

# LEAN MACHINE: OUR APPROACH TO SUSTAINABLE ENGINEERING



**“Machine” is an unfashionable term. It jars with the rustic utopia that is the shorthand for being ‘green’.**

“I’m an unabashed engineer. I live to invent, design and make machines”.

**Introduction  
by James Dyson**

But machines and being green don’t have to be at odds. On a planet of finite resources, engineers and their inventions surely have an important role to play. We are by our very nature problem solvers, striving to make things work better. And using energy and materials sparingly and ingeniously is a prerequisite of our job.

It was this lean mindset that got me hooked on engineering. When I discovered the flaw with vacuum cleaner bags – their propensity to clog and lose suction – my goal was to come up with something more efficient. Not to reinvent the bag.

The engineers I work with at Dyson today continue to solve problems that others ignore. Heavy motors that burn out. Unwieldy handheld vacuums that lack oomph. Hand dryers that leave hands wet.

Others might label our resulting machines as ‘eco’. But to me, the very notion of environmental friendliness smacks of marketing hype. Marginal improvements in environmental performance are packaged in a green box and embellished with emblems of nature. It over-inflates the benefit and belittles the challenges faced by Planet Earth. Let’s be frank: an ‘eco’ vac does not save the Amazon rainforest.

So we don’t green wash. Yet here, for the first time, we’re gathering the stories of our lean machines. Why? My intention is that by talking about sustainable engineering, I will encourage the brilliant and idealistic young people that work with me in our Research and Development laboratories to do more. With less.



WHY REINVENT



A PROBLEM



WHEN YOU CAN



ELIMINATE IT?



The problem with bags is simple: as the pores quickly clog with dust, the vacuum's suction plummets. So they need to be replaced. Often. As the dust clogs the bags, the bags clog landfill – with paper or non-biodegradable polypropylene. And long before all this, they need to be manufactured, packaged and shipped around the world.

When James Dyson imagined how industrial cyclone separation could work in a vacuum cleaner, it wasn't his focus to prevent billions of tonnes of landfill waste. It was about improving performance – creating a machine that wouldn't lose suction. But that's where lean engineering succeeds.

Dyson vacuums have no consumables. Dirt is collected in a container and emptied straight into the dustbin. And filters are washable throughout their lifetime. Our newer machines have filters that do not need to be washed or replaced.

Dyson has sold over 50 million vacuums to date. Had all those machines relied on consumables, billions of bags would have been needlessly laid to rest in landfill.



Cyclonic separation is used in industry. Inside sawmills, cyclones remove sawdust from the air, and in oil refineries they're used to separate oils and gases.

## All in a day's work

Lean machines are created by the bright young people that work at Dyson. Part of a 1,600 strong team of engineers and scientists, including James Dyson, they spend their days in laboratories in Malmesbury, Malaysia and Singapore, creating and testing new inventions. Fingerprinted access keeps non-engineers out and secrets in. But while much of what Dyson people do is shrouded in mystery, the question of how they do it is an open secret...

From day one, whether your job is in the Research Design and Development Centre or the Customer Care team, it's not so much about settling in, but getting stuck in. Stuck into technology (everyone strips down and rebuilds a

Dyson vacuum on their first day), and stuck into difficult problems.

In getting stuck in, sometimes you can come up against a brick wall. That's why an experimental approach is so crucial: try things out, fail, adapt the approach and try again. That's how problems are solved and how lean machines come to be.

### Cyclonic velodrome

The goal was to wow the people of Tokyo with Dyson cyclone technology. An enthusiastic

graduate engineer came up with the idea of a transparent velodrome to represent the impact of the G-forces that separate dust from the air. At Dyson, mere concepts don't cut it, so the graduate was set to work with sheets of polycarbonate and his racer bike to prove his idea possible. Within a matter of weeks he was pedalling furiously around his mini-velodrome in Roppongi Hills, Tokyo. Job done and dusted.



## Wafer thin walls

James Dyson understood that people wanted smaller, lighter machines. It's why he challenged engineers to cut wall thicknesses to the bare minimum. There were red cheeks as fragile prototypes developed fissures but by building up material only in these delicate areas, a new generation of lightweight machines was created.

### Slice a Mini in half

It's function, not form, that excites Dyson design engineers. And it's this philosophy that the James Dyson Foundation aims to pass on to budding Brunels through its programme in schools and universities. It's also why Helen, a graduate working for the Foundation, was given a modest sum of money to procure a Mark 1 Mini and then cut it in half to expose its inner-workings.

### Experiments not experience

Rather than recruiting those with the longest CVs, Dyson seeks out bright and enthusiastic graduates and interns at the start of their engineering careers.



We give them responsibility from the outset. Fearless and free is what we want: that's where revolutionary ideas come from.



#### **Conventional motors**

Motors are at the heart of Dyson machines. They perform the important job of converting electrical energy into mechanical actions. To do this well they must be efficient, light and durable. Conventional motors are anything but. A mass of big, clumsy fans, copper windings and carbon brushes which wear out and need replacing. They create lots of sparks, heat and wasted energy. So Dyson engineers designed a new kind of motor.

## **Why must motors be big and greedy?**

#### **The Dyson digital motor - V6**

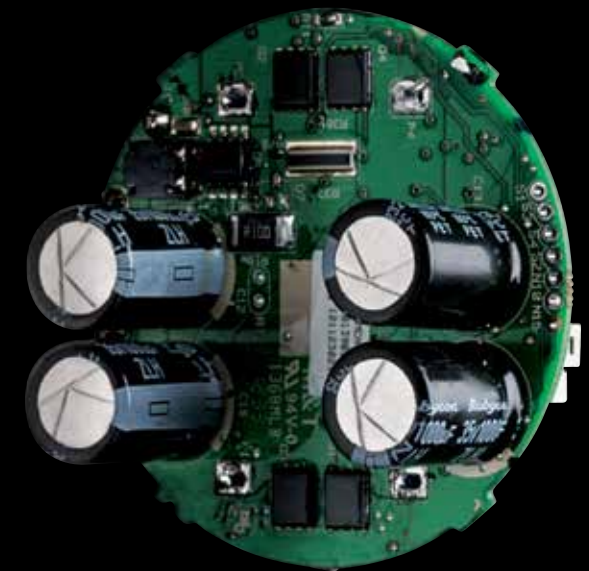
This mini lean machine uses digital pulse technology to spin at up to 110,000 times a minute. It is small, power-efficient and much lighter than conventional motors – weighing just 218 grams yet generating 425 watts of power. It is engineered to have the same pick-up performance as a number of more energy-hungry full-size machines.

Revolution takes time and investment. The patented Dyson digital motor V6 was seven years in development. Since 1999, Dyson has invested over £150 million researching and developing its digital motors.



90% of a Dyson vacuum's lifetime environmental impact occurs when it's switched on and in use. Our efficient motors have reduced average floorcare energy consumption by 40% per unit since 2008.

# A Dyson digital motor every 6 seconds.



## **Robots, assemble!**

The compact Dyson digital motor V6 is crammed with high tech components. To ensure the performance and quality, they must be assembled with absolute precision.

Even human hands with their incredible dexterity are unable to carry out such an intricate assembly. So we employed high speed, highly efficient robots – 50 of them, to be exact.

## **Micron accuracy**

Take the job of fixing ball bearings in place. Only a microscopic amount of adhesive is required. Too much and the ball bearings move out of position, preventing smooth operation. The robots use microdots to accurately apply tiny amounts of glue. This reduces waste and helps prevent motor failure.

Thanks to the army of lean machines carrying out such precise operations at speed, our fully-automated assembly line in Singapore is now able to produce six million Dyson digital motors a year – one every six seconds.



Our digital motor factory, Dyson Westpark, has received ISO 14001 certification for Environmental Management. Engineers continually look for ways to operate more efficiently. For example our printed circuit board assemblies used to come packed individually in electrostatic bags, producing lots of waste. Dyson engineers created reusable electrostatic trays – housing more PCB boards and reducing needless landfill.



## Waste of energy. Waste of paper. And a waste of time.

For years hand dryers clung to lavatory walls, content to spew out expensive hot air that never actually dried one's hands. That's because conventional hand dryers rely on evaporation – heating air which contains dirt and bacteria – and blowing it onto wet hands gradually turning moisture into vapour. It's too slow – typically taking up to 43 seconds.

So what about paper towels? They're expensive and energy intensive, requiring tree felling, mulching, bleaching and transportation. Then refilling, disposal and landfill. Even recycled paper towels, despite claims of being environmentally friendly, are barely an improvement due to the energy expended in reprocessing and redistribution.

A Dyson Airblade™ hand dryer scrapes hands dry – with 430mph sheets of cool air generated by the Dyson digital motor – drying them in as little as 10 seconds.

A dry-time of 10 seconds, and using cold air not heated air, means far less energy is consumed – one sixth of that used by the hot air dryers that preceded Airblade™ technology.



Dyson engineers worked with the Carbon Trust to develop a method to assess the real environmental impact of products through their lifecycle. From materials and manufacture, through to distribution, use and disposal, this robust methodology helps engineers focus on the biggest environmental improvements.\*

### Materials matter

The energy used when Dyson machines are switched on is by far our biggest environmental impact. But materials are important too.

The less raw material we use, the less drain on resources and the less energy-intensive processing required. It also means lighter, more user-friendly design.

When tooling suppliers told us that our plastic parts must have a certain thickness, we took a different view: start with the bare minimum. Then gradually build up to the requisite strength.

Ultimately, durability is never sacrificed. We have a stringent testing regime and conduct ruthless finite strength analysis.

### The revolution and evolution of cordless

Dyson cordless vacuums are the epitome of our sustainable engineering philosophy. They're lean thanks to Dyson motors, cyclones and cutting-edge battery technology.

Our latest cordless vacuums outperform many corded full-size machines – using only a fraction of the energy and materials. They also represent a 9% reduction in weight and materials-related carbon emissions compared to their predecessor cordless range.

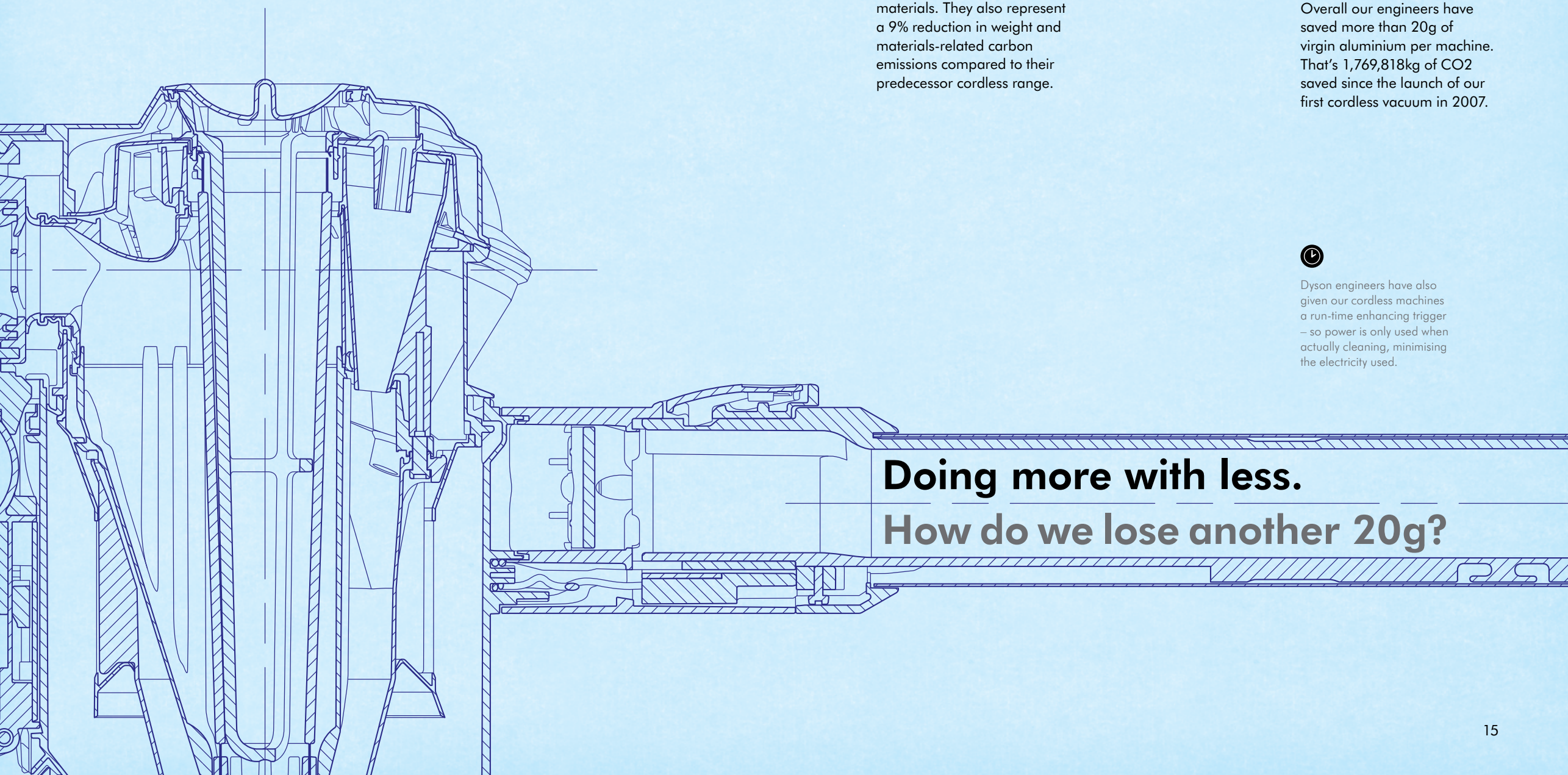
### The strength of geometry

Rather than adding material for strength, Dyson engineers relied upon design and geometry. For example, the 15-cone cyclone pack gave engineers the chance to trim the cross-section of cyclone walls from 2mm to 0.7mm.

### Shrinking the boundaries

Aluminium is a strong, lightweight material, but it relies on an energy-intensive extraction process. So Dyson engineers slimmed the aluminium wand by 0.3mm. They compensated for the loss of strength by creating an inner plastic tube, with a double-walled web design that minimises materials.

Overall our engineers have saved more than 20g of virgin aluminium per machine. That's 1,769,818kg of CO<sub>2</sub> saved since the launch of our first cordless vacuum in 2007.



Dyson engineers have also given our cordless machines a run-time enhancing trigger – so power is only used when actually cleaning, minimising the electricity used.

**Doing more with less.**  
**How do we lose another 20g?**





## First. Less material.

Dyson engineers completely reinvented the personal fan. Instead of relying on rotating blades to 'chop' the air, they accelerated it through an annular aperture, harnessing a phenomenon known as the Coanda effect. The surrounding air is drawn in and a smooth, powerful, high-velocity flow is projected out. With no blades and grilles, there are fewer components to manufacture and less material to ship around the world.



## Second. Less energy.

In the next generation of Air Multiplier™ fans, airways have been tuned to significantly reduce turbulence. The motor no longer needs to work so hard to generate the same cooling performance – resulting in an 18% reduction in carbon emissions, as well as 75% lower noise levels.



**Third.**  
**99.9%**  
**bacteria-free.**

The Dyson humidifier has patented Ultraviolet Cleanse™ technology – a three-minute cycle that kills bacteria, ensuring that any mist projected is always 99.9% bacteria-free.



We don't just try to get the most out of resources and energy, we also look for ways to apply our new technologies to problems others ignore. Dyson engineers and microbiologists discovered that there was a problem with existing humidifiers: either they don't work or they can blow bacteria out into the air with the moisture.



**280 counts of bacteria within 2 minutes of activation.**

Ultrasonic humidifiers don't treat the water so any bacteria in the tank will be transmitted directly into the room where it can be inhaled.

Other humidifiers use a sponge filter to evaporate moisture into the air. This sponge sits inside the machine and can harbour bacteria.



**Hygienic humidification**

Using Air Multiplier™ technology as a basis for its powerful air distribution, Dyson engineers developed a new and hygienic approach to humidifying air. Ultraviolet light is used to kill bacteria that grow in the tank when the machine's not in use. The water then runs into a piezo chamber, where it is exposed to the ultraviolet light for a second time.



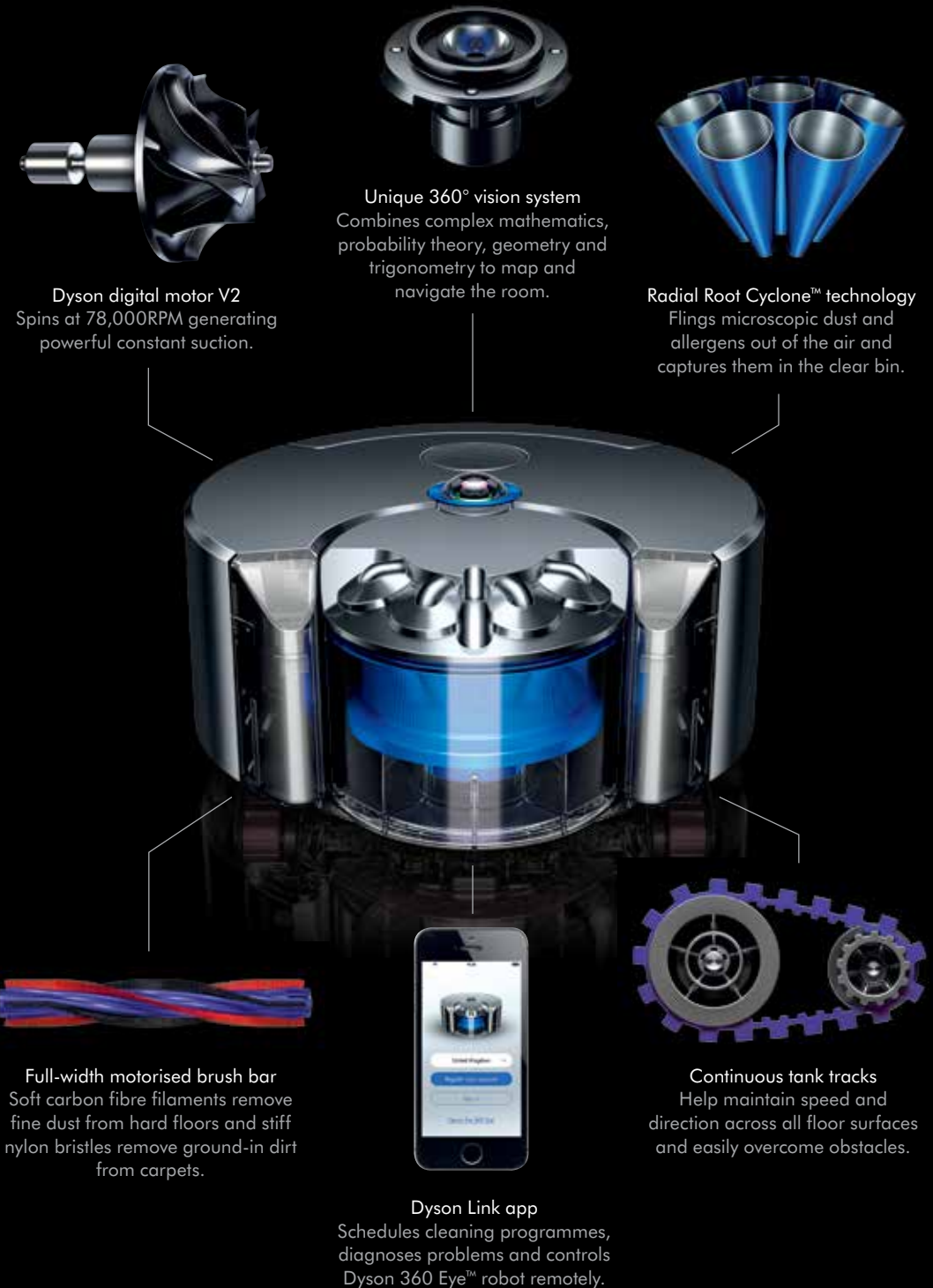
# And finally, a robot that vacuums.

The ultimate in lean machines: a robot that does the job for you. But only if it works efficiently.

We've been working on the robot cleaner since 1999, but it isn't as straightforward as strapping a cyclone to a computer. Making something that looks like it works is easy. Making something that actually does the job is a different matter.

Other robot vacuums have started to appear. They pootle around your room looking purposeful. But when it comes to the primary purpose of a vacuum cleaner – sucking up dirt and dust – some other robot vacuums are guilty of the ultimate inefficiency: weak suction power. And many can't see the room – bouncing around at random, cleaning the same spot over and over.

Technology you won't find in any other robot vacuum.





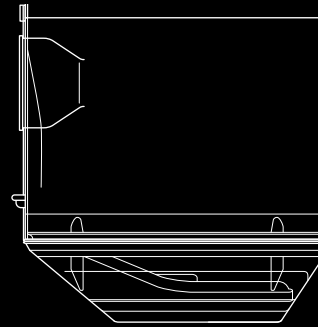
# A 360° panoramic camera builds a complete picture of the room.

To create the Dyson 360 Eye™ robot vacuum, we melded cutting-edge robotics with our energy efficient digital motor and battery technology.

It uses a 360° panoramic camera to build a complete picture of the room – then calculates its path using complex mathematics including probability, geometry and trigonometry.

It covers each part of the room just once, so it doesn't waste energy going over old ground. And it's the only robot vacuum with tank tracks to help it stay on course over different surfaces.

We can now achieve what was impossible in 1999: a robot vacuum that cleans your home effectively and efficiently.



## Built to last.

We live in a throw away world. Some manufacturers build weak products and sell them cheaply. After a few years, if you're lucky, you're compelled to throw away the duff machine and buy a new one. It's called 'design for obsolescence'.

Dyson machines are built light, lean and durable. From design through to material selection, testing and after-sales service, our philosophy is to keep Dyson machines working.

Dyson machines are made of tough materials. For example, a Dyson vacuum's clear bin is constructed of polycarbonate – the same material used in riot shields.

But engineers constantly review our material selection, scouring scientific breakthroughs for proven benefits.

Materials piquing their interest include carbon nanotube technology, graphene and bioplastics.

Prototypes are subjected to months of repetitive and rigorous testing – a different rig for every part. During development a Dyson vacuum will be dropped onto a hard floor over 5,000 times and travel 1,357km on a turntable. It'll take some 120 engineers 50,000 hours and 550 tests to be satisfied that it's tough enough.

Along with mechanical testing, we use robots to recreate human actions – one prototype will undergo 10,000 twists and tugs.

Finally, machines are exposed to real human bashing and kicking. In the case of our hand dryers, we sought to replicate potential abuse from vandals. Only by testing to the point of failure can we identify weak points and build machines that last longer.

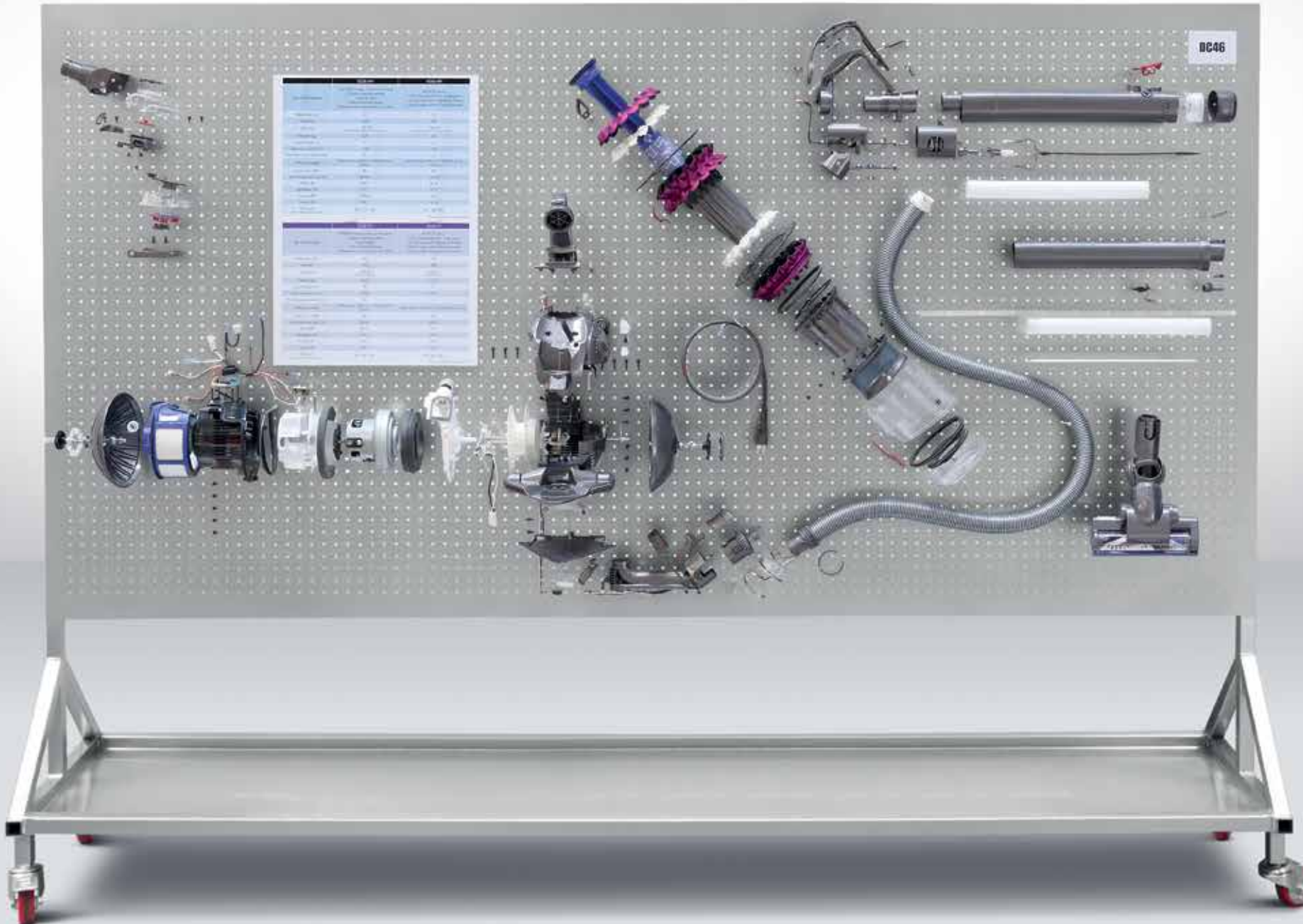
Confident in the rigours of this test regime, we offer a unique no quibble guarantee that includes parts and labour. And after that, there's support online, over the phone or in person, at our American service centres.

All Dyson machines contain high quality materials, almost all of which can be reused and recycled. That's why we operate service workshops where machines are refurbished and sold as discounted certified machines.

And to encourage end-of-life recycling, we offer trade-in promotions – accepting any make of vacuum and offering new, more efficient Dyson technology.

# Lean.

# From source to ship to shop.



Many modern supply chains are complex and Dyson's is no different. In order to produce the 26,000 machines that roll off production lines each week, we work with several hundred companies from all over the world. Collectively they contribute to the Dyson technology you see in a shop.

Some of our suppliers are multinational manufacturers, but many are small, family run start-ups – not dissimilar to Dyson in its early days.

As a customer, Dyson is demanding (some would say difficult). We only want to work with those who are as excited as us about solving problems and creating new technology.

Our demands aren't limited to performance and quality. They extend to the conditions any Dyson components are made in. As a prerequisite of working with us, Dyson suppliers must sign up to our stringent ethical code.

Dyson's Corporate Social Responsibility team works with suppliers every week to ensure that standards are being met. If a supplier falls short of these standards, they are given a set time to remediate. And should they fail, we look for another supplier who commits to meet the ethical and environmental standards we expect.



# 1

## Precision tooling

Great chunks of steel press molten plastic into components. An energy and material intensive operation is being made more efficient through the use of hot runner systems, reducing resin waste. Tooling suppliers are also developing more multi-cavity tools, allowing for the production of multiple parts in one mould, reducing material and energy use.





# 2

## Spray painting

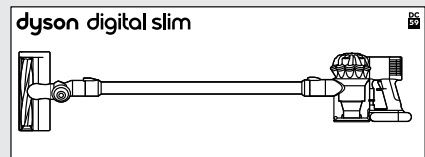
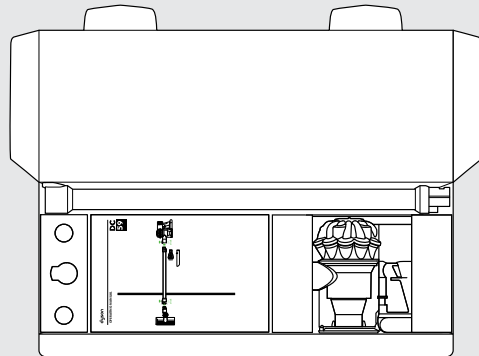
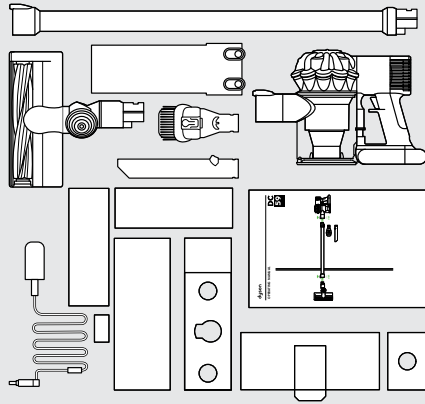
Painting is an energy intensive operation. By improving the positioning of robotic arms, our engineers achieved a 30 second faster cycle time for the painting of our new Dyson Air Multiplier™ fan – as well as a decrease in reject rates, reducing waste.



# 3

## Efficient assembly

With one Dyson vacuum cleaner born every 3.3 seconds, assembly needs to be highly efficient. Components are synchronised to arrive just in time.



**Less cardboard**

Packaging for our latest cordless machines has been efficiently designed so that it consumes 20% less cardboard than its predecessor.

**Fewer inserts**

Cardboard inserts, which buffer the machine in transit, have been reconfigured so that the latest cordless vacuum needs only five inserts (compared to eight in our previous cordless packaging).

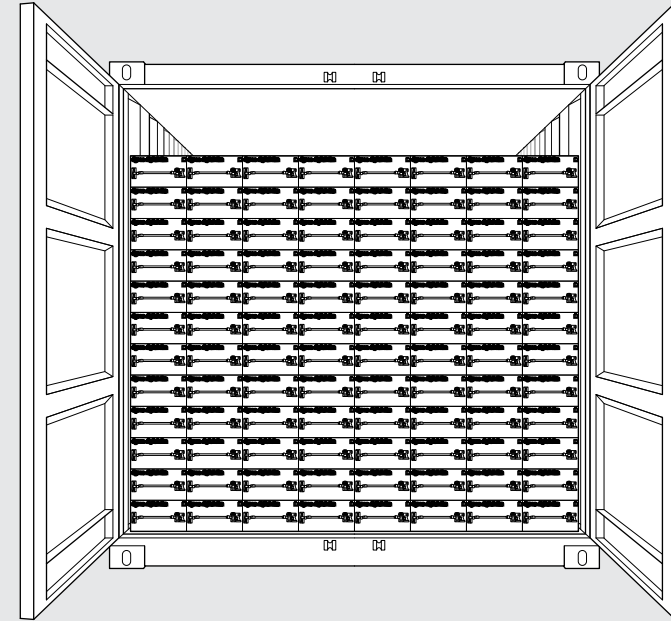
**Smaller boxes**

More compact packaging not only saves on raw materials but also allows us to fit 60% more boxes in a shipping container.

**4**

**Packaging**

Unlike many manufacturers, Dyson has, wherever possible, avoided using expanded polystyrene due to the difficulty in recycling it. Instead, our packaging engineers have found a way to tight-pack our machines with recycled corrugated cardboard, minimising environmental impact.

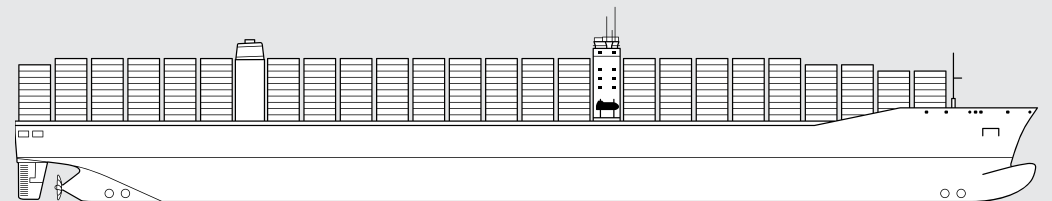


**Pallet free**

By loading boxes directly into shipping containers, without the use of bulky wooden pallets, we can squeeze 30% more cordless machines into each container.

**Ship shape**

The average vessel carries 5,000 containers, each 12 metres in length. If such a vessel were dedicated solely to our latest cordless machines, 4,335,000 extra boxes would be shipped thanks to lean packaging and logistics.



**5**

**Shipping**

As our machines get smaller and our packaging gets smarter, we can fit more into a shipping container. We also load directly into containers without the use of pallets. Consequently our container use is up from 70% in 2005 to 97% in 2013, reducing transport emissions per unit.

# Others look 'green'.

Just because a box is green, or a machine is branded with leaves, it doesn't mean there's anything meaningful inside. What counts is the technology. And not just whether it's energy efficient, but also whether it performs effectively. After all, what's the point in low consumption if it takes five times longer to clean – or it doesn't clean at all?

Over past decades the wattage of European vacuum cleaners has crept higher and higher – often exceeding 2,000 watts. In response to this, European Ecodesign legislation (introduced in 2014) places a 1,600 watt power limit on all domestic full-size vacuum cleaners. In 2017 this will drop to 900 watts.



2,400 watt

# Ours are lean.

Dyson has never used a vacuum motor bigger than 1,400 watts. And since 2008 we've been using motors half that power. Like in our DC24 and DC50 vacuums.

Dyson was the first vacuum cleaner manufacturer to campaign for lower motor wattage as part of the European Ecodesign legislation.

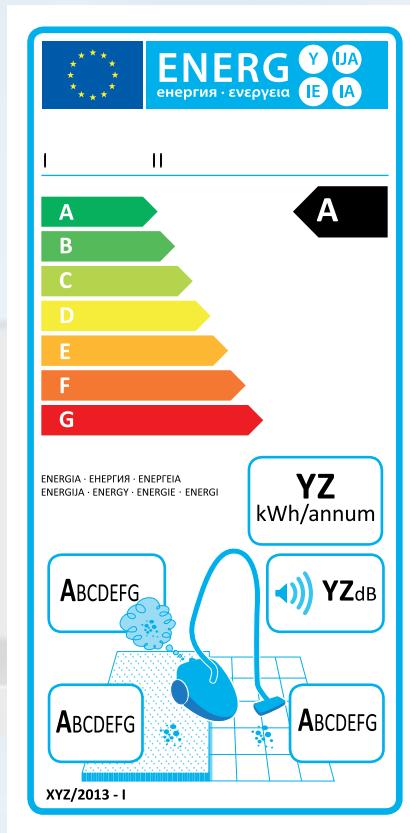


700 watt

# What Europe's Energy Label doesn't tell you.

## Ratings don't reflect real use

The Energy Label tests empty vacuums in laboratory conditions. But vacuums don't stay empty. Bagged vacuums lose suction as they fill with dust, so performance drops. Some machines even compensate by increasing power during use.



## Waste from bags and filters is ignored

The Energy Label doesn't take into account the environmental impact of consumables. In Europe alone, bagged vacuums generate 126 million bags to be disposed of each year – by landfill or incinerator.

## The Energy Label is under judicial review

In the meantime, to find a truly efficient vacuum, look beyond the label. At Dyson, efficiency goes much further than basic testing. It is defined by the relentless engineering of each component to perform well in real life conditions.

The European Commission's Energy Label for vacuum cleaners aims to make it easier for customers to identify the 'greenest' and most effective machines. However, because of the tests it uses and the way they're carried out, it fails to give an accurate indication of efficiency or performance.

Dyson machines are designed for their real life use in the home, not for their performance on a label. Take the Dyson Cinetic™ vacuum. We developed advanced cyclone technology. The rubber tips of 54 cyclones vibrate at high frequency to prevent clogging. The result is a machine that is so efficient at dust separation that it requires no bags and no filters to wash and replace.

Dyson Cinetic™ tips ensure highly efficient separation of dust from the air



# Wanted.

## Lean engineers to save the world.

Engineers create practical solutions to 21st century challenges, like population, air pollution and health. Big challenges require more engineers.

Yet with engineering and science suffering something of an image problem, more young people are gravitating towards the 'safe' professions of law, medicine and finance. Engineers risk becoming an endangered species.

The James Dyson Foundation is a registered charity that aims to reverse this trend by encouraging young people to solve problems with their hands and minds. To breed more lean engineers.

£35 million has been invested in this work to date. Each week, the Foundation visits schools and universities to lead design workshops and give young people a taste of what it means to be an engineer.

The Foundation also works directly with teachers, providing free resources like an "engineering box", packed full of machines to be disassembled and analysed, as well as ideas for lessons. 200,000 young people have benefited so far.

FOUNDATION  
JAMES  
DYSON



# The James Dyson Award

Every year the James Dyson Foundation celebrates the most promising student inventions with the James Dyson Award. The brief is deceptively simple: "Design something that solves a problem". Naturally, some of the best entrants have put sustainability centre stage.

## Airdrop. Edward Linacre. (2011)

Airdrop was a response to the huge drought gripping Australia in 2010. Inspired by the Namib Desert beetle which lives off the dew it collects on its back in the early mornings, Edward investigated low-tech atmospheric water harvesting solutions. And so came Airdrop.



## Safety Net. Dan Watson. (2012)

Overfishing is a global problem, particularly when juvenile fish are caught by industrial vessels. Safety Net proposes a solution: a series of LED-illuminated rings are fitted into the trawler net to allow young and unmarketable fish to escape. They use a kinetic energy harvesting system that ensures that the lights shine brightly, without relying on batteries.



## MOM. James Roberts. (2014)

According to the World Health Organisation, 75% of deaths resulting from premature birth could be avoided if inexpensive treatments were more readily available across the globe. MOM reduces this problem with a low cost, inflatable incubator for use in developing countries. Providing the same performance as a £30,000 modern incubation system, MOM costs just £250 to manufacture, test and transport to the desired location. James was struck by the fact that standard incubators are acrylic shells – they waste energy by not insulating properly. By designing his incubator to be inflatable, James makes use of a zero-cost, natural insulator: air.



## Bump Mark. Solveiga Pakstaite. (2014)

Best before dates are often inaccurate, leading to fresh food being thrown away. Bump Mark is a solution to the problem. The label consists of solid gelatine set over a bumpy plastic sheet. Gelatine decays at the same rate as protein-based foods. As the gelatine decays, it becomes a liquid and the bumps underneath can be felt. If the label feels smooth the food is fresh: if there are bumps the food has started decaying.

## Lean machines of the future.

The future holds some big challenges: a growing population, pressure on resources and the natural environment. The next generations of engineers and their ability to come up with ingenious and efficient solutions to difficult problems will have an important role to play.

With this in mind, James Dyson asked young Dyson engineers for their thoughts on the challenges Dyson should tackle over the coming years.

### Kyle

I am particularly interested to see how we can apply research into graphene to create new lean machines that are not currently possible with present technology.



### Chloe

We should develop batteries that promise better efficiency over long lifetime, creating more efficient technology and leading to more advances in design and engineering.



### Gary

Everything in your home with a plug or battery is full of inefficiencies. I'd like to see us make entire homes more efficient – making the design, manufacture and usage much leaner.



### Kevin

A major world challenge is water conservation. We can find new ways to tackle this challenge. How about a waterless shower?

\*In collaboration with the Carbon Trust, Dyson has produced a method to measure the environmental impact of electrical appliances and paper towels. The carbon calculations were produced using GaBi software provided by PE International, based on product use over 5 years and using the US as a representative country of use. Dry times for products were evaluated using DTM 769 to 0.149g of residual moisture.

JN.70488 16.02.15

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