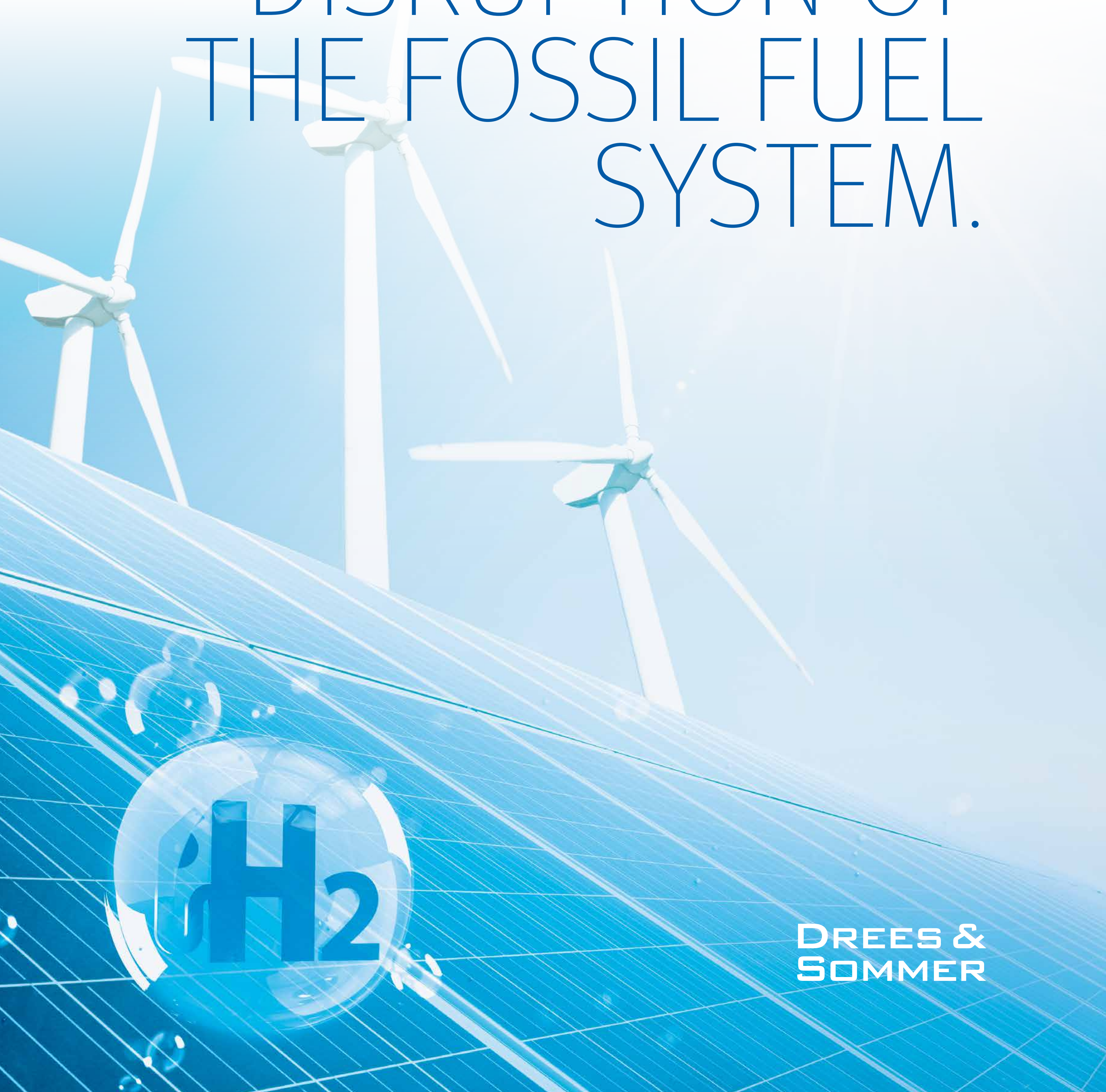
IN FOCUS

# BLUE PLANET WITH A FUTURE. DISRUPTION OF THE FOSSIL FUEL SYSTEM.




DREES & SOMMER


The large quantities of carbon emissions from fossil fuel combustion are causing environmental pollution on a global scale and must stop as soon as possible. However, the alternative offers huge opportunities: global cooperation between a large number of industry players to give a massive boost to renewable energies.

Hans Sommer

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The negative consequences of a business as usual approach to greenhouse gas emissions are known – the main one being catastrophic global warming. We must not let our descendants face the impacts of our failures.

We can still avert the worst effects, but we will not succeed in doing so merely through regulations and bans, or even through targeted assistance. Instead, the world's energy needs should be met from now on by massive annual increases in the supply of renewable energy from sources such as wind and solar, and related secondary energy sources like hydrogen. Global thinking and action is essential to enable this step to be taken. It is crucial to involve as many market participants as possible – including those that have up to now been engaged in extracting or supplying fossil fuels.

In addition to CO2, a lot of capital is also circling the globe, urgently seeking investments. It should be possible to convince as many companies as possible from the energy sector – and also new players – that they can open up a new business field with a great deal of pioneering spirit and thus contribute to the energy supply of the 21st century. Extensive collaboration and the rapid expansion of renewable energies should be supported by a swift and significant increase in carbon emissions prices. This and complete openness to all technologies will do far more to support the transformation process than the imposition of different limits. The availability of a wide range of renewable energies will quickly make it uneconomic to use energy from fossil fuels.

If we take this approach to saving planet Earth, the global economy will see a huge upturn. Geographers and engineers will explore and develop suitable locations for renewable energies, including many in developing countries. The upturn will be driven by a number of sectors: the solar and wind energy sector; the chemical industry, with production plants for hydrogen and methane gas or e-fuels; and electricity suppliers, with large-scale projects to lay new transmission lines and new infrastructure for the electrification boom. And we could hand over to our descendants in 2050 a blue planet with a globally prosperous economy operating on green energy.

So, taking "*the blue way*" as our approach, let us make the Earth our planet of the future, instead of looking for it somewhere in outer space!

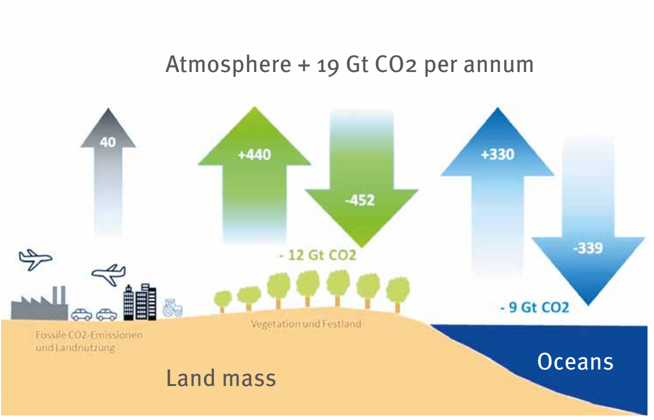
# How is carbon dioxide formed, and why has it become a problem?

Carbon dioxide ($CO_2$) is a natural by-product of cellular respiration by plants. It is released by the decomposition of dead organisms, or from natural sources such as volcanic gases. Without carbon dioxide, there would be no plant growth: plants absorb $CO_2$ and use it to produce oxygen by photosynthesis. $CO_2$ is thus not only a natural component of the atmosphere – it is also important for life on Earth.

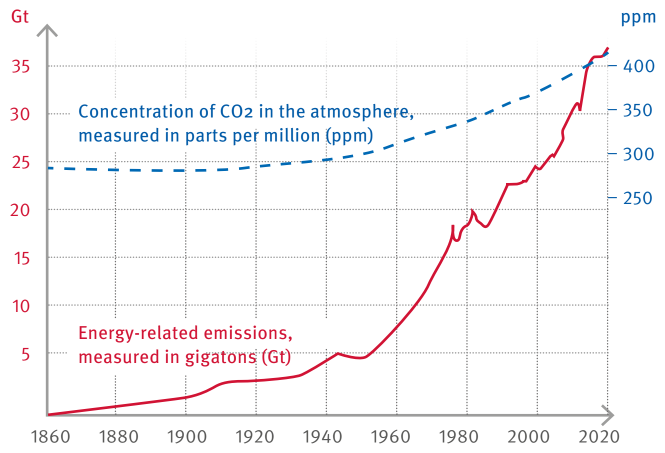
With the Industrial Revolution, around 250 years ago, another emitter of carbon dioxide emerged: humankind. Prior to this, the $CO_2$ content of the atmosphere had been relatively stable for thousands of years. However, natural $CO_2$ is not static. It is released by some continual processes and absorbed by others. As the graph of the global carbon cycle shows, carbon from the land and the oceans is roughly in balance – and has been for a long time. In the carbon cycle, carbon is exchanged between carbon sinks and carbon sources. In this way, over the course of the Earth's history a relatively stable dynamic equilibrium became established – until humans intervened.

## ///// *We are disrupting the carbon cycle's balance to an extent no longer tolerable.*

Since industrialization began, $CO_2$ has been released in ever larger quantities through the combustion of fossil fuels. We use these, for instance, for energy production, industry, transport, and air conditioning in buildings.




Schematic illustration of the global $CO_2$ cycle consisting of emission and reduction processes (per annum).




Trend in $CO_2$ emissions (after Professor Quaschning)

The current 40 gigatons of carbon dioxide may seem small in comparison to the total amount that flows through the carbon cycle in the course of a year. However, the amount is growing because the land and the oceans cannot absorb the additional carbon. $CO_2$ is a long-lived greenhouse gas – once it is released into the atmosphere, it does not disappear easily. The graph shows the trend in annual $CO_2$ emissions and their concentration in the atmosphere since 1860.

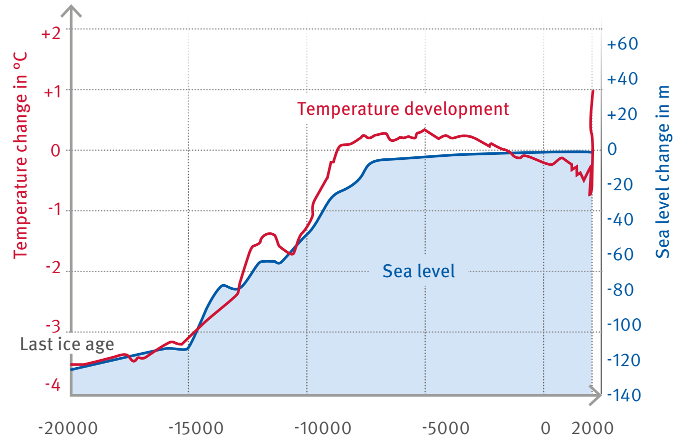
Emissions caused by humans have led to an increase of more than 40 percent in the concentration of $CO_2$ in the atmosphere today compared with before industrialization began (around 1750). This concentration is leading to continuous global warming. This is basically gaseous waste, which has to be reduced as quickly as possible, and completely avoided in the future.

It is also a fact that three so-called climate toggle switches are already flipped: The destruction of many coral reefs, the collapse of the West Antarctic ice sheet and the melting of the of the Arctic sea ice. Even the major $CO_2$ sinks such as the oceans, the Amazon rainforests, and the Nordic coniferous forests are in danger of absorbing less and less $CO_2$.

The individual developments influence each other. The greatest influence on slowing down the negative development will be the consistent acceleration of decarbonization.

# The consequences of the increase in carbon dioxide

Climate change is having an impact on all regions of the world. The polar ice caps are melting and the sea level is rising. Some regions are experiencing extreme weather events and higher rainfall with increasingly frequency, while in other areas heatwaves and droughts are occurring more often.




Sea level in relationship to global warming

Between the last ice age and 1750 (start of measurement period), average temperatures globally rose by just 3.5 degrees Celsius, but sea level rose by 140 meters. This spells out the dangers of the current climate change and brings home the fact that one degree of global warming is a very serious matter. It is also worrying that since the year 2000 – a period hardly visible on the scale – there has been a rapid increase of more than one degree Celsius, the impact of which has really not yet been noticed in the sea level.

## ///// *Our global air conditioning system is breaking down!*

In addition to the rise in sea level, which will be more noticeable in the long term, there are other changes. It is already apparent that the Gulf Stream no longer functions correctly. This ocean current is extremely important for the climate of western Europe; it is the continent's heating system. Another weather phenomenon, which occurs in the Pacific, is El Niño. This causes unpredictable ocean currents which could become much more frequent in the future through climate change. Flooding, tornadoes, droughts, aridity, wildfires and landslides – the consequences of El Niño are often destructive and devastating. The consequences for the climate could be dramatic, as a pronounced weakening of the Gulf Stream could lead to a stronger El Niño in the Pacific.

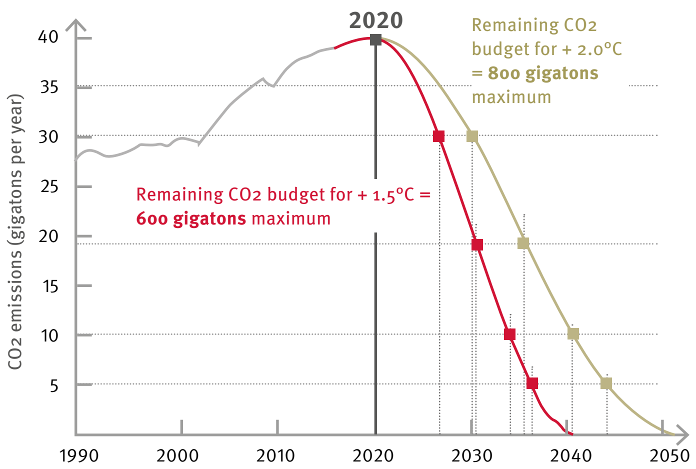
Generally speaking, heavy rains and other extreme weather events such as storms and cold snaps will become increasingly common. Southern and central Europe will also be hit more frequently by heatwaves, wildfires and drought. Aridity is affecting an increasing area of the Mediterranean region, while in northern Europe the climate is becoming wetter, and winter floods may become the norm there. Some urban areas are already affected by heatwaves, flooding or an increase in sea level. They often find it very difficult to adapt to climate change. Some of the most severe impacts are being felt by agriculture and forestry, for which specific temperature and precipitation levels are especially important. Also, climate change is taking place so rapidly that many plant and animal species are having difficulty adapting.

# The Paris Agreement of 2015

The developments and issues described have been known for a long time and in December 2015 they resulted in the Paris Agreement. This sets out a global framework for fighting climate change: global warming must be kept well below 2° C, and measures must be pursued to limit it to 1.5° C. Unfortunately, the efforts made in the past five years have not been sufficient, so we have already reached a point where, even if the Agreement is adhered to in the future, global warming of 1.5° C would be significantly exceeded by 2050.

The fact is that if global warming is to be curbed, we must only emit a certain additional amount of $CO_2$ into the atmosphere. However, it is not possible to put a precise figure on this allowable amount. As we are already at a level of global warming above 1°C, the remaining margin is somewhere between 0.5° and 1°C. Also, there are other greenhouse gases and some uncertainties exist regarding the reaction of the climate system.

It is therefore not surprising that the carbon budget compatible with the Paris Agreement is set at between 150 and 1,050 gigatons (Gt) of $CO_2$. To validate this figure, we will assume in the following example that, to limit global warming to 1.5°C, the global community still has a carbon credit of 600 Gt, while to meet the limit of 2°C it has 800 Gt. If, to achieve the 1.5°C limit, we began to reduce $CO_2$ emissions radically now, the annual emissions would have to be reduced to a maximum of 30 Gt per annum as early as 2027 and to 20 Gt per annum by 2030. In 2034 emissions would have to be at a maximum 10 Gt per annum, and zero emissions would have to be achieved by 2040.

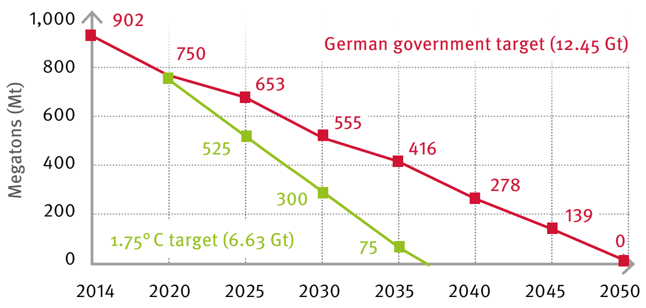



Annual $CO_2$ budget and necessary decarbonization (after Prof. Quaschning)

It would only be possible to postpone this target further into the future if we began at the same time to remove large quantities of $CO_2$ from the atmosphere – by offsetting with negative emissions. Unfortunately, the more likely scenario is that we will have to accept global warming of roughly 2° C – leaving a remaining maximum budget of 800 Gt of $CO_2$, which would give more time for decarbonization. One way or the other, urgent global action is needed.

### What the Paris Agreement Means for Germany

According to studies by the climate researcher Stefan Rahmstorf, in 2016 the national carbon emissions budget of Germany – which, as an industrial country, produces higher emissions than the global average – was 9.7 gigatons. By the beginning of 2019, as much as 2.4 gigatons of this had been used up, leaving a remainder of 7.3 gigatons; at the beginning of 2020, the remaining carbon budget was around 6.6 gigatons.

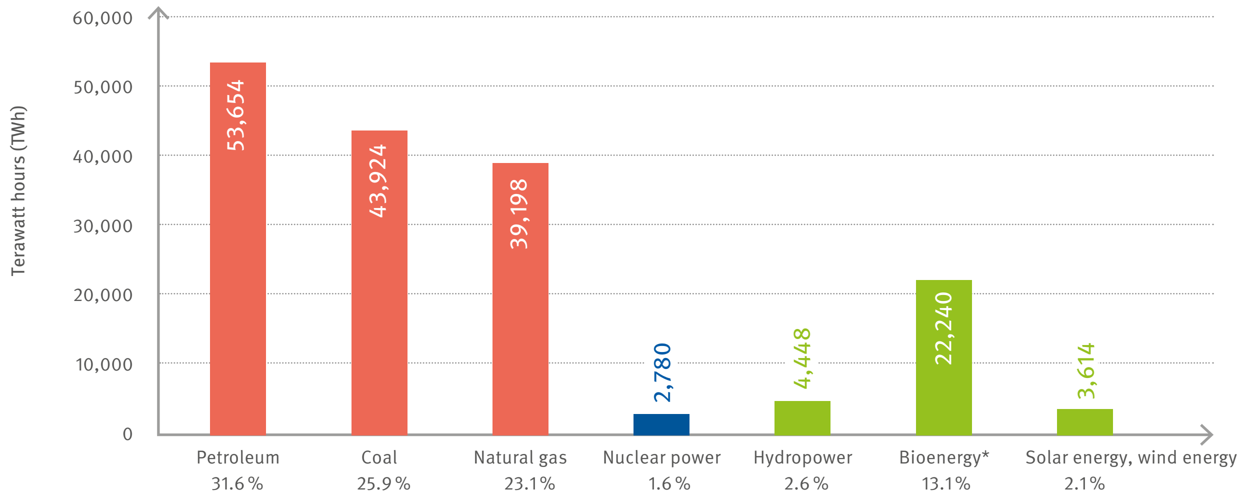



Climate targets for Germany – reduction of $CO_2$ equivalent

To meet at least the 1.75°C global warming target under the Paris Agreement, there would have to be a linear reduction of six percent every year in Germany's emissions – approximately 6.6 gigatons in total. This would mean zero emissions would be achieved by around 2037. However, the federal government's current road map aims for zero emissions by 2050, with an annual linear reduction of roughly 2.6 to 3.7 percent. This would mean remaining emissions of around 12.5 gigatons.

On April 24, 2021, the Federal Constitutional Court has ruled that the regulations of the Climate Protection Act of December 12, 2019 on national climate protection targets and the annual emission volumes permitted until 2030, which have been in place since then, are incompatible with fundamental rights. An unlimited progress of global warming and climate change would therefore not be in accordance with the Basic Law!

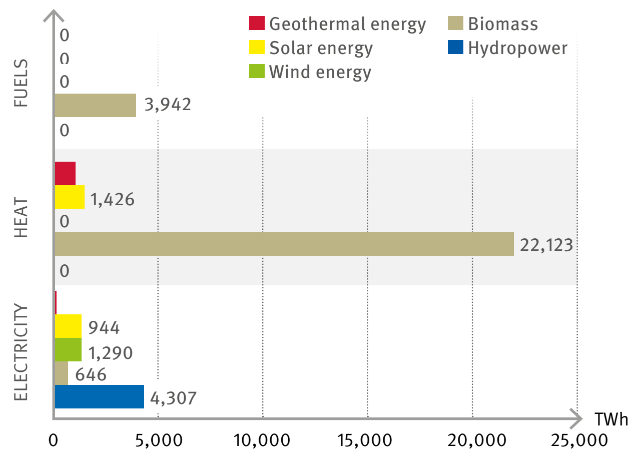
# The analysis: fossil fuels are currently the dominant source of primary energy globally




Global primary energy consumption (2019) by source approximately 170 terawatt hours (TWh)

Fossil fuels accounted for around 137,000 TWh, or more than 80 percent, of global energy consumption in 2019. The share of nuclear power is currently in the region of 1.6 percent and will be at most doubled, including all nuclear power plants under construction or planned.

Renewable energies account for altogether 17.4 percent, of which bioenergy, which is used for heat production, contributes the largest share globally. The potential for growth here is also limited, if a further reduction in land carbon sinks – forested areas – is to be avoided. The same applies to hydropower. Further expansion here also has to be limited to avert further damage to the environment. The fact is that only solar and wind energy are left to replace fossil fuels, and they currently only account for 2.1 percent.

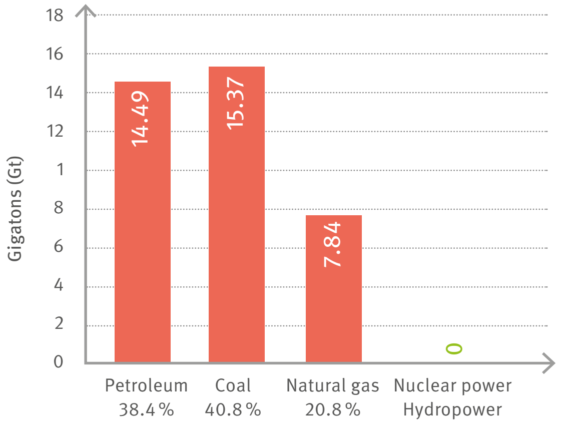



Global share of renewable energies by sector

However, this would mean that the energy currently being produced by wind and solar plants would have to be increased 40-fold to replace fully the terawatt hours of energy currently produced in one year from fossil fuels. But even this would not be sufficient by a long way, as only an electricity equivalent would be generated in this way. However, a significant share of primary energy is not used for electricity production. For instance, petroleum products are mainly used as a fuel for vehicles and for heat generation. As these applications can only gradually be replaced by electricity – or in some cases not at all – energy is lost in the transformation process, as in the case of hydrogen production through electrolysis, for which in turn additional energy has to be generated.

# *“the blue way”* – the way out of the crisis

**The $CO_2$ Emissions of Fossil Fuels**
As different fossil fuels emit different amounts of carbon dioxide, the emissions weightings differ from the distribution for primary energy. The highest level of pollution comes from coal combustion, followed by petroleum. The emissions from natural gas are significantly lower.




Global $CO_2$ emissions from fossil fuels: approximately 37.7 gigatons (Gt)

From this analysis it can be concluded that coal has to be replaced most urgently, followed by petroleum products. Natural gas will have to be used as a substitute for a transition period and should therefore be last to be replaced by renewable energies. The main substitute for fossil fuels as a primary energy source will be wind and solar energy, which currently account for barely three percent of renewable sources.

As it may be impossible, in today’s world, to completely replace such large quantities of fossil fuels with renewable energies in the time remaining, there must simultaneously be a massive reduction in global primary energy consumption. It is therefore of great importance to begin by doing everything possible to reduce energy consumption.

Because every kilowatt hour that will not be consumed in the future will no longer have to be produced in the first place. And the more that is saved, the more likely the planned energy turnaround will be successful.

The current problems are clearly caused by human beings, and multiplied by industrialization. A simple and effective step would be to cease or significantly limit many activities that cause an increase in $CO_2$. Unfortunately, the majority will not act responsibly, although they are aware of the problem.

*///// Cutting down and cutting out are not exactly in homo sapiens’ DNA.*

Based on this knowledge, since the 1980s we at Drees & Sommer have been pursuing “*the blue way*” strategy. It is only when ecology and economy are in balance that sustainable action can be implemented and become a (new) normality. This means climate effectiveness not by means of radical austerity, but by intelligent technological solutions that enable human beings to deal with energy in a sustainable and viable way without causing damage. Of course, part of the solution is also to protect nature, particularly the oceans and the rainforests, rigorously and using all available means. However, this is far from enough, and unfortunately it is difficult politically – although thankfully under President Biden the United States is back on the path to decarbonization.

For this reason, the global community must move swiftly and boldly to usher in an industrial age in which energy is not obtained from fossil fuels. There is no other way to get to grips with decarbonization within the required time frame than by increasing many times over the number of solar and wind energy plants in all suitable locations around the world.

*///// Sun, wind and hydrogen will cause a boom in the global economy – and create the basis for a livable future on earth.*

Generating and trading in these new energies will replace fossil fuel energy rapidly and on a massive scale – if we want it to. This step will be worthwhile. Powerful global players, major investors and industries in all countries can invest in this future with strong prospects for good business in the medium term, while ‘saving the world’ at the same time.

We need pioneers with large amounts of capital – like those in the days of the railroad construction in the 1870s and 1880s, who did not allow any obstacles to get in their way and were convinced their actions would end in success.

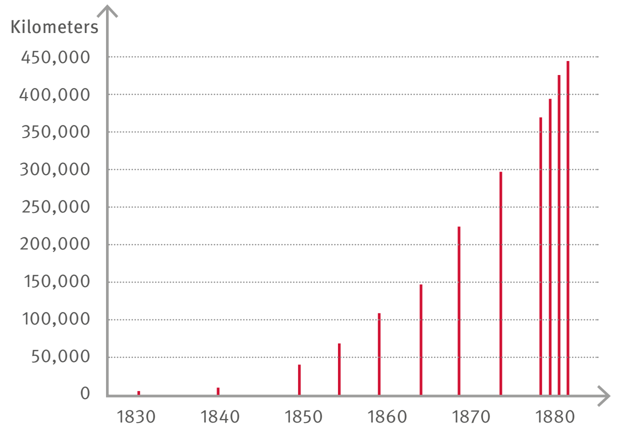
One of these was Cornelius Vanderbilt, who opened up the American West with the Hudson River Railroad and the New York Central Railroad and ultimately made USD 150 billion in today‘s money. However, he took risks and recognized that the development of the railroads had to be done on a large scale.

Railroad construction in North America
© Oakland Museum of California

The situation we are in today is similar, with the global potential to implement new technology on a large scale. Because generation of green electricity is only possible intermittently (when the sun is shining or the wind is blowing), it has to incorporate thermal and chemical energy storage. For logical reasons, the best locations for electricity generation will be those places where there is sufficient wind, or strong solar radiation and a large number of sunny days.

However, it also has to be possible to transport the electricity and the chemical storage products to consumers. This requires high-voltage direct current (HVDC) lines including, over long distances, high-voltage direct current (HVDC) transmission lines, the longest of which is currently around 1,700 kilometers long. Alongside this, land and water transport routes are necessary. Finally, to distribute the electricity it will be necessary to expand the infrastructure in the countryside and in metropolitan areas.

A large-scale cooperative project will be needed to achieve this, with the new economy, the big petrochemical companies, investors and the manufacturing industry joining forces. They will evaluate suitable locations around the world and advance the generation of green electricity and green hydrogen on a scarcely conceivable scale.




Growth of the railroads, in kilometers

A significant increase in carbon prices will help to get the project up and running quickly. The net-zero scenario, for instance, is based on a considerably higher carbon price, rising to USD 250 per ton of $CO_2$ in developed countries and USD 175 per ton in developing countries by 2050.

*///// Added together, a huge number of individual projects will become the biggest global project in the history of humankind.*

Based on this kind of pricing, a target could be set – for instance, to replace 80 percent of the current contributions of coal and petroleum products (including transformation losses of around 100,000 terawatt-hours per annum) in the next 15 years with direct electrification, and to establish a hydrogen economy. That would amount to roughly 6,720 TWh per annum on average. Assuming that solar and wind energy would each generate 50 percent of this, this would mean 3,360 TWh per annum each – necessitating an addition of roughly 1,400 gigawatts of power for both sources, every year.

That may seem utopian, and it would require a lead time and construction period of around three to five years, especially at the start. However, it would definitely be possible, with the same pioneering spirit as mentioned above and the incentive of carbon pricing, as in the net-zero scenario. Then, by 2040 coal and petroleum would largely be replaced and natural gas consumption could be reduced. But where could plants of this kind reasonably be developed on a large scale? A number of organizations, institutes and universities have already given some thought to this.

## Solar Power Plants and Photovoltaics

Since 2010 Solargis, a Slovakian company, has been developing and operating an international platform for fast access to data for almost every location on Earth. The database is used to optimize the construction, evaluation and management of solar power plants worldwide. ESMAP is a partnership between the World Bank and 19 partners, which helps low and middle income countries to promote growth through sustainable energy solutions. The aim is to achieve universal access to assistance for decarbonization in the energy sector by 2030 – within the framework of international commitments with regard to climate change.

A search tool at https://globalsolaratlas.info provides information on the solar energy potential of different types of solar installations for sites anywhere in the world. The results show the yield per megawatt (MW) in gigawatt-hours (GWh). For instance, the following values per megawatt-peak (MWp) are given for large photovoltaic power plants:

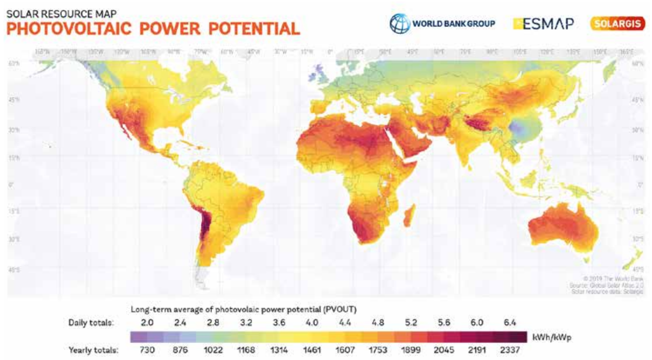
- 1,013 GWh for Templin in the German federal state of Brandenburg, at an average of 5 hours of sunshine per day = 5,060 GWh per day
- 1,713 GWh for Rabat in Morocco, at an average of 9.5 hours of sunshine per day = 16,273 GWh per day
- 1,941 GWh for Hagl on the Red Sea in Saudi Arabia, at an average of 10.2 hours of sunshine per day = 19,800 GWh per day

Looking at these figures it is clear that at a similar cost in terms of technology, the output that can be achieved in the right places in the world is more than four times that at our latitude.

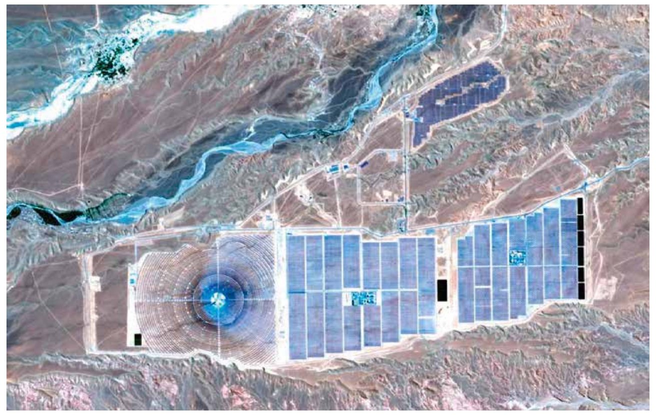
Perhaps the most interesting are solar thermal power plants, for instance with relatively inexpensive parabolic troughs. Plants of this kind are already in operation in Spain, Saudi Arabia and the United States. The advantage of these is that they can be combined with a heat storage medium (for instance, molten salt), which enables them to deliver electricity up to ten hours after sunset. Large solar plant modules are currently in the order of 150 to 200 megawatts, but they are combined into even larger plants. For instance, Noor solar power plant in Quarzazate, Morocco, has an output of 580 MW (0.58 GW) in an area of 18.3 square kilometers. It also has a salt storage capacity of up to seven hours.

As mentioned above, an annual contribution of 1,400 gigawatts would be needed from solar power to decarbonize coal and petroleum-fired power stations within 15 years (after start-up). To generate this would require around 2,400 plants similar to Quarzazate on an area of 45,000 square kilometers. This could be split between solar heat and photovoltaics – for instance 400,000 megawatts from solar thermal power plants and 1,000,000 megawatts from photovoltaic power plants. Overall, this would require an investment of roughly EUR 2.9 trillion per year. That figure is around 3.4 percent of global gross domestic product.

But is it even possible to calculate in this way? There would be a lot to gain, and countless new jobs would be created. Poorer countries with a lot of sun or wind could benefit. Therefore, the question should instead be as follows: Could industry deliver, with the appropriate lead time? As mentioned earlier, this would be the biggest project in the history of humankind.




Map with global solar potentials from Solargis
Source: www.globalsolaratlas.info



Thermodynamic Solar Power Plant Noor, Ouarzazate, Morocco

Worldwide areas with particularly high wind
Source: Cristina Archer/Mark Jacobson of Stanford University 2005,
see https://web.stanford.edu/group/efmh/winds/global_winds.html for details)

Windparks
offshore
and onshore

## Wind Power Plants

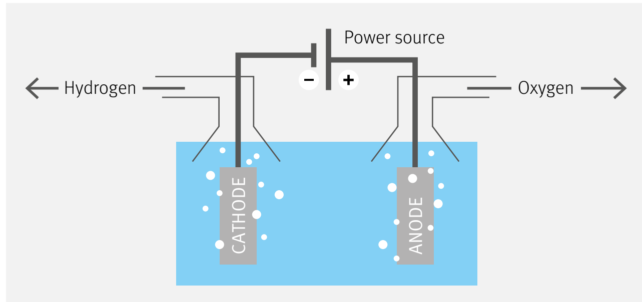
According to a 2005 study conducted at Stanford University, the world's energy demand could theoretically be fully met by wind power. The researchers calculated wind speeds at 80 meters – the hub height of then state-of-the-art 1.5-megawatt wind turbines. They used their data to develop a global wind map to help in the selection of locations for wind power plants. The wind speeds specified were very conventional, as the hub height of state-of-the-art plants now is between 140 and 160 meters and their output ranges from 8 to 12 megawatts offshore and 4 to 5 megawatts onshore.

In North America there are several regions suitable for cost-effective wind power generation, likewise in Central America. In South America, the areas of strongest wind are in Chile and Tierra del Fuego. One of the stormiest regions in the world is the North Sea. In Africa there are fewer places with high wind capacity, but the best are in Western Sahara and Morocco. In the southern hemisphere, there are individual sites in South Africa and Mozambique, and in the Indian Ocean on the island of La Réunion. In Asia, the greatest potential is in Japan and China. Australia has four large windy regions on the northern and southern coasts of Western Australia, in addition to Queensland, South Australia, Victoria and Tasmania. It is important always to assess whether a wind power plant would be compatible with nature and civilization at any particular site.

An addition of 1,440 gigawatts every year would mean, for example, 200,000 five-megawatt onshore wind power plants and 40,000 ten-megawatt offshore wind power plants – an overall investment of around EUR 1.1 billion per year. Wind energy is thus relatively cost-effective as an investment, but lacks the storage capacity of solar thermal power plants, and maintenance is more costly than with photovoltaic power plants.

## Hydrogen Production

As a universal storage medium, green hydrogen is an indispensable adjunct to solar and wind power generation. During electrolysis, electricity is used to split water ($H_2O$) into hydrogen ($H_2$) and oxygen ($O_2$) in an electrochemical process.



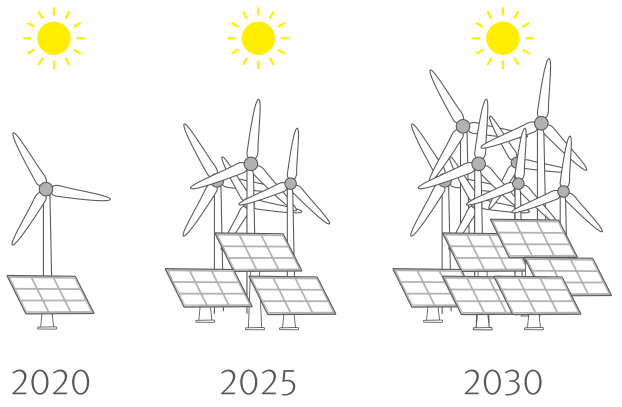

Construction of a water electrolysis

Therefore, the production of hydrogen requires electricity – preferably generated at low cost in regions where more electricity is produced than consumed. Ideally, to avoid the use of drinking water for electrolysis, sea water should be used. This is desalinated beforehand. Additional electricity is needed for this process, but the amount used is acceptable in comparison to the electricity required for electrolysis.

Electrolysis is more than 80 percent efficient under continuous operation. Intermittent operation – for instance to process surplus electricity produced from wind – is possible and also useful, but efficiency declines with the number of hours of operation.

Therefore, from an economic point of view, it makes sense to produce the hydrogen primarily by using electricity from large solar plants in regions with high solar potential and access to seawater. For our region, this means North Africa, the Arabian Peninsula or Iran. In addition to the necessary conditions for production, this would require a transport structure for hydrogen or hydrogen-based products, which would have to be constructed if it is not already in place.

# Decarbonization in the individual sectors




Growth in renewable energies

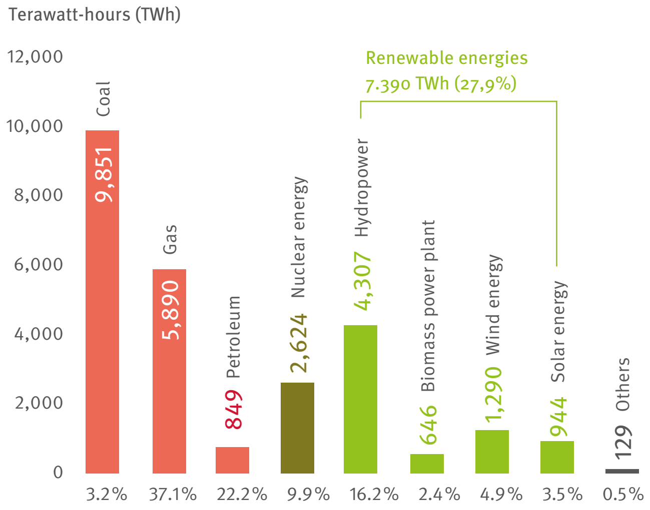
Decarbonization will undoubtedly be based on a rapid increase in renewable energy from wind and solar sources. Ultimately it is a matter of common sense to take all possible steps to achieve the climate targets mentioned above. The possibilities differ from sector to sector. Climate targets cannot be achieved in a national context alone – international, even global, cooperation is needed. Also, short-term – and short-sighted – profit-based thinking cannot take priority, at least for a transition period. After all, this is about taking an intelligent approach to creating the basis for a livable future environment for our children and grandchildren.

Energy that is not consumed will not create any more CO2. This means the carbon footprint of as many sectors as possible must be reduced so that today's huge gap in the supply of green energy can be closed more quickly. For this reason it is imperative that we use every means available to improve energy efficiency, especially as energy-saving improvements pay for themselves in the medium and long term in the vast majority of cases.


The following sections will consider electricity generation itself, as well as discussing the opportunities in three sectors: industry; transport and travel; and buildings and construction. All the proposals are based on the availability of sufficient electricity from renewable sources globally, with the balance between solar and wind power being dependent on regional conditions.

**Electricity Generation Sector**

The energy shares from the electricity supply are included in the three sectors discussed. Nevertheless, electricity generation also needs to be considered separately, as it lends itself very well to rapid decarbonization through conversion to renewable energies.




Global electricity generation by energy source (2018)

The share of renewable energies in electricity generation is already almost 30 percent. Hydrogen currently accounts for a large proportion of this, at almost 60 percent – but it cannot be increased indefinitely. The situation is similar for biofuels. Therefore, any growth in energy generation will mainly come from solar and wind sources.

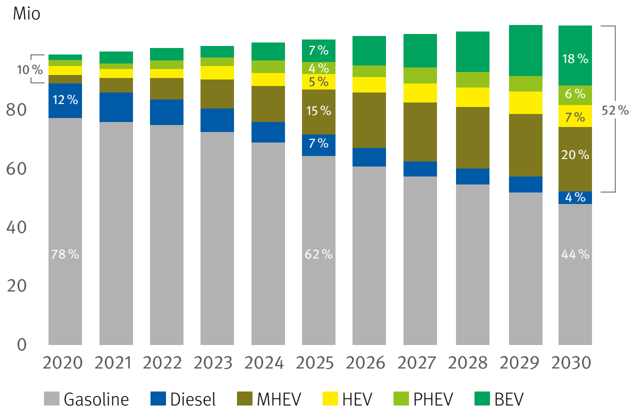
However, for a secure 24-hour electricity supply, storage is needed. This will mostly be provided by batteries, but large salt storage tanks will also be used for solar thermal power plants, and hydrogen storage might be provided via hydrogenation of CO2.

The biggest challenge of all will be to generate the considerably larger quantities of electricity that will be needed in the future and provide the necessary distribution networks (for instance, for electric vehicles and heat supply).

Electrification will require additional cross-regional and transnational high-voltage direct current (HVDC) and high-voltage alternating current (HVAC) transmissions lines. In metropolitan areas the electricity infrastructure will have to undergo massive upgrading while in operation.

**Transport and Travel Sector**

With a share of around 98 percent of the total consumption, the most important sources of energy for passenger and freight transport are fuels; of these, around 94 percent are based on petroleum or gas. Biofuels accounted for roughly 4 percent in 2019. Electricity currently accounts for roughly 2 percent only.



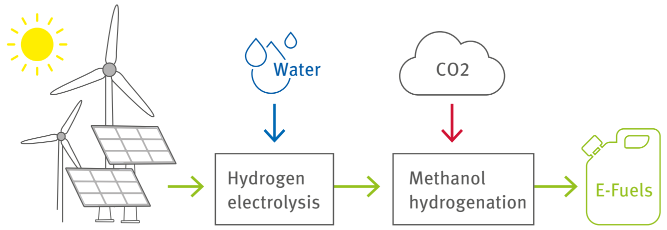

Forecast for annual global vehicle sales up to 2030 (Source: BCG)

According to a market assessment by Boston Consulting Group, manufacturing overall will continue to increase. According to this forecast, fully electric vehicles will only account for around 18 percent of global car sales in 2030. Including the various hybrids, electric vehicles will account for more than 50 percent of new vehicles, but vehicles using fossil fuels will still make up 44 percent. Even if the trend towards electric vehicles accelerated considerably in some countries, in 2030 there would still be more than two billion end-of-life vehicles with combustion engines on roads around the world. A significant reduction in the CO2 caused by fossil fuels would thus only be possible if two complementary measures were taken:

- For new vehicles, quickly changing the propulsion technology from combustion engines to electric or fuel-cell.
- For the huge number of existing combustion engine vehicles, and especially for airplanes, replacing fossil fuels with hydrogen and/or e-fuels. This would not challenge the intended electrification of transport, but has to be seen as a sheer necessity in order to reduce CO2.

However, as mentioned earlier, both of these measures will require a quantum leap in the generation of green electricity and green hydrogen, as well as power-to-X plants (plants with technologies for the storage or alternative use of temporary electricity surpluses).

Therefore, it makes sense to locate both hydrogen production and e-fuel production plants in places where the potential capacity for generating electricity from renewable sources is significantly higher than the local energy consumption. Possible such locations would be in the Middle East or in North Africa, but of course also in other places in the world – ideally where all the logistics systems are already in place for the transport of petroleum products. This means intelligent selection of locations in terms of both qualitative and quantitative factors.




Production of e-fuels with green electricity

It would be sensible to involve the current producers of fossil fuels in the process of conversion to solar and wind-powered electricity, and in the production of hydrogen and e-fuels. The necessary CO2 can, where available, be diverted from industrial emissions. Of course, for the climate it would be most effective if the necessary CO2 could be extracted from the atmosphere in less industrialized regions using new technologies.

Via the QR code you get access to further information and a video on DirectAir capture systems (ETH Zurich).

Further reductions in CO2 emissions are possible through optimized traffic management and congestion control, for instance by encouraging the use of local public transport or increasing the number of people working from home. The transition could be supported by subsidized tickets for local public transport, and weatherproof, secure bicycle shelters. For business trips, rail must become the alternative to road or air travel, especially as the travel time can be used effectively.

### Industry Sector

Industry uses a third of the world's energy (partly electricity and partly fuels), in addition to large quantities of petroleum as a raw material for the chemical industry. Industrial energy consumption could be reduced by 20 to 30 percent through the use of efficient technologies.

In the global effort to combat climate change, energy efficiency in industry has become very important in terms of environmental policy. For instance, up to 40 percent of energy used in industry is lost as waste heat. In the industrial manufacturing process, the best way to improve energy efficiency is using electric power, which creates a large amount of industrial process heat. This thermal energy can be recovered, for example from the plant's extracted air.

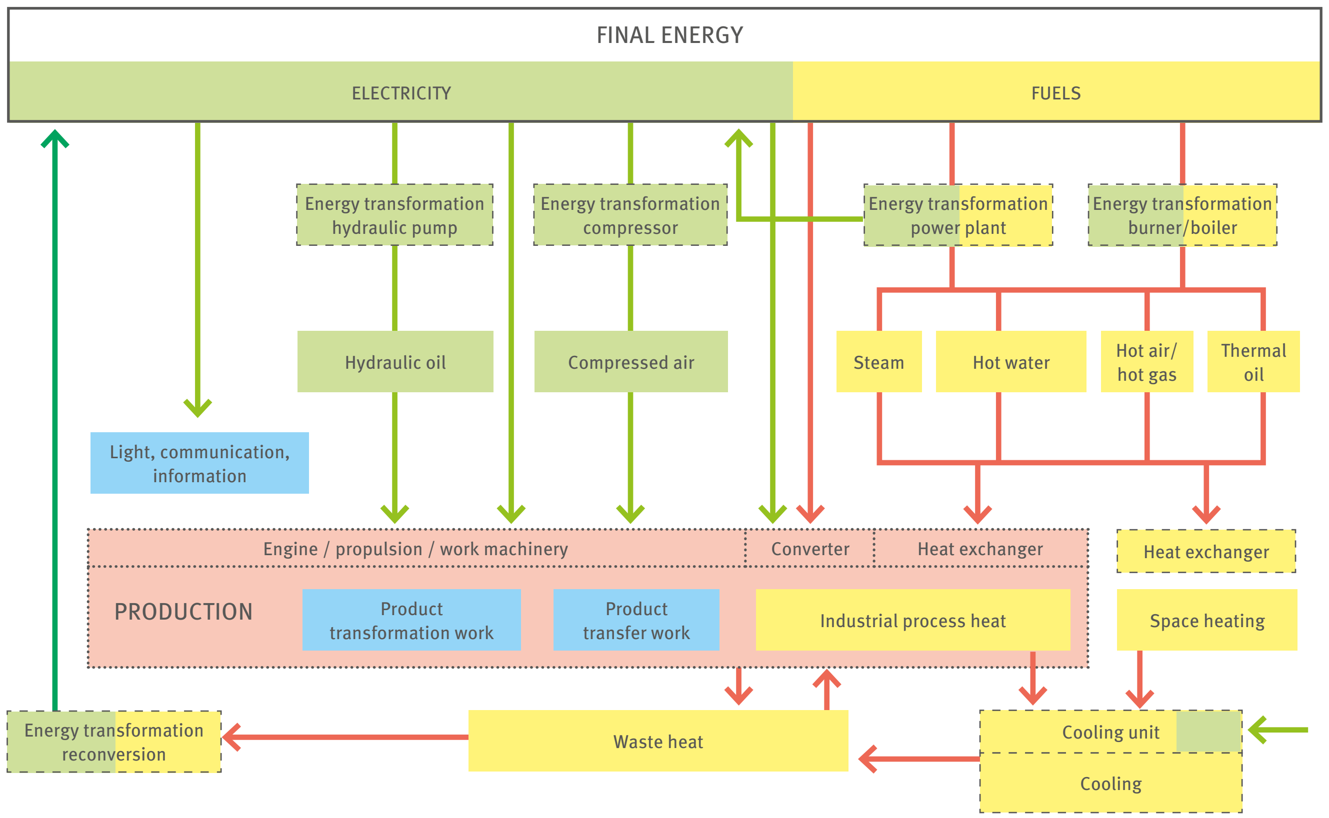
Combined heat and power (CHP) is also an important energy-saving technology. It uses mechanical power to generate electricity while simultaneously using the waste heat formed by this process as process heat or thermal heat. Intelligent control concepts enable machines to be switched off in off-peak hours, minimizing standby losses and cutting the annual electricity consumption by as much as half.

Another energy-saving measure is to replace old energy-guzzling pumps with high-efficiency pumps, as almost a quarter of industrial energy is consumed by pumps alone.

The use of hydrogen is also of great interest in industrial manufacturing. For example, it is an important raw material in the chemical industry for manufacturing ammonia (for fertilizers, fibers, plastics, cellulose paper etc.) and methanol (solvents, cleaning agents, softeners etc.), and is also a component of polymers (plastics).

A further important use for hydrogen as a replacement for carbon is being tested in the steel industry. This involves using hydrogen in the place of pulverized coal, which produces only water vapor instead of $CO_2$. In direct reduction (DR) plants, hydrogen is expected to replace natural gas.

Blast furnace gas, which contains carbon, will also be converted into fertilizers, plastics or fuels in the future in order to reduce $CO_2$ emissions further. However, this all requires significant modifications to manufacturing equipment. Overall, industrial processes offer great potential for $CO_2$ savings. However, a large quantity of green electricity is also needed to take advantage of this potential.



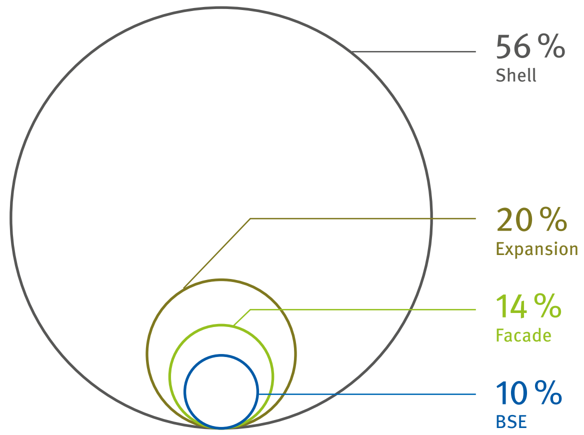

Energy flows in the production process (after Steinbeis-Europa-Zentrum)

### Building and Construction Sector

With regard to both energy consumption and $CO_2$ emissions, in the building and construction sector it is necessary to consider both the construction phase and the operating phase. The amount of gray energy used in the construction process is, roughly speaking, around the same as the energy needed for 50 years of operation and for demolition. Recent studies assume that the primary energy consumed in the different phases is as follows:

– Gray energy: 55 percent
– Operating energy: 40 percent
– Energy for demolition and reuse: 5 percent

However, this means that the main concern should not, as is currently the norm, be the operating energy – i. e. mainly the use of heating, cooling and electricity – instead, much more attention should be given to the construction method and the sourcing of materials.




Distribution of gray energy when erecting a building (Hegger, Manfred, et al., Energie Atlas, 2007)

The most important considerations for reducing gray energy are made during the design and planning phase. This is because building size and compactness influence the total amount of gray energy, as does the choice of materials used in construction. For this reason, the design, in particular, has to take into account not just aesthetics but also construction methods – following the example of the automobile industry. This change can only be achieved through modularization, which also involves integral planning and conception. This includes defining the carbon footprint of the construction materials used. For this reason, a responsible circular economy (Cradle to Cradle®) is unavoidable in the construction industry. It is very important to understand that, before it is even used, every new building has already consumed a huge amount of primary energy that can no longer be saved. With current construction methods, this energy is around 1.7 times the primary energy consumed over 50 years of operation.


Platform Building Material Scout

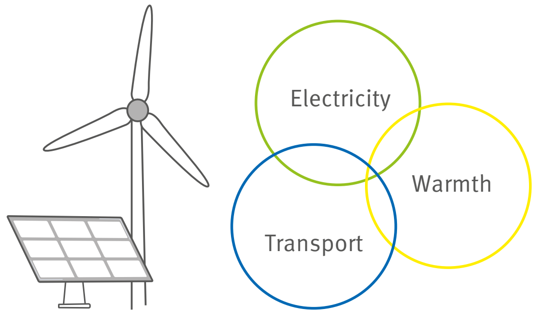
The energy needed to operate the building is different, as this can be influenced in time. The amount of energy required differs greatly depending on where the building is located in the world. Most of the operating energy is for heating and cooling and depends on the design and structure of the building. For an energy-saving and electrified future, we will need very energy-efficient heating, ventilation and air conditioning technology, in addition to intelligent insulation. This must be backed up by AI-controlled building automation systems that can react rapidly to the relevant climatic conditions. Building air conditioning systems must be complemented by energy-efficient domestic appliances and the increased use of photovoltaic and solar thermal systems, which must be supported in the short term by major incentive programs, and networked in city quarters. A lot of money can be saved in this way through solutions that can be implemented quickly. As mentioned above, $CO_2$ pricing can also give great impetus to such plans.

*///// Imposing requirements and providing assistance are better than prohibiting.*

In principle, imposing requirements and providing assistance are preferable to prohibiting – although not in all cases. Future houses should all have to be built to passive house standards where possible. These would require minimal, if any, active heating, cooling and ventilation. The average potential $CO_2$ saving compared with the initial value is estimated at 20 to 45 percent for new buildings, while for general renovations of older buildings, the possible energy saving is estimated at as much as 50 to 70 percent.

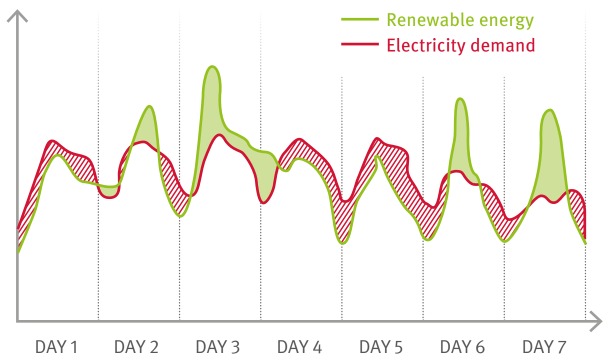
# Sector coupling

Energy is more than just electricity. It also includes the energy consumed for heating or transport. Unlike the electricity sector, the transport sector and heating and cooling systems for households and enterprises are still quite dependent on fossil fuels.




The networking of all sectors – referred to as sector coupling – helps to achieve the climate goals

To ensure that the energy transition is also a long-term success, we have to convert not only the electricity sector to renewable energies, but we must also place more emphasis on renewables in the heating and transport sectors. There is one problem with renewable energies: the amount of electricity generated is not constant – as, for instance, with a nuclear power station. In addition to a storage medium such as hydrogen, the electricity needs consumers that can be connected flexibly according to demand and availability. The term sector coupling describes the integration of the different energy sectors: electricity, heating and transport (mobility).




Green electricity and electricity demand are different

**Heat Supply**

The energy demand for heat supply in Germany is around twice as high as the electricity demand. Fossil fuels continue to play a major role in this sector. Power-to-heat technologies such as heat pumps are being introduced to remedy this and to encourage the use of renewable energies. In the boiler room, these work by using electricity to absorb heat from the ground and compress it. The heat extracted is then used for the heating system. This effect can be enhanced further by cost-effective heat reservoirs. This type of heating is particularly beneficial for well-insulated buildings. All in all, therefore, there is a range of alternatives for heat supply, and technologies to replace methods that use fossil fuel have already been tested.

Intelligent solutions for supplying districts with locally produced, renewable energy by means of comprehensive system integration and consistent focus on users' needs will make a considerable and sustainable contribution to the energy transition.

**Transport**

There is great potential for electrification in many areas of the transport sector, but this sector actually has the lowest use of renewable energies (5.6 percent in 2019). Electromobility connects the electricity sector to the transport sector. In rail transport, electrification has for the most part already taken place. Unlike liquid or gas fuels, electricity has to be stored in chemical form in batteries or in a modified form. Electricity can also be used as output energy in power-to-X technology and converted into hydrogen or e-fuels.

However, storage or conversion always involves some loss of energy. Energy integration facilitates the decarbonization of all sectors through the use of renewable energies. This means that fossil fuels will gradually be replaced by renewable energy sources. Linking different sectors with the aid of intelligent technologies will be of crucial importance here. Additionally, energy integration creates greater flexibility in the demand for electricity. In this way, the fluctuations associated with the use of renewable energies can be balanced out without the need for investment in energy storage.

# Summary

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Emissions of carbon dioxide as a cause of environmental pollution should become a thing of the past – as soon as possible. This will not happen without money – which is available, and people are looking for places to invest it. To trigger change, however, we have to think and act globally. Regional and national target definition, procedures and regulations will be replaced by a global approach.

It will be possible, more quickly than one might think, to link up the energy systems of the different regions of the world and especially the key industry players. The latter will become the pioneers of the energy transition, and will tackle the solar, wind and hydrogen project pragmatically on a global basis. The pioneers will also include the companies that currently continue to extract and market fossil fuels, as the majority of the people working for these companies also have children and grandchildren whose future they are concerned about.

But what does this mean for Germany? As an industrial and exporting nation, we will benefit on a large scale from the overall advances. However, we have to realize that, even after the disruption of the fossil fuel system as a primary energy source, we still cannot be fully self-sufficient in energy.

The objective of meeting regular electricity demand by generation from regional renewable sources seems achievable. However, as an exporting nation, Germany will continue to import energy – but in the form of hydrogen, e-gas or e-fuels, for example. Electricity will also be imported to balance out the fluctuations in the supply of renewable energy. However, this is perfectly alright, if all the countries in the world together end carbon emissions, thus stopping global warming.

Note: The figures in the graphs have been carefully researched. However, due to the different data basis, they should be regarded as orders of magnitude in order to make the correlations plausible and comprehensible.

# IMPRINT

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