The e-Mission.
Electric Mobility and the Environment.
Change is coming. But not only out on the road ... … but also in the way we think.

We are on a mission – an e-Mission, where “e” stands for electric. Electric mobility is on its way – electric mobility from Volkswagen. Electric powertrains hold the key to long-term sustainable mobility. Fleet trials have already been successfully completed. And the first volume-production all-electric vehicles of Volkswagen Group will soon be taking to the road. Volkswagen has designated 2013 the Year of the Electric Car. But getting an electric vehicle on the road is only one side of the coin. Electric vehicles from Volkswagen need to form part of an approach that takes a wider range of issues into account. Volkswagen stands for responsible business practices towards its employees, towards society and towards the environment. Ultimately, our aim is to become the world’s most eco-friendly automaker.

We are well aware that electric mobility is more than just a new form of propulsion. It is also one that will massively change the car as we know it, the way it is used and the way it is manufactured. New resources and materials will be required, from lithium for the batteries to neodymium for the electric motors. Production systems will have to be restructured and employees will have to be trained to work with new electric technology and components.

We are raising the bar substantially in terms of sustainability. In other words, we are facing an automotive sea change. Electric mobility is changing the way we think. We will have to think hard, for example, about fundamental questions such as: what raw materials and resources offer the best long-term prospects? What is the best way of minimising manufacturing emissions for electric components? And above all, how will the electricity to power the electric cars of the future be generated? And how will this affect the overall environmental footprint of electric mobility?

This brochure sets out our answers to many of these questions. Because we are not only looking to build electric cars. We will also be delivering responsible solutions that address the wider implications and infrastructure of electric mobility. Obviously an electric car is emission-free at the point of use. But for Volkswagen, the responsibility does not stop there. We are raising the bar substantially in terms of sustainability. Our aim is to ensure that electric mobility is carbon-neutral over the entire vehicle life cycle. In other words, targeting zero emissions is our e-Mission. The e-Mission is based on our life-cycle-oriented approach to environmentally sustainable product development, which is firmly anchored in our corporate principles. This approach highlights not only the more familiar environmental impacts of the car, but also the less obvious ones, impacts which at first glance might appear unrelated to the automobile and road traffic. Particularly at a time of far-reaching change in the automotive industry, this work throws up important and fascinating challenges, the most exciting of which are set out in this brochure.

Dr. Rudolf Krebs, Wolfram Thomas
»Electric cars run with zero emissions.«

But electricity doesn’t grow on trees.
Electricity has the power. But for electric cars, some kinds of power are better than others.

Wind energy is one of the big hopes of the future for electric vehicles. The annual output of a single 2-MW wind turbine would be enough to keep over 4,000 electric cars charged for a year, assuming an average annual mileage of 10,000 kilometres.

Electric cars are emission-free at the point of use. But how do things look when we trace the electricity back to its source? Do we even know where the energy we’re putting into electric cars comes from?

Some of us might simply say the electricity comes from a socket in the wall. And indeed, it can often be difficult to be more precise than that. After all, each country and region has its own generation mix. For example a typical compact-class electric car running on the average European electricity mix would emit 88 g CO₂ per kilometre. This is less than most combustion-engined vehicles, but not much less.

In China, it would emit 184 grams of CO₂ per kilometre, almost twice as much as a fuel-efficient diesel model. The same electric car charged at an average German household power socket would lead to CO₂ emissions of around 112 grams per kilometre. However, if that electricity was sourced exclusively from wind turbines, those emissions would fall to no more than one gram per kilometre.

For Volkswagen, therefore, it is clear that the goal must be to charge electric cars solely from regenerative energy sources. In China, it would emit 184 grams of CO₂ per kilometre. This is less than most combustion-engined vehicles, but not much less. In China, it would emit 184 grams of CO₂ per kilometre. This is less than most combustion-engined vehicles, but not much less.

In sum, to offer a truly eco-friendly solution in terms of overall emissions – and not just at the point of use – electric cars must be powered by electricity from renewable energy sources.

Volkswagen made green power available for the German fleet trials of the electric Golf in 2011/2012. This 100% renewable energy was sourced, for example, from hydroelectric power plants in the Alps. Certificates of origin for this power were issued by the TÜV NORD technical specification body. Audi AG is investing in an offshore wind turbine project in the North Sea. These turbines are currently generating around 53 GWh of power a year. This amount of power would meet the requirements of a medium-sized city for a whole year, or keep almost 30,000 electric cars running for 10,000 kilometres.

In future, e-cars could further assist the energy revolution by taking on an additional role as energy storage buffers. Wind energy, for example, is not always available when it’s needed. So cars recharged overnight with wind energy could feed back some of this buffered electricity. Volkswagen is working closely with partner companies and research establishments to develop appropriate solutions. In another approach to decentralized “swarm” power, Volkswagen EcoBlue combined heat and power plants could likewise be used as a way of meeting peak demand. These can be operated on natural gas or biogas, and can therefore make a significant contribution to reducing CO₂ emissions.
»So e-cars that run on green power produce no CO$_2$ at all?«

But they don’t fall from the sky either.
Zero-emission production.
The green factory.

The evening sun bathes the rooftop solar panels in a fiery red glow, as the wind rotates the wind turbines, rustles the leaves in the “energy-wood” plantation and ripples the surface of the rainwater retention basin. Sometimes there can be something almost romantic about a low-carbon factory.

Where does a circle begin and where does it end? The answer to this somewhat philosophical question is, of course: nowhere. The principle behind the perfect vehicle production system is exactly the same. Production is organised as a sustainable energy and resource loop. Every drop of water is recycled over and over again, almost endlessly. The energy used to power the production lines comes exclusively from renewable sources. And it is generated entirely on-site.

What might the low-carbon factory look like? Most likely the site would be planted with trees and bushes that would be used to produce biogas or as a heating feedstock. The rooftops would be studded with solar panels and the skyline with wind turbines. Because the model factory would not only consume energy but produce it as well.

So the goal for new factories of the future is clear: they must be resource-efficient, low-emission operations. But existing factories too offer huge opportunities for reducing emissions. They must simply be converted step by step to operate at similar levels of efficiency to a new factory. Of course, emissions reductions on this scale can only be achieved by adopting a holistic approach.

The Volkswagen Group has set a target of reducing carbon emissions from its factories around the world by 25% by 2018. In concrete terms, these cuts will relate to energy and water consumption, emissions and waste. For more information, see www.volkswagenag.com > The Group > Strategy.

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Energy strategy

Volkswagen is currently investing around €600 million in renewable energy expansion. The aim is to reduce the greenhouse gas emissions associated with our production-related energy supplies by 40% by 2020.

New low-CO₂ gas-and-steam power stations, for example at the Kassel plant, will be used to meet the energy and heating needs not only of Volkswagen factories, but of nearby residential areas as well. Use of solar panels can likewise bring big energy savings. For example the 318,000 square-metre solar panel system at the SEAT plant in Martorell will be used to meet the energy and heating needs not only of Volkswagen factories, but of nearby residential areas as well.

Pioneering plants

Thanks to state-of-the-art production processes and excellent site planning, the Volkswagen Chattanooga plant became the first and only automotive plant in the world to date to achieve platinum certification under the LEED (Leadership in Energy and Environmental Design) programme.

The Ingolstadt plant today recycles 95% of its metallic production waste. The Chemnitz engine plant recently received the ‘Factory of the Year 2011’ award from the German trade magazine “Produktion” and management consultants A.T. Kearney.

Environmental management

Environmental management systems are designed to ensure a continuous improvement in production-related environmental protection. Environmental management systems have been in operation at Volkswagen plants for many years. These systems are audited in line with the ISO 14001 standard. Virtually all Volkswagen Group sites are certified to this standard.

Environmentally compatible production technologies

Environmentally compatible production technologies used at Volkswagen include hot-forming. The technical objective here is to produce body components offering the same or even higher strength than conventionally formed steel components while at the same time using less material.

By reducing the weight of some components by as much as 36%, significant CO₂ savings can be achieved at the production stage too.

For more information, see www.produktion.de
A whole new electric ball game.
Green production of electric components.

The Volkswagen Beetle is the ultimate symbol of personal mobility. But we need only compare the manufacturing technology used to build Volkswagen Beetles in the 1950s with the technology used to build the Golf thirty years later to realise that automotive manufacturing is constantly reinventing itself. Now, a further thirty years on, we are heading for another massive transformation.

Electric cars have a battery instead of a fuel tank, power electronics instead of a gearbox and magnet-powered motors instead of pistons and crankshafts – and all these components require energy-intensive development, production and assembly.

The extraction of rare earth elements like neodymium, for example, is a highly energy-intensive process. That is why it is so important to step up the use of secondary (recycled) raw materials in order to conserve resources. Because at the current state of the art, battery production and the associated upstream processes account for around half of all CO₂ emissions generated in the manufacture of an electric vehicle.

Of course, technical progress never stands still. In future, new battery cell technologies with a higher energy density will reduce material consumption per battery – and at the same time improve the carbon footprint of battery systems.

However, manufacturing processes can only be improved on the basis of experience. Although electric mobility is widely considered a “revolutionary” technology, manufacturers and suppliers are wisely adopting an evolutionary approach.

Battery-related systems account for a large proportion of overall vehicle CO₂ emissions at the manufacturing stage. So we need to focus on the battery cells and the raw materials and processes that go into producing them. The associated emissions are largely due to the use of materials such as cobalt and copper, where the extraction process is highly energy- and CO₂-intensive.

It takes considerably more energy and resources to manufacture a battery system than to build a plastic fuel tank. However, we are working to improve this situation – assisted by joint ventures and research alliances with battery manufacturers.

Employee training
What must employees be aware of when working with high-voltage electrical systems on the e-vehicle production line? To equip them for their new tasks, Volkswagen employees are receiving comprehensive, ongoing skill training.

New qualifications are already being added to the existing range of occupational profiles at Volkswagen. Far from being just “passengers” on our journey into a low-emission future, our employees are also being encouraged to put themselves in the driving seat as change drivers.

Battery research alliances
Volkswagen Group Research is collaborating with Munster University to develop new types of battery cell for electric vehicles.

The Volkswagen-Varta battery research joint venture was set up to gain more manufacturing experience in this area. The aim is to develop extensive in-house expertise in the field of battery technology, leading in the long run to optimised electric vehicles and processes – not least in terms of their environmental footprint.

Electric drivetrain production in Kassel
At its Kassel plant, Volkswagen is setting up a new production facility for electric drivetrains. This facility will act as an international role model for more environmentally compatible and employee-friendly production. It will also serve as a hub for new materials, new processes and new products, every detail of which will be focused on resource-efficient design and vehicle manufacturing.

Battery production in Braunschweig
Since 2007, the Braunschweig plant has been the Volkswagen Centre of Competence for the development and manufacture of electric vehicle battery systems. Among other things, since 2010 it has also been home to the pre-production centre for the electric Golf.

Electric drivetrain production in Wolfsburg
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There is a well-known saying that when a butterfly flaps its wings on one side of the world, it can cause a hurricane on the other. To be sure, the reality may not be quite that dramatic, but we do indeed live in a connected world. It is not enough to take a local view or a regional approach when operating in a networked and globalised community, with suppliers across the globe.

Volkswagen has been implementing its “Sustainability in Supplier Relations” policy ever since 2006. This policy is based on four key elements:

• Sustainability requirements for suppliers, which all suppliers must read before submitting quotes;
• An early warning system for minimising risk;
• A transparent procurement process;
• A supplier monitoring and development process.

The first step, for all suppliers, is to complete a digital questionnaire. Expert teams at the individual Group brands and in the different regions evaluate the suppliers’ responses. The focus is on supplier development through dialogue. Because efforts to achieve sustainability can only be successful based on close cooperation to which all partners are firmly committed. Joint targets will help us in this quest, along with shared practices and procedures.

To further improve the environmental performance of our vehicles we have therefore made it mandatory, for example in VW standards 99000 and the Standard Components Specifications.

Our suppliers undertake to comply with VW standard 01155, VW standard 99000 and the Standard Components Specifications. They must also respect the following additional requirements:

• Creation and application of environmental management systems;
• Active dealing with ecological challenges;
• Avoidance of damage to health and the environment;
• Environmentally friendly waste disposal and recycling;
• Employee training in environmental protection.

Volkswagen and NABU

The purpose of the Internal Environmental Award of the Volkswagen brand is to motivate sustainable behaviour in the workplace. The award-winning solutions show that environmental protection has become a way of life for our employees and that their commitment goes way beyond the normal course of duty. The Award commends and pays tribute to the dedication and personal initiative of employees on matters relating to environmental protection, both at our German sites and at Group sites within Europe.

Raw Materials Analysis

Growth in e-mobility will lead to increased demand for a variety of raw materials used in vehicles, which could potentially create market shortages. „Raw Materials Analysis“ is a tool used by Volkswagen to assess the risks to its raw materials supplies. This early warning system helps to select the most appropriate technologies and safeguard long-term supplies. In order to obtain an early indication of corruption risks that could affect resource supplies, Volkswagen takes part in regular discussions and exchanges with the Extractive Industries Transparency Initiative (EITI).

Volkswagen and NABU

Over the course of more than ten years, Volkswagen and Germany’s largest environmental organisation, NABU (Society for Nature Conservation), have forged a unique form of cooperation. The aim of this relationship, in which mutual respect for the different interests and standpoints of our two organisations has been key to achieving a successful working partnership, is to raise public awareness of environmental and sustainability issues.

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In this networked and globalised world, we all share a collective responsibility for the conduct of our partners. Only by working together can we achieve our goal of sustainable personal mobility.

Seeing the bigger picture. Responsibility doesn’t stop at the factory gate.

It’s one thing to commit to sustainability in principle. And another to make it a daily way of life. Volkswagen has chosen the second route. And we are encouraging our suppliers and partners to do the same.
»But won’t old electric cars create a new waste problem?«

Raw materials are precious gifts – too valuable to waste.
And they all lived happily ever after.

Recycling provides raw materials for new e-mobility.

Extracting raw materials requires a lot of energy. Smart end-of-life vehicle recycling solutions enable these valuable raw materials to be recovered. This helps to conserve resources and reduce the carbon footprint of our products.

This is the point where the life cycle comes full circle. In other words, this is where a car ends one life and begins another. Today, when a vehicle comes to the end of its useful life, virtually none of it needs to be consigned to the scrap heap.

Ever-increasing market demand means that end-of-life vehicles are becoming an important source of raw materials. Electric vehicles in particular contain some of the most valuable raw materials of our times, such as cobalt, rare earth elements and other valuable metals. Recovering these materials at the end of the vehicle life cycle makes good ecological and economic sense, because materials such as cobalt can be reused time and again. And while a kilogram of cobalt has a relatively high carbon and energy footprint immediately after extraction, that footprint is reduced over the course of time when the cobalt is recovered by high-quality recycling processes, minimising the need for extraction of new material.

In this way, vehicle and component recycling provides a source of “secondary” raw materials. These replace primary raw materials, reducing the need for their costly extraction and transportation. In the Life Cycle Assessment, this recycling earns a credit whereby the reduction in future raw materials extraction is offset against the vehicle’s environmental footprint. So every gram of an end-of-life vehicle that does not have to be landfilled improves its Life Cycle Assessment.

Vehicle recycling with the Volkswagen SiCon system

Electric vehicles are too valuable to be simply scrapped at the end of their useful life. Not only the battery but the rest of the vehicle as well is a source of raw materials which must be put to good use. Consequently, recycling techniques are a focus of ongoing development work at Volkswagen.

One such technique is the Volkswagen SiCon process, which is used to recover raw materials from end-of-life vehicle shredder residues. With the aid of this multi-award-winning process, a 95% recovery rate can be achieved for end-of-life vehicles. Once the battery has been removed, the process is suitable for recycling e-cars too.

LithoRec – recycling lithium-ion batteries

Growth in electric mobility will result in increasing numbers of end-of-life lithium-ion batteries. Fortunately, high recycling rates are already achievable for the lithium, cobalt and other metals contained in these batteries.

The feasibility of such recycling has been demonstrated by the LithoRec project, in which Volkswagen is a partner. Tests have shown that around 90% of the battery’s raw materials can be recovered with the LithoRec processes – thereby helping to reduce dependence on imports of raw materials and ensure security of supply.
Strategic planning and implementation.

Taking a longer view.
Reducing emissions – the Volkswagen e-Mission

Even when it comes to something as simple as buying fruit in our local supermarket, we question its origin, name and weight. But what about when it comes to building cars? Here too every component comes from somewhere, and it comes complete with its own life story. The more materials go into making a car, the bigger the traces they leave behind. Only by continuously reasessing its products from every angle can a carmaker continuously improve their environmental performance. The instrument used for this purpose – the Life Cycle Assessment or LCA – is therefore based on the following three pillars.

Vehicle manufacturing

Raw materials extraction and vehicle production

The more efficiently raw materials are used, the smaller the volume of material that needs to be extracted. Manufacturing a vehicle involves installing a large number of different components, and the manufacturing pathways for all these components must be taken into account when calculating the carbon footprint of the finished product. The raw materials extraction and processing stage and the use phase account for the largest single fraction of a vehicle’s total life cycle CO₂ emissions.

Use phase

Energy pathways and driving emissions

When calculating the CO₂ emissions of its vehicles in the use phase, Volkswagen assumes an average lifetime mileage of 150,000 kilometres. A well-to-wheel analysis, which looks at the entire energy chain, allows carbon footprints to be calculated for a wide range of different fuels, or in the case of electric vehicles for a variety of electricity pathways. For combustion-engined vehicles, the use phase accounts for the largest single fraction of the vehicle’s total life cycle CO₂ emissions.

Recycling

Disposal, recycling and recovery of materials

The recycling stage is the point where one vehicle life ends and another begins. Recycling allows valuable resources to be reused, thereby reducing the overall energy consumption of the product.

Following the clues

Detective work is all about reconstructing events on the basis of the evidence left behind. And in the same way that human beings leave behind traces of DNA, so the consumption of raw materials always leaves a trail too, in the form of energy consumption and the resulting emissions.

The purpose of the Life Cycle Assessment is to follow up this trail. The Life Cycle Assessment identifies everything that went into the manufacture of the vehicle. This comprehensive analysis looks particularly at the environmental footprint of components, raw materials and raw material extraction processes. The detective work covers virtually the entire spectrum of materials used, from start to finish, which is why it is sometimes referred to as a cradle-to-grave analysis.

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Environmental Commendations

In its Environmental Commendations, the Volkswagen brand documents advances in the environmental performance of its vehicles across their entire life cycle. This guideline reflects Volkswagen’s self-imposed commitment to environmental protection. We have spelt out this commitment in our Group Environmental Principles Products – a commitment to the continuous improvement of our vehicles at every stage of their life cycle, with particular reference to climate protection, resource conservation and healthcare.

Think Blue.

Automakers have responsibilities – towards their customers and towards the environment. “Think Blue.” is more than just food for thought; it’s a state of mind. It’s a global call to action – sustainable ecological action. Electric mobility at the Volkswagen brand is inspired by “Think Blue.”

Audi balanced mobility

In its ambitious “Audi balanced mobility” initiative, Audi is exploring ways of achieving carbon-neutral premium mobility. The Audi brand also publishes Life Cycle Assessments for individual vehicles.
Vehicle development targets
A roadmap for the future must be based on targets. The Volkswagen “Group Environmental Principles Products” provide us with a clear sense of direction. These principles are a statement of our commitment to sustainable vehicle design. For a new form of mobility. For carbon-neutral mobility.

Group electric mobility strategy
This is an umbrella for all the strategically relevant activities relating to e-mobility in the various parts of the Group. The Group will soon put electric vehicles into production and aims to be the market leader in the field by 2018. An important aim of the Volkswagen Group is to ensure that electric mobility is carbon-neutral by using renewable energy sources. This underlines our commitment and sense of responsibility in respect of sustainability.

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Electric vehicle fleet trials
In the course of 2011 and 2012, the Volkswagen Group carried out numerous fleet trials, in Europe and around the world, in which electric vehicles from Audi, SEAT, Skoda, Volkswagen and Volkswagen Commercial Vehicles underwent intensive testing.

Fuel cell vehicles
Volkswagen is supplying a number of fuel cell vehicles to support the Clean Energy Partnership Berlin and California Fuel Cell Partnership demonstration programmes. The aim is to demonstrate the everyday practicality of this technology, using prototypes, and to gain important feedback for ongoing development work.

e-gas
Surplus wind power is used to generate electricity for electrolysis of hydrogen, which can then be used to power fuel cell vehicles. Alternatively this process can be taken a stage further and the hydrogen converted into “e-gas”, a synthetic methane gas. This gas is chemically identical to natural gas and can either be used directly to power internal combustion engines or can be stored in the public gas grid and then converted back into electrical energy.

Many roads lead to Rome.
The Powertrain and Fuel Strategy.

By offering not just one but a number of different vehicle concepts, it is possible to cater for different drivers and different requirements. Electric cars are no exception to this rule – and the electric vehicles of the future will continue to offer a wide range of individual choice. Since e-mobility solutions are initially aimed at meeting the needs of urban users, the product range will reflect the diversity of today’s urban society.

Different horses for different courses, as the saying goes. Just like conventional cars, electric vehicles will be able to meet many mobility requirements – but not all. This is no reason to be disappointed. After all, there are limits to the abilities of combustion-engined models as well.

Electric cars offer a driving range that is sufficient to cover most day-to-day trips. For long distances a plug-in hybrid is the appropriate solution. These run on their electric motor around town but on longer journeys the motor is supplemented by an efficient combustion engine. A further possible alternative for long-distance mobility would be fuel cell vehicles running on renewably generated hydrogen.

An important requirement in the field of personal mobility, particularly for urban users, is flexibility. At the same time, growing environmental awareness is paving the way for swift and widespread acceptance of alternative powertrain solutions. In Germany, plans are in place at national level to ensure a successful market introduction of electric vehicles. The government has announced a target of getting one million electric cars up and running on German roads by 2020. Since electric mobility will be phased in only gradually, however, for many years a variety of drive systems will continue to coexist side by side.

All Volkswagen powertrain concepts pursue the same target: to conserve fuel and energy, and in this way to reduce CO2 emissions and resource consumption. Use of SunFuel biofuels which do not compete with food production, and partial electrification of vehicle powertrains are among the ways in which vehicle CO2 emissions can be significantly reduced. Volkswagen is pursuing many different approaches to powertrain electrification. The aim is to offer the most appropriate vehicle concept for every individual mobility requirement.
The right solution for every requirement.

On the starting grid.

Electric cars are already a reality in the Volkswagen Group. In 2012 a limited-production all-electric model will hit the road, followed in 2013 by volume-production models. 2014 will see the Volkswagen Group launch plug-in hybrids, too, followed by a steady expansion of the e-vehicle product range in subsequent years. These vehicles will allow us to achieve significant long-term reductions in our fleet CO\textsubscript{2} emissions. And that’s not all. We are also pursuing an even more ambitious objective. Our mission – the e-Mission – is to build electric cars that achieve zero emissions across the entire vehicle life cycle. Volkswagen is on the way to fulfilling this mission and has already set the stage for the future. We are committed to renewable energy as this will enable us to radically reduce CO\textsubscript{2} emissions, not only during the vehicle use phase, but also at the manufacturing stage. In our efforts to build cars as resource-efficiently as possible, we analyse our resource pathways in depth. We are also researching advanced recycling solutions for electric components. And we are working closely with our suppliers to make electric mobility as environmentally friendly as possible at every stage in the production chain. We are training our employees for new tasks and are engaging and involving them in this journey into the automotive technology of tomorrow. And we are developing integrated mobility solutions in which cars and other modes of transport will work together in the quest for emission-free mobility. In other words, we are doing everything we can to make the electric car a true zero-emission vehicle. We are already on our way. The e-Mission has begun.

**The e-Mission:**

electric mobility with zero emissions over the full life cycle.
The Life Cycle Assessment (LCA) on which this brochure is based was independently validated by an expert panel comprising representatives of TÜV Nord CERT GmbH, Braunschweig University of Technology and PE International AG. The methods and data used in completing this Life Cycle Assessment conform to the requirements of standards DIN EN ISO 14040:2006 and DIN EN ISO 14044:2006. The facts and figures, LCA results and conclusions are valid and comprehensible.