Technologies for generating energy: turbomachinery // full project information from p. 17

In his keynote speech, **Dr Benjamin Witzel,** Head of Fuel Flexibility, Hydrogen & Carbon Capture at Siemens Energy, outlined the role that gas turbines play in the energy transition, how to make a successful switch to using hydrogen and what challenges this entails.

How gas turbines can help decarbonise the energy sector

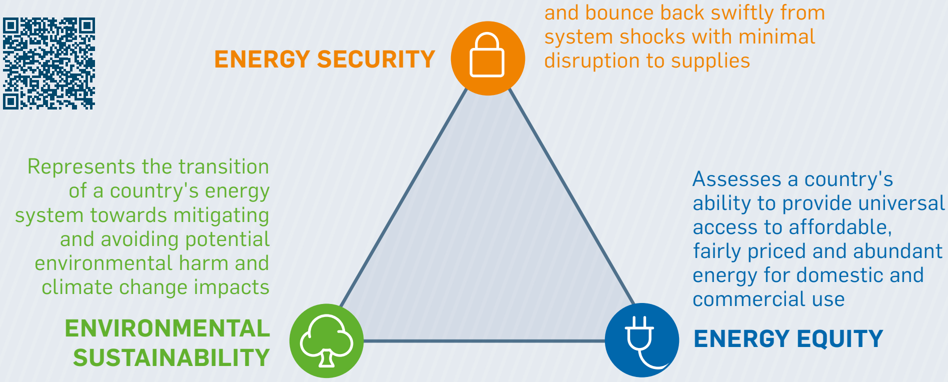
In a recent study, S&P Global assumes that over 50 billion tonnes of CO_2 equivalents will be released into the atmosphere in 2024 – with almost one third stemming from electric power and district heating. The good news is that this is predicted to be the peak of greenhouse gas emissions in both of the scenarios examined in the study and that levels will start to decline, primarily due to the expansion of renewable energy sources. Dr Benjamin Witzel, Head of Fuel Flexibility, Hydrogen & Carbon Capture at Siemens Energy, describes the hurdles that the energy transition faces as the **»energy trilemma«:** energy must remain affordable, there must be a reliable supply at all times, and it must be sustainable – i.e. ideally from renewable sources.

This presents a conundrum of contradicting objectives for which there is no easy answer. There are technical solutions for many challenges – even the reliability of the energy supply is an issue that can be resolved. The biggest issue today, however, lies in the costs: starting with the development of new technologies, carrying over to their production, and finally to their operation, which in the case of the latter are largely dependent on the price of fuel. This therefore requires a mix of different measures depending on the country, region and requirements. However, it is clear that turbomachinery will continue to play an essential role in all scenarios in the years to come.

FIGURE 9

World Energy Trilemma

// World Trilemma Index 2022, www.worldenergy.org



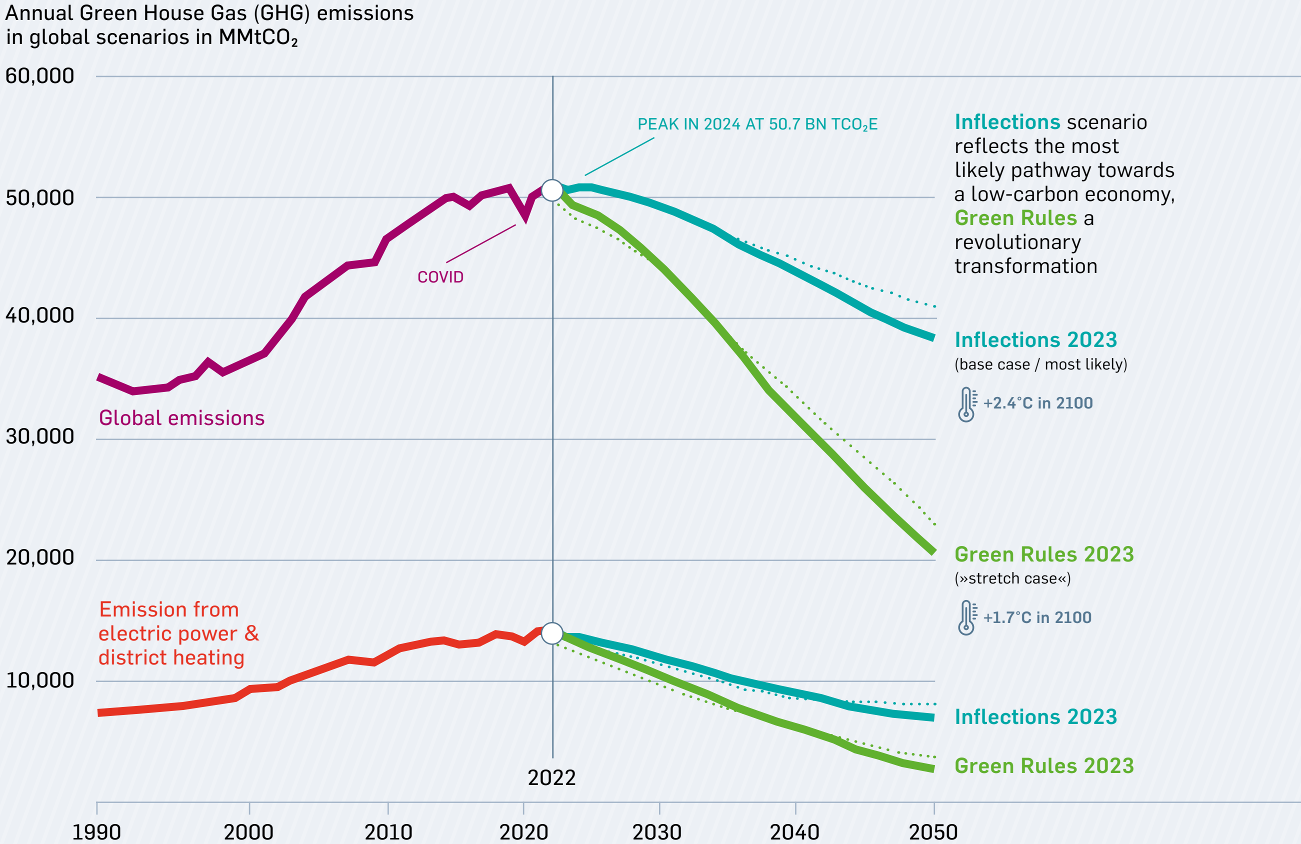


ABBILDUNG 10

Why Decarbonize? GHG Emissions need to be decreased to limit Global Warming

// S&P Global »Energy and Climate Scenarios – Energy outlook to 2050« (July 11, 2023), Siemens Energy 2023

Gas turbines are indispensable

Gas power plants will primarily serve to compensate for fluctuations in power supply, such as when renewable sources fail to deliver sufficient power during a period of low sunlight or wind. As such, gas turbines will be operated in a significantly more cyclic manner, e.g. no longer for 8,000 hours a year, but instead for just 1,000 hours with multiple system start-ups a day. Because the durability of certain materials and components is less limited by operating hours than by the number of cycles, however, material stress levels due to cyclic loading can increase despite fewer operating hours.

But as Benjamin Witzel explained, switching to the exclusive use of smaller turbines that can operate for longer periods is not an optimum solution either: »In this energy system, the gas turbine acts as a battery by reconverting chemically stored energy such as that in the form of green hydrogen. The requirement is then to deliver a high power output at a given moment, but also to an elevated degree of efficiency due to the high fuel costs. Therefore, the use of high-efficiency turbines of the 600 MW class will continue to have its merits.« He added that a gas turbine of this size requires significantly lower investment costs compared to, for example, ten 60 MW turbines. But those who depend on flexibility and who must operate the turbines in a very cyclic manner could benefit from smaller units.

In the future, he believes it will be essential to reconcile competing objectives more effectively: even today, flexibility is often more important than that last tenth of a percent of efficiency. »It's impossible to optimise everything at the same time. Some turbines are more efficient, whilst others can be used more flexibly. Our job is to get a sense of the where customer's needs overlap the most,« Witzel explained. Although requirements differ depending on the country, more and more customers are explicitly asking how much hydrogen they can admix to natural gas. »For some types this is 10 %, while for others it is 75 %,« he said. It will even be technically possible to switch to 100 % hydrogen in the future. But at the moment, very few customers are able to provide an uninterrupted supply of hydrogen in the quantities needed for operation.

Scaling up developments

By 2030, all new Siemens Energy gas turbines are planned to be »H_2-ready«, meaning that after replacing certain components such as the combustion system and auxiliary systems, up to 100 % hydrogen can be admixed with natural gas. Siemens Energy is currently operating approximately 20 different types of turbine worldwide, all of which were originally designed for burning natural gas. Evolutionary advancements for operation using 100 % hydrogen are not conducive as the flame speeds when burning hydrogen are too high, and the challenges related to the substances used (e.g. due to hydrogen embrittlement) or the reliable detection of potential flame flashback are too complex. The only way to tackle these challenges is with new developments.

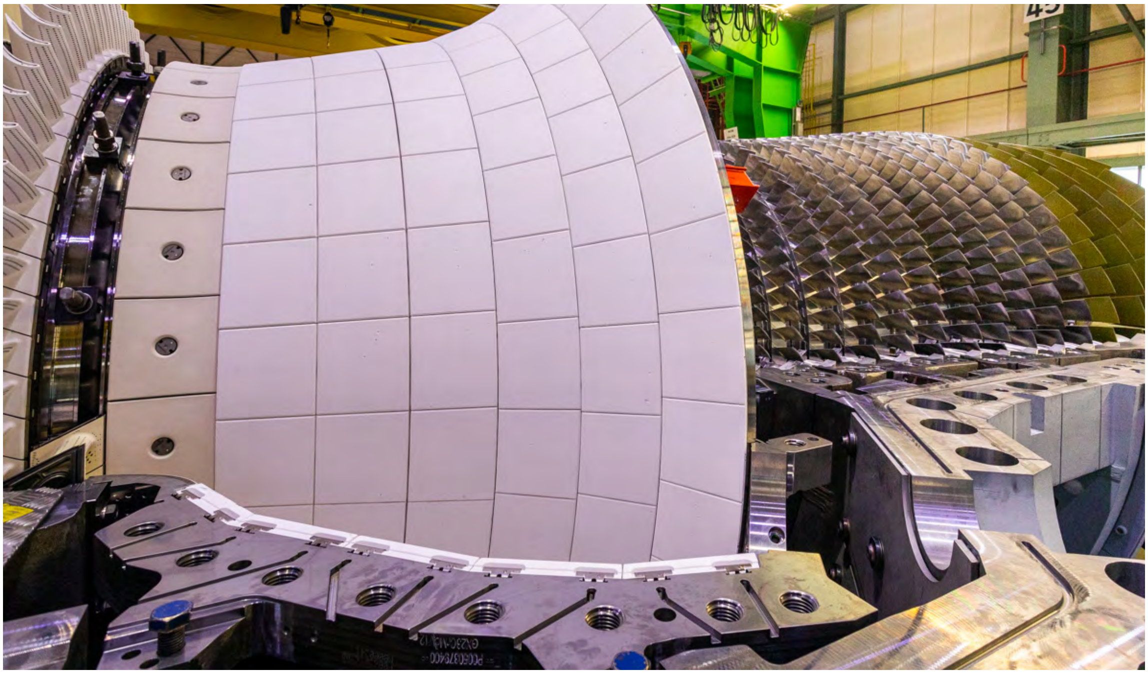
However, the broad portfolio of gas turbines cannot be switched to operating solely on hydrogen all in one go. For this reason, Siemens Energy is starting by developing base technologies such as the combustion system or ceramic materials on a smaller scale. Once a certain level of technological maturity is reached, the results can then be scaled to larger turbines. Smaller units such as the SGT-400 with an output of 13–15 MW are much cheaper to develop and test. For example, smaller burners can be produced using rapid prototyping methods such as selective laser melting. In addition, Siemens Energy requires less hydrogen for validating a 15 MW turbine than for a 600 MW turbine.

One challenge in developing new technologies for 100 % hydrogen combustion is the still limited availability of the fuel. This sometimes poses a significant problem as early as the development phase: for a single test on the complete machinery for an SGT-800 turbine, Siemens Energy's gas turbine facility in Finspång, Sweden, purchased almost all the available hydrogen in Northern Europe. Acquiring such large quantities of green hydrogen is not yet feasible. So where is the fuel to come from? Benjamin Witzel believes there will be practically no alternative to importing additional hydrogen from countries such as North Africa or Australia and shipping it to Europe, as the future domestic production capacities will be too low. All the same, six pipelines are planned in Europe by 2030 to enable the import and distribution of hydrogen. And by 2032, all power plants in Germany with a capacity of more than 100 MW are to have been integrated into the H_2 Start Net.

Methanol and ammonia as alternatives

One practical alternative for liquid fuel can be found in methanol derived from renewable or biological sources. »Dual-fuel«turbines use different fuel passages in order to utilise both liquid and gaseous fuels, such as hydrogen and methanol. While hydrogen serves as a substitute for natural gas, methanol is used as an alternative to liquid fuels such as heating oil. Existing turbines in lower power classes can be converted to run on methanol relatively easily, allowing Siemens Energy to offer customers a solution quickly. But more importantly, sufficient quantities of methanol will be available for smaller turbines.

While German and European policymakers currently favour hydrogen as a green energy source, turbines designed to burn gaseous or liquid ammonia are being developed in countries such as Japan. The advantage? Like hydrogen, ammonia can be produced from renewable energy sources, yet it offers significant advantages in terms of its transportation. This is an important factor for countries like Japan, which rely on energy imports due to their limited land surface area. As is the case with hydrogen, burning ammonia does not produce any CO_2. Nonetheless, Benjamin Witzel remains critical of the use of ammonia as the substance is



highly toxic – accordingly, alongside concerns about its general handling, the possible ammonia emissions produced due to incomplete combustion or start-up failures remain unresolved. Moreover, burning ammonia produces significantly higher nitrogen oxide emissions from the nitrogen bound in the fuel compared to current natural gas turbines. A further challenge when burning ammonia is its very low reactivity – unlike that for hydrogen. A system optimised for ammonia is unlikely to offer the flexibility of being able to use another fuel type in a dual-fuel turbine.

But regardless of which fuel is used in future: »There is no one single solution for the energy transition, but a mix of measures. We need to expand renewable energies, invest in infrastructure such as pipelines and power grids, develop new technologies and ensure reliable supply chains,« Benjamin Witzel concluded. And there is still much to be done when it comes to defining the corresponding standards and regulations. To overcome all these challenges, the industry must continue to collaborate closely with universities and research institutions – much like FVV and Siemens Energy are already doing.