



# Toward a new energy system

A holistic view of how we can shape  
the energy transition together

White paper

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**SIEMENS**  
ENERGY

# Toward a new energy system

Energy is the beginning of everything, the basis of civilizational development and the foundation of all economic progress. To make it future proof, we need a balance of affordability, reliability, and sustainability. This includes a phase-out of coal, the expansion of renewables, the further development of H<sub>2</sub>-capable gas power plants and grid stability services, as well as storage solutions that step in when the wind isn't blowing and the sun isn't shining. Together, these steps and technologies can ensure energy security and make a decarbonized energy system possible.

## Preface



Climate change is real and one of the greatest challenges in the history of humankind. The impact of global warming is no longer theoretical. We're seeing the consequences: droughts, fires, and floods at our doorstep and in every corner of the planet. We're experiencing the warmest years since weather records began.

We are at a turning point. As the latest IPCC report states, "To limit global warming to 1.5 degrees Celsius, greenhouse gas emissions must be reduced by 45% from 2019 levels by 2030."<sup>1</sup> This requires nothing less than a complete transformation of the global energy system.

The world needs a more diversified energy mix and a massive expansion of renewable energies – along with corresponding infrastructures and storage capacities. The phase-out of coal is an important first step. Switching to gas significantly reduces CO<sub>2</sub> emissions. If every coal power plant in operation today were converted to our modern combined-cycle power plants,

emissions in the electricity sector could be cut in half. What is more: Green hydrogen can be used in our gas turbines as a sustainable fuel replacing natural gas. We're able to co-fire up to 75% hydrogen and are planning for 100% by 2030.

Our technologies are a backbone of affordable, reliable, and sustainable energy systems – but honestly, we can't do it alone. Business, government, and society must work together to create a new and sustainable energy landscape. Global partnerships are needed to balance the energy trilemma – not only in the face of geopolitical crises, but also in managing the energy transition and achieving net-zero climate targets. Siemens Energy stands at the ready. This white paper gives an overview of concrete steps to drive the energy transition – step by step and with a clear direction.

**Karim Amin**  
*Member of the Executive  
Board of Siemens Energy*

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<sup>1</sup> "The evidence is clear: the time for action is now. We can halve emissions by 2030"; Press Release, IPCC, April 4, 22.



# 1 What can take coal's place?

Today, the world is tackling climate change with a growing sense of urgency. At the COP 26 summit in Glasgow in 2021, for the first time, a climate resolution was agreed on to phase out coal use. For good reason: Global emissions from coal came to 14.8 Gt in 2020, just 350 Mt short of its peak in 2014.<sup>2</sup>

With considerable ambition, this document aims to show the direction in which the world is heading. In 2020, coal contributed around three-quarters of the electricity sector's CO<sub>2</sub> emissions, which, in turn, represented 36% of all energy-related CO<sub>2</sub> emissions.<sup>3</sup> And now, based on announced pledges and stated policies, energy-related CO<sub>2</sub> emissions should fall by 40% by 2050.<sup>4</sup>

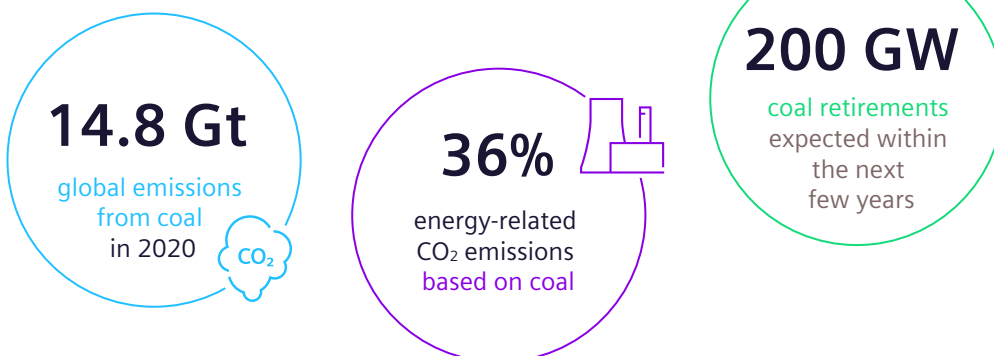
And the shift away from coal is important, even though it's clear even more needs to be done to reach net zero by mid-century. For one, we need to ensure energy supply.

Approximately 200 GW of installed coal power plants are expected to exit the market within the next few years (mainly in Europe, North America, China, and other parts of Asia) – and possibly even more if China ends its support for building new coal-fired power plants abroad.<sup>5</sup>

It's a necessary step toward an economy with net-zero CO<sub>2</sub> emissions. However, while necessary, it's not enough to do so by mid-century.

With coal being scaled back on an unprecedented scale, we have an excellent chance of reducing CO<sub>2</sub> emissions. But with the reduction in coal-fired power plants, we lose not only balancing and dispatchable power, but also grid stability. Yet these services can't be replaced solely by the rising share of renewables, such as solar and wind. The future renewable-based electricity system needs technologies that provide reliable dispatchable power with a zero carbon footprint and grid stabilization.

This becomes even more important in light of the growing global energy demand. In 2021, it was up a stunning 6%, the highest increase since 2010.<sup>6</sup> And it's expected to grow significantly more, thanks largely to e-mobility and the rising use of electricity in other economic sectors (the "all-electric society"). Unsurprisingly, it's expected that most of the additional demand will be met by renewables, which are high on governmental agendas worldwide. But, as indicated above, renewables alone can't ensure a stable energy system. We need dispatchable energy, and we need grid stability services. That's why we need to continue grappling with the question: How can we build a stable decarbonized energy system based on renewables?



<sup>2</sup> "CO<sub>2</sub> emissions"; Global Energy Review 2021, IEA.

<sup>3</sup> World Energy Outlook 2021, IEA, p. 124.

<sup>4</sup> "Executive Summary"; World Energy Outlook 2021, IEA.

<sup>5</sup> See footnote 3.

<sup>6</sup> "Surging electricity demand is putting power systems under strain around the world"; Press Release, IEA, January 14, 2022.

## 2 2030: A changed energy landscape

As we phase out coal, the goal is clear: an economy with net-zero CO<sub>2</sub> emissions by 2050. At the same time, energy demand keeps rising and needs to be met. Moreover, the additional capacity needed will have to be provided by alternative energy sources. Although the exact path toward that goal is unknown, based on analyses conducted by the IEA (International Energy Agency) and other organizations, there appears to be a clearer idea of what the energy mix will look like in 2030.

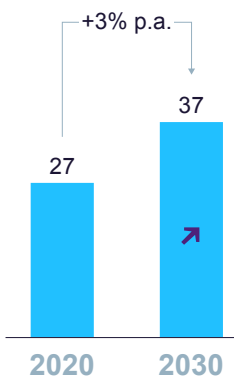
In most market scenarios, by 2030, the rising energy demand will largely be met by the accelerated expansion of renewables, namely, solar and wind. Whereas in 2020, worldwide renewables were responsible for 30% of electricity generation, their share is projected to increase by about 45% in 2030

based on announced national pledges.<sup>7</sup> But if we're to reach net zero by 2050, renewable energy generation needs to increase by another 15%, according to the IEA World Energy Outlook 2021.

At the same time, there'll be an immediate need to supply balancing and dispatchable power along with grid stability. Understandably, these are essential features that fluctuating renewables can't continuously deliver. But if these features can indeed be provided, the share of renewables can grow even further. The power may mainly come from thermal power plants increasingly running on clean fuels, such as hydrogen – not only at the utility scale, but also when it comes to industrial applications. And given the current geopolitical climate, we can expect an accelerated transition.

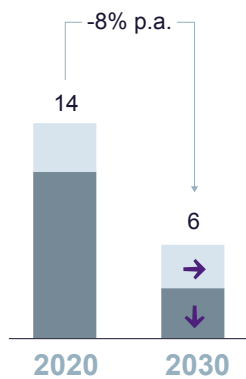
### ⚡ Steady increase in power generation

1000 TWh (generation)



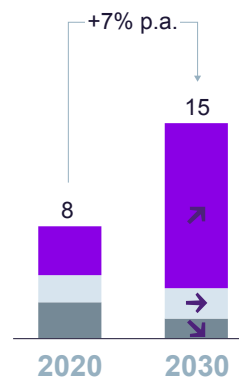
### ☁️ Strong decline in coal emissions

Gt CO<sub>2</sub> in electricity and heat sectors



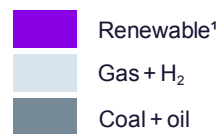
### 🌞 H<sub>2</sub> + gas enables renewable growth

1000 GW (installed capacity)



Source: IEA Net Zero by 2050 – A Roadmap for the Global Energy Sector.

<sup>1</sup> Includes renewables and others (fossil fuels w/CCS, nuclear & battery storage)



Meeting the challenges of our time: By 2030, coal emissions will go down, while gas and hydrogen power generation will enable the growth of renewables, meeting the growing power demand.

<sup>7</sup> World Energy Outlook 2021, IEA, p. 125.

## 3 Market and regulatory mechanisms

However, this scenario won't come about on its own. There need to be political as well as financial frameworks promoting investments that help realize a decarbonized energy system. Four levers are key for these frameworks: 1. carbon pricing, 2. environmental regulations, 3. funding and financing programs, and 4. power market design.

**1. Carbon pricing** mechanisms that are effective and reliable can help ensure that switching from fossil to carbon-neutral energy becomes a business case for all energy-consuming sectors, similar to how wind energy has been promoted in the past few decades. For instance, governments around the world collected more than \$45 billion generated by carbon pricing systems in 2019. These funds need to be re-invested in low-carbon infrastructures or used to support technological advances. According to the IEA Energy Outlook 2021, to reach net-zero emissions by 2050, carbon prices should by then have risen to \$250/ton CO<sub>2</sub> in advanced economies and \$200/ton CO<sub>2</sub> in other major economies.<sup>8</sup>

**2. Environmental regulations** not only put a time limit on operating fossil-powered plants, they also support future-proof gas power plants, investments in hydrogen infrastructure, and access to hydrogen for power generation. Regulations also need to reduce bureaucracy in order to expedite approval of energy transition projects.

**3. Funding and financing programs** need to be aligned with the goal of phasing out coal as well as helping to replace capacity in ways that complement renewables. For instance, under the 2020 Framework Program for Research and Innovation,<sup>9</sup> the EU is co-funding several pilot projects supporting decarbonization, among them Hyflexpower, an industrial scale hybrid power plant in France.

**4. Power market design:** In energy systems with high shares of renewable electricity, more and more, the role of thermal power plants is to provide reliable capacity. They may only run during limited operating hours, but they ensure security of supply and keep the systems stable. Their value needs to be remunerated by the energy markets. Today, countries with 'energy-only markets' value energy (kWh) but not capacity (kW). Hence, they don't provide sufficient investment signals related to offering capacity. For this reason, it will be necessary to establish separate power and capacity markets to ensure sufficient investment in security of supply.

### Reference:

Saillat-sur-Vienne, France<sup>10</sup>

#### Hyflexpower



- First fully integrated power-to-hydrogen-to-power industrial-scale demonstrator
- Upgrade of SGT-400 for up to 100% H<sub>2</sub> operation in 2023
- First operation with natural gas and H<sub>2</sub> in 2022
- Led by a consortium comprised of Engie Solutions, Siemens Energy, Centrax Gas Turbines, and other companies and universities

<sup>8</sup> World Energy Outlook 2021, IEA, p. 103.

<sup>9</sup> World Energy Outlook 2021, IEA, p. 135.

<sup>10</sup> "HYFLEXPOWER: The world's first integrated power-to-X-to-power hydrogen gas turbine demonstrator"; Press Release, Siemens Energy, May 29, 2020; "Our Project"; HYFLEXPOWER website.

## 4 Coal-to-gas shift: Moving to zero CO<sub>2</sub> emissions

There are two key features required in a renewable electricity system. The first: Dispatchable power alongside balancing power. The second: Grid stability. Gas power plants provide both of these benefits to the extent necessary for a stable energy system. This is possible because the technology is mature and their economics are sound. Also, their CO<sub>2</sub> emissions can be further reduced with the help of efficiency upgrades and

carbon capture. Combined heat and power (CHP) plants can even reach a fuel effectiveness of up to 90%. The ultimate switch to hydrogen should result in carbon-free energy generation by 2050 at the latest. As previously stated, considering this projection, it's not surprising that the added amount of gas power is projected to stay stable at 40–60 GW per year, at least until 2030.

### Replacing coal capacity with highly efficient H<sub>2</sub>-ready CCPPs

Coal power can be replaced by gas power (natural gas, LNG, LPG, and so on) in two ways – by building new power plants or by repurposing existing ones. Compared to a coal plant of the same capacity, a new state-of-the-art combined cycle power plant (CCPP) can reduce CO<sub>2</sub> emissions by approximately two-thirds. Indeed, this is what a new CCPP in Komotini, in the northeast of Greece, is expected to achieve by saving up to 3.7 million tons per year when compared to a coal-fired power plant (see next page).

Furthermore, the infrastructure around shut down coal plants can be wisely used to switch to a highly efficient H<sub>2</sub>-ready CCPP. This conversion is known as a full repowering, and not only does it facilitate the repurposing of existing assets, but it also has the potential to lower investment costs when compared to a greenfield project. Moreover, repurposing existing assets involves shorter implementation times, less paperwork, and fewer permits. Apart from reducing CO<sub>2</sub> emissions, this also leads to an increased efficiency from an average of 38% up to 63%.

### References:

#### Marl, Germany<sup>11</sup>



#### CHP plants at chemical park

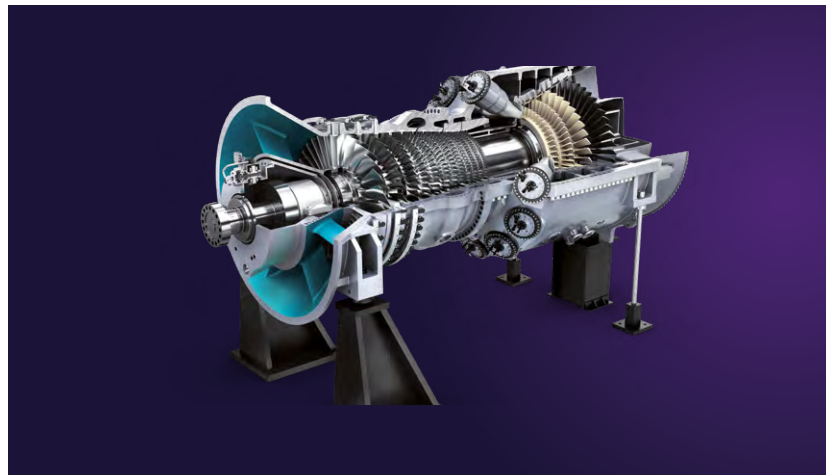
- Three 90 MW CHP plants
- Produce electricity and process steam for Marl chemical park
- District heat for 2,000 homes
- Replaces the last coal-fired plant at the Marl chemical park
- Annual savings: 1 million tons of CO<sub>2</sub>, equal to taking 500,000 cars off the road or planting 46 million large trees
- Full EPC with 3 × SGT-800 gas turbines including steam extraction and supplementary firing
- Fuel efficiency will exceed 90%

<sup>11</sup> "A million tons of CO<sub>2</sub> lighter"; May 2021, Siemens Energy.

Komotini, Greece<sup>12</sup>

CCPP

- World’s most powerful combined cycle power plant in 1×1 configuration with 877 MW electrical capacity
- Enables phaseout of lignite power plants
- Reduces CO<sub>2</sub> emissions by up to 3.7 million tons per year compared to a coal power plant
- SGT5-9000HL gas turbine, SST5-5000 steam turbine



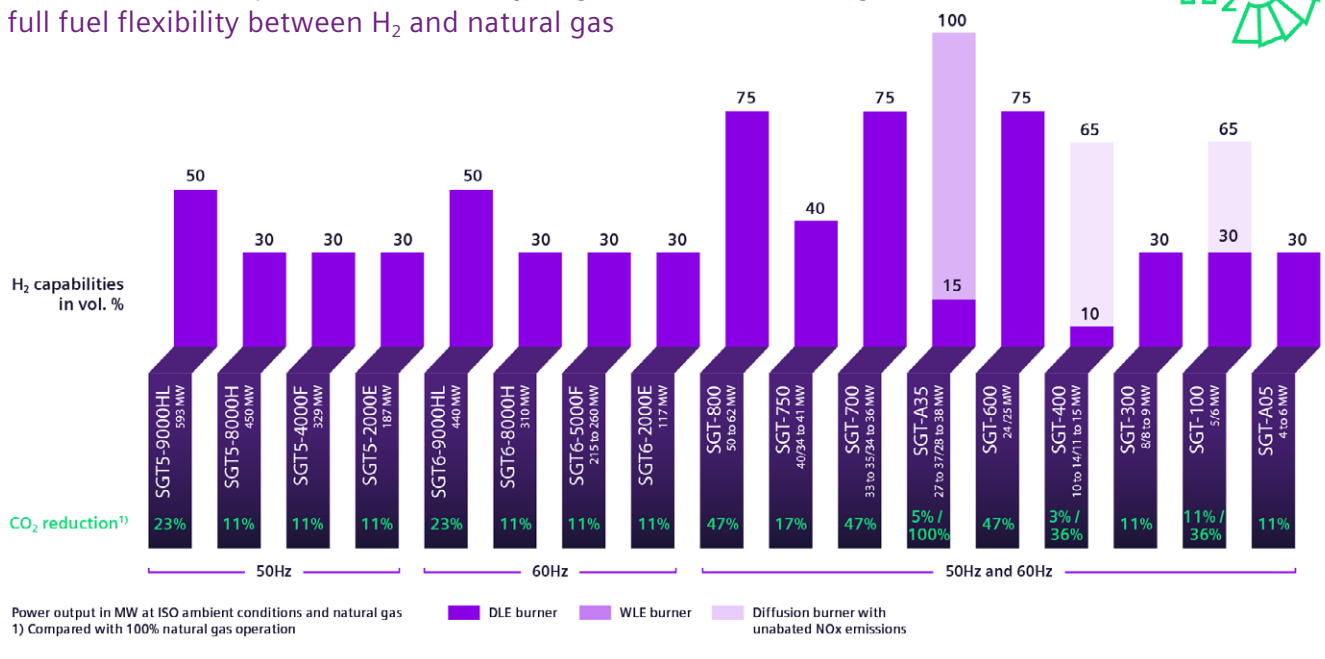
Future-proofing gas power plants with hydrogen and carbon capture

Future-proofing gas power plants means equipping them with turbines that are capable of co-firing clean fuels, mainly hydrogen or other e-fuels. Many major gas turbine OEMs, including Siemens Energy, today have turbines capable of operating with an admixture of 30–70% hydrogen, and are

working toward 100% hydrogen by 2030. Unsurprisingly, most want their gas power plants to be hydrogen-ready. To address this demand, as of 2021, TÜV Süd in Germany has been offering “H<sub>2</sub>-Ready” power plant concept certification,<sup>13</sup> and Siemens Energy is the first company to have received it.

Hydrogen capabilities of Siemens Energy gas turbines

The mission is to operate with 100% hydrogen while maintaining full fuel flexibility between H<sub>2</sub> and natural gas



<sup>12</sup> “Siemens Energy’s HL-class technology enables Greece to reduce CO<sub>2</sub> emissions and protect the environment”; Press Release, Siemens Energy, September 30, 2020.  
<sup>13</sup> “Siemens Energy is the first manufacturer to receive certification for “H<sub>2</sub>-Ready” power plant concept”; Press Release, Siemens Energy, November 16, 2021.

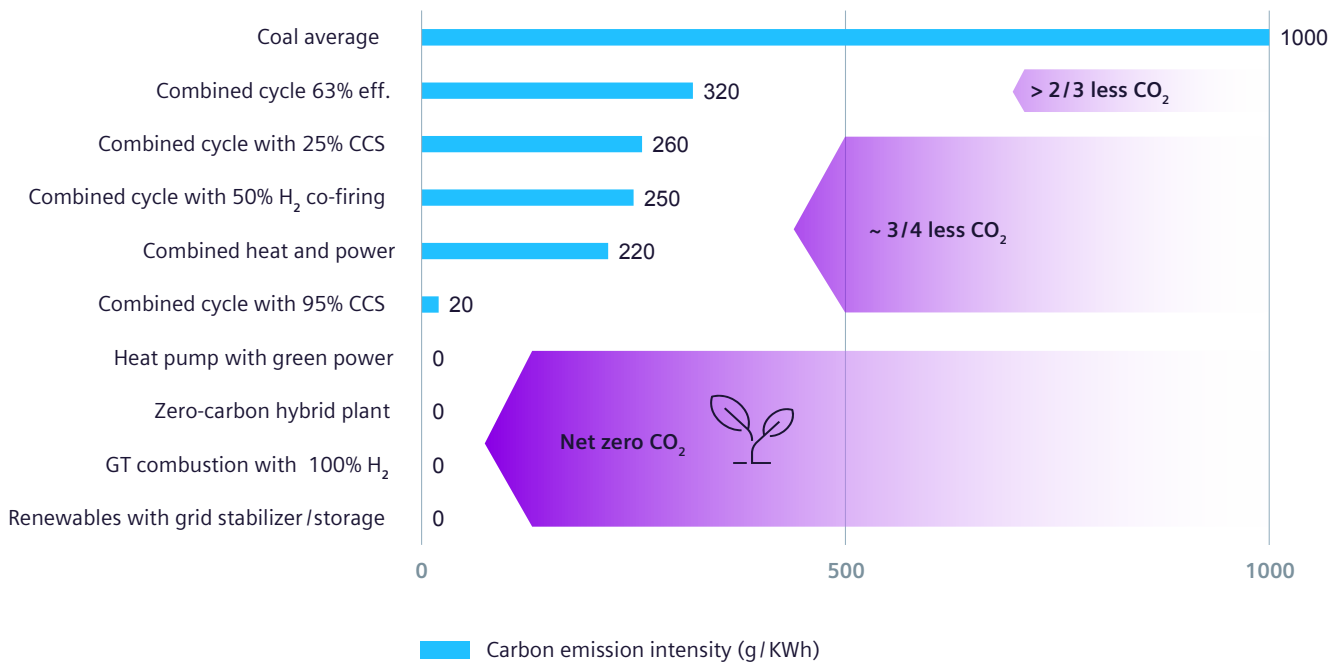


Regulators and policy makers have certainly taken note. For example, in the EU, there's been a push to operate more electrolyzers faster, including more storage options and grid connections. Under the REPowerEU program, the EU proposed a 'Hydrogen Accelerator' program that would result in 20.6 million tons of green hydrogen being produced annually by 2030.<sup>14</sup> If the electrolyzers producing hydrogen are powered by renewables, they can prevent greenhouse emissions altogether.

40 GW in the EU by 2030 may not appear much compared to total available capacity. Yet, this number can be compared to the early days of wind and solar. In order for green hydrogen, as well as other clean fuels, to be available at scale, production needs to

be increased, while production costs must conversely decrease due to economy of scale and corresponding innovation. Also, infrastructure for distributing and storing hydrogen is still widely missing. In short: Major investments need to be made. To encourage these, approval processes need to be shortened and CO<sub>2</sub> prices progressively increased. Also, financial incentives should be considered to make investments in hydrogen production and distribution a realistic option.

Next to hydrogen, another option for reducing the emissions of gas power plants is carbon capture technology. While promising, its technological as well as economic validity is still being evaluated.



Big impact: By shifting from a coal to a combined cycle power plant, more than 2/3 of CO<sub>2</sub> emissions are cut. And by integrating H<sub>2</sub> co-firing, CCS, or renewables along with storage, it's possible to reach net zero.

<sup>14</sup> "Questions & Answers on REPowerEU"; May 8, 2022.

## References:

### Leipzig, Germany<sup>15</sup>

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#### H<sub>2</sub>-ready CHP

- The CHP plant supports Leipzig's decarbonization strategy by generating power and district heating independent from lignite
- Aims to completely decarbonize gas turbine operation through hydrogen
- Two H<sub>2</sub>-ready SGT-800 gas turbines installed
- Mid-term co-firing 30% to 50% hydrogen, long-term 100%



### Teesside, United Kingdom<sup>16</sup>

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#### CCPP with carbon capture

- Front-end engineering design (FEED) studies for carbon capture at a gas power plant in Teesside, UK, planned to be completed by the end of 2022
- Gas power plant with fully integrated carbon capture technology
- Carbon will be stored securely offshore in the North Sea
- Part of UK government's Carbon Capture, Usage and Storage (CCUS) program



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<sup>15</sup> "Gas turbines from Siemens Energy are providing Leipzig with a climate neutral power supply"; Press Release, Siemens Energy, November 19, 2020.

<sup>16</sup> "Net Zero Teesside takes major step forward as first engineering contracts are awarded"; Press Release, December 15, 2021.

## 5 Decarbonizing heat

Though it's crucial to replace coal-fired power plants with sustainable energy generation, we can't leave out the essential factor of decarbonizing heat generated by fossil fuels, namely coal, oil, and natural gas. Half of the world's energy use in 2021 was heat. And 51% of that global heat use came from industrial processes<sup>17</sup>, especially in the glass, steel, chemical, and pulp and paper industries.<sup>18</sup> In total, heat-related industrial CO<sub>2</sub> emissions stood at 7.8 Gt in 2020.<sup>19</sup> Thus, without decarbonizing heat, net zero will never be achieved.

Here, we want to draw attention to two key elements for decarbonizing heat: heat pumps and combined heat and power plants.

Heat pumps operate based on a simple principle: with a certain amount of additional energy (in most cases, electricity), they lift heat from a low-temperature heat source to a usable level at the heat sink or consumer. In this way, they generate much more heat than a direct conversion of electric power to heat could ever achieve. This also shows how heat pumps can facilitate

decarbonization, if renewable electricity is used for their operation.

Industrial sources consist mainly of industrial waste heat, for example, from steel plants. Other heat sources are also possible, for instance, geothermal heat, ambient air, or even rivers, seas, and oceans. Unsurprisingly, while they're presently not yet economically viable without funding, in the coming years, heat pumps are expected to be deployed on an industrial scale, bringing with them the electrification of the heat sector.

One special application case are novel high-temperature heat pumps providing a temperature of 150°C. These heat pumps can help industries capture waste heat and reuse it to provide hot water or steam for process heating, which wasn't possible in the past. Moreover, these pumps can be used for district heating or targeted expansion of low-temperature heat sources to the level of district heating in areas with high heating demand.

### Reference:

Berlin, Germany<sup>20</sup>

#### Large-scale heat pump for district heating

- Generates district heating using waste heat from a cooling plant and electricity from renewables
- High-temperature heat pump (8 MWth) enables temperature levels from 85 to 120°C
- 6,500 t of CO<sub>2</sub> emissions savings
- 120,000 m<sup>3</sup> of cooling water savings



<sup>17</sup> "Heating"; IEA, 2020.

<sup>18</sup> "Strengthening Industrial Heat Pump Innovation"; White Paper, 2020.

<sup>19</sup> "Renewable Heat"; IEA, 2021.

<sup>20</sup> "Vattenfall and Siemens Energy help advance a climate-friendly heating supply for Berlin with large-scale heat pump"; Press Release, Siemens Energy, March 25, 2021.



The basis for any heat pump is, of course, an adequate heat source. But not every city or municipality has access to industrial waste heat, the option of tapping geothermal heat, or even a river or sea nearby. However, most cities at least have sewage plants carrying heat. Other possible heat sources are waste incineration plants, data centers, and electrolyzers. In sum, there's a wide range of potential applications for heat pumps. Numerous governments have recognized this and established economic development incentives.

Combined heat and power is another option for decarbonizing heat. By replacing a coal district heating plant with a gas-fired CHP plant, huge GHG savings are achievable today. By switching to low-carbon or zero-emissions fuel, such as hydrogen or biomass, maximum fuel efficiency can be achieved, and any heat produced for district heating or process steam can also be carbon-free. Thus, CHP plants fired with hydrogen or other climate-neutral fuels are another relevant part of decarbonizing energy in Europe and other parts of world.

## Reference:

### Shanghai Orient Champion Paper, China<sup>21</sup>

- Fuel shift from coal to gas
- On-site power generation, first to be used in Chinese pulp and paper industry
- Two single-shaft SGT-300 gas turbines installed
- Reduction of carbon footprint by 60%
- Process steam for drying process



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<sup>21</sup> "On-site power generation for Shanghai Orient Champion Paper"; Siemens Energy.



## 6 Maintaining grid stability

With the transition to renewables as a main source of energy generation, grid stability is at risk, as renewable power adds no inertia to the grid. As a result, the risk of power outages increases.

Thus, it's no surprise that rotating masses as a stand alone solution are already being added in grids with a high share of renewables. Especially at former power plants, rotating grid stabilizers (RGSs) are being installed by converting existing generators. The result is a large piece of spinning machinery made out of the generator, which can also operate as a synchronous condenser and is usually combined with a flywheel. When connected to the grid, it

provides inertia by spinning continuously without generating any power. It contributes to the stability of the system by spinning in sync with the grid frequency and dampening fluctuations, just as car shock absorbers dampen the impact of a bump in the road.

In addition, RGSs support voltage stability by providing reactive power and enhance grid strength at connection points by providing short-circuit power. And they are designed to respond instantly, without delay. As a result, RGSs make it possible to avoid stranded assets and contribute to a decarbonized energy system.

### Reference:

#### Moneypoint, Ireland<sup>22</sup>

##### Rotating grid stabilizers

- Converts a 915 MW coal power station into a green energy hub
- Rotating grid stabilizers (RGSs) enable increased integration of wind power
- A synchronous condenser is installed as a key component and incorporates the world's largest flywheel
- Ireland plans to reach 70% renewables by 2030
- Supports coal phase-out by 2025



<sup>22</sup> "Siemens Energy's grid stabilizer technology to help Irish grid exceed renewables penetration limit"; Press Release, Siemens Energy, May 4, 2021.

## Voltage control over long distances

But RGSs aren't the only option for helping maintain grid stability. Over long distances, it's particularly difficult to maintain high voltage control with intermittent renewables, such as wind and solar, which supply the bulk of renewable electricity. As their supply can fluctuate, it's necessary to sustain voltage control. A reactive electronic solution is static VAR compensators (SVCs). Instead of a spinning mass, they use power electronics. They help operators avoid blackouts caused by excessive loads and surges, insufficient voltage, or natural catastrophes that might take out parts of the grid.

Finally, it takes smart control systems to manage a complex grid facing an increasing

share of renewables and the corresponding fluctuating power flow, decentralization of production, and ever-increasing energy demands. These controls require higher capabilities beyond monitoring, controlling, and automation systems. They need to be intelligent and able to react quickly to changing conditions, such as weather, varying energy demand and supply, and so on. Moreover, smart systems like these don't just help maintain reliable power distribution, they also help operate power plants in cost-efficient ways and with the smallest possible carbon footprint. This can be realized, for instance, by ramping up energy generation when demand is high and slowing it down when it's low.

### Reference:

#### Mobile STATCOM, USA<sup>23</sup>

##### Relocatable grid stabilization solution

- Mobile solution including all components mounted on trailer
- Bridges the gap after phasing out coal-fired power plants until new measures take effect
- Supports CO<sub>2</sub> reduction and renewable integration
- Dynamic voltage control by Siemens Energy SVC PLUS technology



<sup>23</sup> "World's first mobile STATCOM: When grid stabilization gets wheels"; Siemens Energy Magazine, May 23, 2018.

## 7 Preparing for net zero: Hybrid power plants and sector coupling

It's clear that gas power plants and grid stability technologies are necessary enablers of renewables today. But in the long run, they'll also become essential to hybrid power plants. Such plants usually combine at least two elements of renewables, thermal power generation, or energy storage. They can also include additional elements, such as grid stability technology, electrolyzers, or heat pumps. They're expected to play a large role in distributed energy generation, for example, for municipalities or industries that may require tailored flexible power plants to suit their needs.

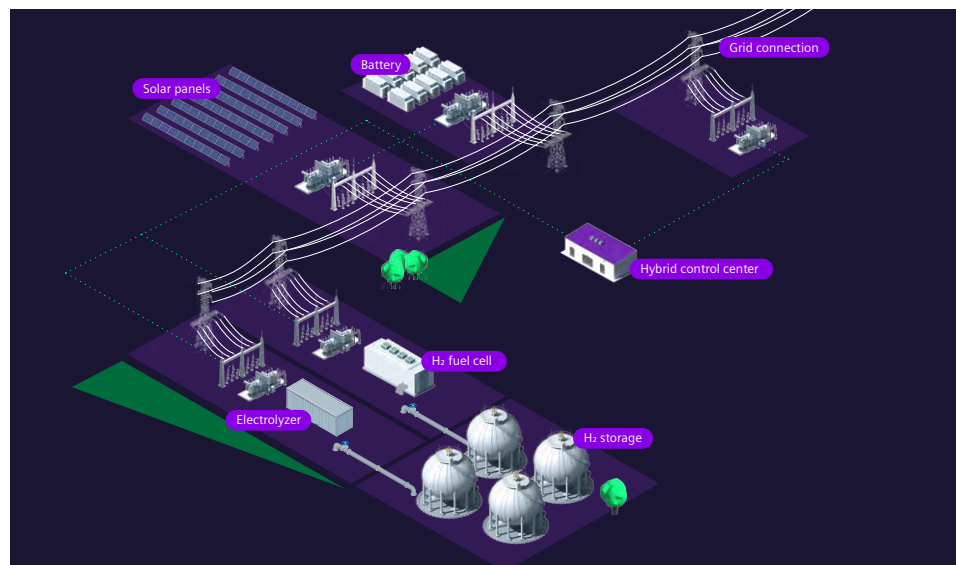
Let's take a closer look at a hybrid power plant's three core components, which all have shortcomings. Renewables are fluctuating; energy storage eventually runs out; and thermal power is only sustainable if operated with an eco-friendly fuel. If all three components were integrated, the weaknesses of each element could be addressed. The volatility of renewables could be significantly minimized, and thermal power generation could be continuous. Energy storage can't deliver continuous energy supply on its own, but when combined with thermal power and renewables, this deficiency can be avoided. An ideal integrated approach, however, requires a fourth element: a smart control system and dispatch optimizer that manages such a dynamic system. By combining all the aforementioned parts, they can be adjusted to a site's specific needs, thus enabling their optimized use.

Any hybrid power plant being constructed will have to address site-specific requirements as well as technological and economic boundary conditions. Simply put, windy regions are well-suited for integrating wind power, whereas sunny regions are optimal for integrating photovoltaics. That's why any hybrid power plant will represent a site-specific, tailored mix and match of technologies.

Finally, the most important benefit of hybrid power plants likely goes beyond the energy generation sector. The key term here is sector coupling, whereby excess energy can be transferred to all consuming economic sectors, such as buildings, mobility, industry, and agriculture. Consequently, the potential risk of curtailing energy generation can be addressed, as utilities can use long-term storage for seasonal balancing to help deal with a mismatch of supply and demand.

### Reference:

#### French Guiana, France<sup>24</sup>



### Hybrid power plant

- Large-scale hydrogen state-of-the-art hybrid power plant
- Combines PV, batteries, an electrolyzer, and a fuel cell
- Supplies electricity to 10,000 households with zero carbon emissions
- Scheduled to be commissioned in the fall of 2023

<sup>24</sup> "Siemens Energy will build climate-neutral power plant using hydrogen to supply 10,000 households in French Guiana"; Siemens Energy Press Release, November 3, 2021.

## 8 The social impact

Another important aspect of changing the complete energy system is its social impact. Globally, millions of jobs will be lost at coal power stations, associated mines, and oil and gas companies. And this doesn't just affect people's material livelihoods. Work is also a matter of personal identity for many people, even for entire regions. Therefore, while advocating for decarbonization, it's important to see how, for example, clean energy technologies may help provide local employment in future-proof jobs.

If we do it right, new jobs will be created in clean energy, which is projected to generate more jobs than those being lost in the coal industry.<sup>25</sup> These jobs will be available in green energy generation, energy-efficiency measures for buildings, and manufacturing. The World Energy Outlook estimates that compared to today, another 13 million workers should be employed in the clean energy sector, given the current energy policies and

government pledges worldwide.<sup>26</sup> Likewise, a recent McKinsey report found that in Europe, "the net-zero transition would create an estimated 11 million jobs, while eliminating 6 million, resulting in a net gain of 5 million jobs."<sup>27</sup>

These changes will be accompanied by various government programs, for example, the transferring of qualified personnel from the fossil fuel industries to other new energy sectors, such as renewables, carbon capture technologies, and hydrogen production, among others. For example, the United Kingdom has a North Sea Transition Deal in place that aims to "support and anchor the expert supply chain that has built up around oil and gas in the UK, to both safeguard and create new high-quality jobs."<sup>28</sup> Other countries around the globe are engaging in similar initiatives. Likewise, companies such as Siemens Energy are also heavily investing in continued education of personnel.<sup>29</sup>



<sup>25</sup> World Energy Outlook 2021, IEA. p. 54.

<sup>26</sup> See footnote above.

<sup>27</sup> "How the European Union could achieve net-zero emissions at net-zero cost"; Report, McKinsey Sustainability, December 2020.

<sup>28</sup> "North Sea Transition Deal"; Policy Paper, March 24, 2021.

<sup>29</sup> In 2021, Siemens Energy spent €58 million in continuing education. See "Our ESG targets and performance"; Company Presentation, Siemens Energy, August 2022.



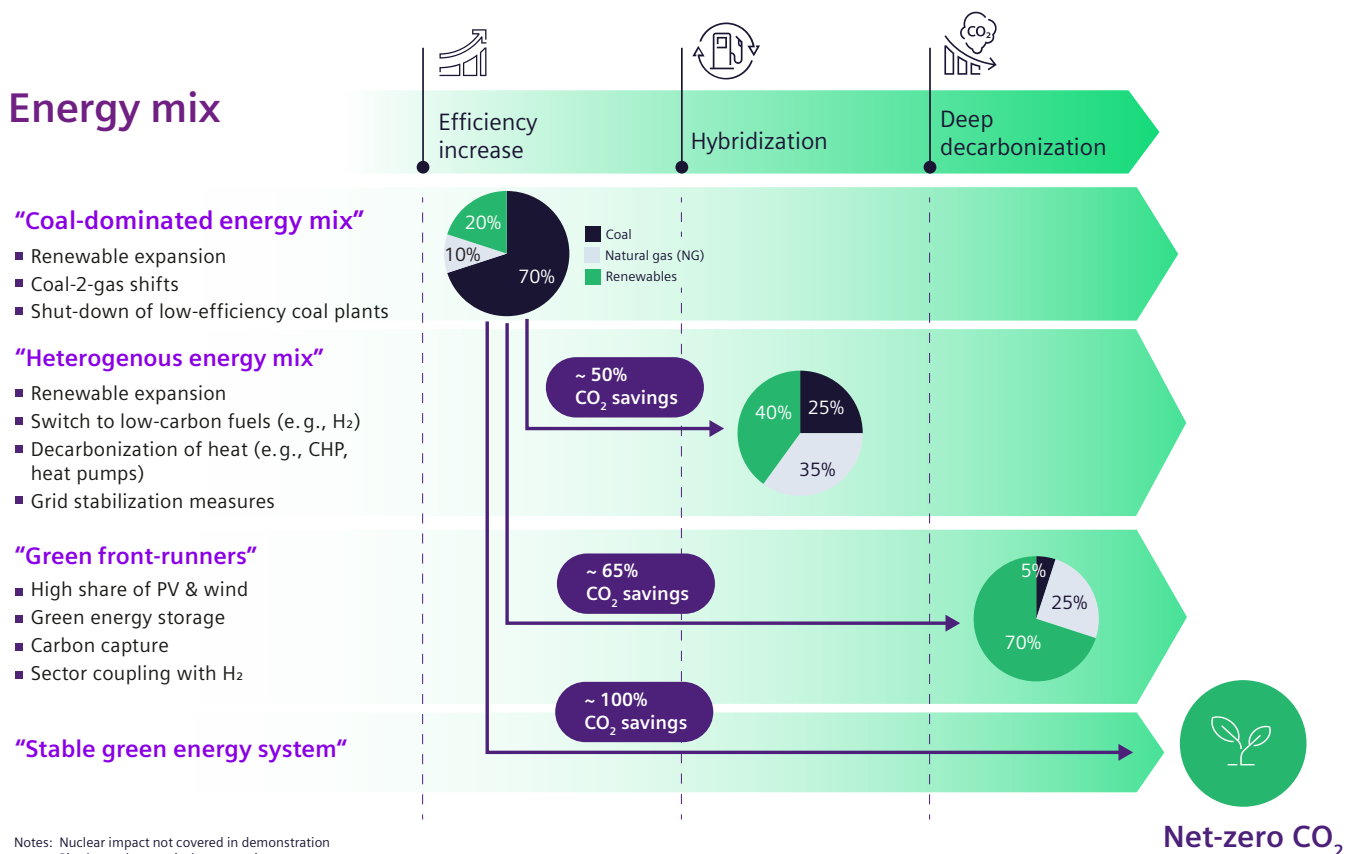
## 9 Whereto begin? Meeting countries at their starting point

Finally, while we have all these technological possibilities at our disposal, it's clear that as we push for decarbonization and coal phase-out, every country – even every industry – will experience different pressures in the process.<sup>30</sup>

Countries with abundant renewables, such as Brazil, New Zealand, and Canada, are close to zero coal, yet they can still benefit from decarbonization measures, measures that can increase the share of green fuels, and the co-firing of hydrogen in gas plants in order to reach net zero. And since their share

of renewables is comparatively high, these countries also have demands for grid stabilization measures, with the noted exception of hydropower dominated countries.

Other countries with a more heterogeneous energy mix, such as the US, Germany, and Japan, can reduce CO<sub>2</sub> emissions by approximately 65% by building H<sub>2</sub>-ready gas power plants. They can use natural gas as a bridging fuel while continuously increasing the share of hydrogen, using carbon capture technologies, pushing renewables, and employing grid stabilization measures.



30 Numbers in this section are based on Siemens Energy market analysis.

However, the biggest potential in terms of reducing emissions can be found in countries with a large share of coal-based energy generation, such as India, China, and Poland. For these countries, the necessary steps are clear: a massive expansion of renewables and a continued coal-to-gas shift.

And while all of these countries certainly need tailored solutions to balance the triangle of energy policy – sustainability, security of supply, and economic

efficiency – they're all aiming for the same thing. After all, they all committed to the "phase-out of unabated coal power" at COP 26. That means all countries have at least this goal in common, regardless of where they're starting out. Replacing coal-fired power plants is an essential part of this goal. And while each country requires solutions tailored to their respective energy systems, the necessity to enact changes remains the same.



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