of energy, or 20-25% of the domestic battery bank, but that can be replenished in half an hour. In the morning, everyone had showers, Gideon cooked bacon and eggs and we all had several espressos before running the dishwasher. That dropped the overall battery bank from 97.9% to 85.3%. There is a speed penalty of around 12% below 7 knots and about 8% above.

Propulsion

You really don't miss the engine noise, vibration and smelly exhaust of a diesel engine. As well as being silent and smooth, electric motors instantly deliver full torque. I nearly ended up flat on my back, surprised by the acceleration.

She has two 9.6kW electric motors. 'We detuned them to 8.5kW so the system isn't hammered,' said Gideon. 'The extra 15-20% would only deliver an extra 0.1-0.2 knots.' Each motor is housed in a saildrive leg and weighs 34kg (75 lb), including prop and anode. Gideon made them from titanium alloy – even the nuts and bolts were custom-made.

Motors are water-cooled. It was hoped the run-off could

Domestic systems

To test the boat's generators, she is loaded with every possible appliance: microwave, fridge and freezer, dishwasher, air conditioning, watermaker, electric induction hob, electric toilets – even the saloon and cockpit tables can be lowered on electric legs.

Domestic systems, however, run on the minimum of power. The water-cooled fridge and freezer draw 2A per hour. The motogens are water-cooled, too – and their run-off heats water in the calorifier. She has LED lighting inside and out, the warmth of which



Electric-flush toilets add to the power demands on the Green Motion system



The power-hungry galley has an electric oven and hob, a fridge and freezer, boiling water on tap for drinks, an espresso machine and a dishwasher

convinces me that halogen has had its day. A 'Quooker' tap delivers boiling water on demand, using very little power and saves you having to boil a kettle. Everything has a safety breaker, and a dump regulator dissipates any excess power.

Green eMotion has LED cabin lighting and navigation lights



The bus bars will be downsized. The green dump resistors dissipate excess power



The Schenker watermaker is fitted below the boat's diesel generator



Green eMotion also has an air conditioning unit



Hatches in the cockpit sole make it easy to clear a prop wrap

be used by the calorifier but the system's efficiency means it's not warm enough. Inboard mounted saildrives mean the water flow is smoother and the props more efficient. There's no prop wash over the rudders, but Gideon turned the 13.4m (44ft) cat around in a 15m-wide (50ft) canal without the slightest hitch.

The 16x9 three-blade props are custom-made from 5082 and 6082 aluminium, which can be welded and won't corrode in seawater. Titanium would have cost six times more. The props have a DAR (developed area ratio) of 71%, compared to the 60% of the average yacht prop. Like tug props, they make the most of the instant torque.

The props are mounted on the forward end of titanium shafts, and counter-rotate, eliminating prop walk. Gideon is testing 18x9 and 18x10 props to improve efficiency by up to 50% (the first number is prop diameter in inches and the second is the distance forward one revolution will move the prop, also in inches). Higher diameter means lower RPM and higher efficiency.

Batteries

She has nine Mastervolt lithium ion batteries: six in the propulsion bank, two for domestic use and one for the generator. Each weighs 50kg (110 lb) and costs €4,000 (£3,300) but



The Li-Ion batteries cost €24,000. Prices will have to fall...

the advantages over lead acid batteries are enormous. Lead acid cells charge slowly and need replacing after 500 cycles. Lithium ion batteries fully charge in an hour and can cycle from 100% right down to 10%. Green eMotion's bank has run through 5,000 cycles already – and has actually increased in capacity by 5%.



Mast-mounting the D400 wind generator improved its output by a factor of 2.4

Wind generator

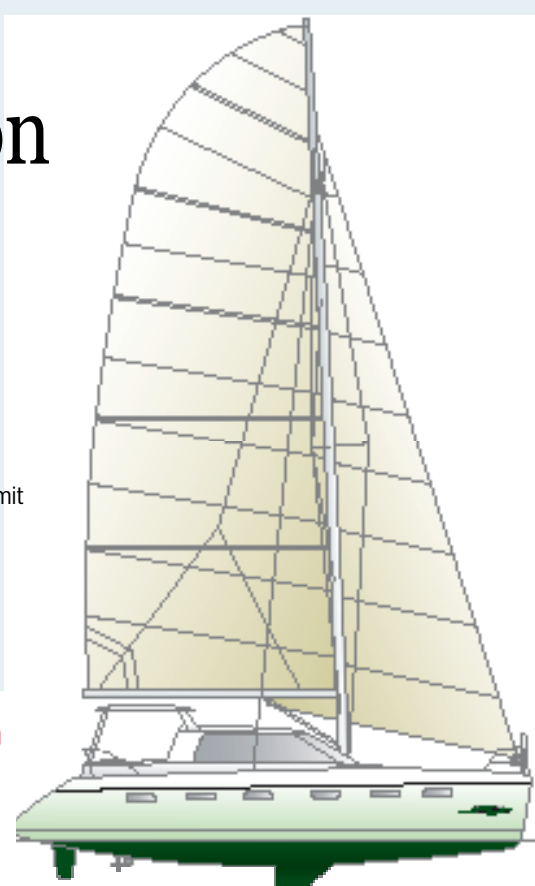
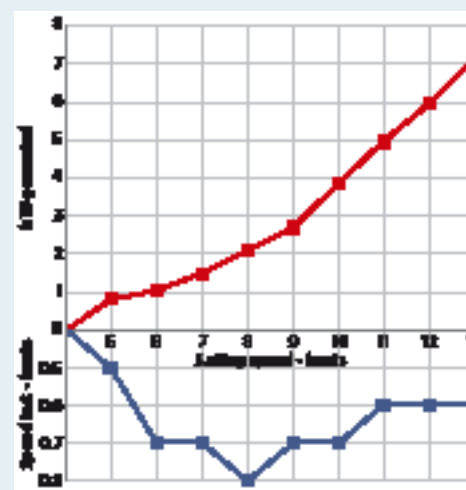
Gideon used to have two Air Breeze wind generators pole-mounted aft of the cockpit but they never delivered the amps expected. Now he has an Eclectic Energy D400 mounted at the masthead, around 21m up. In stronger breeze and clearer air, the masthead unit delivers on average 100W per hour, more than twice as much electricity as a pole-mounted unit. In 17 knots of average windspeed, I noted the wind generator was delivering 5A at 28v, about 140W. And the masthead mount makes the turbine's noise and vibration far less intrusive.

TECHNICAL

Green eMotion

- Price guide £700,000 (€822,500)
- LOA 13.4m (44ft)
- LWL 12.99m (42ft 6in)
- Beam 7.49m (24ft 6in)
- Displacement Basalt: 6,400kg (14,110 lb)
- Carbon 5,800kg (12,787 lb)
- Sail area 113.5m² (1,220sq ft)
- Water 650 lit (143 gal)
- Fuel 600 lit (132 gal)
- Cabins 2/4
- Engine 2 x 9.6kW (26hp)
- Designers Angelo Lavranos and Gideon Goudsmit
- Contact African Cats
- Tel 0031 297 582881
- Web www.africancats.com

Kilowatts generated and speed lost at a range of sailing speeds



ARTWORK: MAXINE HEATH

'You really don't miss the noise, vibration and smelly exhaust of a diesel engine'

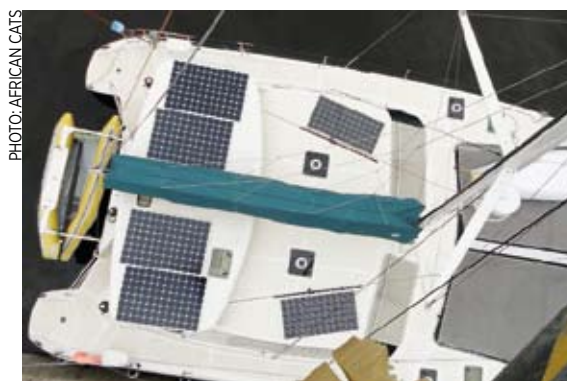
Converters and inverters

There are six Mastervolt converters, one on each of the six propulsion batteries, to ensure even charge distribution, and two other custom-designed, US-built converters, one from 25-150v and one 150-25v, the boat's two systems. There is also a Victron Quattro 5000, a 5kW inverter, that delivers the 230V AC, 50Hz required by the Smeg induction hob and electric oven. Victron and Mastervolt thought the AC sine wave produced would not be clean enough to power the hob but the system works perfectly. There's also 220v AC shore power and, if Gideon fits an inverter, he can send into the grid any extra power he generates.



Six converters – one each for the six propulsion batteries in series

PHOTO: AFRICAN CATS



Solar panels

Three of the four Sunpower 300W solar panels on the rigid bimini and coachroof supply the propulsion bank while the fourth supplies the domestic bank. They weigh 15kg (33 lb) each, but Gideon expects the next generation will be lighter and more efficient.

Generator

The 22kW generator can recharge the batteries during extended calms, but is rarely used. It has been significantly modified to lower weight and improve efficiency

to around 81%. Simply by tuning the generator, Gideon has managed to get the same power at 2,200rpm that he used to at 2,600rpm. Engine mountings were changed from stainless steel to carbon fibre

and the plywood base has been replaced with Coosa composite, bringing the total weight down to 212kg (467 lb). Now, though, Gideon has found a new 40kW generator that weighs just 95kg (209lb).

Meet the genius who created this amazing boat: p68

Green eMotion embodies innovation – not just in her self-sufficiency with power but also in her construction



Zeal, passion and knowledge

I've always been an inventor,' Gideon says. 'When I was 12 my parents had a small castle in the Dordogne with a stream running through it. I used bicycle generators to make electricity from the river.'

Gideon was well ahead of the game when, in the 1970s, he designed three carbon-free offices with wind generators, solar panels and triple glazing. There were also heat sinks in the thick, heavily insulated floors that captured the heat produced by staff and office equipment during the day, stored it overnight and released it by time delay switch an hour before staff arrived. The buildings are still running today.

Though the Goudsmit family made its money with land, Gideon amassed his personal fortune when, on the eve of the millennium, he sold his car dealerships – a puzzlingly ironic business for someone so environmentally aware.

After owning various Moodys and Hallberg-Rassys, Gideon wanted something quicker. 'On an ocean crossing, a good average speed for a 40-45ft monohull is 5-6 knots,' he said. 'I wanted a lighter, faster boat. I visited nearly every French multihull yard, but I couldn't find what I wanted.' He eventually bought a St Francis 48 cat in South

Africa, but soon had a list of 500 things he wanted to change. So in 2001 he asked Angelo Lavranos, who had designed the St Francis 48, to go back to the drawing board. They worked together for six months perfecting the design, before founding the African Cats together.

Proof that it works at sea

Green eMotion sailed from Durban to the Azores, then on to Amsterdam, a passage of 8,000 miles. In three months, seven weeks of which was spent on passage, she used 274 litres (60 gallons) of diesel, mostly in the Doldrums.

Without time constraints, or with better weather routing, the voyage could easily have been made without any fossil fuels.

It's encouraging that boatbuilders are contacting Gideon about the Green Motion system, but he still sees room for improvement. 'You will generate four times as much electricity at 10 knots as you will at 7 knots,' he said. 'By adding some propulsion

while generating, we can generate even more electricity than we use.' He is working with the Slovenian company that makes his throttles to develop software that automatically calculates the settings for optimum electricity generation.



Using a little current to make the props turn faster while generating, in this case 17Ah, the power generated is increased significantly, 52Ah here. Software is being developed to optimise the balance automatically



PHOTOS: CHRIS BEESON

Gideon Goudsmit helms Green eMotion across the Markermeer during our test

Passion and know-how

Gideon's passion and phenomenal knowledge about the boat is absolutely compelling – it's no surprise he made a fortune in sales. Whatever I pointed to, Gideon knew its weight, its construction, how it performed and how it could be improved. The result of his zeal is a project strewn with firsts: the first ever basalt fibre yacht; the biggest vacuum-infused carbon structure ever built; the first ever fossil fuel-free, ocean-going, luxuriously appointed performance cruiser.

The boatbuilding industry is already reaping the benefits and the inventions that have emerged from his project have dragged forward research in this area by a decade. With fuel prices rising, fuel quality falling and an ever-increasing list of environmental requirements in the most beautiful parts of the world, there's no doubt the market is ready for a boat that uses no fuel. If Green Motion doesn't win every major ecological award in the marine industry next year, then I'm a Dutchman. ▲