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CARBON NEUTRAL

Opportunities For Utilities In A Decarbonized Environment

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POWERING DOWN ON CARBON EMISSIONS

Climate awareness is increasing rapidly around the globe. Environmental regulatory frameworks are being adopted and social trends are developing towards climate-friendly consumption. In line with the changing needs and demands of stakeholders on products and businesses as well as government agendas, companies are actively seeking to reduce their carbon footprint. The accelerating transformation to a carbon-neutral industry provides utilities with the opportunity to play a key role in lowering carbon emissions and profit from new business fields. 34 percent of all energy-related carbon emissions, the main driver of climate change, are caused by industrial processes. Within those, seven sectors (iron and steel, chemical and petrochemical, non-metallic minerals, non-ferrous metals, machinery, food and tobacco, and paper pulp and printing) account for more than 85 percent of the industry's global carbon emissions. To achieve reductions and help industrial players reduce their carbon emissions we have identified four technology clusters utilities can address.

Bridge Technology covers biomass for heat generation, a technology that is of high importance in the short-term in most sectors. However, business models are only attractive in the long term in selected sectors. Since utilities already use co-firing of biomass in their own combined heating plants, they are well-positioned to implement this fuel switch also at industrial players. Besides, utilities can add value to the construction, supply, and operation phases of biomass heat generation plants.

Power autonomy has very high short- and long-term potential, due to a continuous shift towards decentralized zero-carbon electricity generation and therefore can be referred to as a main element of **Core Technology.** Utilities can leverage their knowledge from conventional and renewable power generation and grid operation to set up low carbon/renewable energy projects and services. Offering entire solutions consisting of intelligent software, renewable generation assets and batteries increases the value-add utilities can offer their industrial customers.

Niche Technology includes electrification of heat, waste heat recovery, and system integration. They have a high priority in selected sectors where utilities must provide highly diversified solutions for industrial clients. Operating heating networks are likely to emerge as a profitable business model for utilities, where large scaling distributes recovered heat within industrial parks and towards households can be achieved. Additionally, utilities can speed up the establishment of electrification of heat by providing zero-carbon electricity and load management solutions.

Hydrogen and carbon capture and utilization/storage (CCU/S) have the highest emission reduction potential in the long-run. Targeting the most energy-intensive sectors, these **Next Generation Technologies** are likely to play a major role in several industries' path to carbon neutrality. Utilities can leverage competitive advantages and scaling effects by generating hydrogen with zero-carbon electricity and by providing hydrogen infrastructures. Given the predicted high importance of CCU/S in certain sectors, the early establishment of partnerships for storing and transporting CO_2 is key for utilities.

These playing fields result in various specific and overarching business models that give rise to new roles for utilities. Four archetypes provide guidance for developing a suitable approach to support the industry's path to a carbon-neutral future. Depending on their skill set, strategic direction and capabilities, utilities can choose to cover one or more of these archetypes.

REDUCTION ENABLER
Those who focus on established resources and technologies like biomass and renewable electricity to support industrial clients in reducing their carbon emissions already today.

GREEN INFRASTRUCTURE PROVIDER
Constructor and operator of required infrastructure solutions for power, heat, and gaseous products like biogas, hydrogen, or captured CO_2 to exploit the full potential of carbon reduction technologies.

SPECIALISTS
Experts with a deep understanding of existing processes from industrial clients that are able to embrace dedicated tasks along the value chain, like developing custom-tailored software or hardware solutions.

INNOVATION PARTNER
A utility that collaborates with industrial clients to develop future technologies, like hydrogen or CCU/S to help businesses ensure profitability by combining high research efforts, partnerships with start-ups and solid funding.

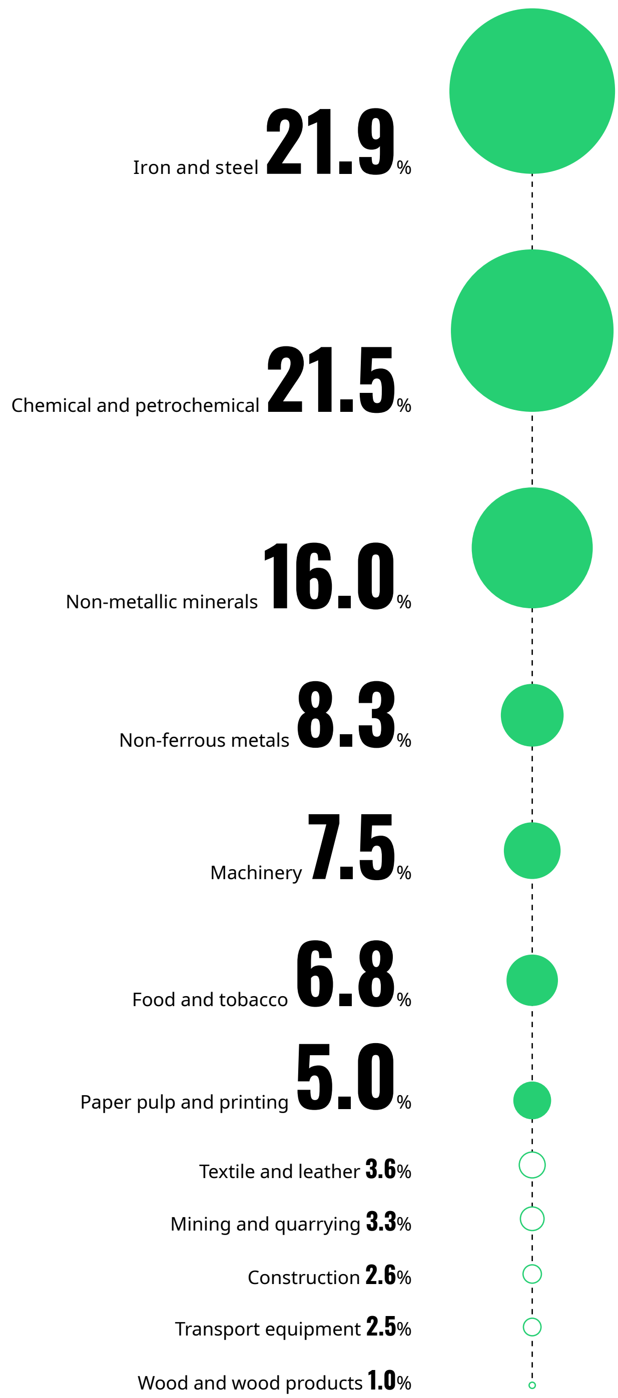
Since there is no stand-alone solution, a synergistic cooperation between different archetypes, industrial companies, and external partners opens the door to an enormous carbon reduction potential. For example, in the European Union, a reduction of energy-related carbon emissions of one-third by 2030 compared to 2015 could be achieved in the seven focus sectors given that the industrial players pursue the goals set in the European Green Deal.

THE CURRENT STATE OF THE CLIMATE BATTLE

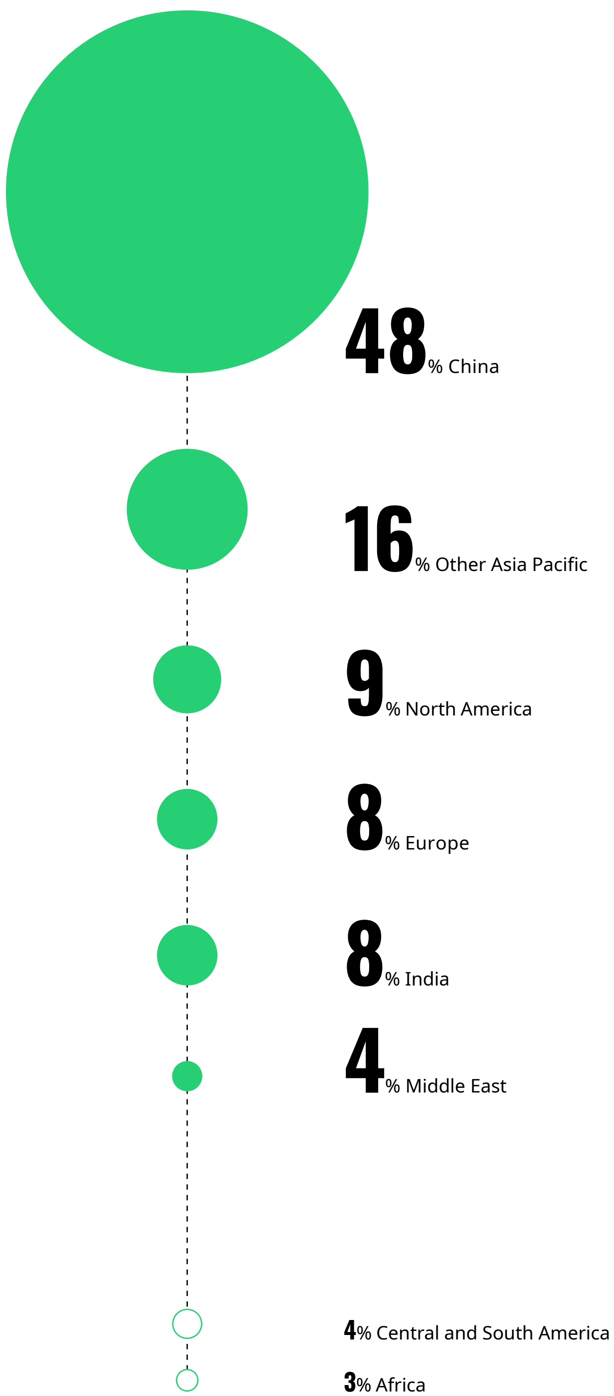
Worldwide, companies across industries are under pressure to actively pursue a reduction of their carbon footprint. The industrial sector accounts for 34 percent of all global carbon emissions and thus plays a major role in decarbonization efforts. There are different regulatory attempts, such as the Paris Agreement to limit global warming to two degrees Celsius, or the European Union target to become an economy with net-zero greenhouse gas emissions by 2050. Aside from these political approaches, there is also pressure from society and other groups to become green such as the Fridays for Future movement initiated by Greta Thunberg. Furthermore, corporate players are intensifying their carbon reduction efforts. In sum, these developments result in a growing awareness for reducing the carbon footprint on the industry side.

This is reflected in the rising share of carbon-related posts on social media platforms by industrial companies. This applies in particular to energy-intensive industries like iron and steel, chemical and petrochemical, and non-metallic minerals where the share of carbon-related posts has more than tripled from 2017 to 2019. The growing awareness and the evolving political frameworks are changing the expectations of industrial companies towards energy supply, emission reduction, and related infrastructure.

CO_2 EMISSIONS PER INDUSTRY SECTOR



CO_2 EMISSIONS PER REGION (INDUSTRY SECTORS)



This is an opportunity for utilities as they are actively accelerating the path to zero-carbon already today. Utilities will likely be the leading and guiding players to satisfy the increasing demand for zero-carbon energy and the emerging need for emission reduction technologies. In order to be successful in this challenging environment, utilities have to reduce the carbon intensity of their existing offerings on the one hand and expand and reshape their business in the next decades on the other hand. With the right strategy, customer needs can be met and at the same time significant economic potentials can be revealed.

The requirements and needs towards energy supply vary across industries and regions. This study focuses on the seven sub-sectors with the highest emissions, namely iron and steel, chemical and petrochemical, non-metallic minerals, non-ferrous metals, machinery, food and tobacco, and paper pulp and printing. Together they cover more than 85 percent of the industry's global energy-related carbon emissions. These exclude feedstock and process emissions. More than 50 percent of these carbon emissions are caused by the sub-sectors iron and steel, chemical and petrochemical, and non-metallic minerals alone. From a regional perspective, China is by far the largest emitter amongst the regions followed by the rest of the Asia Pacific region. Besides those regions, North America, Europe (including Russia), and India have the highest emission levels.

REDUCING CARBON EMISSIONS SECTOR BY SECTOR

The analyzed industries consist of several main sectors. However, the sectors differ highly regarding their processes and products. For example, the iron and steel sector only includes the casting and manufacturing of basic iron and steel, while the machinery sector consists of a large variety of different products like fabricated metal products, computers, electronics and optical products. Except for the non-ferrous metal and machinery sector, all sectors require more heat than power input. Even though the shares of heat and power input are mostly similar, the properties of the required heat input vary considerably. Most energy intensive sectors also require significant process heat. For example, more than 80 percent of the iron and steel sector's heat demand is used for heating processes that go well beyond 500 degrees Celsius. In contrast, the paper pulp and printing industry mostly requires temperatures between 100 and 200 degrees Celsius for their processes.

The machinery industry mainly uses their heat input for space heating and cooling purposes. The heat requirements, industry processes, and the economic viability of renewable technologies are considered in assessing the potential to switch to zero-carbon electricity and heat. Switching to renewable heat is more complex in general than switching to renewable power. This applies especially to sectors with high heat levels. In paper pulp and printing however the potential to switch to renewable heat is higher which can be deduced from the fact that carbon neutral heat has a share of more than 50 percent already.

INDUSTRY SECTOR	POTENTIAL TO SWITCH TO ZERO CARBON:*		DISTRIBUTION OF TOTAL ENERGY DEMAND:	
	ELECTRICITY	HEAT	POWER	HEAT
Iron and Steel Casting and manufacture of basic iron and steel	●●○○○	●○○○○	21%	79%
Chemical and petrochemical Manufacture of chemicals, pharmaceuticals, chemical, medicinal chemicals and botanical products	●●●●○	●●○○○	23%	77%
Non-metallic minerals Manufacture of non-metallic mineral products (mainly cement, glass and ceramic)	●○○○○	●●●●○	14%	86%
Non-ferrous metals Casting and manufacture of basic precious and other non-ferrous metals (mainly aluminum, copper, zinc)	●●●●○	●●○○○	65%	35%
Machinery Manufacture of fabricated metal products, computer, electronic and optical products, electrical equipment and machinery	●●●●○	●●●○○	60%	40%
Food and tobacco Manufacture of food products, beverages and tobacco products	●●●●○	●●●●○	25%	75%
Paper pulp and printing Manufacture of paper and paper products; Printing and reproduction of recorded media	●○○○○	●●●●●	25%	75%

Very low ○○○○○
Very high ●●●●●

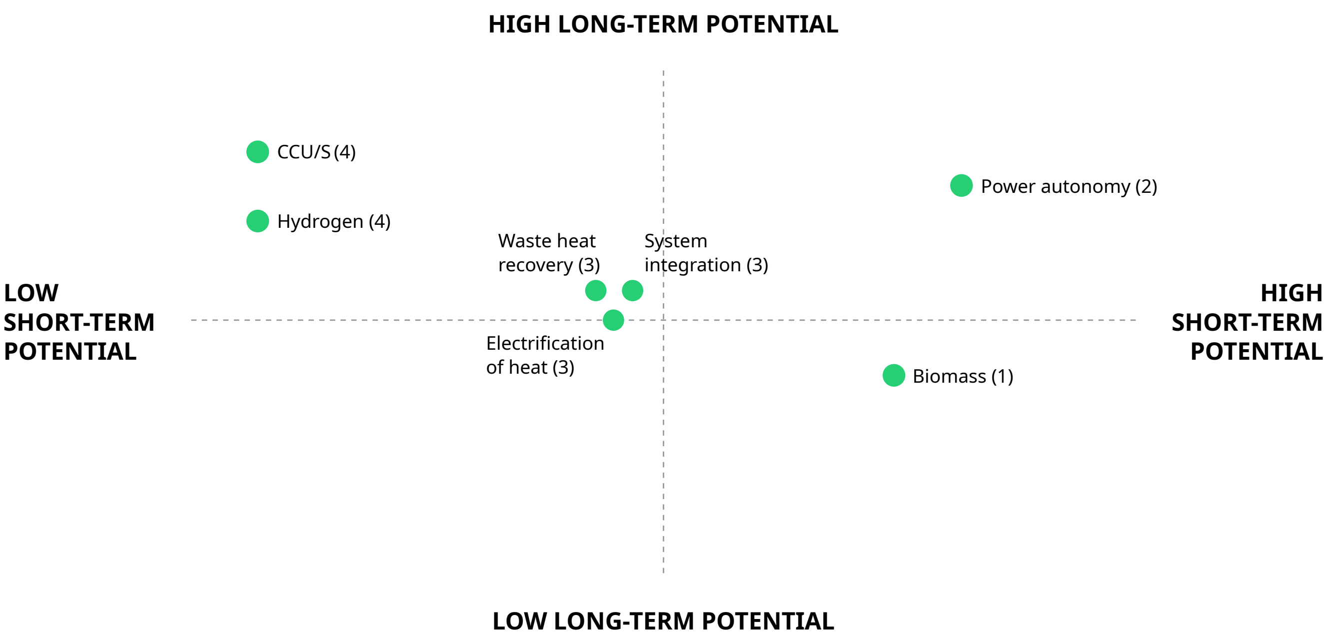
* Short to medium term

FOUR STRATEGIC PLAYING FIELDS

There are several options for reducing energy-related carbon emissions in the industrial sector. On the one hand, there are offerings for carbon-neutral heat, namely **electrification of heat, biomass,** and **hydrogen** for heat generation. On the other hand, there are carbon-neutral and autonomous systems for electricity. Besides, the technology fields **waste heat recovery** as well as **system integration** cover measures that increase energy efficiency using waste heat either for other heating purposes or for power generation. The last technology group is **carbon capture and utilization or storage (CCU/S)** which aims to capture emerging carbon emissions in order to further utilize or store them.

These seven technology groups differ regarding the CO_2 reduction potential, the maturity of the underlying technologies and the required investment. Based on these factors, the short-term importance of the technologies can be derived. In the long-term perspective, the priority of those technologies was analyzed based on the CO_2 reduction potential and the expected deployment by 2040. Mapping the technologies along the two dimensions of short- and long-term priority reveals **four distinctive playing fields**. Those playing fields cluster similar technology approaches and offer opportunities for utilities.

The first strategic playing field consisting of Biomass is considered a **Bridge Technology (1)**, as it plays a role in most sectors today but will only remain a sustainable energy source in selected sectors in the long run. Different stages of power autonomy are highly relevant in a short- as well as in a long-term perspective and must be built up continuously as a **Core Technology (2)**. Electrification of heat, waste heat recovery, and system integration have a high importance in selected sectors and are thus considered as **Niche Technologies (3).** Hydrogen and CCU/S can be characterized as **Next Generation Technologies (4)** since they offer a high potential across sectors that depends on further technological advances.



DANIEL FAVA

CEO
eni Gas & Power France

What are the expectations of clients towards utilities in driving the reduction of the industrial carbon footprint? How will these expectations change in the future?
Nowadays, energy is at the same time a significant part of production costs and the main source of emissions for manufactured products. Therefore, companies are becoming more and more sensitive to reduce their energy consumption with ecological and economical objectives. They expect help and services from Eni to allow them to optimize their energy consumption. Eni's objective is to become the energy partner of its customers, with a wide range of services to better know their consumption and implement solutions to reduce it. A huge increase of these expectations is foreseen in the future, in order to respect energy transition and low carbon emission objectives.

What experiences did you make in the implementation of carbon reduction technologies for industrial clients?
Eni has several solutions to reduce a carbon footprint. It is possible to make carbon offset. So the client neutralizes its CO_2 emissions for gas consumption. Eni offers green electricity, which means electricity produced from renewable energies (wind, solar ...). Another solution of Eni for industrial customers is CCS proprietary technology. Eni can optimize consumption with Optim'Eni service, a platform which follows energy consumption every day and gives alerts in case of peak consumptions. Eni has also financed a very large range of energy consumption projects of its customers via Prim'Eni, a program based on white certificate mechanism.

BRIDGE TECHNOLOGY

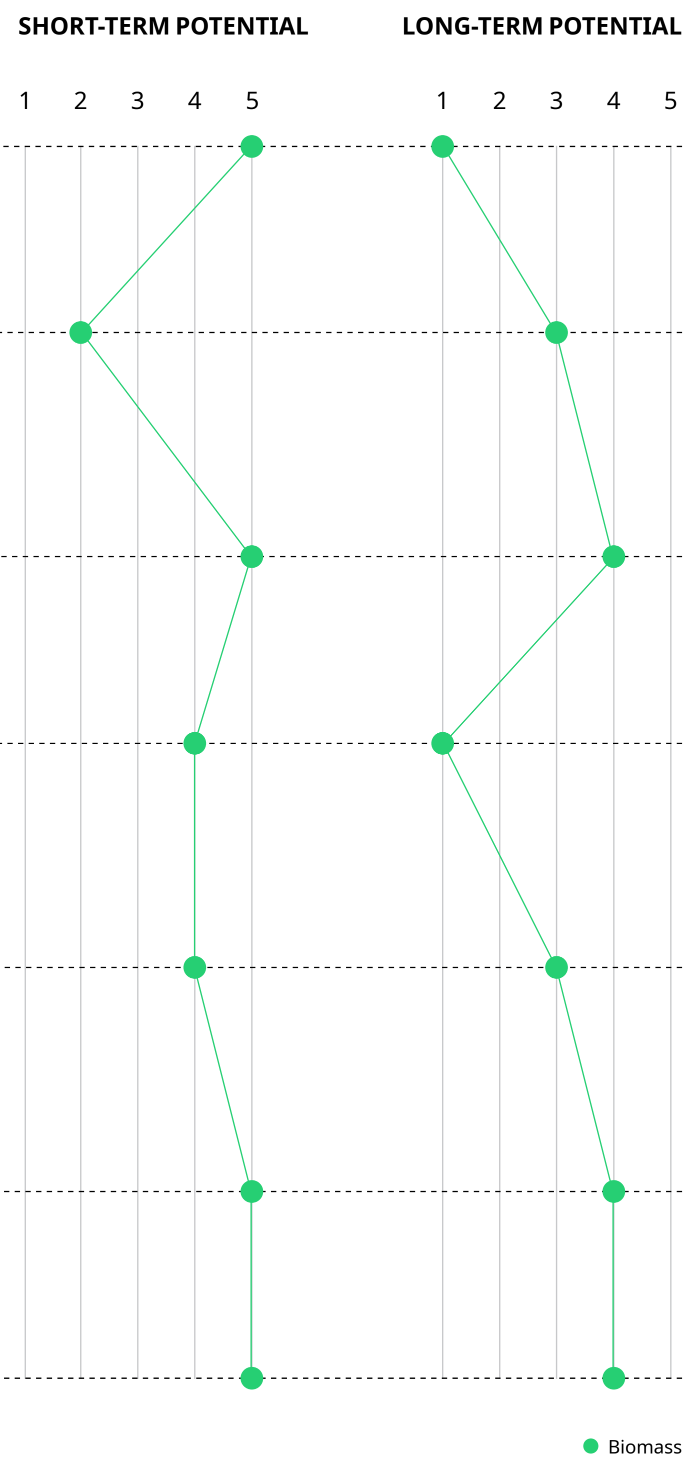
Bridge technologies play a major role in a short-term perspective but have a decreasing priority in the long-term. This applies to the use of sustainable **biomass** for heat generation. The technology is very mature and implemented in various examples across industries. Biomass originates from a variety of sources which includes organic residuals, industrial waste, and municipal solid waste.

PROPERTIES OF CARBON-REDUCING TECHNOLOGIES IN DIFFERENT SECTORS

There are two general application fields of biomass for heat generation which can be distinguished by the required heat levels of the industry sectors. On the one hand, biomass can be mixed with fossil fuels like petroleum, coal and natural gas for high-temperature production processes in the iron and steel, non-metallic minerals and non-ferrous metals industries. On the other hand, biomass can be utilized as an exclusive energy source for low and medium heat generation in the machinery, food and tobacco, and paper pulp and printing industry. In the chemical and petrochemical sector biomass as feedstock predominates biomass as an energy source leading to a rather low priority.

Despite the high priority in the short-term, biomass will likely lose importance in most sectors in the long run and therefore serve as a Bridge Technology. Reasons for the decreasing priority are the competition between land usage for the cultivation of energy and food crops, the increasing water scarcity, the rising availability of low-cost zero-carbon electricity, and the evolvement of superior zero carbon technologies for high heat production environments. Nevertheless, biomass will likely remain relevant for the food and tobacco as well as the paper pulp and printing industry where waste material from the production process can be used. The availability of waste material in the paper pulp and printing industry is leveraged for instance by Dalkia, an EDF subsidiary, and Smurfit Kappa, the world leader in paper packaging. They operate a biomass cogeneration plant in France and share the resulting energy types. The generated electricity is sold to EDF, while Smurfit Kappa uses the low-pressure steam to dry paper at its plant. Among waste wood from surrounding forests, the combustion unit is also fueled by waste residues from the paper pulp and printing factory. The plant has reduced the carbon footprint of both companies by 200,000 tonnes CO_2 per year. Furthermore, biomass has a long-term potential for space heating applications like in the machinery industry. Currently, the only major alternative technology for zero-carbon space heating is electrification of heat.

INDUSTRY SECTOR



Iron and Steel
Casting and manufacture of basic iron and steel

Chemical and petrochemical
Manufacture of chemicals, pharmaceuticals, chemical, medicinal chemicals and botanical products

Non-metallic minerals
Manufacture of non-metallic mineral products (mainly cement, glass and ceramic)

Non-ferrous metals
Casting and manufacture of basic precious and other non-ferrous metals (mainly aluminum, copper, zinc)

Machinery
Manufacture of fabricated metal products, computer, electronic and optical products, electrical equipment and machinery

Food and tobacco
Manufacture of food products, beverages and tobacco products

Paper pulp and printing
Manufacture of paper and paper products; Printing and reproduction of recorded media

CORE TECHNOLOGY

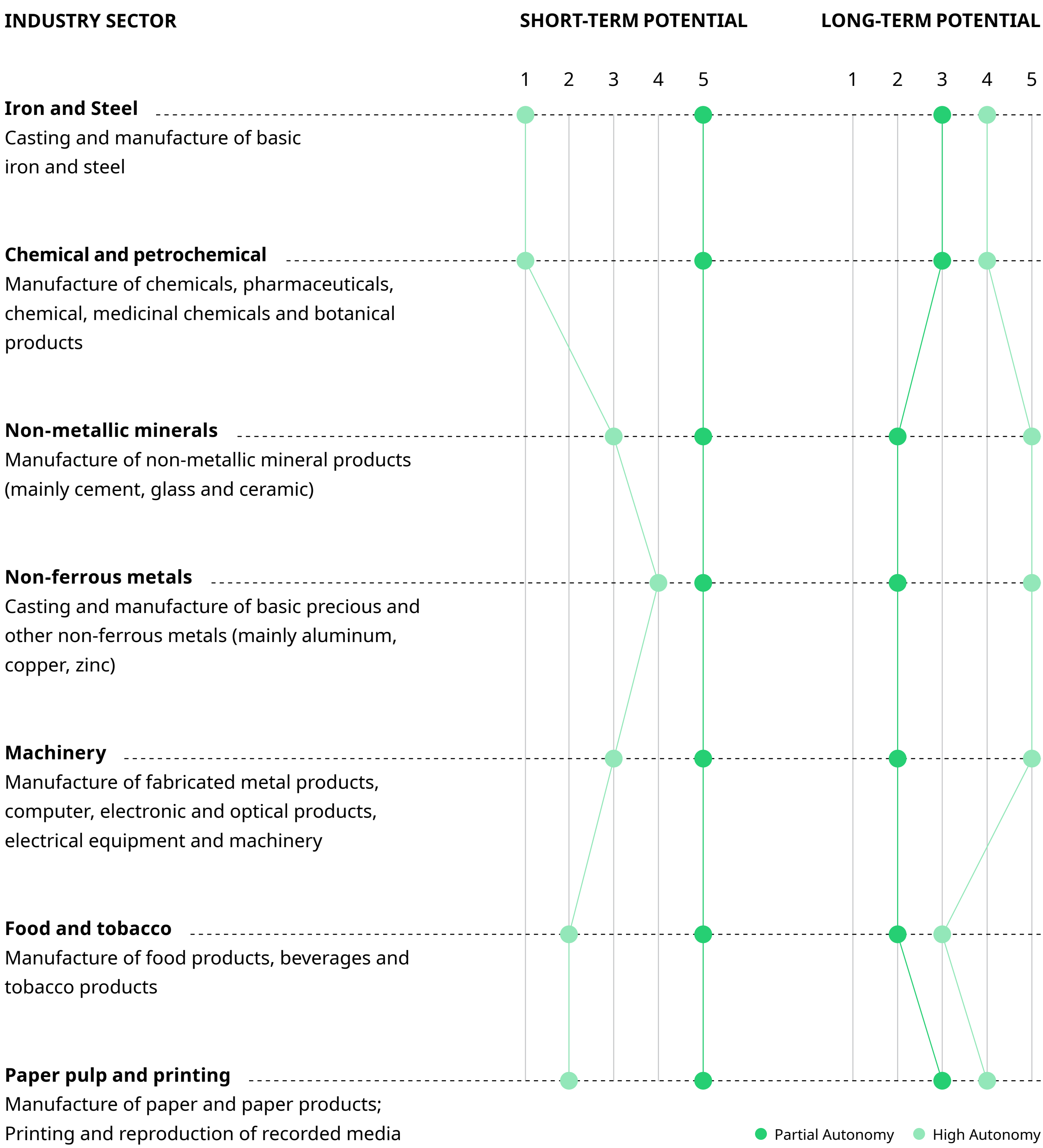
The playing field Core Technology covers technology solutions that play a major role in the short-term as well as in the long-term in reducing the industries' carbon emissions. This applies to power autonomy through local solutions for carbon-neutral power generation. Power autonomy evolves over time and is therefore divided into **partial autonomy** and **high autonomy**. Partial autonomy describes a setup in which conventional electricity from the grid is supplemented by locally generated zero-carbon electricity while the grid still serves as the major electricity source. In the case of high autonomy, most of the electricity is sourced from local zero-carbon electricity generation. Consequently, highly autonomous solutions do require storage and load management systems.

PROPERTIES OF CARBON-REDUCING TECHNOLOGIES IN DIFFERENT SECTORS

In the short-term, partially autonomous solutions are highly relevant in all industry sectors as this technology is ready for implementation, the required investment is rather low, and the process continuity is not endangered. As storage technologies evolve in a long-term view, high autonomy will slowly replace partially autonomous solutions. This trend will likely begin in the non-ferrous metals and the machinery industry as electricity is the main energy source in these sectors. In the iron and steel as well as in the chemical and petrochemical industry, high autonomy will probably not be equally important as in other sectors since the relative share of power in the energy mix is lower and technologies like hydrogen or CCU/S will emerge in the future. Nevertheless, those sectors should not be neglected as their electricity demand is high in absolute terms and is likely to increase by at least 50 percent in a long-term perspective.

LEVELIZED COSTS OF ELECTRICITY

In this group, the maturity of the technology and the price of electricity generation are major influencing factors. To unlock the full potential of decentralized power autonomy, the cost of renewable electricity must be lower than the one of conventionally generated electricity. Levelized costs of electricity (LCOE) is a common measure to compare the average net present cost of electricity generation for a generating plant over its lifetime. On a global level, the LCOE of utility-scale renewable electricity generation technologies is decreasing considerably. For example, the LCOE of solar photovoltaic (PV) technologies declined by over 70 percent from 2010 to 2018 while the LCOE of wind power generation dropped by roughly 25 percent. Following this trend, renewable electricity prices for solar, wind and hydrogen plants will probably be lower or equal to conventional electricity prices by 2030. Thus, power autonomy will likely have a major impact in cutting down the industry's carbon footprint.


INDUSTRY SECTOR
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LONG-TERM POTENTIAL
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Manufacture of paper and paper products; Printing and reproduction of recorded media
Partial Autonomy
High Autonomy

DR. ALEXANDER FENZL

E.ON Country Head
B2B Solutions
Germany

How can utilities help industrial clients to reduce their carbon footprint today and in the future?
In order to persist and be successful in the future, it is important that companies work sustainably in every respect. This applies particularly to the use of energy. Through their collaboration with E.ON we are already preparing companies today for the requirements of tomorrow's new energy world. In this way, we help them to significantly reduce their energy costs and CO_2 emissions and at the same time ensure that their company's operational business runs smoothly.

What are key success factors for utilities in this role?
E.ON has high ambitions for climate protection and energy-efficient energy solutions to improve people's lives. With increasing regulatory pressure, companies are therefore looking for new technical and regulatory ways to reduce their energy costs in the best possible way and to reduce their CO_2 emissions sustainably. In consideration of this, we use innovative and established technologies to design the most economically sensible and efficient solution for our B2B customers.

In this way, together with our customers, we create a sustainable future for our planet and a profitable future for companies.

What is a key project where E.ON helped an industrial client to reduce their CO_2 footprint?
E.ON has developed a system for the "retail" segment that can reduce the energy consumption, especially of supermarkets by up to 35 percent. The partners E.ON and Real are implementing the concept for the first time in Germany at the Real site in Krefeld. An intelligent building management system takes over the control of heating, ventilation, air conditioning, lighting and cooling. From this point on, a self-learning measuring and control system learns how the electricity consumption of the individual components behaves during the day, in order to subsequently optimize the total electricity consumption through intelligent control technology. Retail markets generally have a high energy intensity. With the E.ON system, the real-market Krefeld will significantly improve its carbon footprint. The system is therefore particularly suitable for large branch networks.

DR. HANS-JOSEF ZIMMER

Member of the Board of Management of EnBW AG

What technologies will play a role in reducing the carbon footprint of industrial clients?
In order to achieve the reduction targets in industry, all gaseous and liquid energy sources, such as natural gas and oil, must and will be replaced by climate-friendly alternatives. While electrification will play a major role in passenger and light-duty transport, from today's perspective hydrogen or other green synthetic fuels will be needed in the mid- and long-term perspective especially for heavy duty, aviation, shipping, industry.

Which of these technologies will be the most important ones from an EnBW perspective?
From EnBW's point of view, climate-friendly hydrogen will be one of the most important technologies for CO_2 reduction in industry in the next decades. One example is the steel industry: provided sufficient financial support by the government, the use of direct reduction of iron with green hydrogen instead of blast furnace route alone might reduce 1,2 Mt GHG-emissions each year.

EnBW group as an important player in the German gas market also intends to play a significant role in the developing sector of climate-friendly hydrogen in the future.

What experiences has EnBW made in the implementation of carbon reduction technologies for industrial clients?
One example of EnBW's activities to reduce industrial customers' GHG emissions is energy efficiency auditing: In 2019 and 2020, our energy consultants identified almost 1,000 measures to improve energy efficiency at over 100 customers (from industry and trade/retail/services) and evaluated them with sophisticated profitability calculations. If our customers were to implement all the energy optimization measures identified, almost 22,000 t of CO_2 per year would no longer be emitted in their plants in the future.

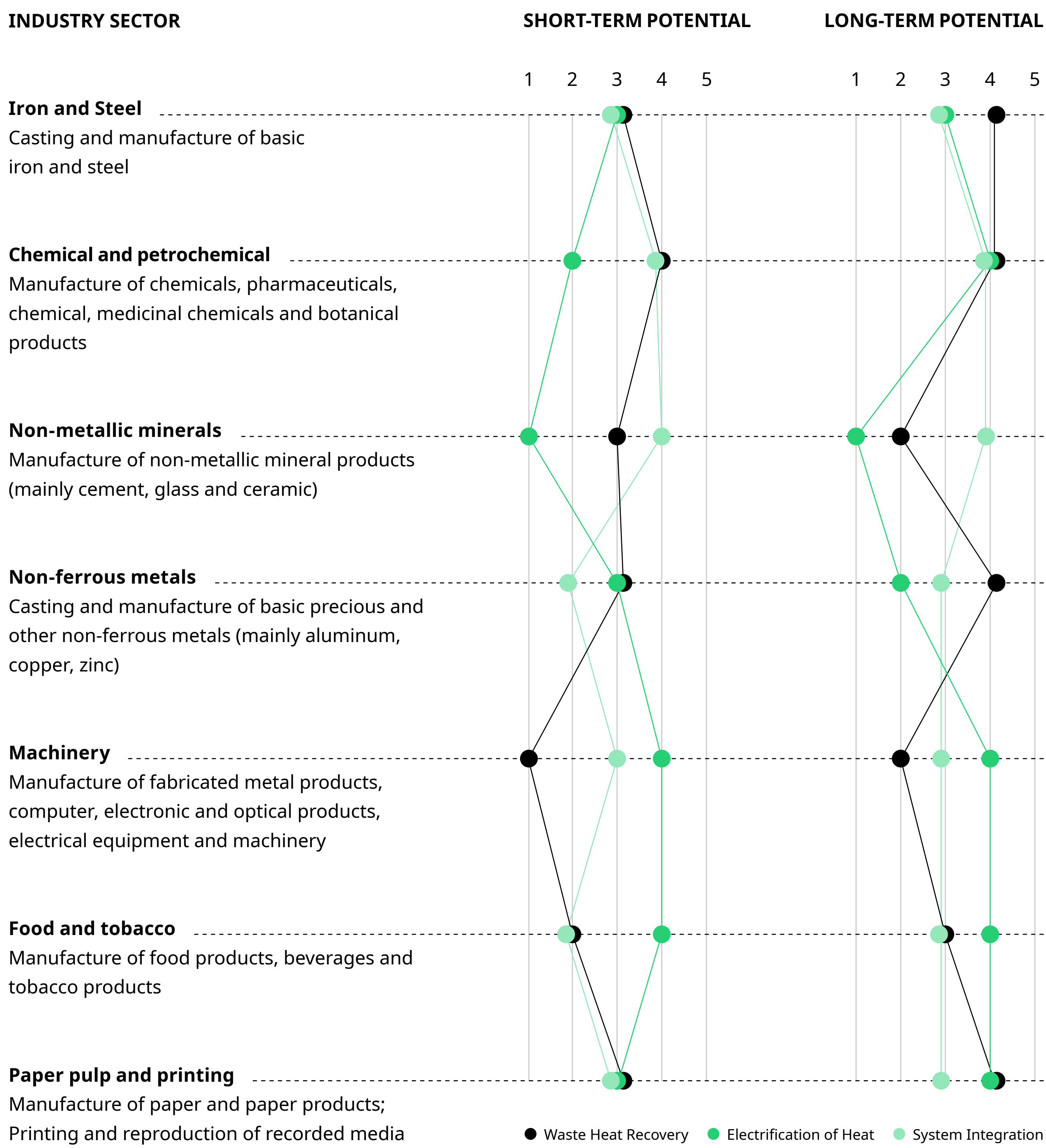
NICHE TECHNOLOGY

Niche Technology covers technologies whose implementation is highly dependent on local circumstances and the industry sectors' requirements. Therefore, the short-term priority is on average at a medium level and slightly increases in a long-term perspective. Waste heat recovery and system integration are implemented in medium to high-temperature processes to extract the waste heat. In the case of system integration this waste heat is transferred to electric power. For waste heat recovery the heat is used either directly for pre-heating the same process, via a heating network to heat other industrial processes or to feed district heating systems. Both technologies are subject to intensive development and will likely be applicable to a higher number of processes soon. Electrification of heat describes the generation of heat with electricity as an energy source instead of conventional fossil fuels. The technology is ready for low and medium-temperature processes and research is being conducted for the application on high temperatures.

PROPERTIES OF CARBON-REDUCING TECHNOLOGIES IN DIFFERENT SECTORS

Electrification of heat will emerge as a major priority soon, especially in low to medium temperature level industries like machinery, food and tobacco, and paper pulp and printing. The technology is ready to efficiently generate these heat levels but lacks efficiency for higher temperature levels. Therefore, the implementation of the technology for high heat levels is a long-term priority. Furthermore, the effective usage of this technology is highly dependent on the zero-carbon electricity price. However, the technology competes with biomass, which produces heat out of the omnipresent plant/wood waste and bark for providing low to medium heat levels.

In contrast to electrification of heat, waste heat recovery and system integration focus on the usage of waste heat and not on heat generation. The recovered heat can be used to preheat internal processes and has solid potential in the food and tobacco, and paper pulp and printing industry. There, heat is used for drying intermediate products. This leads to a rather low priority for waste heat recovery in these sectors in a short-term perspective and only to a slightly higher priority in a long-term view. Waste heat recovery as well as system integration can increase their efficiency by recovering higher heat levels from sectors such as iron and steel, chemical and petrochemical, and non-ferrous metals. Both technologies can thus leverage their potential when applied in industrial parks. System integration can contribute to a high autonomy solution by recovering heat and converting it to zero-carbon electricity power.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Manufacture of paper and paper products; Printing and reproduction of recorded media
Waste Heat Recovery
Electrification of Heat
System Integration

NEXT GENERATION TECHNOLOGY

Next Generation Technology includes approaches that are not fully developed today but are likely to unleash a major impact on carbon reduction after future technological breakthroughs. This applies to all types of CCU/S as well as to the use of hydrogen produced by zero-carbon electricity for heat production.

PROPERTIES OF CARBON-REDUCING TECHNOLOGIES IN DIFFERENT SECTORS

Carbon capture and hydrogen technologies have a very similar profile regarding their priority development over time and sectors. The short-term priority of hydrogen as a replacement for fossil fuels to generate heat is low due to inferior technology readiness. However, there are several promising use-cases for hydrogen in the future. Focusing on hydrogen as a heat source, there is an emerging potential in industries with high heat levels.

CCU/S has a low potential in a short-term perspective. The foremost reason is the lack of available technology for industry-scale applications and the high associated investment costs for these technologies. Nonetheless, from a long-term perspective, there is a high potential for CCU/S in emission-intensive industries with a high CO_2 concentration level in their emissions. This applies to the iron and steel, chemical and petrochemical, and non-metallic minerals industries. The priority of CCU/S soars on the one hand because there are no alternative, comprehensive zero-carbon technologies available for sectors with high heat levels. On the other hand, the facilities in the above-mentioned sectors often have a lifetime of beyond 50 years. In contrast to process innovations, implementing CCU/S does not require rebuilding facilities. This results in a high future priority despite the additional costs of CCU/S for companies.

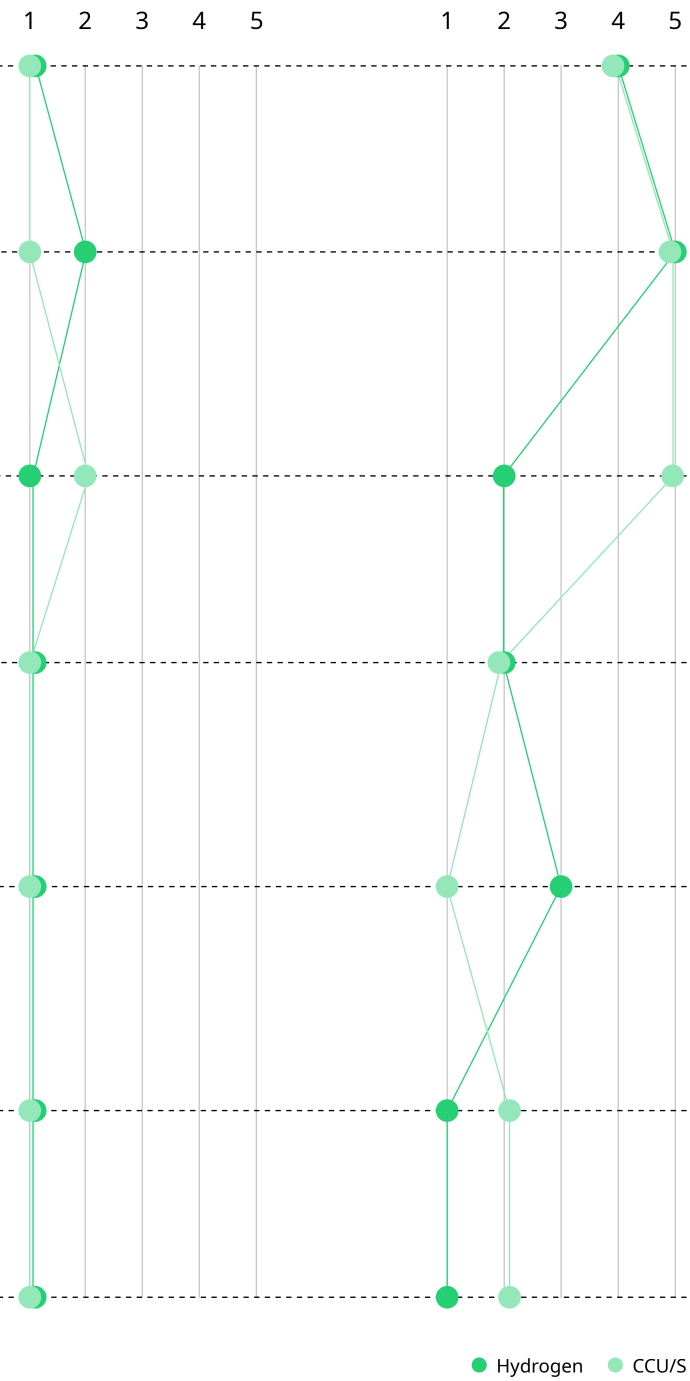
ECONOMIC VIABILITY OF NEXT GENERATION TECHNOLOGY

Key success factors for hydrogen are the availability of sufficient zero-carbon electricity and a solid network of adequate infrastructure. The economic viability depends on competitive zero-carbon electricity prices. Like for hydrogen, the availability of suitable infrastructure plays a key role for CCU/S. From an economic perspective the distance between the capturing site and the storing facility is crucial. Thus, it is uncertain which part of the carbon emissions can be stored via CCS and which part can be stored and used via CCU. In general, impact factors for both technologies are the CO_2 price and regulations like a border tax for carbon-emission intensive products that are uncertain from today's point of view. In particular, the differences in the willingness to pay between a carbon neutral produced product and an alternative heavy-emission product are critical.

THE PATH OF HYDROGEN

Hydrogen is part of the Next Generation playing field and is currently more recognized in public and politics than CCU/S which is often perceived rather skeptically. For hydrogen, a foundation of national strategies and public support exists. Currently, China is the main producer of hydrogen. Japan pioneered with its hydrogen initiative in 2017. Recently, the European Union presented its initiative for green hydrogen. It is characterized by various national strategies and hydrogen generation via electrolysis powered by renewable energy. In particular, Germany fosters science and research, promotes the development of a domestic hydrogen market and encourages the transformation processes within the industry. Overall, the variety of individual actions around the globe give rise to exciting economic and political dynamics.

INDUSTRY SECTOR	SHORT-TERM POTENTIAL	LONG-TERM POTENTIAL



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Manufacture of paper and paper products; Printing and reproduction of recorded media

CCU/S RESEARCH TO POLITICAL AND PUBLIC SUPPORT

The CCU/S technology is facing challenges in its development to a mature technology in the political and public area as well as differences in regional storing potentials. From a political perspective, a structured regulatory framework enables corporates to test small scale storing sites and leverage early investments. Due to local decision power on the feasibility of storage technologies, the evolutionary status of CCU/S technologies varies between encouraging countries like Norway and Canada and less supportive countries. Furthermore, there is still a lack of international guidelines for the implementation of CCU/S projects and trading carbon certificates although article 6.4 of the Paris Agreement sets an initial framework.

From a public point of view, acceptance and awareness of the CCU/S technology is a key barrier. This is highly dependent on the quality of information campaigns and the effort to include the public in an open discussion with political and corporate stakeholders. Countries with quality campaigns like Australia and the Netherlands demonstrate high public trust in the technology. Gaining the trust of the population is not only crucial to foster the rollout of the technology but also helps to increase the willingness to pay for carbon-neutral products.

GEOGRAPHICAL POTENTIALS

Across all four playing fields, there are technologies that rely directly or indirectly on natural resources. The use of biomass requests enough supply of organic residuals and waste. Renewable power generation requires solar irradiation, wind resources or running water systems. Similarly, electrification of heat depends on carbon-neutral electricity and for CCU/S there have to be geologically suitable storage capacities. As the considered regions across the world differ in geographical conditions, the way to become carbon neutral in an economically viable manner varies as well. Africa and the Middle East are predestined for solar PV applications, Europe and North America can leverage their high potential for on- and off-shore wind power generation. Central and South America has a substantial amount of biomass for heat and power generation available. The situation in China and India is more difficult in general than in other regions, as they have to serve a vast energy demand. However, both regions can profit from solar PV applications and China in particular has good conditions for hydropower generation.

In all regions, major storage resources for CO_2 exist. When applying a time horizon of 100 years, only India and the Middle East would reach their limits. This also means that political conditions and the public opinion are much more important for the successful implementation of CCU/S. In theory, some regions have the potential to cover their energy supply using a single energy source. Africa for example could only rely on energy generated from solar photovoltaic plants. However, in reality, a solar-power-only strategy comes with a range of negative side effects, like the excessive requirements of energy storage facilities. Consequently, an intelligent mix of different energy sources and generation technologies is likely to be utilized in all regions to reach the objective of carbon neutrality.

What are the prerequisites for a successful carbon reduction in the industrial sector?
This is our chance of the century: the historic economic crisis, caused by the Covid-19 pandemic and the climate crisis, can be resolved. The prerequisite is a clear path of transformation towards a decarbonized and sustainable economic system. To incentivize that transformation, climate emissions need to become globally traded commodities based on a worldwide emission database. The emission prices must be traded transparently with a compensation mechanism which includes differences depending on region.

Which technologies will play a major role in the reduction of the industry's carbon footprint in Europe?
It will be a mix of technologies. First of all, we should use the potential of the existing economic viable technologies like photovoltaic and storages to optimize the energy balance sheet for industrial customers. Secondly, as we will not be able to reach zero carbon footprints in all industries, technologies like "Carbon Capture and Recycling" will play a major role. Thirdly, technologies like hydrogen for industrial process or recycle-batteries for electric mobility will play an important part.

What experiences did you make in the implementation of carbon reduction technologies for industrial clients?
Our industrial customers are highly motivated to lead the change in their sector. The key is to provide them economically viable business models. This is currently the case for photovoltaic projects, which we are implementing across all industries very successfully. Additionally, we are running hydrogen projects with industrial clients (in the steel and petrochemical sector) and offer carbon compensation strategies. One thing is clear, in the end the costumer will decide and those industries which are frontrunners will have a relevant competitive advantage.

THE NEW ROLE OF UTILITIES

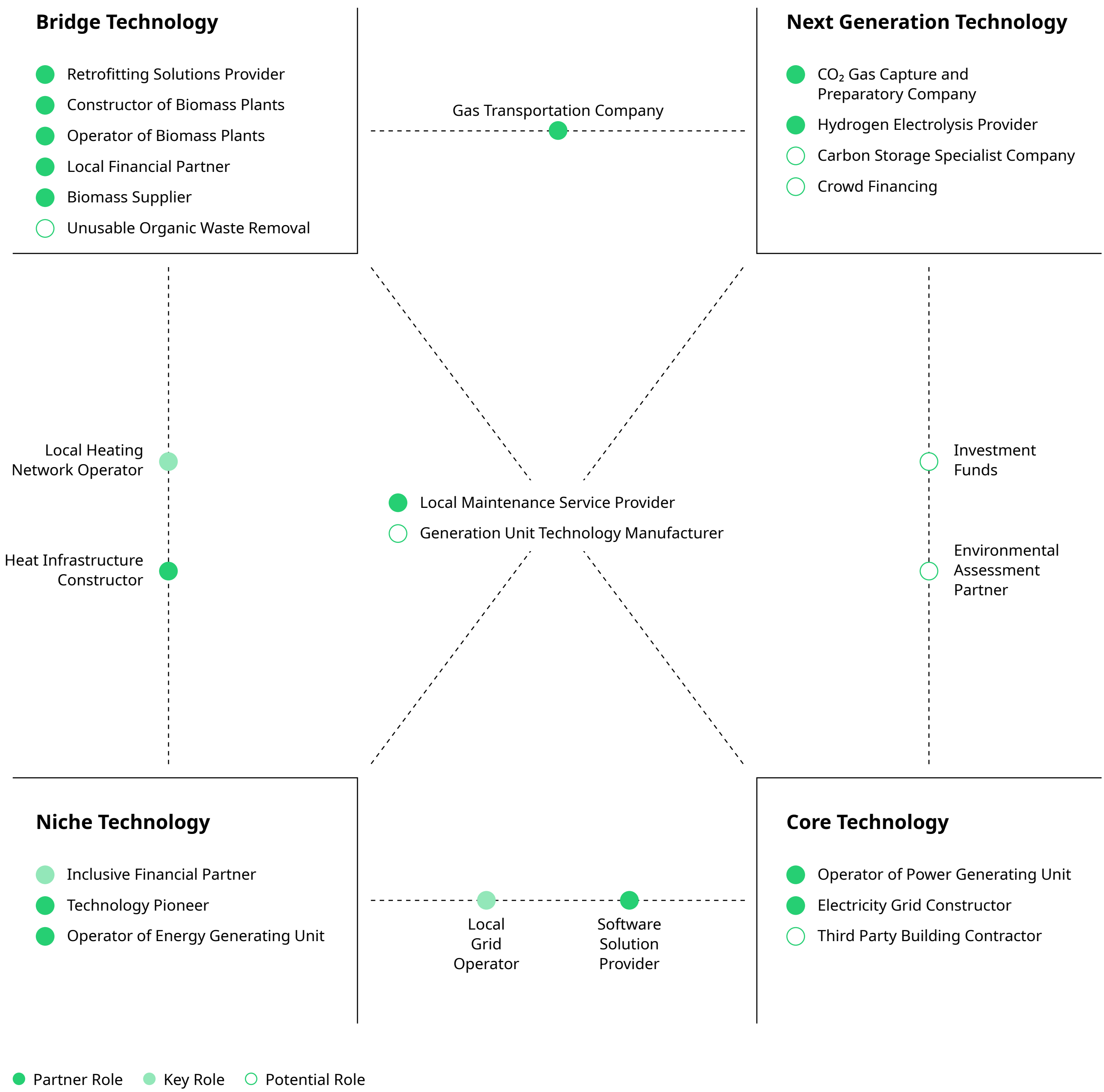
Utilities can build on strong capabilities and comprehensive experience in supporting industrial companies to reduce their carbon footprint. In order to support industrial clients with profitable business models, utilities must clearly define their strategy. The strategic direction should build on the utilities' current product and services portfolio and aim at ensuring sustainable long-term profits in the energy market of tomorrow. There are four strategic archetypes that utilities can occupy. Each archetype covers an excerpt of utility roles clustered along with their characteristics and required capabilities. Within these archetypes, a utility can occupy one or more roles, furthermore utilities can focus on one archetype or diversify themselves across several of them. To provide the industrial customers with integrated offerings along the value chain, utilities however also need to collaborate with external partners covering activities beyond the scope of utilities' operations. Hence, establishing strong partnerships is beneficial to all parties. In combination with those partnerships, the unique skill sets and features of utilities assign them to one or more of the following archetypes.

Utilities that help industrial clients to reduce their carbon emissions based on established technologies already today can be described as a **Reduction Enabler**. In order to serve the specific needs of clients determined by regional particularities, legal requirements, and financial conditions, the utility can realize opportunities by building on strong local presence and a local partner network. Furthermore, they can focus on expanding some of their traditional business fields like building and operating biomass plants within the playing field of Bridge Technology. In the playing field of Core Technology utilities can foster the implementation of renewable energy assets like solar or wind farms in local systems providing partial autonomy for selected industrial clients.

To exploit the full potential of carbon reduction technologies, infrastructure solutions for power, heat, and gaseous products (like biogas, hydrogen, or captured CO_2) are required. Utilities operating in this field can be referred to as **Green Infrastructure Providers**. They can leverage their experience in constructing, operating, and managing interregional infrastructure. This includes the extension of heating networks for Niche Technologies as well as the construction of completely new infrastructure for Next Generation Technologies. However, this comes with high upfront investments that will only pay off gradually over an extended life cycle. Transforming existing infrastructure to utilize it in new ways such as using natural gas pipelines for distributing hydrogen can lead to competitive advantages since they reduce upfront investment costs and are ready for application without requiring extensive retrofits. Thus, utilities with an existing infrastructure are well positioned to occupy this role in a specific region. Green infrastructure providers emerge as connectors between different clients and stakeholders across all playing fields and are a crucial element in the expansion of carbon reduction technologies.

In each playing field, there are highly specialized and specific roles. Utilities can embrace dedicated tasks along the value chain and therefore act as **Specialists**. In order to establish themselves as specialists, utilities have to completely understand existing processes from the industrial client and require a highly skilled labour force. Based on this particular expertise they have to develop custom-tailored solutions that stand out from other offerings on the market. With this very narrow industry focus, a cross-regional or global approach helps to gain further knowledge and profit from the resulting scaling effects. Regarding Bridge Technology, utilities can retrofit existing furnaces to enable the usage of biomass. Intelligent software solutions are of special interest for utilities in the playing field of Core Technology.

DIFFERENT ROLES OF UTILITIES AND PARTNERS



Specializing in the efficient use of waste heat is a key action for utilities that bundle their efforts towards Niche Technologies.

Utility roles summarized by the **Innovation Partner** archetype are highly innovative and future-oriented. Establishing profitable technologies requires respective investments in applied research, human capital, laboratories, and pilot sites. To build up competences, utilities could partner with emission-intensive customers for executing pilot projects and they could collaborate with start-ups and research centers for developing new technologies and solutions. By acquiring other businesses, utilities can speed up the innovation process. Nonetheless, the research and technology development process implies a deferred break-even point, requiring a solid financial foundation on the utilities' side. The gained knowledge from pilot sites can be transferred to profitable global scale solutions in the Next Generation Technology playing field. Providing solutions for the electrolysis of hydrogen from renewable power and specializing in CO_2 gas capture and preparation are examples of potential roles within the Innovation Partner archetype.

As is the case with the technological solutions, no archetype is a stand-alone solution for helping the industry to reduce their carbon footprint. Only the combination of technologies and utility archetypes will lead to success in this challenging task. Furthermore, an intense and sustainable cooperation of utilities, industrial companies, and external partners is crucial. This holistic approach opens the door to an enormous potential of reducing carbon emissions globally. For example, in both the European Union and the United States, energy-related carbon emissions can be lowered by more than **50 million tonnes of CO_2 by 2025** compared to 2015 in the seven focus sectors with the support of utilities. To enable these reductions, the industrial companies in the EU and US would have to stick to the goals agreed upon in the Paris Agreement. If the industrial players in the EU pursue the objectives stated in the European Green Deal, energy-related carbon emission reductions of one-third by 2030 (compared to 2015) would be achievable. This equals **200 million tonnes of CO_2** that the industrial sector could avoid through the assistance of utilities.

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