IN FOCUS

FROM PARASITISM TO SYMBIOSIS – WE CAN DO IT!

DREES & SOMMER

Some scientists accuse human beings of parasitic behavior because we take everything from our host, the Earth, that we think we need for our existence without a thought. Geologically speaking, the time span for which humans can live on our planet is very short. For coming generations of our species we have to do our utmost to maintain the Earth's livable condition for as long as possible.

The parasitic behavior began more than 5,000 years ago in the Neolithic period or perhaps earlier, with slash-and-burn agriculture to create new arable land. It intensified with the beginning of industrialization, when people started to help themselves to all kinds of natural resources on an increasing scale. To satisfy the energy requirements of ever-larger machines and motorized transport using combustion, we also took fossil fuel energy from the Earth's interior, beginning with coal and followed by oil and natural gas, using all imaginable methods. We are now also using the perfidious method of fracking.

The Earth has for a long time been reacting by developing a fever, in the form of global warming, as a result of the increase in carbon dioxide (CO2) in the atmosphere. It is now beginning to struggle. The impacts are being seen in the form of heatwaves, severe storms, flooding, water shortages etc. This has not happened overnight. Nor is it irreversible. If we all wanted to, it would be possible for us to change our parasitic relationship with the Earth into a symbiotic one, until we are living more in tune with nature again.

What Can Be Done?

For a start, we must not extract any more carbon from the geosphere – that is, the solid portions of the Earth. Instead we have to take it from the atmosphere, the biosphere and first of all the technosphere. We have to transform this technosphere into a technical cycle from which we recover carbon again and again. The other thing we must do is to remove more carbon dioxide from the atmosphere than we emit.

The energy pathway (page 25) is the decarbonization of energy production using solar energy, geothermal energy, wind, biomass and hydrogen instead of energy from fossil fuels. The aim is gradually to reduce human-induced carbon emissions to zero, in order to prevent the concentration in the atmosphere from increasing above the current alarming record value of more than 420 ppm (parts per million). The way to achieve this is clear, in principle – but we must actually do it, without any further delay.

The materials pathway (page 29) is recarbonization by capturing carbon from the atmosphere, the biosphere and the technosphere instead of from the geosphere as we have done up to now. Decarbonization and recarbonization can allow us to return to a predominantly natural carbon cycle (as shown in figure 2). The carbon cycle of the oceans and the landmass is largely balanced. If it were possible to turn human activities around so that they help to create a carbon sink, in theory the balance could be reestablished.

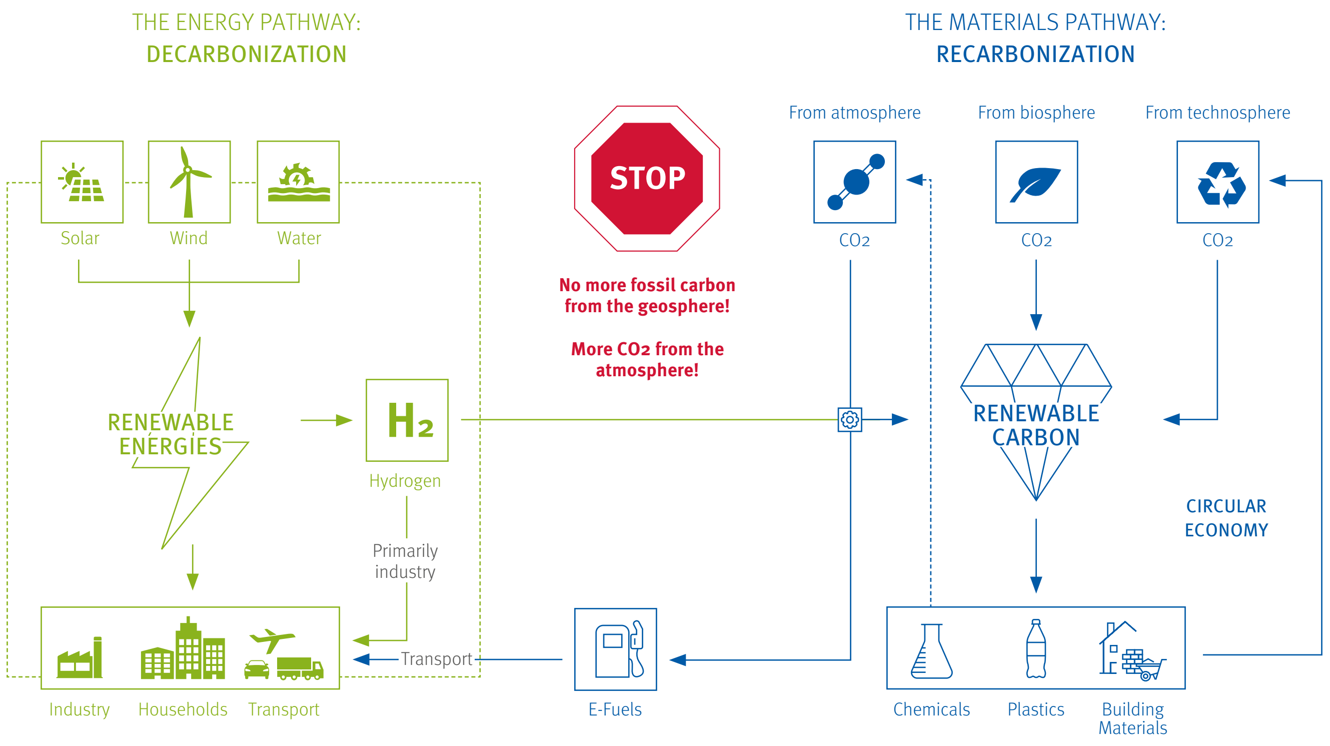


Fig. 1: The two pathways to combating global warming

Human Activities Help to Create a Carbon Sink

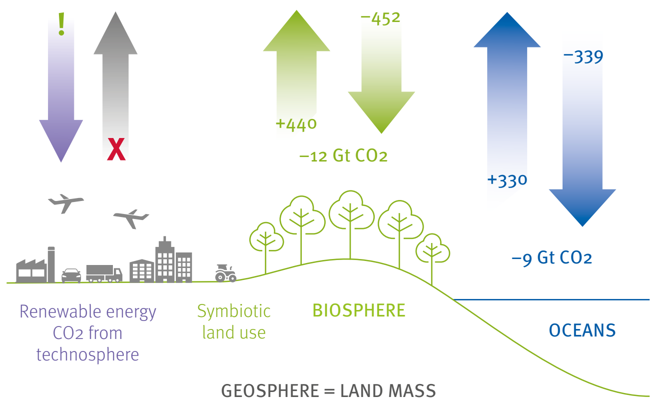


Fig. 2: Reversal of human-induced carbon emissions to create a carbon sink by 2050

'By 2100 we will reduce the CO_2 concentration in the atmosphere to pre-industrialization levels.'

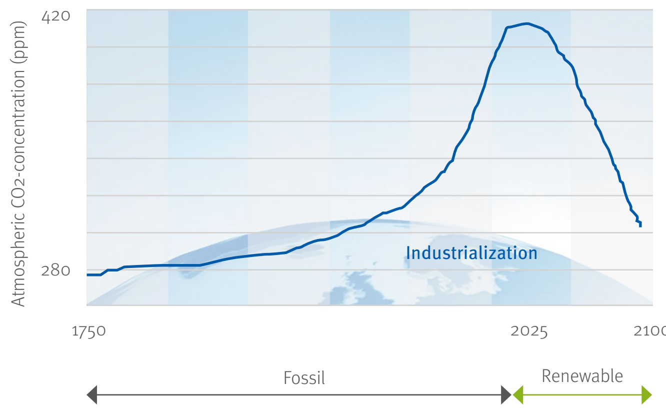


Fig. 3: Vision 2100 – an atmosphere as it was before industrialization

For instance, storing carbon in the products of the chemical and plastic industry and other products, such as construction materials, could reduce the carbon in the atmosphere again. In other cases, such as in e-fuels, at least no additional carbon is produced.

Other countermeasures to create carbon sinks include protecting woodlands and rainforests and reforestation, in addition to restoring peatlands. Natural, growing peatlands extract CO_2 from the atmosphere and store it in the peat. On average, peatlands store around 700 tons of carbon per hectare – six times more than a hectare of forest can store. Semi-desert greening is also being considered for certain semi-arid areas. This involves seawater desalination using renewable energy. If we switched to a predominantly vegetarian diet and reduced livestock numbers, there would also be a very positive impact.

All these activities are about giving back to our environment in a kind of symbiotic relationship, instead of damaging it further. Human beings are therefore in transition from a fossil fuel-driven to a regenerative industrial age.

If we systematically implement decarbonization, recarbonization and other measures that acknowledge our symbiotic relationship with the planet, we can return the atmosphere to its pre-industrial condition by 2100, and thus hopefully preserve our world for future generations. It is too late to rehabilitate the areas that have already been destroyed – melted glaciers, extinct species etc. However, we could prevent further harm.

The Current Situation in Relation to Climate Change Mitigation in Germany

Germany reached its climate target for 2022 and reduced its greenhouse gas emissions compared with the previous year. However, the results for the individual sectors vary significantly: While industry, agriculture and the waste management sector are all well below their targets, the buildings and transport sectors have clearly exceeded theirs.

Energy Sector

In the energy sector, 2022 initially brought a sharp increase in emissions. The reason for this was an increase in the use of bituminous coal and lignite for energy production. Overall, however, the energy sector just managed to meet its 2022 emissions target of 257 million tons of CO_2 equivalents.

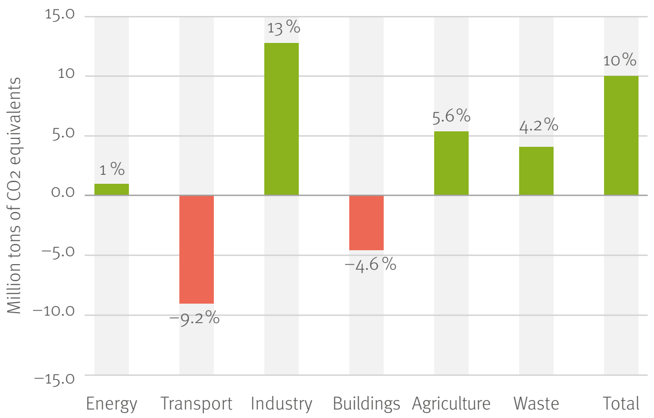


Fig. 4: Difference between the 2022 targets for the sectors and the levels achieved

The share of renewable energies in the electricity sector as a whole continues to grow, but too slowly. Electricity production from renewable sources has grown by nine percent in comparison with 2021, and now covers 46.2 percent of Germany's gross electricity consumption. The share of renewable energies as a proportion of gross final energy consumption – the total consumption of electricity, heat and fuels – has also increased, albeit only to a little higher than 20 percent.

Apart from the need to expand renewable energies hugely (especially wind and solar energy), the greatest challenges are to increase storage capacities, expedite the expansion of the network, and increase sector coupling. Drees & Sommer is actively working with partners on solutions to these problems.

Transport Sector

According to official figures, transport sector emissions exceeded the target for the year, at 148 million tons of CO_2 equivalents – the permitted level was 138.8 million tons.

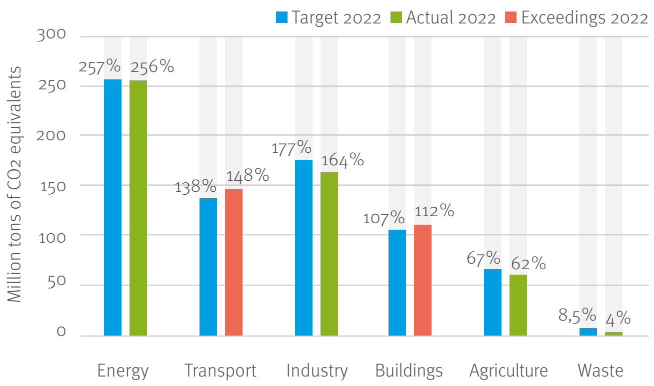


Fig. 5: Comparison of target achievement by sector (target/actual)

After the relatively low volumes of car traffic in 2021 as a consequence of the pandemic, traffic increased again during the past year – along with fuel consumption. Prices at the pump were reduced by a fuel price rebate in Germany. Also, although 2022 was a record year for registrations of new electric vehicles, the growth was not sufficient to compensate for the increase in emissions.

There was a jump of 16 percent in the use of renewable electricity for transport, but sales of biofuels stagnated over the same period. This meant that the share of renewable energies in the total final energy consumption remained the same as in the previous year at 6.8 percent, according to the German Environment Agency.

It has already been decided that electric motors are to be the norm in future car manufacturing. Combustion engines using only e-fuels are an option in principle, if they are available in appropriate quantities and at competitive prices. However, we will initially need these products chiefly in the chemical industry and for the manufacturing of plastics, as well as in aviation, shipping and heavy goods vehicle transport.

Industrial Sector

Emissions in the industrial sector dropped by 19 million tons of CO_2 equivalents – or 10.4 percent – in 2022. The target was around 177 tons, but the emissions only amounted to 164 million tons.

The war in Ukraine and the soaring energy costs connected with it have resulted in sharp falls in energy use. This primarily affected the metalworking and chemicals industries, which used significantly reduced amounts of fossil fuels (with the exception of anthracite). Manufacturing figures are also declining in some areas, especially in the energy-intensive industries. This has already prompted talk of a partial deindustrialization.

The Power-to-X pathway, which entails the production of electricity-based fuels such as hydrogen, methane or methanol in global regions rich in solar and/or wind resources, presents a great economic opportunity for Germany. Domestic companies are currently leading the way in many key technologies for the production of these synthetic fuels. These include electrolysis, the catalysts used for the synthesis processes, and the construction of the complex chemical plants themselves.

In this sector, Drees & Sommer is primarily involved in process improvements, the use of hydrogen, and sector coupling.

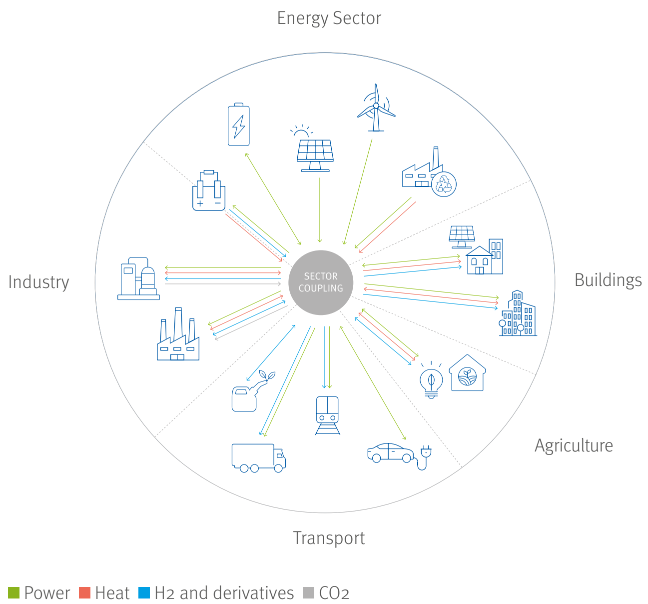


Fig. 6: Sector Coupling for an integrated overall system

Buildings Sector

Although the buildings sector reduced its emissions by 6 million tons of CO_2 equivalents compared with 2021, it still exceeded the target set for 2022, which was 107.4 million tons of CO_2 equivalents, while the quantity emitted was 112 million tons. Also, the reduction in comparison with 2021 was not the result of energy-saving measures, but primarily the higher energy prices and the mild weather, which had the effect of reducing people's use of heating and hot water. The main increases were in sales of light heating oil, which rose by around 9 percent to replenish stocks again after the low level of heating oil purchases in 2021.

The buildings sector faces big challenges. Germany's heating systems are on average 17 years old. In 40 percent of apartments, the radiators are at least 20 years old and should be replaced. The demand for heating system upgrades is strong, and the opportunities are potentially also huge. The replacement of these heating systems would reduce CO_2 emissions significantly. Building construction also generates high levels of CO_2 equivalents, which we must also take into account. The current and future possibilities are covered below in a separate section, along with the approaches taken by Drees & Sommer.

Agriculture and Waste Management Sectors

The agriculture and waste management sectors both remain significantly below the specified annual emission targets. Instead of 67.6 million tons of CO_2 equivalents, the agriculture sector recorded 62 million tons. This was mainly attributable to a further decline in pig farming. The quantity of chemical fertilizers used in agriculture was also lower due to the rise in costs as a consequence of the war in Ukraine.

At 4.3 million tons, the emissions from waste management are also well below the specified level of 8.5 million tons. The main reason for this is the banning of organic waste from landfill.

Cost-Effective Ways to Avoid CO_2 in the Buildings Sector

The construction and buildings sector is one of the biggest climate change culprits, and currently accounts for 38 percent of global CO_2 emissions. This figure includes building operation – the CO_2 emissions from the consumption of energy in the form of natural gas, heating oil or electricity for heating and hot water systems and air conditioning. It also covers the CO_2 emitted during construction, including energy consumed in the manufacturing of construction materials and process-related CO_2, such as from the burning of limestone during cement manufacturing.

At Drees & Sommer, we began to look at how CO_2 emissions could be reduced as early as the 1980s. Initially our aim was to reduce the energy wasted in running buildings, and since 2000 we have not used any fossil fuels in buildings occupied by ourselves. However, to make a real impact, we have to consider the complete life cycle; in other words, we need to take into account factors such as the manufacturing of construction materials, while also making everything cost-effective. According to Drees & Sommer's 'blue way', ultimately only a symbiotic relationship between ecology and economy leads to success.

- **Glazing:** often only single-glazing or in need of upgrading
- **Façade profile:** often without thermal separation
- **Thermal insulation:** often lacking or of insufficient thickness
- **Solar protection:** not centrally controlled by electromechanical system
- **Sealing layers, sealing profiles** torn or disintegrated
- **Condensation:** accompanied by strong cold air drop
- **Contaminant loads:** often within the façade
- **Ventilation and air conditioning:** ineffective, not up to modern standards of comfort
- **Electrical installations:** mostly outdated and difficult to upgrade

The recent decisions by the German federal government are a response to the fact that Germany has a great deal of catching up to do, as far as reducing CO_2 emissions in the buildings sector is concerned. In energy renovation, a key role is played by the interaction between the shell of a building, the technical building services and the building physics. These three elements have a particularly strong impact on the indoor climate and the energy used for heating and cooling.

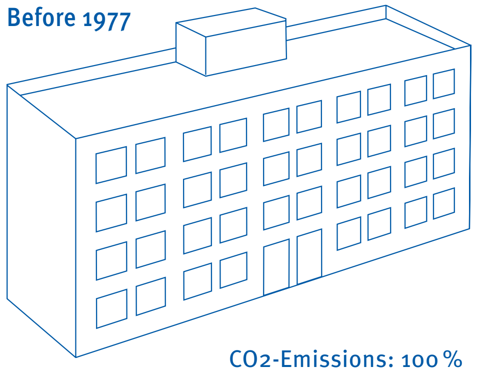
Although there are certainly solutions for sustainable heat production, as described in a later section, these generally involve a fairly expensive structural upgrade of the building. Of course, it mainly depends on the condition of the building. Buildings of an older type of construction often have typical defects that are not necessarily considered initially.

Heating generators designed for low-temperature heating systems usually require modifications on many fronts: improvements to the building's roof and façade insulation are usually unavoidable, along with transformation of the heat output in the building. The latter generally entails replacing all the radiators. This alone is expensive enough – and if any of the defects described above are discovered, a gut renovation is likely to be needed.

The investment costs for optimizing existing buildings with the aim of sustainable, carbon-free heat production must be affordable for the owners. Grants alone will certainly not cover the entire cost. Before every upgrade, owners should obtain comprehensive advice on a long-term approach – regarding not only structural issues, but also possible changes of use and the most appropriate project workflow. Depending on the scope of the work, property owners may not be able to avoid having to vacate the building, unless an intelligently designed workflow can get around the issue. For this to work, the individual tasks and consequences with regard to the future use, cost-effectiveness and feasibility have to be examined carefully.

The diagrams below show the differences between the tasks for buildings erected before 1977, when the first German Thermal Insulation Ordinance (1. Wärmeschutzverordnung) was passed, and for buildings that it is possible to build today (2022) and in the future (2035).

Before 1977



CO_2-Emissions: 100 %

NEW OFFICE BUILDING BEFORE 1977
(THERMAL INSULATION ORDINANCE)
(5,000 GFA, 15,000 GV,
expected useful life 50 years)

Construction
- Solid
- Weak/uninsulated
- Simple façade
- Low technological standard
- Construction materials non carbon-efficient

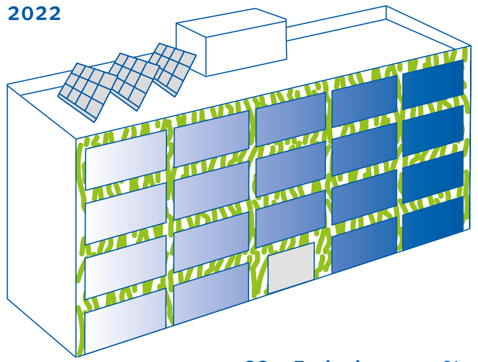
Cradle to Cradle® – properties
- Origin: primary material from the geosphere: 98 %
- Usable in future:
  High-quality RC technosphere/biosphere: 20 %

Energy supply/building services
- Oil-fired heating
- Mains electricity
- non-energy efficient

Environmental performance (CO_2 per year)

Building construction	55 t CO_2/a
Building energy requirement	352 t CO_2/a
Users' electricity consumption	124 t CO_2/a
Energy produced by the building	0 t CO_2/a
Total CO_2-Emissions	**532 t CO_2/a**

2022



CO_2-Emissions: 25 %

NEW OFFICE BUILDING 2022
(5,000 GFA, 15,000 GV,
expected useful life 50 years)

Construction
- Solid
- High standard of insulation
- Highliy insulated façade
- High tecnological standard
- Construction materials more carbon-efficient

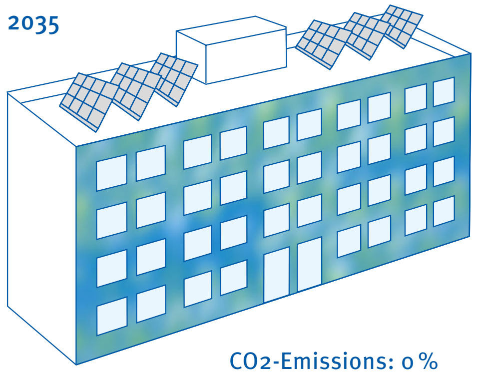
Cradle to Cradle® – properties
- Origin: primary material from the geosphere: 95 %
- Usable in future:
  High-quality RC technosphere/biosphere: 30 %

Energy supply/building services
- Geothermal, heat pump (or similar)
- Photovoltaics 150 m²
- Mains electricity
- High energy-efficiency

Environmental performance (CO_2 per year)

Building construction	41 t CO_2/a
Building energy requirement	124 t CO_2/a
Users' electricity consumption	59 t CO_2/a
Energy produced by the building	–88 t CO_2/a
Total CO_2-Emissions	**135 t CO_2/a**

2035



CO2-Emissions: 0 %

NEW OFFICE BUILDING 2035
(5,000 GFA, 15,000 GV,
expected useful life 50 years)

Construction

› Modular construction components
› High standard of insulation
› Translucend façade, adaptive
› Very high tecnological standard
› Some construction materials a CO_2 sink

Cradle to Cradle® – properties

› Origin: primary material from the geosphere: 50 %
› Usable in future:
High-quality RC technosphere/biosphere: 75 %

Energy supply/building services

› Geothermal, heat pump (or similar)
› Photovoltaics 250m²
› Mains electricity
› High energy-efficiency

Environmental performance (CO_2 per year)

› Building construction	14 t CO_2/a
› Building energy requirement	69 t CO_2/a
› Users' electricity consumption	37 t CO_2/a
› nergy produced by the building	–120 t CO_2/a
Total CO_2-Emissions	**0 t CO_2/a**

In buildings erected **before 1977** the idea of Cradle to Cradle® (C2C, see page 32) or the true circular economy was unknown. Ninety-eight percent of the primary materials for construction originated from the geosphere. Around 20 percent are reusable after demolition. The CO_2 emissions amount to 523 tons per annum (defined as 100 percent), of which building energy and users' electricity consumption account for 477 t/a. Bringing these emissions down as close to zero as possible and making this effort cost-effective is clearly a huge task. It requires an optimum of analysis, planning and implementation.

For a new build today, it is possible to design and implement both the building and the technology. However, the true circular economy in the form of Cradle to Cradle® is still in its infancy, meaning that the construction materials and building elements to support C2C are not readily available yet. As a result, 95 percent of the primary material still originates from the geosphere. Around 30 percent of the materials can be reused after demolition.

Thanks to the optimized interaction between building's shell, the building services and the building physics, the energy supply situation is significantly better. The building in the example has a heat pump with geothermal energy, and uses photovoltaics. Additional digital data and processes contribute to the reduction of the building energy and users' electricity, with the result that the energy production for the building services only causes CO_2 emissions of 94 t/a, around a quarter of the quantity produced by the pre-1977 new build.

In twelve years, the influence of C2C will have grown. New technologies such as intelligent façades will also have a positive impact. These digitally-controlled façades will change their physical behavior in response to the weather conditions, and will probably also have integrated solar cells to produce additional electricity.

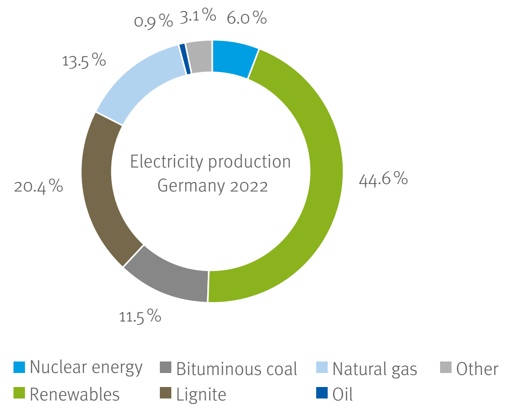
In 2035, only around half of the primary material for the building will originate from the geosphere. Approximately 75 percent of all the materials used will be reusable or recyclable without any loss of value after the building is demolished. The CO_2 emissions from the actual construction will only amount to a third of the quantity produced in 1977. The total CO_2 emissions will be zero. Further measures, such as photovoltaics other than for the building's own use, will make the building a carbon sink.

The diagrams show that if we want to reduce CO_2 emissions over the entire life cycle of the building we have to consider two aspects, which we will go into in greater detail below. They are the energy consumption during use (energy pathway = decarbonization) and the construction method, including the materials used (materials pathway = recarbonization), which in future must be based on true circular economy principles in respect of the resources used in the construction materials.

The Energy Pathway – Decarbonization Through Energy-Efficient Building Operation

The only way to reduce CO_2 emissions from building operation is by a gradual switch from fossil fuel energy sources to renewable energy sources.

Electricity production in Germany 2022



Breakdown of renewable energies 2022

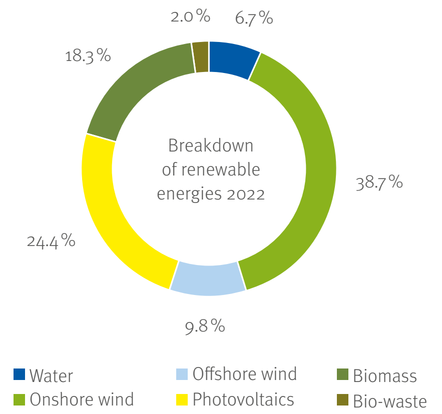


Fig. 7: Electricity production in Germany in 2022 and the share of renewable energies

However, at present only around 45 percent of electricity is produced from renewable sources. Given the current electricity mix, for every use of electricity – regardless of the statutory definitions – on average more than 50 percent of that electricity is causing CO_2 emissions from fossil fuel energy. This applies equally to electric vehicles, heat pumps and general electricity usage in buildings.

Primary energy consumption, Germany 2022

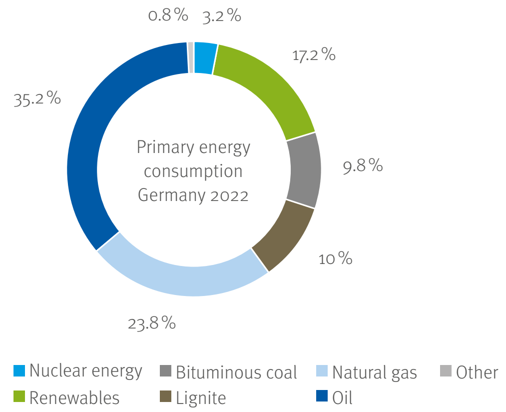


Fig. 8: Share of renewable energies in primary energy consumption in Germany in 2022

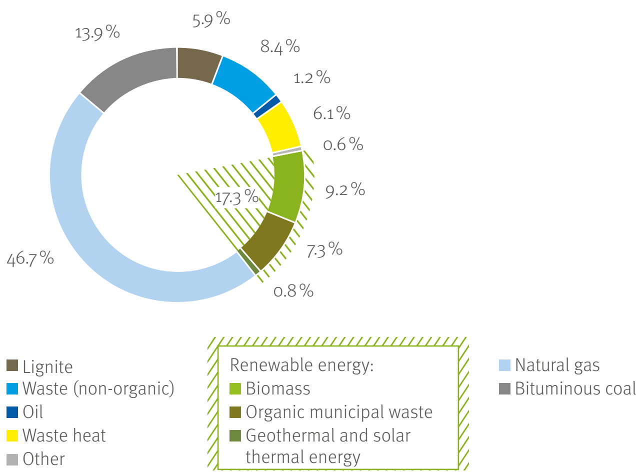
However, renewable energy should in future cover not only existing electricity demand, but also a large portion of the overall primary energy demand. Up to now, only a share of up to 17.2 percent has been covered. In other words, renewable energies will have to be expanded sixfold unless we save substantial amounts of energy instead.

A very large share of fossil fuel energy is used for heat – especially for heating homes. The emissions are highest from the use of heating oil, followed by liquefied gas and natural gas. To deal with this, the German federal government wants to switch to other energy sources for heat production as quickly as possible, for both new buildings and older buildings.

In well-insulated new buildings this is okay, and it is generally being done anyway. However, in older buildings it is much more important to accelerate the reduction of the buildings' energy requirements as a first step (e. g. over five years) by issuing specifications and setting up a well-funded attractive grant scheme. Provisions for low-temperature heating systems could also be included. The second step should be to switch existing residential buildings to energy sources with low CO_2 emissions, and this should be coordinated with the development of a green electricity supply. It would be disastrous if the population were forced to buy heat pumps which then had to be operated mainly with fossil fuel-based electricity (especially from coal).

Expansion of District Heating for Entire Quarters

As a nationwide solution there are plans for a huge expansion of district heating, which is certainly an efficient approach. District heating networks can be very flexible and use a number of different heat sources, both central and decentralized. The difficulty is that at present district heating is by no means as sustainable as many people think. District heat is usually produced in large power plants with cogeneration, smaller combined heat and power (CHP) plants, waste incineration plants, or district heating plants – with coal, natural gas, biogas, oil, wood and wood products, solar thermal energy, and refuse (biogenic and non-biogenic) in various combinations and processing forms as a fuel.



* The heat provider and injections from industry and other
** Provisional

Fig. 9: Average energy mix for district heating in Germany in 2022

The lion's share of the energy for district heating currently comes from fossil fuels, particularly natural gas and coal. Only around 18 percent comes from renewable sources, especially biomass and biogenic refuse, and less than 1 percent is geothermal or solar energy. There is definitely still significant potential for expansion, at least in the case of geothermal energy. A further pathway to improving sustainability is based on sector coupling, through the integration of industrial waste heat into district heating networks.

The transportation of district heating becomes significantly less efficient from a certain pipe length, which is why the consumers usually live within a radius of 10 kilometers (the maximum is 20 kilometers) from the power station. Where the distances are shorter, the system is referred to as a local heating network.

Connection to a district heating network has some advantages: it saves space, no fuel purchases are necessary, there are no maintenance costs and it is easy to operate. Also, no building renovation is required, although of course it is helpful. The disadvantages, depending on the region, are the usually relatively high costs and being tied to a specific provider. Connection is often compulsory.

Overall, however, district heating is a sensible way to reduce the CO_2 emissions of entire city quarters, especially with the potential for sector coupling. Also, the efficiency of the plants is improving continuously. Only more sparsely populated regions are not being offered district heating for the foreseeable future. The only options in these areas are individual systems or small local heating networks (e. g. bioenergy villages).

Heating With Heat Pumps

There has been a lot of hype recently around the use of electric heat pumps. However, with the current measurement basis (–10 bis –15 °C) they are only cost-effective for operation as a low-temperature heating system. This is generally feasible in new buildings, but it is difficult with buildings dating from before the introduction of the German development bank energy efficiency standard KfW55 EE, and buildings heated by normal radiators. These cases call for renovation followed by energy improvements – including replacement of the heaters and hydraulic balancing.

However, our climate has already changed measurably. In recent winters the temperature has only fallen below 0 °C for a few hours. If this continues – and that looks likely – in many cases expensive insulation might not be necessary, and perhaps only some of the old radiators would need to be replaced by new and more efficient ones.

As a further alternative, higher temperatures can also be achieved by using high temperature heat pumps – although these use significantly more electricity. Hybrid solutions are another option, in which a gas-fired boiler starts up, for instance, on the few hours during the year when the temperature falls to –5 °C or lower. Of course, this is more cost-effective, especially if the gas boiler is already in place.

A general process for a heat pump-ready renovation at current temperature specifications could take the following shape:

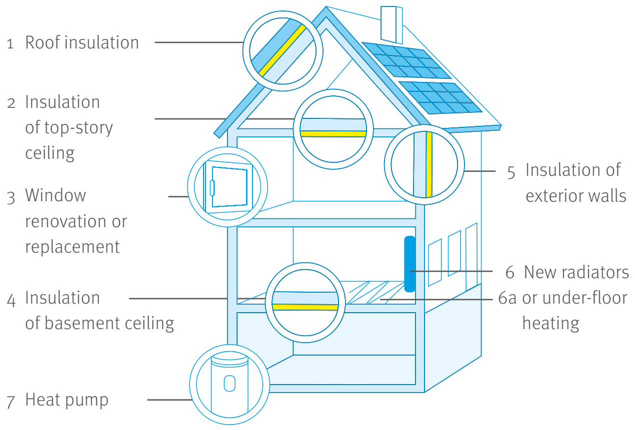


Fig. 10: The sequence of the steps in an energy renovation process

If the building is equipped for a low-temperature heating system (heat pump-ready), there are various options.

Air-to-Water Heat Pump

How the heat pump produces energy from air can be explained in a simplified way using the example of a refrigerator. While a refrigerator transfers warm air from the inside to the outside, the air-to-water heat pump brings the warmth from the surrounding air into a room. A fan actively draws in the surrounding air and transfers it to an air-to-air heat exchanger (evaporator) built into the heat pump. A refrigerant circulating inside the pump changes its physical condition and evaporates even at low temperatures. A compressor compresses this refrigerant vapor to raise it to a level at which it can be used for heating and hot water.

A heat pump operated with the current electricity mix only performs around 30 percent better overall than natural gas heating in terms of CO_2 emissions.

Air-to-Water Heat Pump With Photovoltaic (PV) System

Heat pumps with a PV system and battery storage are an effective and sustainable combination. With the electricity produced by the photovoltaic system, the heat pump can provide heating energy directly. This reduces operating costs significantly and the entire system works in a more environmentally-friendly way. The German federal government provides grants for the purchase of heat pumps and photovoltaic systems, individually and as a hybrid system.

Heat Pump With Geothermal Energy

There is a lot of heat stored beneath the surface of the earth, which makes it one of the most important sources of heat. Below a certain depth, the ground temperature is around 10 °C. The temperature is very constant in comparison with that of the ambient air. Even if the upper layer of earth is frozen, geothermal heat pumps work efficiently because the difference between the heat source and the flow temperature stays relatively small, even in winter.

The mechanics are basically the same as in air-to-water heat pumps, except that there is more basic heat available, especially in winter. However, the geothermal probes make the equipment significantly more expensive, which is why they are more suitable for large buildings (almost all high-rise buildings). A further advantage is that they provide very inexpensive cooling in summer, purely through circulation and without the use of the heat pump. Unfortunately, the geothermal probes are not allowed everywhere.

Heat Pump With Geothermal Energy and PV System

The most effective and also the most sustainable way of producing heat is to combine a heat pump with geothermal energy and a PV system. The heat pump is for the most part able to operate on the solar energy produced by the PV system. In this way, the building can even generate surplus energy.

The energy potential of the environment at a glance

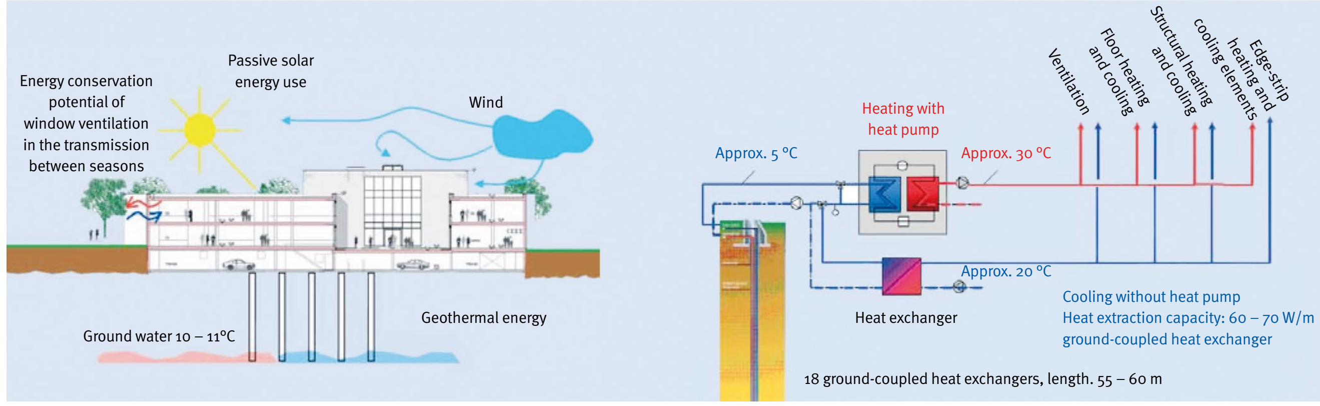


Fig. 11: Geothermal generation of heating and cooling.
Heating yield: Approx. 4.5 kWh heat for 1 kWh electricity

Heating With Wood Is Not Sustainable

Contrary to popular opinion, heating with wood is not carbon-neutral. The notion that a tree burnt in a stove in winter will grow back in 50 years (perhaps) is a naïve fallacy, and to offer grants for wood burning is absurd. The CO_2 emissions are even higher than for fossil fuel energies such as coal or gas. Wood burning also produces carbon monoxide, nitrogen oxide, methane, soot and other harmful emissions.

Basically, wood-fired heating systems of any kind should be banned, at least within residential areas or cities. The only exceptions allowed should be for rural areas or isolated farms with managed forests. Existing plants should be upgraded with an optimum combustion control system such as that developed by Karlsruhe Institute of Technology (KIT).

“Wood is the most highly polluting and environmentally harmful fuel to burn.”
Achim Dittler, Karlsruhe Institute of Technology (KIT)

The only wood products that are really environmentally friendly are durable ones such as items of furniture, which also store the tree’s carbon and so act as carbon sinks. The only wood that should be processed into wood pellets is sawdust or waste timber or wood that has previously been used, provided that the latter has no further use as a material. Unfortunately, forests are now being cut down for the production of pellets, as for instance in Romania.

Heating With Hydrogen

The extent to which green hydrogen could be used for heating is debatable. At present this is more of a theoretical discussion, owing to its high costs and low availability. Nevertheless, green hydrogen could be injected into the existing gas network, for instance at a concentration of 10 percent (and more in the future).

Fuel cells can provide electricity and heat to buildings at the same time. In combination with thermal energy or electricity storage devices, they could become a component for sector coupling. However, the investment and maintenance costs are relatively high, so the system is more suitable for big consumers – and only when inexpensive green hydrogen becomes available.

Gas water heaters are the most widely used water heaters in existing buildings. The investment costs are comparatively low, and the operation and maintenance procedures are established. The cost of converting them into hydrogen water heaters would be low.

However, these possible solutions are currently not high on the agendas of either energy suppliers or policymakers. There is a simple reason for this: for the near future, there will not be sufficient hydrogen in Germany to use it in buildings for heating purposes. For cost-effective production of green hydrogen on an industrial scale, access to large quantities of cheap, renewable energy is indispensable. Large-scale projects to produce green hydrogen will therefore be focused on areas where there is access to cheap, renewable energy from wind and/or sun.

The Materials Pathway – Recarbonization Through Construction Materials and Processes

In the 1960s and 1970s hardly anyone was interested in whether CO_2 was emitted during the construction phase, whether building materials were healthy, or what happened to the building after the end of its useful life.

In the 1980s and 1990s, Drees & Sommer began to design buildings in a way that minimized the use of energy, and using rainwater – for both commercial and ecological reasons. We were also concerned with avoiding the use of harmful building materials (see Site Manager Manual used for the Berlin Potsdamer Platz construction project in this period). Ultimately what we were interested in was minimizing any harm and avoiding negative impacts. We have come a long way on this path of minimizing negative impacts (especially in the area of energy), but we still have a long way to go.

For this reason we now also have to devote increased attention to the second pathway – maximizing positive impacts through product optimization, carbon sink building products and the circular economy in the form of Cradle to Cradle®. We also need to develop a new understanding of materials incorporated into buildings as a repository for raw materials.

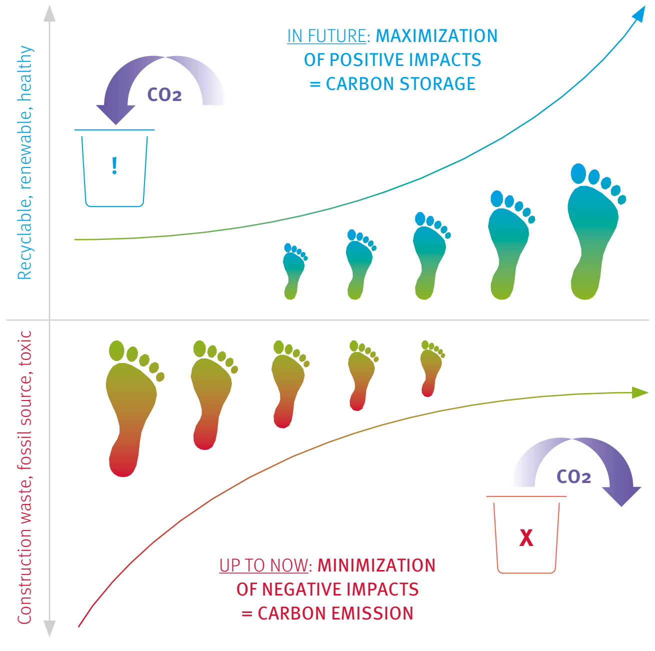


Fig. 12: From minimizing negative impacts to maximizing positive impacts

Optimized and New Construction Materials in Development

For the construction of buildings, gray energy is needed to obtain raw materials and construction materials (cement, steel, aluminum and others) and manufacture building components.

Energy Use for Construction Components

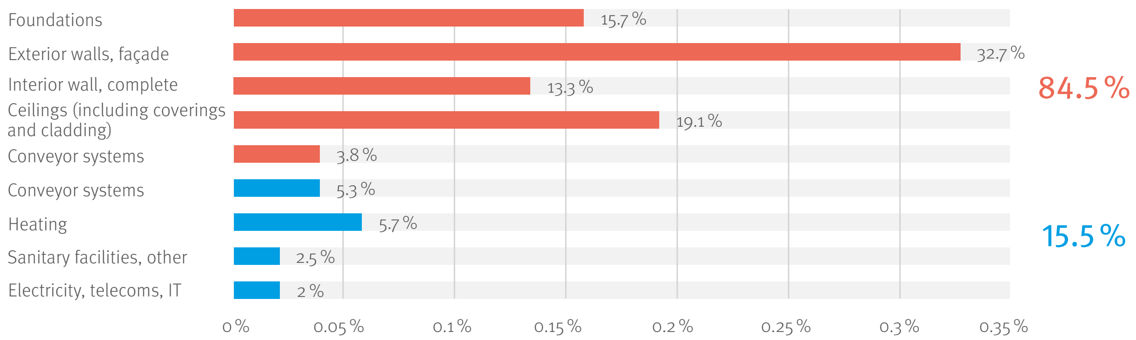


Fig. 13: Comparison of average energy consumption for different building components

The biggest use of energy is for building the shell, the façade and the roof. These cause a large quantity of CO_2 emissions.

53 apartments
Volume: 14,800 m³
Living space: 3,600 m²

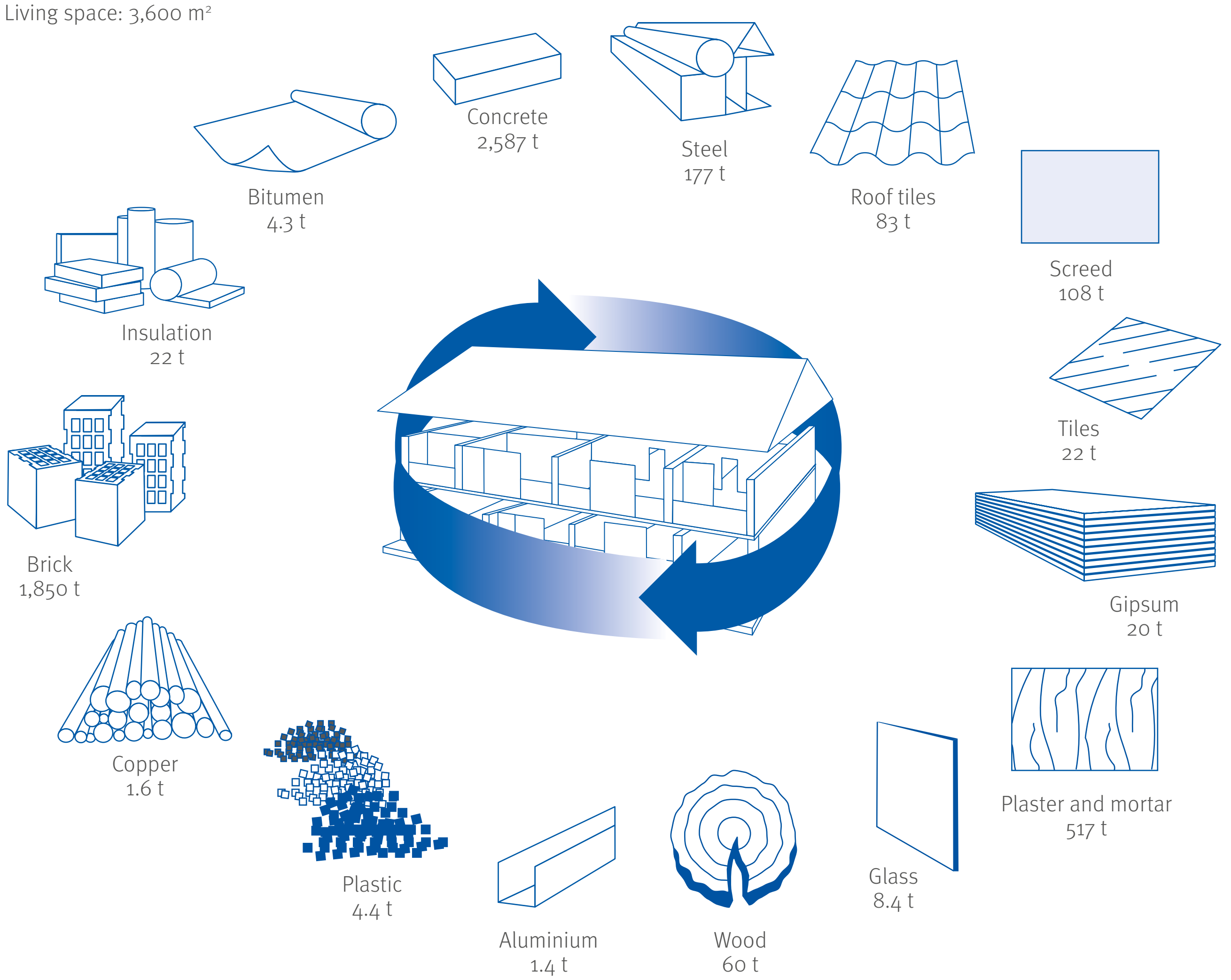


Fig. 14: Construction materials usually used for a residential building, in tons (3,600 m² usable floor area)

Concrete plays a major role in construction (as the diagram shows). We have to put extra effort into developing more sustainable replacements for it and for cement. Development work is already well underway.

Carbon Concrete

Carbon concrete, a combination of concrete and carbon fibers, is stronger, lighter and more durable than conventional concrete. Carbon does not rust and, unlike reinforced concrete, it does not need any concrete cover. The quantity of sand used is therefore significantly lower than for manufacturing reinforced concrete, as are the CO_2 emissions – especially if the carbon is captured from the air. Carbon concrete also scores higher than reinforced concrete in terms of its load bearing capacity and weight. However, the focus here is only on CO_2 reduction; the reuse aspect has not been considered.

Polymer Concrete

In polymer concrete, a plastic (polymer) is used as a binder instead of cement, which gives the material many positive characteristics. When hardened, the product is lighter in weight, which makes it easier to transport and integrate into buildings. Yet the material is stronger than cement concrete and can achieve higher tensile and flexural strengths. Polymer concrete is more vulnerable to impacts, but nevertheless suitable for earthquake zones. Apart from its vulnerability, another drawback is that polymer concrete also only scores points for low CO_2 emissions, not for reusability.

Wood-Based Concrete

Wood-based concrete, or wood-chip concrete, consists of cement as a binder and wood chips or sawdust, which are generally waste products from the timber industry. Impact mills reduce softwood, such as spruce or pine, to the required size. Minerals, water and cement are added to produce wood-chip concrete blocks or insulating panels. Finely ground wood replaces more than 50 percent of the grit or sand content by volume.

Unfortunately, this material is not ideal in terms of C2C compliance, as it consists of a mixture of technical and biological materials that cannot be separated and is hard to recycle.

Cement Manufacturing Without CO_2

A key ingredient in the manufacturing of conventional concrete is cement, which has a big carbon footprint. A company called Sublime Systems has developed a procedure by which it is possible to produce cement using only electricity instead of heat, without having to rely on limestone as a source of calcium and accept CO_2 as a by-product. The product is expected to come onto the market in 2023.

Wood for Construction and Upgrading

Not new, but long undervalued: Wood is a great material for construction in terms of CO_2. The carbon stored during the approximately 50 years that the trees are growing continues to be stored after wood is integrated into buildings, at least for the 50 to 80 years that they will be in use. After demolition, untreated wood can either be reused or shredded and used for chipboard. Treated wood currently has to be incinerated in thermal power plants. Private incineration is prohibited.

However, it is questionable whether we even have enough wood in Europe to embark on large-scale timber construction.

Biochar From Waste Wood

Instead of incinerating waste wood, it can be used to produce biochar. The technology employed to do this generates negative emissions and captures carbon, storing it permanently in a stable form. A procedure using biochar as a basis for creating alternative materials made from fossil fuels and aluminum, for instance plastics for façades, has been developed by a company called Made of Air.

Fungi as Insulation Material

The part of a fungus that often grows underground, the mycelium, can be processed into insulating or construction materials; scientific procedures to do this are currently being developed. Combined with blended by-products, the foam-like material produced from mycelium could be suitable as a resource-conserving alternative to plastic, Styrofoam or plywood.

Steel Production With Hydrogen

To reduce CO_2 emissions in the steel industry, first of all the processes for primary steelmaking have to be changed, with hydrogen used as a reducing agent for the iron ore instead of carbon as in the current procedure. Another way to reduce CO_2 emissions is by scrap iron-based electric furnace steel production. This low greenhouse gas-emitting procedure is already being used for around 30 percent of the raw steel produced.

Steel and the by-products of steel manufacturing (e. g. slag) are the starting point for a number of value chains that are aligned with the principles of the circular economy and enable considerable reductions in CO_2 emissions to be made. Steel can be recycled repeatedly without any loss of quality, which also helps to reduce greenhouse gas emissions.

A Truly Circular Economy (Cradle to Cradle®)

Glass Production

The glass industry can make a considerable contribution if it absorbs CO_2 from process gases, converts it into combustible material with hydrogen produced from renewable energy, and reuses it for glass melting.

This looks especially promising in the case of oxyfuel processes, in which the process gas has a high CO_2 content. However, the method is currently also being tested for air-driven machinery to cover the whole range of procedures used in the glass industry.

Aluminum Use

Aluminum is mainly used for windows and façades. The electrolysis process, during which pure aluminum – referred to as primary aluminum – is produced from the extract ore, bauxite, requires a large quantity of electricity. If it is produced from renewable energies instead of coal, the CO_2 emissions can be reduced from 20 to 4 kilos of CO_2 per kilo of aluminum. It is also crucial that aluminum be reused at the same grade if possible (windows made into windows again, etc.). The recycling rate for aluminum is very high, but significantly lower than the demand. The reserves are still being built up.

Flooring

A positive example: carpet tiles with a backing construction using biobased and recycled filling materials store large quantities of carbon and have a large proportion of carbon-negative materials.

Findings

A large proportion of the CO_2 emissions in the real estate sector is produced not just during operation, but already begins during construction. The reasons for this are:

› energy consumption during the manufacturing (and transport) of the product;
› chemical reactions as part of the manufacturing processes;
› inefficient products;
› insufficient reuse of integrated materials.

This brings us to another segment of the construction industry that has received far too little attention.

Energy efficiency, reduction of CO_2 emissions, and use of renewable energies are now acknowledged to be requirements in the construction industry. However, this is far from enough. In the long term our problem is not a shortage of energy, but of raw materials. As the biggest consumer of global raw materials and the originator of huge quantities of waste, the construction industry has a greater responsibility than almost any other sector of industry.

The reason for this is the linear process by which the sector continues to remove growing quantities of raw materials from the geosphere for the manufacture of construction materials. For a long time this has been causing considerable shortages – for instance in sand mining – as well as harm to the environment. Recycling has improved matters to a certain extent, although recycled materials generally cannot be used for the same purpose as the original materials.

The solution is based on the Cradle to Cradle® concept, the truly circular economy. Cradle to Cradle is an idealized, closed raw materials cycle modeled on nature, in which all the correctly sorted separate raw materials from which a product is made can be reused. Reusable materials will make future buildings into repositories of raw materials.

The circular economy revolves around more repairs, reuse and recycling, and therefore lengthening service lives. The idea is that where possible buildings should be revived instead of demolished, and modernized within reason; if continued use is not possible or reasonable, they should be dismantled and the components recycled instead of being disposed of as waste. For the purpose of sustainable and cost-effective construction, C2C has to be combined with a carbon-free energy supply and optimization of building use by means of digital data and processes. This applies to new builds as well as to the even more challenging renovation of older buildings.

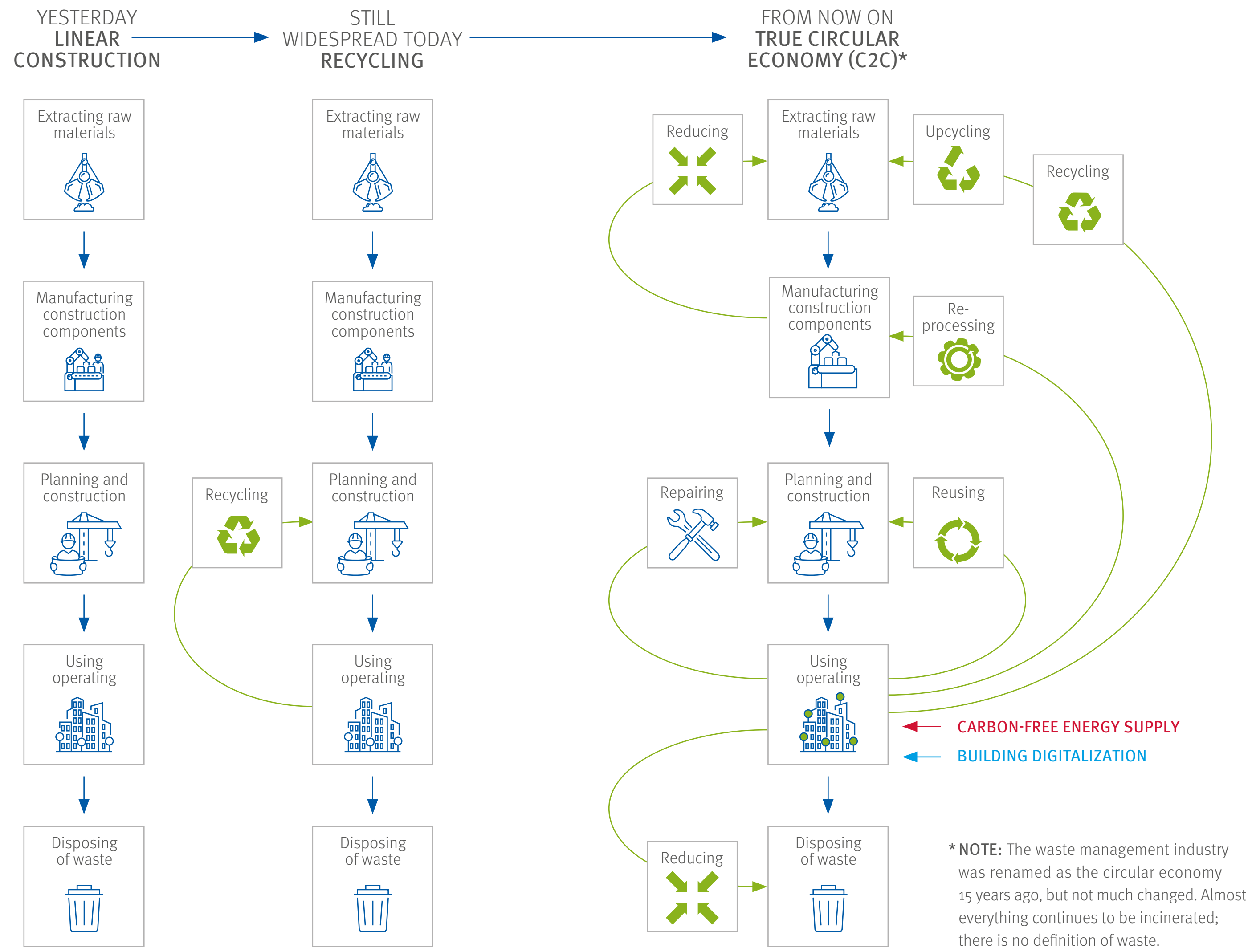


Fig. 15: Changing materials use in the construction industry

Help in planning is provided by good tools such as the **BIM & More plugin** developed by EPEA – Part of Drees & Sommer and Die Werkbank, which brings together a variety of databases and building information modeling (BIM) planning. The product cloud solution enables data to be exchanged between the different participants in the planning phase – including the manufacturers with product data.

C2C AND CO_2 OPTIMIZATION

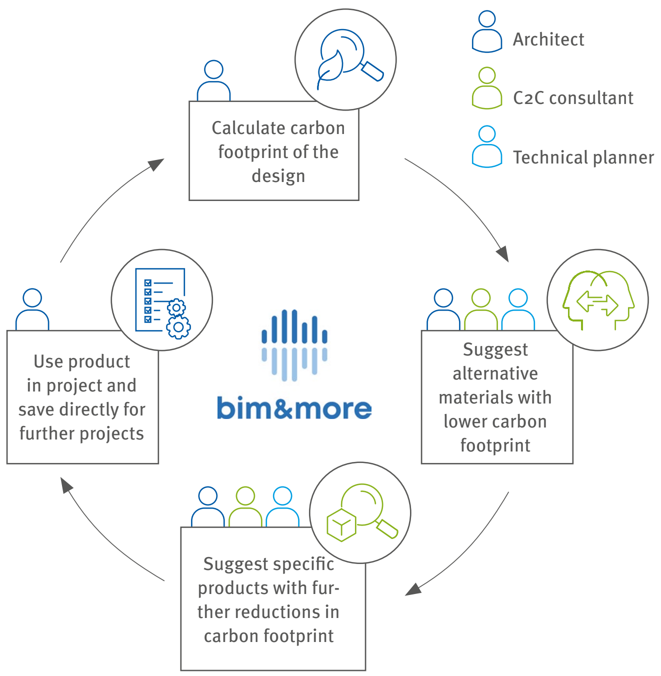


Fig. 16: Combining sustainability criteria with planning, using **BIM & More**

The tool provides an option to create the building circularity passport automatically on the basis of this data. This enables projects to be planned in a way that minimizes CO_2 emissions while also meeting C2C requirements. This is all combined with extensive product information from EPEA and is aligned with the approaches to industrialized construction involved in blue modularity.

In a BIM cloud storage space, planners can save their own data and share it with colleagues. It is also possible to link to platforms such as Madaster and exchange data at a later stage (for updates). BIM & More also offers a number of opportunities for the use of artificial intelligence (AI).

The Approach

Building in line with C2C principles requires a consistent approach, from the preparation and definition of planning content to the handover of the building. In terms of content and cost-effectiveness, this is only possible with digital planning that provides end-to-end database and BIM support.

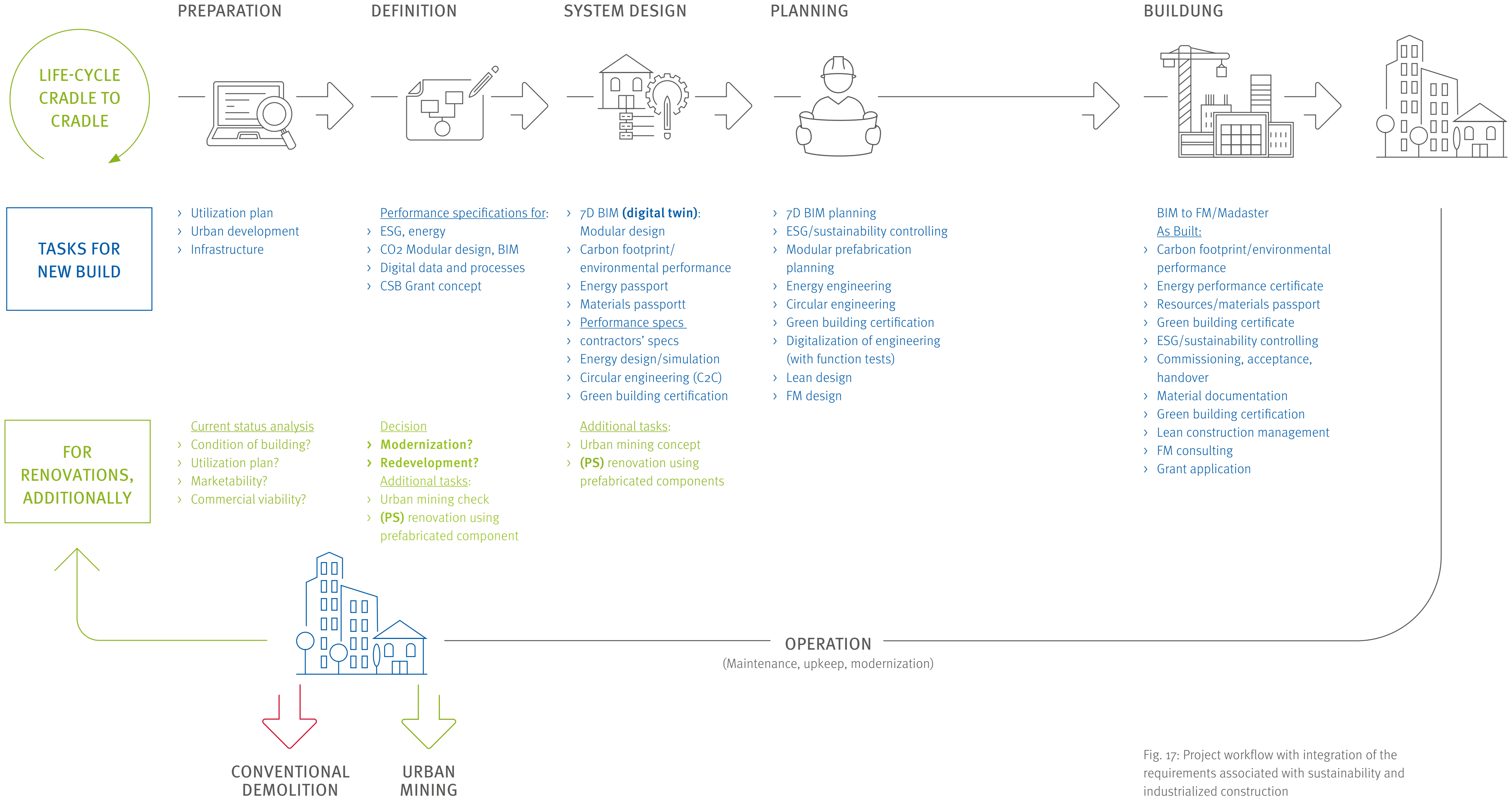
In the preparation phase the task is to analyze and document the constraints that exist. In the definition phase the client's requirements have to be set out in performance and service specifications and possible grants investigated. In the case of a renovation (e.g. one involving modernization) the scope of the work has to be defined. The first aspects to be considered here are the building fabric and the user requirements. The scope can extend to a gut renovation or even repurposing, as part of a redevelopment. This is a matter of commercial viability and cost-effectiveness.

The requirements of the German Climate Change Act (Klimaschutzgesetz) adopted on June 24, 2021 by the German Bundestag, or national parliament, have a huge impact on new builds and an (even greater) impact on the renovation of existing buildings. The new Act brings the deadline for achieving climate neutrality forward by five years to 2045. To achieve the objective, mandatory targets apply for the 2020s and 2030s. The new German Buildings Energy Act (Gebäudeenergiegesetz) brings a further increase in requirements. C2C compliant construction materials will also have to be selected during design. This can all really only be put into execution by modular construction, in which all the information is documented for the individual modules, down to the individual construction materials.

It makes sense to process the contents transferred from the performance and service specifications to the contractor's specifications as 7D BIM information, or as a digital twin. This includes engineering for energy optimization and circular economy as well as modular prefabrication planning and building digitization and digitalization. In the planning phase it is also important to prepare the facility management and manage everything as a lean design.

In the construction phase, the digital twin is created with the aid of lean construction management. After completion, the carbon footprint and the environmental performance evaluation are documented. An energy performance certificate is drawn up, along with a material passport showing all the materials used and their chemical composition. The commissioning, acceptance and handover phase concludes the project, including all documentation, which also forms the basis for the operation and upkeep of the building as well as future renovations.

The loop of the construction and operation cycle will therefore close more and more in the future, as with circular planning many construction materials can be reused or recycled.



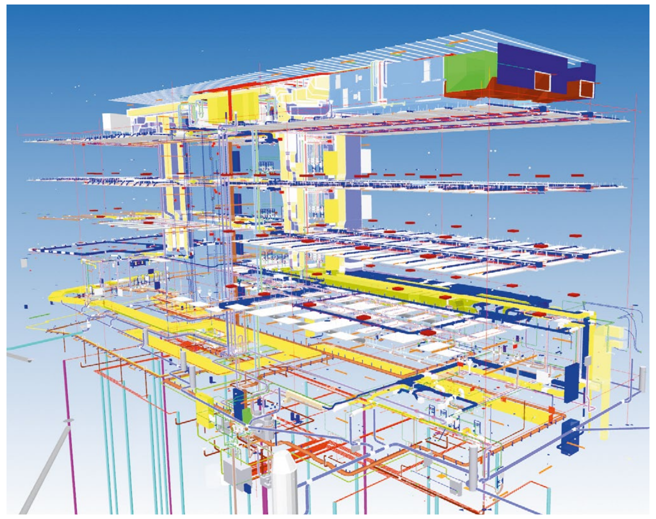


Fig. 17: Project workflow with integration of the requirements associated with sustainability and industrialized construction

Drees & Sommer Innovation Building OWP12: Analysis of the Possibilities in the Living Laboratory

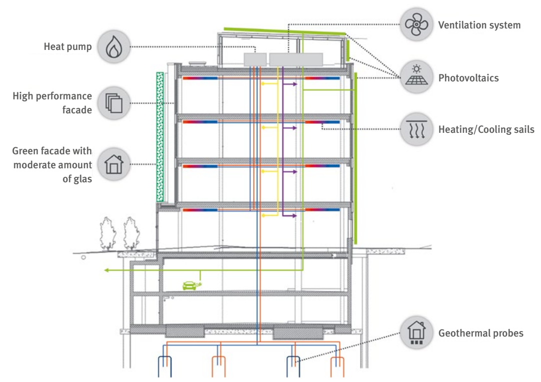
Drees & Sommer's new office building in Stuttgart symbolizes the energy transition in the buildings sector. We designed the plus-energy building to be as recyclable as possible and took care to ensure the materials have no harmful impact on the environment and are easy to dismantle. OWP12 (Obere Waldplaetze 12) produces more energy than is consumed during normal operation. This is due to the newly developed, highly insulated façade construction, photovoltaic panels on the roof and on the south-facing façade, and a large-capacity heat pump that uses geothermal energy from boreholes.

Aided by our subsidiary EPEA, we paid special attention to selecting high-quality, sustainable furniture and materials, using Cradle to Cradle products and C2C compliant materials, where possible.

Although C2C products are not yet available from most manufacturers, CO2 emissions have been reduced by about 20 percent compared to a 1980s building.

Plus-Energy Building

The building owes its energy-plus status to a number of components, the foremost being the geothermal and air-source heat pump and the photovoltaic panels on the roof, which produce around two-thirds of the electricity. We also use waste heat from the staff restaurant and the server room throughout the year so that the unavoidable process energy is not discharged unused. The photovoltaic panels in the south and west-facing façades of the building produce the remaining third of the necessary electricity. Additionally, the window parts in the mullion-transom construction also have insulating glass with integrated wafers. This combination of energy systems ensures that during standard operation the building produces more energy overall than is consumed.



The combination of all these energy systems ensures that the building generates more energy overall than it consumes in standard operation.

Innovation Façade

Years of experimenting and designing by Drees & Sommer experts in collaboration with façade construction company FKN Group based in Neuenstein, near the German city of Heilbronn, have resulted in a novel type of modular façade construction which, thanks to innovative materials (notably sustainable insulating materials) meets very high standards of soundproofing and thermal insulation with exceptionally thin panels. This ensures high space efficiency and enlarges the rentable area of a building – a huge advantage of this façade, named e-coFACE, which should also be of benefit to our clients in the future.

The façade is also very energy-efficient and even produces energy, as described above. For OWP12 it was perfect. The narrow site, right beside a busy highway feeder road, required a high level of soundproofing and thermal insulation, but also a construction method that used as little space as possible. The thermal shell is only 90 millimeters thick. The complete façade with integrated photovoltaic panels is only 210 millimeters thick altogether. For comparison, the total thickness of a conventional façade construction is 400 millimeters.

"Driving innovation can lead to conflicts with building laws. Strong nerves are needed to resolve disagreements."
Thomas Berner, Associate Partner at Drees & Sommer

The innovative façade system's fire safety classification also makes it suitable for use in high-rise construction – it has been certified by the Construction Materials Testing Institute of the Technical University of Braunschweig (TU Braunschweig) and has received national technical approval (abZ) from the German technical authority for the construction sector (Deutsches Institut für Bautechnik – DIBt).

The materials used in the e-coFACE meet the requirements of environmental labels such as DGNB, LEED and BREEAM. The underlying insulation material Calostat is C2C certified. The degradability of all parts, which is planned in detail, provides the possibility of sorting by type; the materials can be recycled or reused after their period of use.

Green façade

We planted a part of the façade to create a living wall. The load-bearing panels of the greenery system consist of aluminum girders and Alucobond panels, the aluminum for which came from recycled sources and is in turn recyclable. The green façade is watered with rainwater, which is harvested in three cisterns in the rooftop systems center and distributed via a gravity system, supplemented automatically if necessary by mains water.

The green facade was designed as a pattern and model for other construction projects. In addition to the materials, the operation was also considered.

Customized Smart Building

Digital aids keep operational energy consumption in OWP12 to a minimum. The apps make the work lives of the staff easier: For instance, they can manage access authorizations quickly and easily, book conference rooms, allocate parking spaces in the parking garage, and automatically adjust the settings for heating, cooling, ventilation or lighting to their own needs. We worked on the necessary IT and sensor technology solutions with our collaboration partners, Phoenix Contact and Solo Lightning.

This kind of intelligent IT infrastructure design offers many advantages

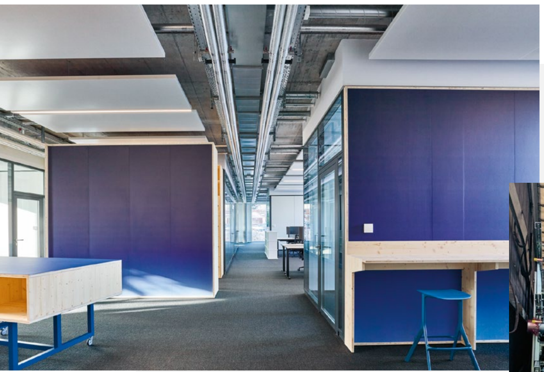
› Integrated network solution
› End-to-end security system design
› WLAN illumination and consolidation points reduce the amount of wiring
› Power over Ethernet (PoE) – supply to IoT gateways and IT equipment
› Sensor technology controls displays and switches them on and off

The first steps, such as monitoring and supervision, optimize the interaction of all parts of the system with the aim of improving efficency in the operation and use of the building.

The MEP Systems Module: Pre-fabricated modular construction components

Eighty percent of building components are currently manufactured on building sites, with only 20 percent being prefabricated. This ratio has to be reversed. Many components can be made anywhere, regardless of the weather, in a factory and then delivered to the building site just in time. For OWP12, we developed two prototypes for a new mechanical, electrical and plumbing (MEP) systems module with Würth.

Compact, prefabricated MEP systems components like this require the use of a digital planning method such as building information modeling (BIM). Looking ahead, the data on dimensions, materials or technical properties entered in the BIM models can be transmitted direct to machines or 3D printers, which then produce standardized manufacturing components.



The modules can be transported to the construction site easily and quickly. They are fully assembled in less than 30 minutes. With conventional building methods, this takes around 12 hours. Shifting production of construction components to a factory makes it easier to find skilled labor, and these employees no longer have to assemble the individual MEP components on site, sometimes in cold or hot weather. Prefabrication also increases the quality of the components, for which precision work is required.

The BIM model also functions as a digital memory, which is valuable for later dismantling. Information such as which modules were made with which materials, and where they were used in the building, is precisely defined, so that at the end of the useful life of the building the modules can be removed and either upgraded and used as a unit in the next office building or recycled as individual components. One thing is certain: nothing goes to landfill.

C2C and Circular Economy = Fit for Future Generations

A Building circularity passport issued by EPEA documents the central C2C-related features of every individual material used in the building, for instance its origin and how recyclable and separable it is, and grades it using a traffic light system. There is a direct link to the BIM model of OWP12 in this case also. A BIM visualization of the C2C grade ensures that optimization potential can be identified easily.

Once the project is completed, the Circularity Passport provides detailed information on which materials can be easily separated and the chemical composition of the products used. It also makes it easy to determine the monetary values of the structures used in the buildings. This information about the property provides a great deal of added value for financing from a risk point of view, for determining the value and for the operation of the buildings.

Planning and Construction Efficiency Through Digital Processes and services

OWP12 also sets a new benchmark in the digitalization of the project workflow: Our team used BIM to coordinate ideas, designs, simulations, schedules, contractor's specifications, budgets, and planning permissions. Before the first digger moved in, we were already able to explore the completed building as a digital twin, from the basement right up to the roof. We identified any inconsistencies in the plan or construction early and corrected them before they could lead to delays on the building site.

This was also the first project on which we integrated lean parameters into BIM. The BIM model showed not only the theoretical planning status; a newly created interface with the LCM Digital tool also enabled it to show the actual construction progress of the takt zones and the sequence of work on the construction site.

This enabled us to make and visualize comparisons between the planned processes (target situation) and possible risks and critical interfaces (current situation) clearly and easily in a digital dashboard. A key advantage of these comparisons is that clients can see the current situation at a glance and identify the takt zone in which their construction project is behind schedule, and where it is making good time. This allows the work teams to be deployed significantly more efficiently.

Conclusion

It has become clear that the fundamental need for climate protection in conjunction with the planned new legal requirements for the green heat transition (GEG Building Energy Act) and the concerns of a true circular economy require a completely new type of planning. This will increasingly have to be modular planning in order to be able to implement the requirements with an industrialized or industrial construction method.

Depending on the age of their buildings, existing owners will have to make major investments sooner or later. Figure 18 shows an example of the urgency of the possible need for action. However, the building quality varies greatly due to the construction method, ongoing maintenance and use. Therefore, this can only be a rough indication.

However, it has also become clear that the need for building renovations no longer depends solely on the age of the buildings. Irrespective of this, the various owners of existing buildings also face very different problems, which are exacerbated by the new legislation. which will be exacerbated by the GEG.

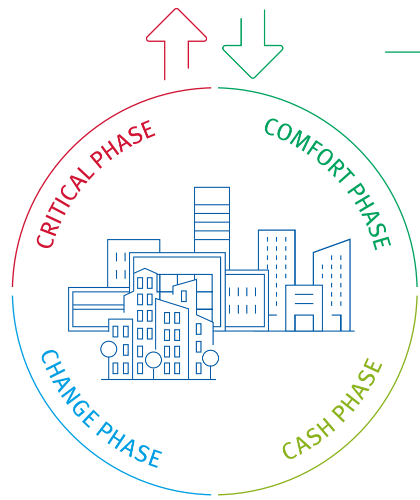
So before jumping into the technical issues, there should always be an overall analysis of marketability, building economics in connection with operation, financing options and a possible exit. Only following such an analysis is the formation of variants of the technical and structural solutions and a feasibility study for the selected variant. In the process, building regulations or other influences can also lead to the selection of a different variant – the "second-best" solution, which is then optimized accordingly.

BEFORE 1983

- Building in very poor condition
- Hardly any thermal insulation
- Gas/oil heating completely outdated
- Completely energy-inefficient
- Modernization urgently needed

1984 – 1996

- High maintenance costs
- Little thermal insulation
- Gas/oil heating outdated
- Energy efficiency below current standards
- Action definitely required



BUILDINGS AFTER 2010

- Minimal maintenance costs
- Good thermal insulation
- Heating system in operation 12 years at longest
- No need for action from structural point of view

1997 – 2009

- Increased maintenance costs
- Reasonable thermal insulation
- Heating system in operation 24 years at lobingest, or upgraded
- Level of energy efficiency still acceptable
- Action needed in the near future

Fig. 18: Action needed for buildings of different ages

The fact is, however, that the new Building Energy Ordinance means that even buildings that are well maintained and in good shape suddenly find themselves in trouble because they have old gas or oil heating systems. In such cases, owners should quickly have an analysis carried out to determine what options are available to them and what the economic consequences might be. In the case of a residential complex, for example, the alternatives vary from refurbishment with no impact on tenants, to refurbishment on an apartment-by-apartment basis with short rent breaks, to to the need to evict tenants in the case of large centralized facilities.

In any case, the prefabrication of modules to reduce the duration of renovation work will play a major role, which in turn requires digital and modularized planning.

Drees & Sommer can support portfolio owners throughout all phases as a professional and experienced partner:

- Analysis of the specific problem
- Development of appropriate general solutions with economic implications
- Feasibility study for the selected solution and clarification with the authorities
- System planning and design
- Implementation with General Construction Management
- Consulting on the operating phase

Hans Sommer
May 30th, 2023

IMPRINT

Drees & Sommer operates internationally, and its clients benefit from its global presence. At 59 offices, our experts support both German and international companies from a range of industries in the realization of their projects. In addition, Drees & Sommer has temporary project offices all over the world – wherever you currently need us.

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