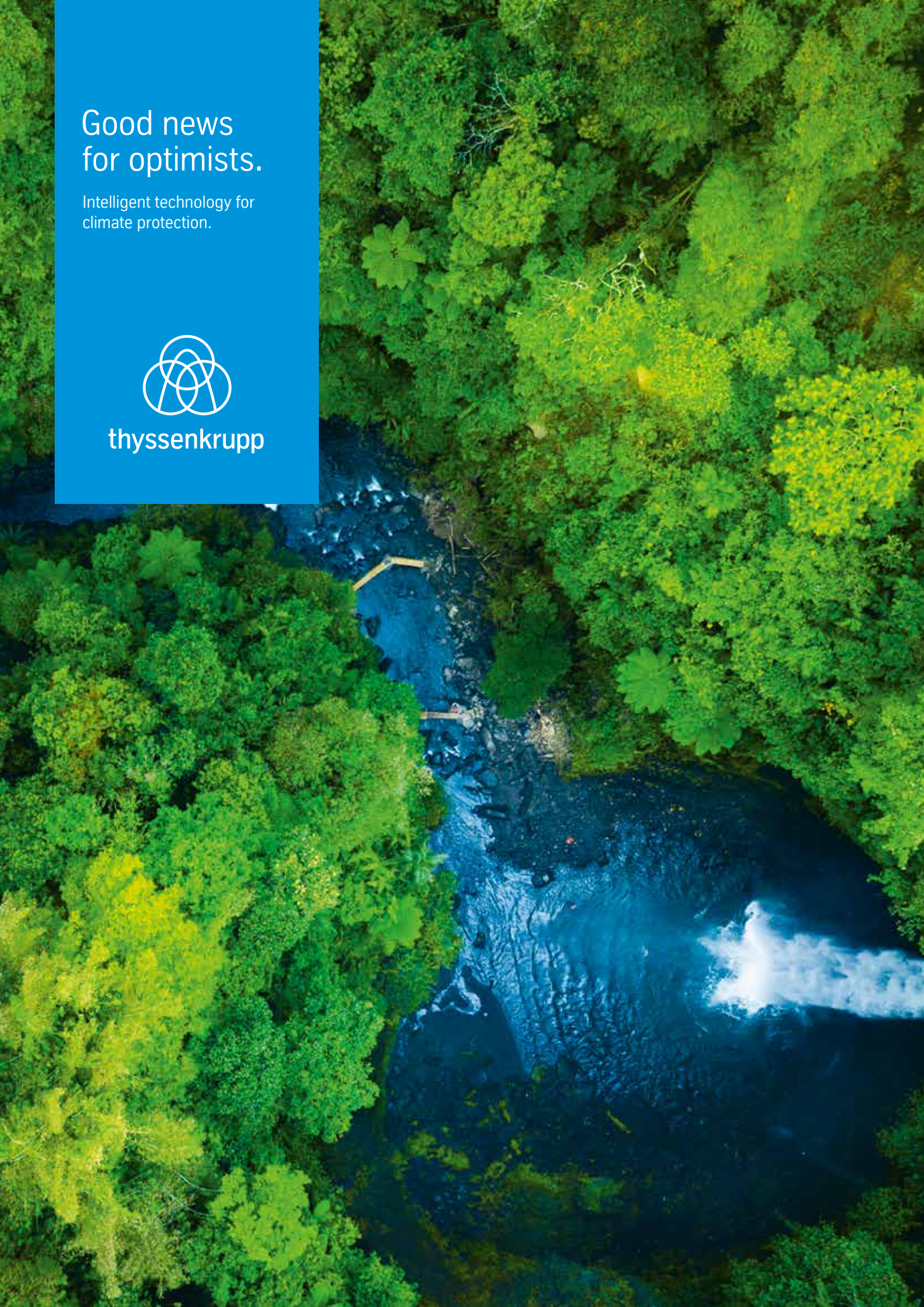
Good news
for optimists.
Intelligent technology for
climate protection.
thyssenkrupp

“Innovation is turning ideas into business success.”

Dr. Reinhold Achatz, CTO, thyssenkrupp AG

The climate goals are achievable – and technology will be the driver.

Thomas Fußhöller heads the Sustainability, Environmental and Energy Management department at thyssenkrupp. Markus Oles is head of Innovation Strategy and Projects. They closely work together on climate protection and believe that the target of net-zero emissions is achievable.

At the UN Climate Conference in Paris in 2015, the world agreed to reduce greenhouse gas emissions to net-zero in the second half of the century. They say that with today's technologies this is already possible. That's a bold statement, right?

Fußhöller: The Paris Climate Agreement of 2015 is a kind of turning point in the climate debate: away from absolute reduction targets for industrial countries only and towards a differentiated approach which permits compensations in places where emissions are unavoidable. In other words, what I emit in the future has to be removed from the atmosphere elsewhere. This is known as net greenhouse gas neutrality, net-zero for short. Carbon cycles play an important role here.

Oles: This is where technology comes into play: from a chemical point of view, CO_2 is just one of many possible carbon compounds. For industrial processes for example in the chemical industry, as well as in the energy and the mobility sectors, it basically has a role similar to that of carbon from coal, crude oil or natural gas. Some of the technologies used for industrial separation, conversion and utilization of CO_2 have been known for over 100 years. And that's why we say: net-zero is achievable under certain circumstances.

If that is true, the utilization of CO_2 would be sufficient to achieve climate neutrality. The decarbonization of the economy would no longer be necessary.

Oles: No, that's not true. Every year, over 50 billion tons of greenhouse gases are emitted. This huge amount cannot be eliminated solely by means of carbon recycling. It has to be a combination of reduction and re-use. In this respect the Paris Agreement is an excellent basis: Avoiding emissions is the main objective. At the same

time, it is accepted that there are unavoidable emissions and that these can be compensated. Complete decarbonization of the global economy, which is often discussed, is technically unfeasible.

Fußhöller: To develop concrete solutions, industries should analyze their carbon footprint closely. We've also done this at thyssenkrupp. And the results don't just apply to us: apart from own emissions from production, the focus is on the entire value chain. The use phase of the products usually accounts for a large share and represents an enormous lever for a carbon-neutral economy. Take the volatility of renewables, for example. Renewable energy is not available round the clock, seven days a week in the same amounts, because the wind doesn't always blow evenly and the sun doesn't shine for 24 hours a day. In the present energy system, supply is steered by consumption. In the energy system of the future the consumption will have to follow supply.

Oles: Organizations that manage this will have competitive advantages in the future. Many large industrial consumers, such as steel and chemical plants, are currently designed to run 24 hours a day, seven days a week, with the same level of capacity utilization. The challenge is how to combine this with the volatility of the new energy system.

What do you suggest? The complete transformation of industrial production?

Oles: Here again, the technologies are available and must be systematically advanced. For example, thyssenkrupp offers solutions such as Carbon2Chem, redox flow batteries and water electrolysis. These energy storage systems create power buffers to allow industrial processes to continue working when not enough renewable energy is available. In the future, energy storage systems will be an integral part of industrial plants. Processes which don't have to run continuously will be designed in such a way that they will produce whenever there is cheap and sufficient energy available. This will stabilize not only industrial production, but also the power grids.

Fußhöller: So net-zero is achievable under certain circumstances, and thyssenkrupp is actively involved in many of the required solutions. However, social conditions will still have to improve in order to implement certain technological solutions – for example, the construction of large wind farms, or storage capacities for CO_2.

Our climate protection efforts are recognized by external experts, too. CDP, a non-governmental organization, has ranked thyssenkrupp for the second time as one of the global leading companies in climate protection. We take this as a motivation for further improvement and good news for optimists.

"All our investments always have the same objective: a better future."

New ideas – the most important raw material for changing the world.

It always starts with an idea. But the idea alone is not sufficient – strength and expertise are also needed to implement it. We at thyssenkrupp are using our international resources and the engagement of our employees to develop innovative technologies for an environmentally friendly and CO_2-neutral industry. See for yourself how well this works.

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#1
Carbon2Chem®
Bringing industries
together. Making joint
use of resources

Carbon2Chem® – CO_2 as a raw material.

The objective of the Carbon2Chem project is convert steel mill gases into base chemicals – including the CO_2 contained in them. This means that the greenhouse gas is no longer emitted into the atmosphere. And: The energy required for the conversion comes from renewable sources.

This required a small revolution, but it was a success. We have overcome the boundaries between individual industries. The process gases from a steel mill become the raw materials for the chemical industry. The fact that thyssenkrupp is represented by 155,000 employees worldwide in many innovation-rich sectors plays a crucial role in the implementation. It means that we have experts in steel working alongside chemical plant builders. This is where the idea behind Carbon2Chem originated. A further 16 partners from basic and applied research as well as from various sectors of industry are involved in the project. The project is being funded by the Ministry of Education and Research.

Up to now, steel mill gases were combusted in order to produce electricity and heat for the steel making process. Carbon2Chem now places the gases at the start of a chemical production chain. This is possible because steel mill gases contain, among other things, hydrogen, nitrogen and carbon oxides, from which a large number of chemical products can be manufactured.

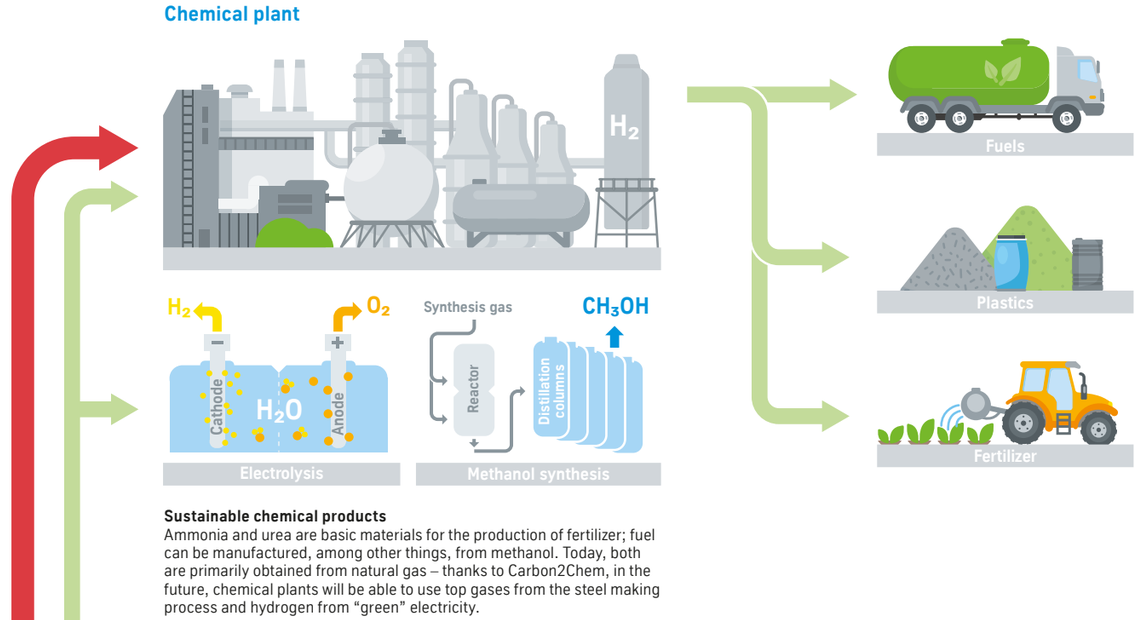
We have established a cross-industry network to use CO_2 as raw material.

Hydrogen serves as the energy source, which is partly already present in the steel mill gases. Further hydrogen is to be produced via water electrolysis using renewable energy. The processes in the steel mill will be modified so that a part of the steel mill gases will be diverted for the production of chemicals if cost-effective surplus electricity is available from renewable sources.

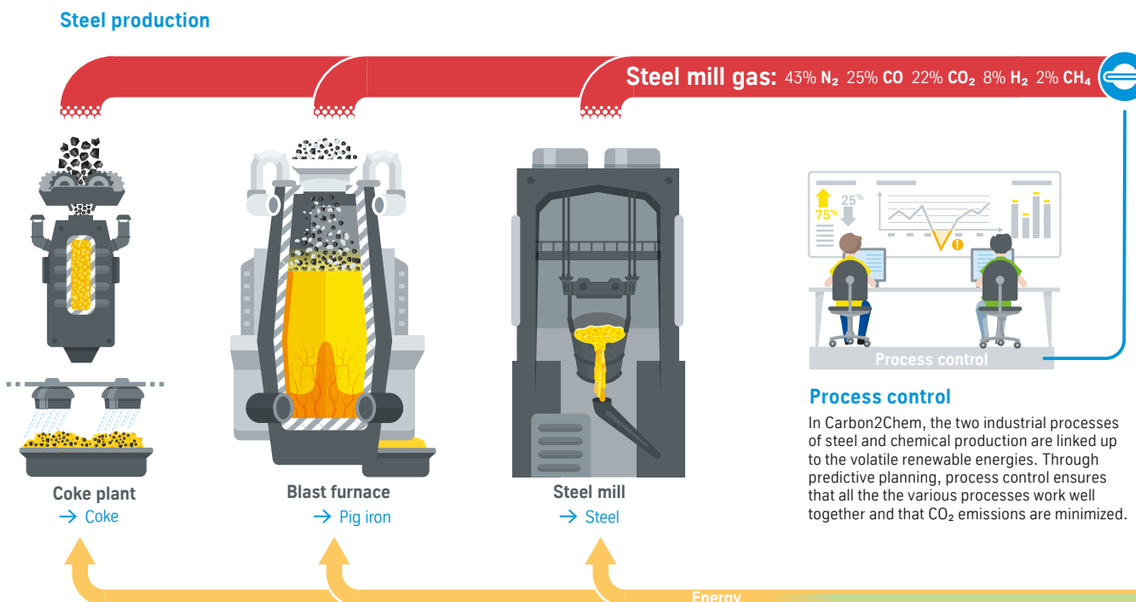
With 0.04 percent CO_2 only represents a small fraction of the air, but it plays a decisive role for the climate as a greenhouse gas: It absorbs a portion of the heat released by the earth into space and radiates it back.

If steel experts and chemical plant builders work together, they can produce something very useful for the environment. Steel mill gases become raw materials for the chemical industry.

Today, we use steel mill gases to produce electricity and heat for the manufacturing process.

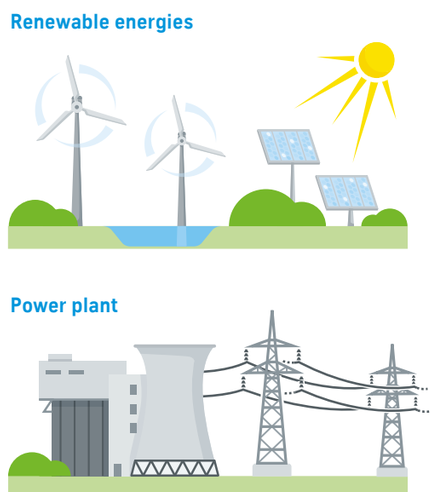


Sustainable chemical products
Ammonia and urea are basic materials for the production of fertilizer; fuel can be manufactured, among other things, from methanol. Today, both are primarily obtained from natural gas – thanks to Carbon2Chem, in the future, chemical plants will be able to use top gases from the steel making process and hydrogen from "green" electricity.



Process control

In Carbon2Chem, the two industrial processes of steel and chemical production are linked up to the volatile renewable energies. Through predictive planning, process control ensures that all the the various processes work well together and that CO_2 emissions are minimized.



Renewable sources of energy
Wind and solar power deliver the electricity to produce hydrogen by water electrolysis. Together with the steel mill gases, it forms the synthesis gas for many chemical products. Alternatively, however, the steel mill gases can also be used to generate electricity and heat for the production of steel.

It is no wonder that the prospects of success for Carbon2Chem are so good, because the fundamental chemical processes and the necessary technologies are well known. The conversion of process gases into ammonia and urea as precursors for fertilizer is technically, but not yet economically, feasible. This process would use part of the CO_2 contained in the steel mill gases. It would also be possible to generate methanol from steel mill gas, a process in which the CO_2 amounts present could be almost entirely used.
You can read about the background to this good news at:
https://www.thyssenkrupp.com/en/carbon2chem/

#2 Smart Energy Storage

Large amounts of energy.
Stored resourcefully.

Smart Energy Storage – energy revolution for the future.

The share of renewables in energy production is increasing, while costs are falling. The irregular nature of the supply of renewable energies means that efficient storage technologies are needed because electricity consumers depend upon regular supply.

Our solution for the stable supply of energy is the use of Smart Energy Storage Systems, which can close the supply gaps.

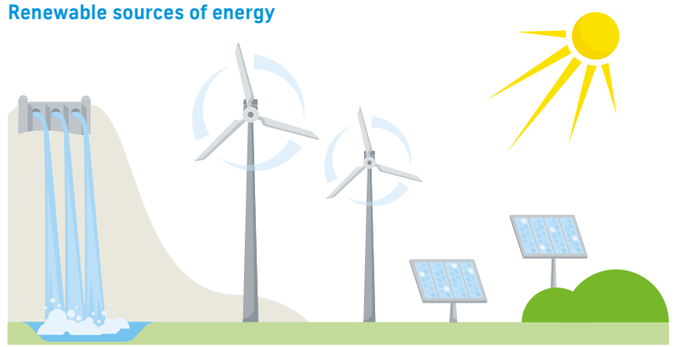
Our redox flow batteries are scalable in terms of storage and output and can therefore be adapted to the relevant needs. In this way several hundred megawatt hours of energy can be efficiently stored and immediately provided when ever required. By way of comparison: Onshore wind turbines have a typical output of two to five megawatts.

Industrial processes rely on a stable electricity supply without interruption or fluctuation.

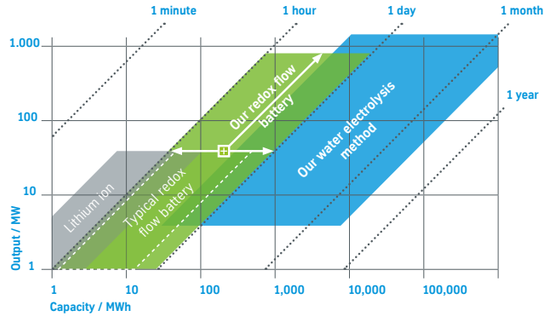
Wind and solar energy fluctuate due to weather conditions.

Batteries serve as intermediate storage systems in order to buffer fluctuations in the energy supply.

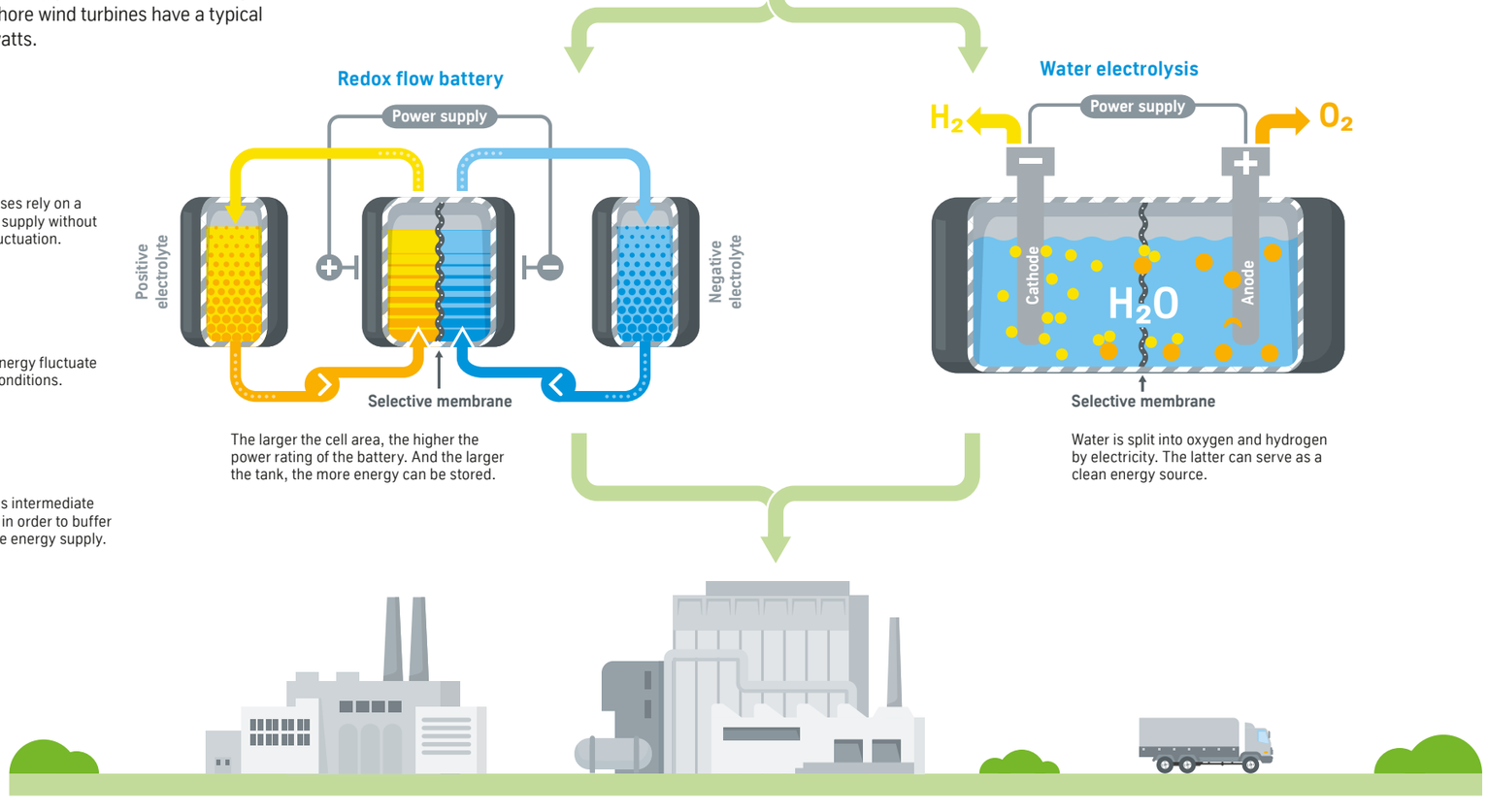
Renewable sources of energy



The wind and sun do not produce electricity consistently. This means that the amount of energy generated depends strongly on the weather.



(This diagram is symbolic and shows the principal relationships.)



The larger the cell area, the higher the power rating of the battery. And the larger the tank, the more energy can be stored.

Water is split into oxygen and hydrogen by electricity. The latter can serve as a clean energy source.

Redox flow batteries store energy in two tanks, which are filled with salts dissolved in liquid. The liquid flows through electrochemical cells, in which the charging and discharging reactions take place. The total active surface area of the cell determines on the maximum power output of the storage system. Our cells are the largest in the world, with a surface area of 2.5 m². The storage capacity can be varied by the size of the tanks. Redox flow batteries achieve an efficiency level of up to 80 percent.

Another large-scale technology is water electrolysis, which uses electrical energy to split water into hydrogen and oxygen. The hydrogen can be stored as an energy source and when required converted back into electricity, for example in fuel cells and gas turbines. It is also a raw material for the production of chemicals such as methane, methanol and ammonia. The efficiency level here is also up to 80 percent.

Two ways to aid the progress of the energy revolution.


#3
Oxyfuel
Our hottest idea for
cleaner combustion.

Oxyfuel – capturing CO_2 with oxygen.

Cement production is a highly energy-intensive process and, on its own, responsible for about seven percent of the worldwide CO_2 emissions caused by humans. And this despite the fact that, since 1990, the cement industry has done a great deal to reduce its emissions, for example by using alternative fuels and improving energy efficiency.

As a major point source of CO_2 emissions, cement plants are therefore especially suited to CCU (Carbon Capture and Usage) solutions. We have developed a solution for very effectively capturing of CO_2 in cement production: The Oxyfuel process, as it is called, is a combustion process in which clinker – a preliminary stage of cement – is produced from limestone. In our process, this is carried out with pure oxygen instead of the ambient air.

Since this means that no nitrogen enters the combustion process, highly concentrated CO_2 is produced. This gas is considerably easier to utilize than the exhaust gas from a conventional combustion plant.

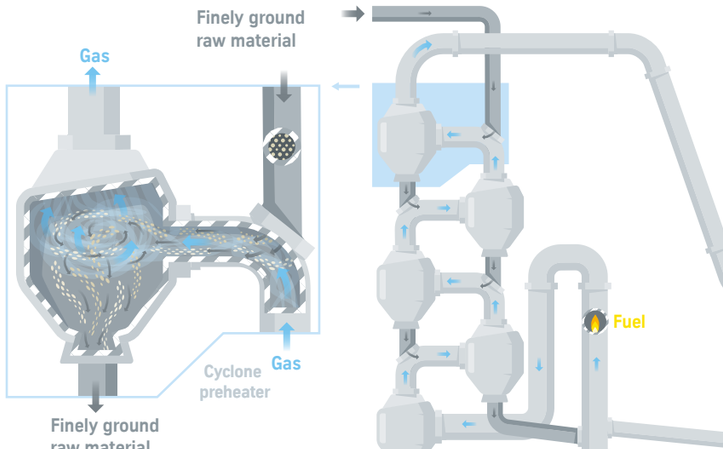
Around 60 percent of the CO_2 emissions from cement production are derived from the conversion of limestone to clinker. This percentage is unavoidable because it is emitted from the raw material and does not come from the fuel. When it is collected and subsequently converted, the CO_2 does not enter the atmosphere and cannot produce climate-damaging effects.

A further advantage of the Oxyfuel technology is that the necessary equipment can be retrofitted in existing cement plants. An argument which should not be underestimated when you consider that such plants are normally designed for a lifetime of 30 to 50 years.

Cement production causes 7 percent of worldwide CO_2 emissions – Oxyfuel technology massively reduces these emissions.

In Oxyfuel technology, the combustion process operates with pure oxygen instead of air.

CCU solution: Carbon Capture and Usage CO_2 is firstly captured and then used.

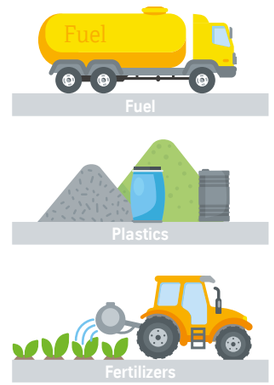


Oxyfuel technology

Oxyfuel technology is based on the principle of combustion with pure oxygen and recirculation of the flue gas. This means that CO_2 can be enriched in an amount which enables relatively simple purification by liquefaction systems. If Oxyfuel technology is completely implemented, theoretically almost all the generated CO_2 can be captured.

CO_2 recycling

Using different processes, CO_2 can be converted into valuable raw materials, for example for chemical products.



Cement production.

Global demand for cement continues to grow. Thanks to thyssenkrupp's Oxyfuel technology, CO_2 emissions from cement production can be considerably reduced by process improvements.

So environmental protection does not have to wait for the construction of new plants.


#4
EnviNOx®
How greenhouse gas
vanishes into thin air.

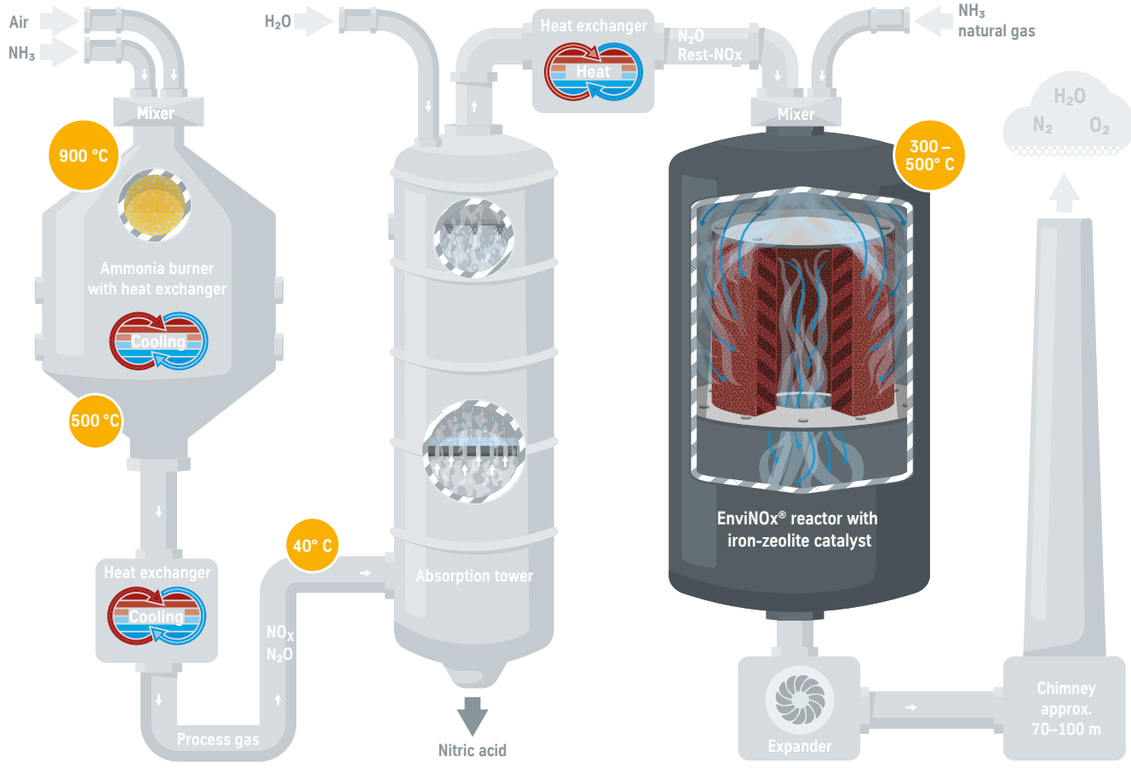
EnviNOx® gets nitrous oxide under control.

Nitrous oxide is approximately 300 times more harmful to the climate than CO_2. The substance with the chemical molecular formula N_2O occurs naturally in the earth's atmosphere, but only in trace amounts. If it appears in higher concentrations, it absorbs the heat that would otherwise radiate into space and thus contributes to global warming.

Large amounts of nitrous oxide are produced, for example, in the production of nitric acid. This is an important base chemicals for the production of fertilizers, for example. More than 400,000 tons of nitrous oxide a year are generated when producing nitric acid. This equates to around 130 million tons of CO_2.

Nitric acid production

EnviNOx technology comprises a catalytic reactor which is installed in the exhaust gas flow and reduces NO_x and N_2O emissions to very low levels.



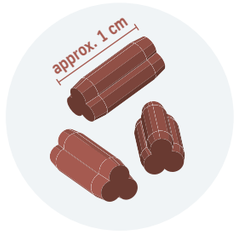
Nitrous oxide is converted to oxygen and nitrogen via a catalyst at temperatures between 400 and 500 degree centrigrate.

In the first step N_2O is converted into oxygen and nitrogen.

At the same time, nitrogen dioxide can be absorbed in water.

Nitrous oxide is around 300 times more harmful than CO_2 – every reduction helps enormously.

Iron-zeolite catalysts

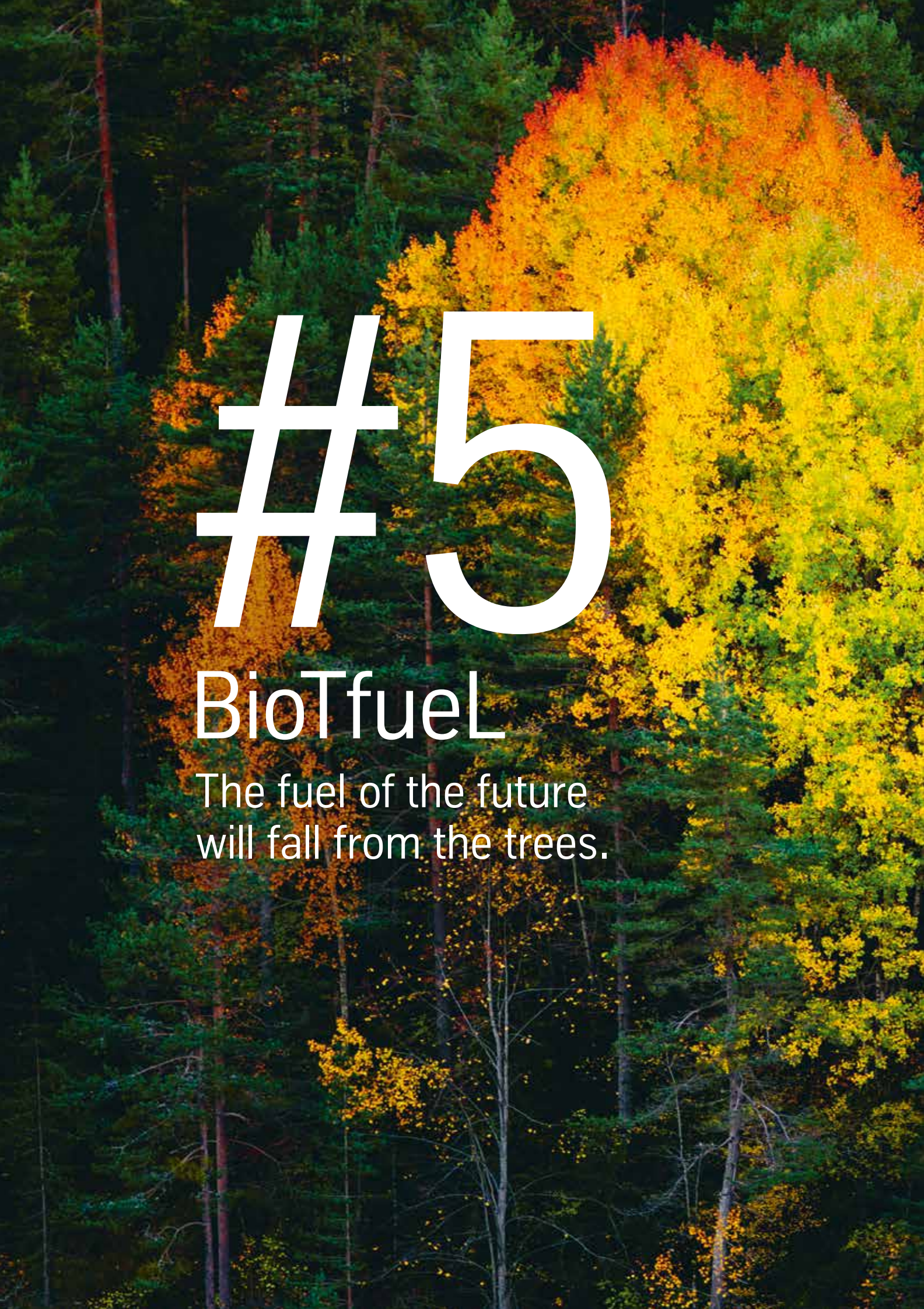


The core of the procedure is the catalyst which is made of zeolites. In the crystal lattice of the zeolites iron is integrated via ion exchange process.

With our EnviNOx process, nitrous oxide can be almost completely removed from nitric acid production.

Through the catalytic reaction the N_2O in the exhaust gas can be converted into its non-toxic components: nitrogen and oxygen. If a reducing agent, such as ammonia, is added at the same time, the nitric oxides contained in the exhaust gas are converted into water and nitrogen. Around 30 EnviNOx systems around the world now achieve savings of approximately 20,000 tons of nitrogen oxide and approximately 56,000 tons of nitrous oxide.

A further benefit: Anyone wishing to use EnviNOx does not have to build a whole new plant. The exhaust gas purification can simply be integrated at the end of the nitric acid production process – a small step for the plant operator and a large step for the climate protection.


#5
BioTfueL
The fuel of the future
will fall from the trees.

BioTfueL – biomass becomes sustainable fuel.

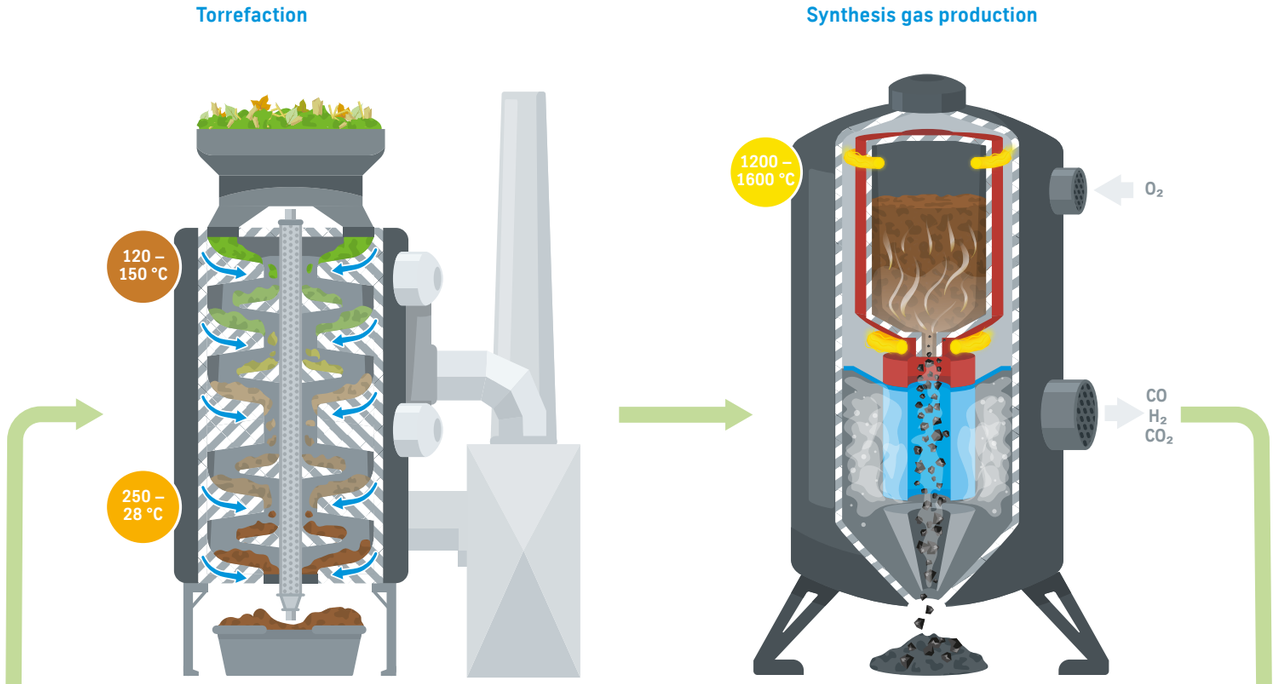
EU legislation requires that the share of renewable energy in the transport sector must increase. Biofuels will play a major role in reaching this target. Fuel from biomass is particularly environmentally friendly if the starting material is waste products such as straw, cut grass, plant and wood residues or rapidly renewable energy cropss, i.e. biomass which is not in competition with food. That is the case with BioTfueL: In this process, together with European partners, we produce climate-friendly biodiesel and biokerosene. These 2nd generation biofuels are particularly high-quality and save up to 90 percent of CO_2 emissions in comparison with conventional fuel. BioTfuels can be used directly in conventional diesel engines in cars, trains and ships, as well as in airplane engines.

To produce fuels by the BioTfueL process, biomass is first, dried, roasted and ground. In a gasifier developed by thyssenkrupp, the synthesis gas is then produced from carbon monoxide and hydrogen: the finely ground biomass is blown in together with oxygen – but only using just enough oxygen to stop the mass from combusting. At 1,200 to 1,600 degrees Celsius, only partial oxidation takes place: Carbon monoxide is produced instead of CO_2, and hydrogen instead of water. And carbon monoxide and hydrogen are the basic materials in he production of biofuel. The energy for the process comes from the biomass itself, as it does for the earlier drying and torrefaction.

At the end of the procedure, the desulphurized and purified synthesis gas has to be converted into biodiesel or biokerosene. And then the mobility of tomorrow can begin: with renewable energies and much less CO_2.

The production of biofuels must not be at the cost of food cultivation areas.

2nd generation biofuels can save up to 90 percent of CO_2 emissions.

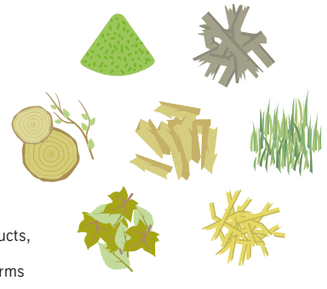


Roasted on a low flame: The biomass is dried, roasted in a similar way to coffee and then finely ground.

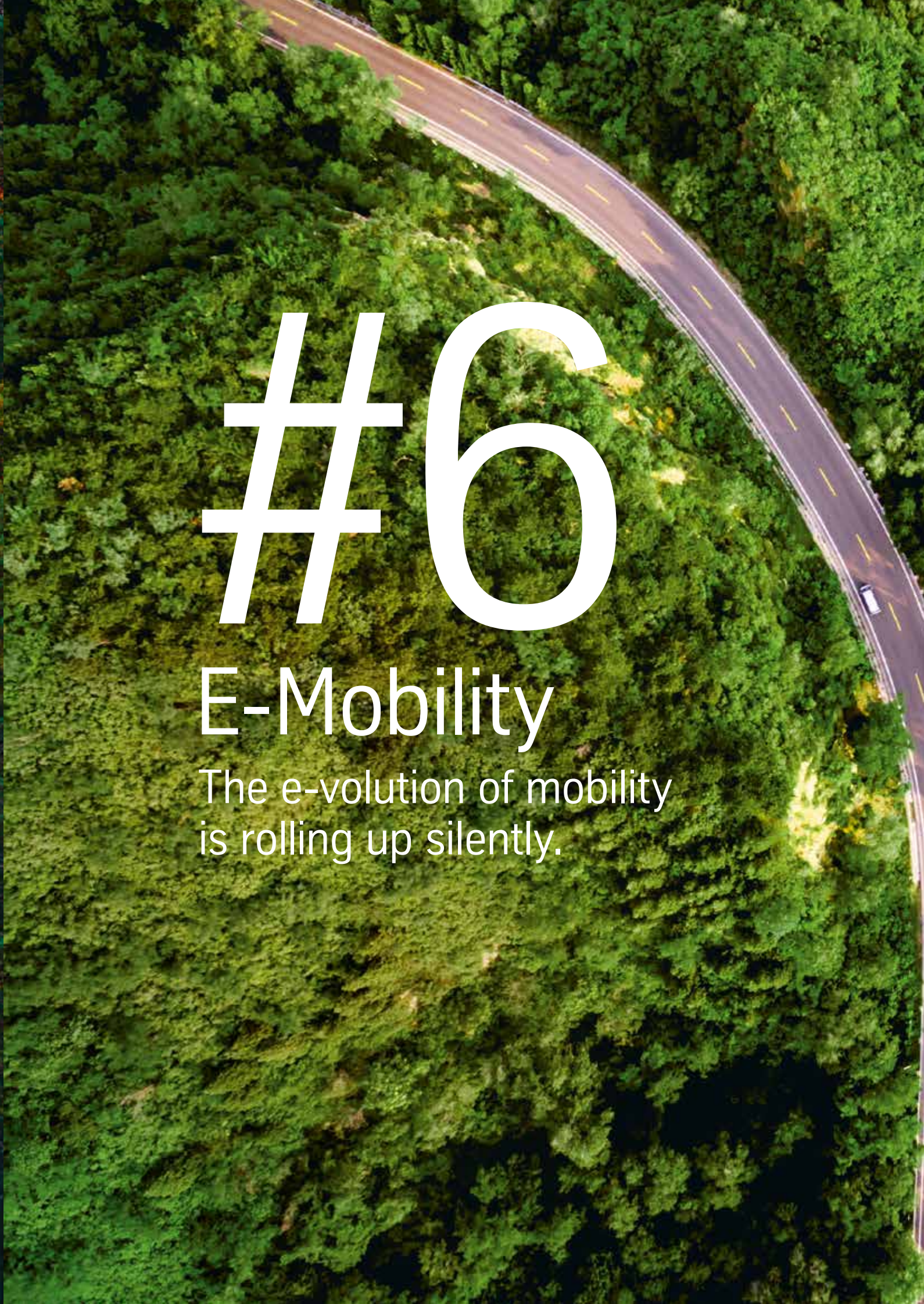
The biomass is injected together with oxygen – but without burning it.

At the end of the procedure, the purified synthesis gas is converted into biodiesel or biokerosene.

Starting material



For some waste products, for us a valuable raw material: Biowaste forms the basis for BioTfueL.


#6
E-Mobility
The e-volution of mobility
is rolling up silently.

Increasing battery capacity while reducing consumption.

There are two key factors in e-mobility which are key to vehicle range: the battery storage capacity and the efficiency of the electric motors. The more energy is available, the higher the range, and the more economically energy is used, the further one can drive.

This is why we are working on both factors simultaneously: on the one hand, we are using our leading position in automotive plant construction to perfect the battery assembly technology. And on the other, we are using special steels to improve the efficiency of the electric motors.

Together with partners from research and industry, we are developing a new generation of battery cells with a revolutionary design. Instead of many encapsulated components with complex connection technology, in the future it will be possible for a large sandwich structure to supply the energy for the vehicle.

The sandwich structure not only saves space, it also greatly reduces the amount of cost-driving connection technology required. This could reduce production costs by up to 100 euros per kilowatt hour. At the same time, the energy density could increase to double the 250 watt hours per liter of battery volume which are normal today – with corresponding effects on the range. In the consortium, we are responsible for the production technology of the innovative cells.

The electric drive offers as much potential as the battery, since special soft-magnetic steels form the core of every electric motor. We have developed our special steels for automotive hybrid and electric motors so that the efficiency of the motor and thus the range of the vehicle are significantly improved. Enhanced electromagnetic properties form the basis for this.

We are developing the e-mobility of the future.

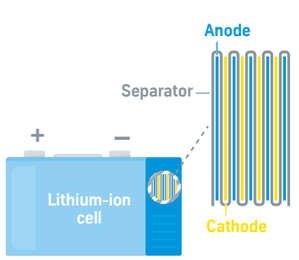
Technology leadership success factor

Our "TechCenter Battery Technology" uses a pilot plant that is fully functional and open to different types of technology. We can test all the processes of battery production here. The "TechCenter Battery Technology" is designed as a co-operative platform where work can be carried out in exchange with industrial and scientific partners.

Factor number 1 for more range: more battery capacity.

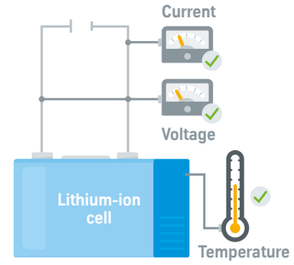
Factor number 2: consume less energy and drive further.

The result of research into batteries and motors.



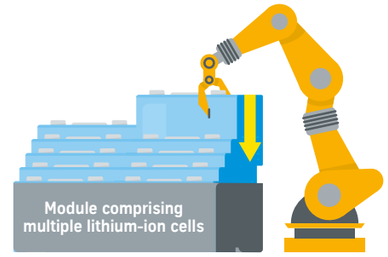
Cell assembly

The production of the battery cell presents a great challenge. The mechanical processes used for this are demanding, since these processes not only have to run automatically and fast but also with the highest precision.



Formation

Then the battery cells are formed – this means that they are completely charged and discharged again for the first time. During the first charging and discharging cycles, formation processes occur in the cell which have a decisive influence on the further cell behavior and on the cell properties.



Module assembly

A battery consists not only of one cell but of many which are coupled together in order to provide the necessary energy to run a vehicle. This is why several cells are combined into modules.

Battery test

It sounds so simple, but it's a complex process – the wiring of the modules and connecting of the cells has to be carried out extremely carefully in order to avoid short circuits and achieve maximum performance. This is meticulously inspected in the subsequent quality control.

Battery assembly

The next step is to join the modules together to make the final battery. thyssenkrupp production technology expertise helps to further automate this process.

More energy efficiency

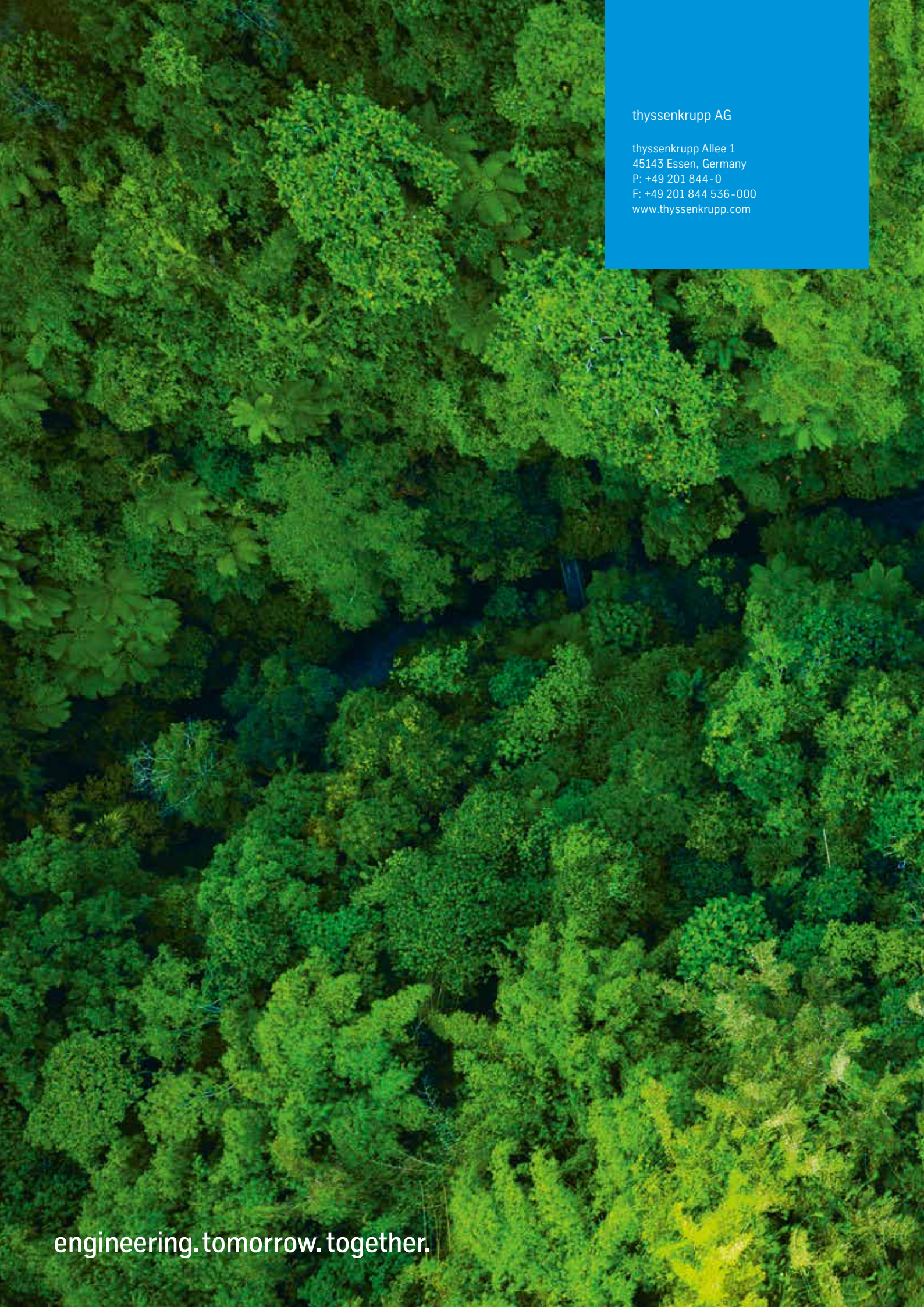
The efficiency of the motor can be enormously increased using highly efficient electrical steel.

More range

More storage capacity at lower costs: thyssenkrupp contributes with production expertise.

“Anyone who understands but does not act has not understood.”

Josef Jenni, Swiss solar pioneer



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