KUKA

Decarbonization

The next industrial revolution

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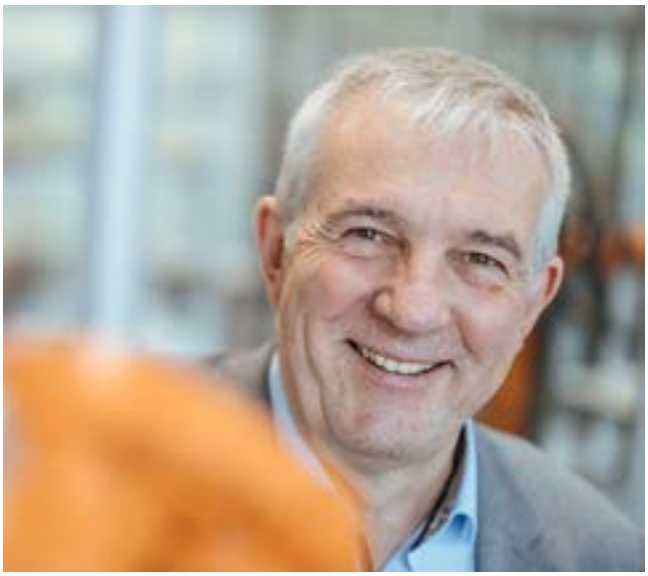
Decarbonization in all its forms has been on our minds for a long time. But the big upheaval is yet to come, especially in manufacturing industry. In this white paper, you will learn what will change in the near future and what challenges and opportunities will await us.

The big picture of decarbonization



Dear Readers,

We are facing a massive upheaval! To finally make significant progress in the energy transition, we need to move away from fossil fuels across all sectors and use renewable energy sources instead.
And we would rather do it yesterday than tomorrow. This change will not only change how we drive cars in the future but will also shape the way we live and produce.
The key word is decarbonization. It refers to the industrial strategy that leads to less and less CO_2 being emitted and ultimately to CO_2-neutral operations. However, decarbonization can only succeed if everyone works together on it, above all the players in manufacturing industry. It is not for nothing that we refer to this transformation as the next industrial revolution. Because one thing is clear: No stone will be left upon another!

As a storage solution for regenerative energy, the battery is a key technology in this process that cannot be bypassed. Not in the vehicle and certainly not in industrial production. We must not forget: Electromobility is only the tip of the iceberg in all of this, and we need to understand the big picture as quickly as possible and include it in our planning. Because climate change does not wait.

With this white paper, we are particularly targeting companies that are open to new things and are interested in how they can transform their processes so that decarbonization succeeds. KUKA brings 125 years of experience to the table, and as a partner we want to take the necessary steps together with the companies in the industry. Because the transformation, which is so urgently needed, cannot succeed on its own.

Let‘s make an important contribution to the energy transition together!

Your Dr. Joachim Döhner
Senior Director Business Development & Strategy Battery, KUKA Systems GmbH & Chairman of the Board VDMA Battery Production Department

On the way to net zero

Why is all this so important? Quite simply because it‘s about our future and that of future generations. The path to net zero is still a long one and is influenced by many different factors.

One fifth of the total CO_2 emissions in Germany is attributable to industry. At 28 percent, the „iron and steel“ sector accounts for the largest share of this.[1]

More than **a quarter of** global primary energy consumption can be covered by renewable energies by 2030, according to experts.[5]

Half of the world‘s largest companies have already set their own decarbonization targets.[2] So the willingness to change is there.

837.451 megawatts of wind power had been installed worldwide by the end of 2021. China is in first place, followed by the USA and Germany.[6] The potential is there.

Greenhouse gas emissions are to be reduced by at least **55%** by 2030 compared with 1990 levels – this is a first step in the European Green Deal, in which 27 EU member states have pledged to become climate-neutral by 2050.[3]

Around **two thirds** of the final energy consumption of industry is required for process heat. Mechanical energy, for example for motors or machines, accounts for around a quarter of consumption.[7]

At **6.3%,** there was still a sharp increase in gloabal coal consumption in 2022 in global coal consumption.[4] In Asia, the plus was 8.9 percent, and in Europe 2.3 percent, compared to the previous year. It should have been clear long ago that this is not the right way to go.

With around **3.5 million** units installed, the number of industrial robots worldwide in 2022 has reached a new record. A thoroughly positive development. According to the International Federation of Robotics (IFR), robots make a significant contribution to energy-efficient production.[8]

1 www.regionale-industrieinitiativen.de/data-fact/dekarbonisierung-the-german-industry; 2 www.rolandberger.com/de/Insights/Publications/Mehr-Tempo-bei-der-Dekarbonisierung.html; 3 www.destatis.de/Europa/DE/Thema/GreenDeal/GreenDeal.html; 4 energiestatistik.enerdata.net; 5 www.unendlich-viel-energie.de/themen/politik/weltweit; 6 www.wind-energie.de/themen/numbers-and-facts/international; 7 www.umweltbundesamt.de/daten/energie/energieverbrauch-nach-energietraegern-sektoren#entwicklung-des-endenergieverbrauchs-nach-sektoren-und-energietragern; 8 ifr.org/downloads/press2018/EN-2023-FEB-16-IFR-press-release-5-top-trends_-_corr.pdf.

The next industrial revolution

Decarbonization, moving away from fossil fuels and toward renewable energy sources, will change manufacturing industry and many other areas of our lives forever. It has long been clear that there is no way around it.

Whether it was the steam engine in the mid-18th century, assembly line production at the beginning of the 20th century or the spread of computers at the end of the 20th century: inventions and new developments have brought massive changes and upheavals and are not considered industrial revolutions for nothing. The inevitable need for decarbonization will now bring another significant step and raise industrial manufacturing to a new level.

The success of the first industrial revolution has resulted in annual global primary energy demand growing from around 8,000 TWh to around 160,000 TWh over the past 150 years.[9] For a long time, most energy was generated by burning fossil fuels such as coal, oil, and gas. But various developments in recent years have clearly shown that this form of energy generation cannot continue. Decarbonization – the switch from fossil fuels to CO_2-neutral and renewable energy sources – is inevitable.

That is why there is no way around decarbonization:

1. Today, the CO_2 concentration in the atmosphere is already about one third higher than ever before. In the 800,000 years before the first industrial revolution.[10] Experts agree that this is the main cause of the observed global warming and climate change.
2. The available fossil resources are not unlimited: To date, a good third of the world's coal reserves, roundabout 40 percent of its gas reserves and just under half of its oil reserves have already been consumed.[11] If the use continues as before, resources could last for a total of about 50 years (coal is expected to last even longer than 100 years), although extraction will become increasingly difficult, expensive, and environmentally damaging.
3. Raw materials such as crude oil and gas are too valuable to simply burn them. For example, crude oil is needed to produce fibers, plastics, and lubricants, while gas is important in the chemical industry for the production of ammonia.

These three reasons alone show: The move away from the use of fossil raw materials for energy – decarbonization – and its substitution by regenerative energies is unavoidable. And this must affect all sectors and industries, not just the automotive industry. After all, the entire global road transport sector currently accounts for only about half of petroleum consumption, and fossil primary energy sources account for less than 15 percent of consumption overall.[12] The impact of ongoing decarbonization will therefore also massively affect and change other sectors, including:

- Sustainable manufacturing and production processes
- New technologies for the generation, storage, and distribution of energy
- Power grids and network structures
- The role of oil and gas states
- Interests of multinational energy companies

9 ourworldindata.org/grapher/global-primary-energy; 10 climate.nasa.gov/vital-signs/carbon-dioxide; 11 ourworldindata.org/grapher/years-of-fossil-fuel-reserves-left
12 www.iea.org/reports/key-world-energy-statistics-2020/final-consumption and ourworldindata.org/grapher/global-primary-energy

Batteries as a key technology of decarbonization

To be able to use more electricity generated from renewable sources, storage technologies are indispensable. This is where batteries come into play, making them a key technology for decarbonization.

Electrical energy plays an important role nowadays and life would be almost unimaginable without it. We use it for lighting, computers, and the internet, we can heat with electricity, operate medical equipment, and move around. And of course, electricity is also used in industrial production in particular. But the proportion of electricity generated from renewable energy sources is still low in global terms. Although it has risen from 19 percent in 2000 to 28 percent today,[13] at the same time the consumption of fossil fuels for power generation has continued to increase.

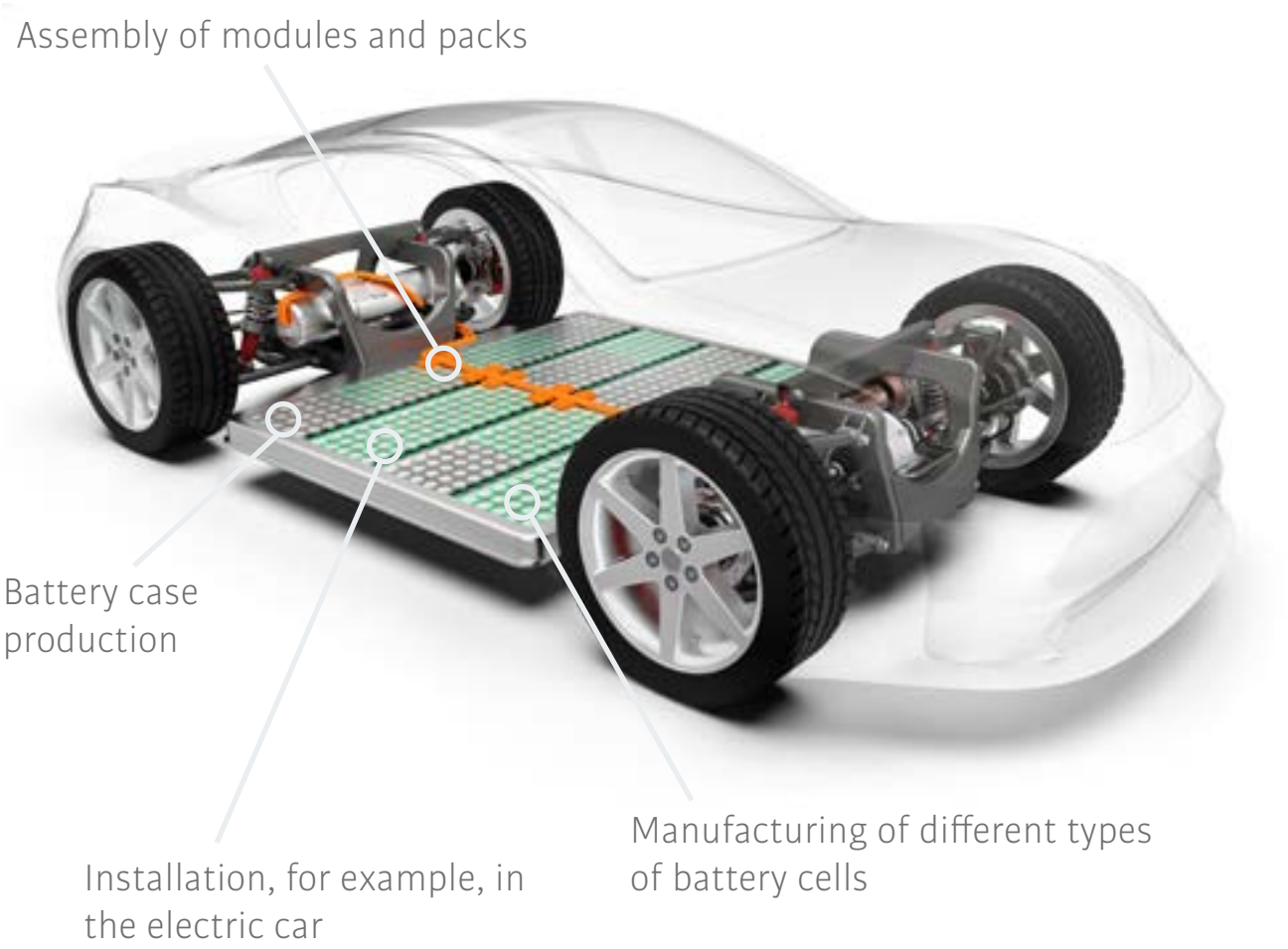
Between supply and demand

What are the causes? A challenge in the use of renewable energy sources such as hydropower, wind energy, photovoltaics, or biomass, which are mainly used to generate electricity: While material-bound fossil energy sources such as coal, oil and gas can be easily stored and flexibly used only when needed, an electricity grid must always maintain a balance between electricity feed-in and electricity consumption. But renewable energy contributions occur when the wind blows or the sun shines – and not necessarily when the energy is needed by the consumer. To achieve a balance between electricity supply and demand at all times, electricity storage systems are needed that can quickly, flexibly and scalable absorb electrical energy and also feed it back into the grid. Lithiumion batteries are ideally suited for this purpose and are thus becoming a key technology for the large-scale use of renewable energies and thus for decarbonization itself. Among other things, decentralized storage systems play an important role here, such as the storage unit at home next to one‘s own photovoltaic system. But it‘s not quite as simple as that: While batteries are currently good at storing energy for a few days in the short term, other storable, renewable energy sources, such as H2 or e-fuels, are also needed for longer storage periods – between summer and winter, for example – or for transport over long distances.

The role of electromobility

Of course, the topic of electromobility is also part of this planning and discussion. For any form of electric drive that

Possibilities of automation in battery production



is not continuously connected to the power grid the required energy supply must be carried along – in rechargeable batteries, for example. In addition to electric cars, this applies to commercial vehicles, off-road vehicles and construction machinery, marine applications, aviation applications and much more. Electric passenger cars may be the largest and most important segment in the public perception. However, other areas, such as commercial vehicles and stationary storage, are experiencing much higher growth rates. Here, continuous use often allows economically attractive business models.

The right storage for the right purpose

Not all batteries are the same. The designs differ – depending on the intended area of application – both at cell level and at module and pack level. Requirements that are often contradictory mentioned: Weight versus costs, energy density versus power density, cycle stability versus fast-charge capability, and intrinsic safety and raw material availability. The battery is thus changing more and more from a standard component to a strategic core element of the energy transition, where its own competencies, design and manufacturing capabilities are becoming increasingly decisive in securing its future viability. Of course, other technologies such as bio-fuels, hydrogen, heat storage and others also are important in order to adequately cover all relevant fields. Nevertheless, batteries in all forms and variants are essential for the success of renewable energies and thus of strategic relevance for sustainable participation in the path to a CO_2-neutral future.

13 ourworldindata.org/grapher/electricity-prod-source-stacked

The Big Picture: Electromobility is just the tip of the iceberg

Electromobility can only play its part in climate protection if it uses renewable energies. And even then, it is only one of many building blocks of the strategy on the way to CO_2 neutrality.

In the public perception, electric cars are seen as the great opportunity to stop climate change. From 2035, no more internal combustion vehicles are to be manufactured in the EU. The U.S. state of California, among others, also wants to ban the sale of internal combustion vehicles from 2035. However, the best electric car will not help the climate if the electricity for driving is generated from lignite. Because then the CO_2 balance is actually worse than a conventional combustion engine. To avoid this, three important aspects must be reconciled for mobility, but also for industrial and private energy use:

- **Energy generation:** The amount of renewable energy must match the amount used on the consumer side.
- **Energy distribution:** The spatial and temporal distribution of renewable energies must match consumption.
- **Energy use** Consumers must be able to use energy in the form that suits their individual needs. .

Far-reaching changes necessary

To ensure this in the long term, technologies, infrastructures, and business models must be rethought and, in some cases, replaced. The changes to be expected in this process are very diverse and far-reaching. The changes in the distribution of storable energy sources are likely to be the least serious, as existing structures can be used here for the most part. The most serious are the necessary interventions in the electricity grids because the use of wind and solar power requires a significantly greater decentralization. Large energy storage systems for network stabilization, local storage, and the integration of electric car batteries into the power grid, up to almost self-sufficient microgrids, are playing an increasingly important role here. And technologies are also needed to transport electrical energy using completely new approaches, such as „electricity tankers“ or superconducting „electricity pipelines“.

While electric propulsion has already gained momentum in passenger transport, the situation is still different in the entire transport sector. This sector currently accounts for around two-thirds of global oil consumption.[14] However, a lot still needs to happen before electric drive can be implemented across the board here, too – especially in terms of the charging infrastructure.

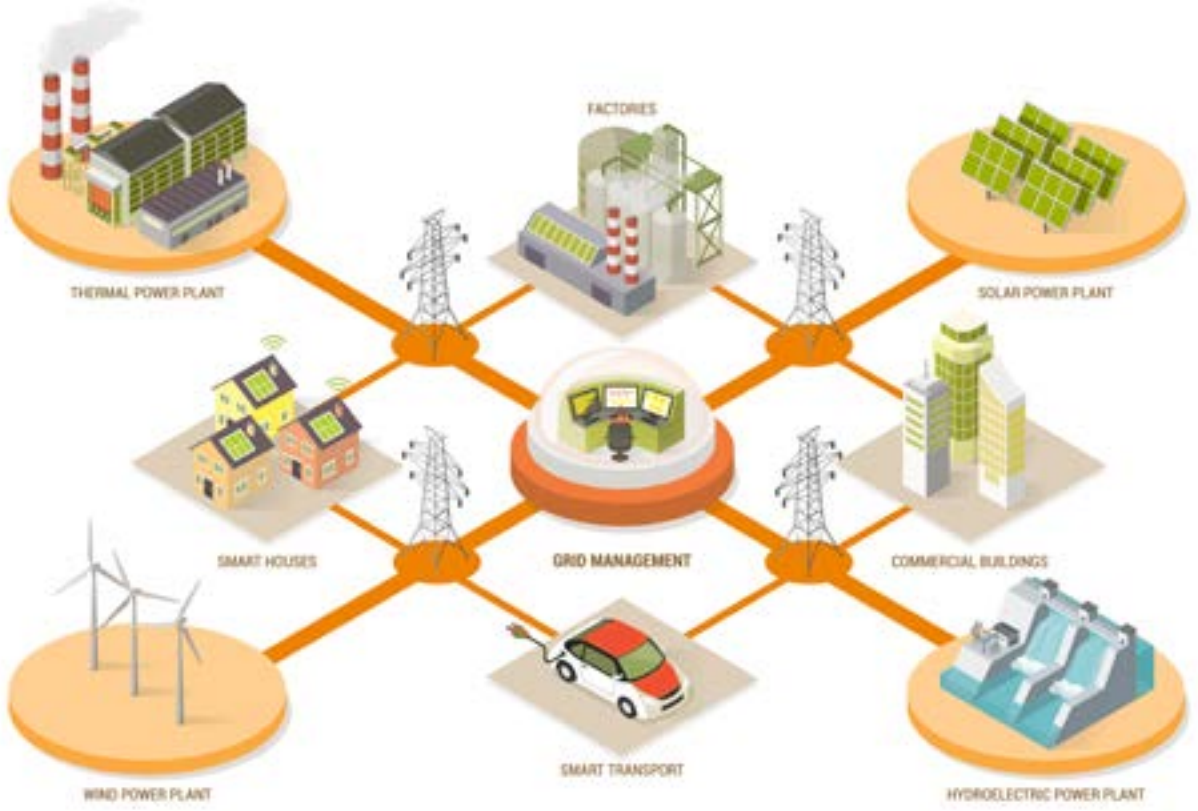
The future of mobility?

Is the electric car really the future or is the fuel cell, which also requires a battery, the right way to go in mobility? Both use an electric motor, except that in the case of the electric car, the refueled electricity is stored in a battery. In the hydrogen car, it is generated in the installed fuel cell and buffered by a battery. The electric car is slightly ahead in terms of CO_2 emissions, and the hydrogen car is ahead in terms of range.

Refueling is much easier with electric cars

But what is much more decisive is that the charging infrastructure in Germany and many other countries around the world is strongly geared toward electric cars, and the electric car is also much easier to use for refueling. The hydrogen infrastructure, on the other hand, is still in its infancy. This also applies to e-fuels: The production of bio-fuels is currently still not very energy-efficient. It can therefore be assumed that e-fuels will initially be used primarily in areas where it is most difficult to replace conventional fuels, such as aviation and shipping.

14 www.iea.org/reports/key-world-energy-statistics-2021/final-consumption



Other relevant manufacturing industry sectors

In all these considerations, no one should forget that electromobility is only the tip of the iceberg, so to speak. After all, mobility is only responsible for around one-seventh of global energy consumption. Many other technologies and industrial sectors – from energy generation to the production of storable energy sources, distribution infrastructure and logistics, and the substitution of fossil fuels in end use – are also experiencing growing strategic importance. Numerous new concepts are necessary to achieve global CO_2 neutrality. This concerns, among others:

- Decentralized renewable energy generation (photovoltaics, wind power, etc.)
- Regenerative power plant technology
- Generation of storable renewable energy sources (e-fuels, hydrogen, etc.)
- Network concepts (decentralization, micro grids, virtual power plants etc.)
- Battery technology (for mobile and stationary applications, home storage and marine applications, etc.)
- Alternative energy storage concepts (heat storage, pressure, and gravity storage, etc.)
- Electrical drive and control technology (for residential, commercial, and industrial applications)
- Intelligent energy demand planning and control
- Energy-efficient production processes
- Energy recovery (heat pumps, DC networks, etc.)

Resistance to the upheaval

However, making massive changes to the existing energy structures is meeting resistance in many places. This is because the economically successful and established system provides jobs and thus a livelihood for many millions of people as well as reliable, good returns for owners and investors. For example, depending on how it is calculated, there are up to 11 energy companies among the 100 largest companies in the world[15] and sales in the energy sector are currently rising sharply. The wealth of fossil fuels in some regions determines geopolitics and global financial flows. In addition, very high investments have been made in energy supply infrastructure: The transport of fossil energy sources via pipelines and ships is a matter of course and only comes into focus in acute times of crisis; the filling station and electricity networks are well developed and reliable in the industrialized countries. Nevertheless, one thing is certain: the upheaval is necessary and unavoidable – but at the same time it also offers great opportunities through active participation in shaping the future.

15 www.fortune.com/ranking/global 500, abgerufen 07.08.2023

The Where and How also matter

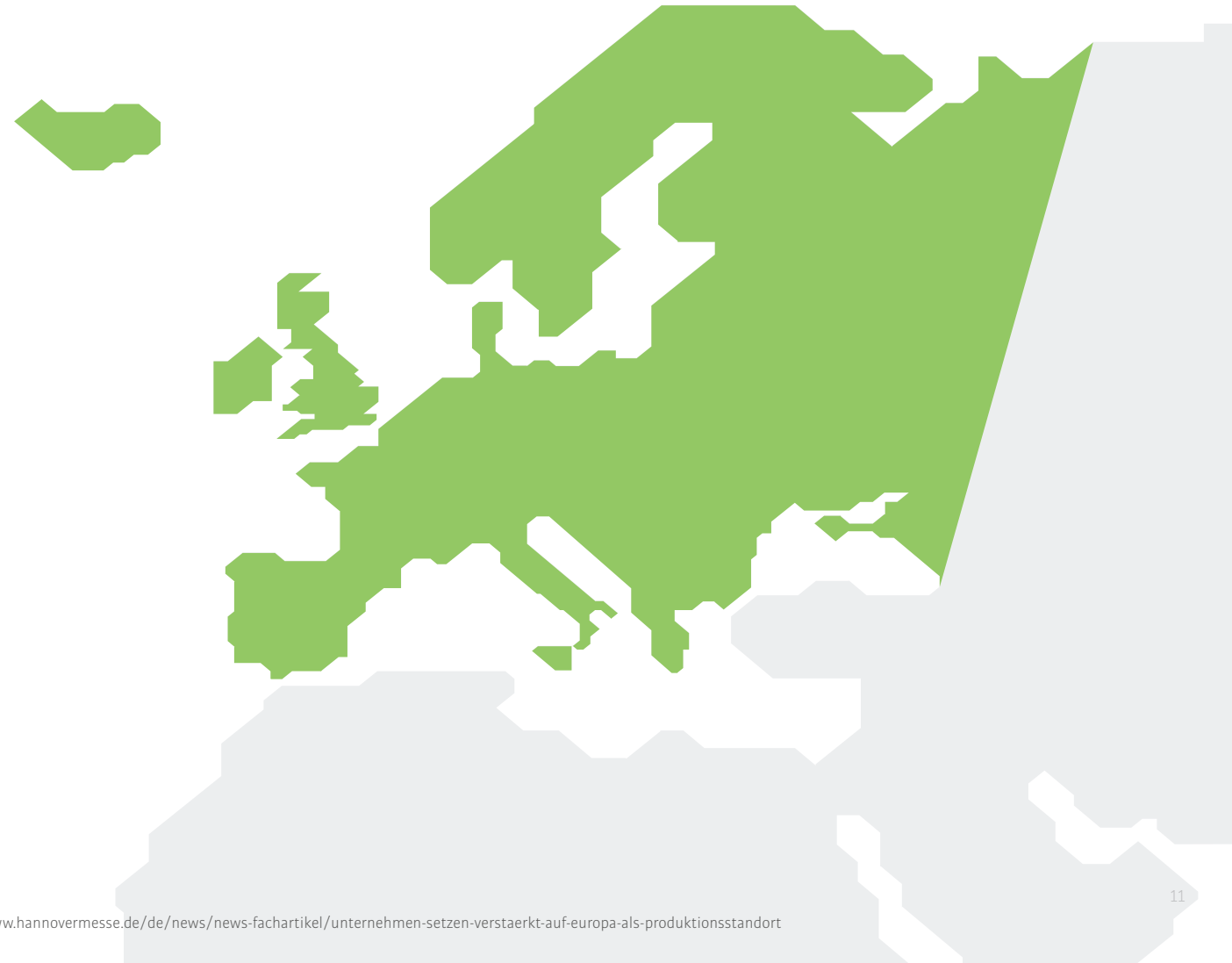
What needs to happen to stop climate change is clear. It has been for a long time. But it also matters where we act, and which technologies are used. Europe as a location is becoming increasingly important.

Where do we produce? The choice of location is becoming more relevant, not only for political and geostrategic reasons. The decision for a production location, especially for new industrial sectors, also plays a role from an economic point of view:

- **Avoiding unnecessary transport routes:** The global transport of goods is mainly by ship or air, which causes a large consumption of oil. Replacing the fuel here with regenerative energy sources is much more difficult than by road or rail. It is therefore important to avoid long transport routes and thus maritime transport as well as air transport.
- **Availability of regenerative energy:** Transporting regenerative energy is a challenge – especially for electricity over long distances. Therefore, production that requires a particularly large amount of energy should also be located where regenerative energy is generated.

Strengthening Europe as a production location

For technology groups and medium-sized companies in the leading industrialized nations in particular, the European countries are therefore once again gaining importance as production locations. This is also supported by politics. For example, through the ‚EU Chip Act' orchestrated by the European Commission: This new law aims to double the share of European semiconductor production to 20 percent by 2030 with subsidies amounting to 43 billion euros.[16] However, these considerations also mean that production will once again be located to a greater extent in regions with higher labor costs. To remain competitive and take full advantage of the opportunities offered by decarbonization, the degree of automation must therefore increase. In other words, reliable and efficient automation technology will be even more crucial than it has been in the past anyway.



16 www.hannovermesse.de/de/news/news-fachartikel/unternehmen-setzen-verstaerkt-auf-europa-als-produktionsstandort

High quality pays off

So, the Where also influences the How. In addition, not only the use of materials but also the use of energy must be considered in production. With the appropriate technologies, this can be reduced. In addition, high-quality production ensures lower scrap and a longer product life. This improves both ecological and economic use. In some cases, even seriously. In the production of battery cells, for example, every percent of avoided scrap in a 10.5 GWh factory per year corresponds to a saving of 5 million euros and 8,000 tons of CO_2 equivalent.[17] Doubling the service life also halves the costs and CO_2 footprint that are prorated from production costs to usage costs. The availability of a production plant – which is decisively influenced by its quality, but also by the strength of the local service organization – is also of great importance. This is because it determines how much benefit operators can derive from the fixed costs (in the form of capital, labor, energy, and CO_2) of a production facility.

How can quality be determined?

Quality pays off – economically and ecologically. But how can high quality be achieved in industrial production? The following points are particularly decisive for this:

- Robust product design
- Consideration of tolerance chains
- In-line process controls to find errors early on
- Tolerant and robust process design
- Holistic view of a production
- Possibilities for maintenance and simulation
- Well thought out logistics routes
- A long service life of the core components
- Data consolidation and traceability

Automation

High quality in Europe as an industrial location can only function ecologically and economically if production is automated as far as possible – by means of appropriate systems and machines.

17 https://www.vdma.org/viewer/-/v2article/render/40011538

Evolution or revolution?

Whether radical change or gradual transformation – the right balance between old and new is what matters. Suitable business models and the right approaches will lead to net zero via decarbonization in the long term. But the way up is long.

Even though decarbonization will completely change the industrial landscape, the transformation is more evolutionary than revolutionary. Because in order to position ourselves sustainably and successfully in the dynamic environment of decarbonization, it is essential to strike the right balance between continuity and innovation. We need to leverage existing competencies and experience and be prepared to break new ground with them. Industrial companies must question their processes and address the extent to which they are dependent on fossil fuels and what changes in production are necessary to be able to use regenerative energy sources. This requires establishing new business models and being not only more agile, but also more courageous. In some cases, it will be unavoidable to take a different geopolitical orientation and enter new alliances. The decarbonization of the industrial landscape is not a self-runner but requires long-term strategies that are linked to political framework conditions on one hand and demand an enormous amount of initiative from the companies concerned on the other.
Depending on whether CO_2 emissions are generated directly or indirectly within the company, a different approach must be taken to reduce them to net zero:

- Increasing energy efficiency by using energy-efficient technology, optimizing procedures and processes and consistent waste heat utilization
- Use of renewable energy, especially in the form of electricity from renewable sources, or the conversion of the energy supply to renewable energies
- Efficiency improvements in energy conversion and use in industrial applications
- Process conversions to avoid CO_2 emissions as part of the production process

The use of robotic systems in industrial manufacturing can also help to achieve the corresponding goals. This is a trend identified by the International Federation of Robotics for the year 2023. Because robots in production contribute to reduce energy consumption, for example through reduced room temperature. At the same time, robots operate at high speeds, increasing production rates and making manufacturing overall more time and energy efficient. So, robots are now designed to consume significantly less energy than previous generations and can even feed electricity generated by kinetic energy back into the grid. Intelligent software systems control energy consumption and help minimize it.

The right partnership decides

To integrate green technologies and sustainable system solutions in the company, it is important to have the right partner. With more than 125 years of experience, we at KUKA plan and implement suitable concepts. From the initial idea to final commissioning and service over many years, we are at your side.

Even less than in the past can today's challenges be tackled alone: Trusting cooperation with reliable and suitable partners is becoming increasingly important. It needs partners like us. As a globally active company, we have 125 years of experience with change and have been able to play an active role in shaping it. On the long road to sustainability, we support numerous industrial companies as a partner with green technologies and system solutions, including:

- Long life of the products
- Sustainable overall concepts
- Less consumption due to good energy efficiency
- High recycled content of materials

In doing so, we do not only act as a robot manufacturer, but also contribute our expertise in the conception, planning, and implementation of production systems as a solution provider. As a partner for system integration – whether for a single production cell or a complete production line – we at KUKA Systems think sustainability from the very first idea and integrate corresponding processes into projects and our own product developments.

Six good reasons for working with us

Change cannot succeed alone. Together it can. KUKA Systems brings with it what is crucial for successful cooperation on the way to its own climate strategy.

1. Technologies and industries in focus

We always keep an eye on both current tasks and topics relevant for the future, such as e-drive technology, batteries, fuel cells or automated modular house construction, in all our activities and innovations.

2. Reliability, efficiency, and user-friendliness

In everything we do, we attach importance to reliable and efficient products that are easy for our customers to operate. To this end, we develop appropriate concepts, provide training at our sites, and develop the products so that they fit our customers‘ needs exactly. Adaptations are no problem in this respect.

3. Innovative and high-quality solutions

We are continuously developing our solutions and are always working on new concepts and processes, such as support for DC networks. Quality, high reliability and a long service life are particularly important to us.

4. Competence and cooperation in partnership

Both as a supplier of automation products and manufacturing solutions and as a supplier of complete production systems, we work together to meet our customers‘ challenges and involve all relevant idea providers in the processes to find the individually perfect solution in the end.

5. Global presence

We are represented all over the world and are familiar with regional requirements and special features. Our service teams are also available worldwide and provide long-term support for automation projects in a wide range of industries.

6. Routine in dealing with change

We have more than 125 years of experience with transformation technologies and have since witnessed and helped shape numerous changes. Therefore, we are able to support our customers in all their current and future challenges.

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