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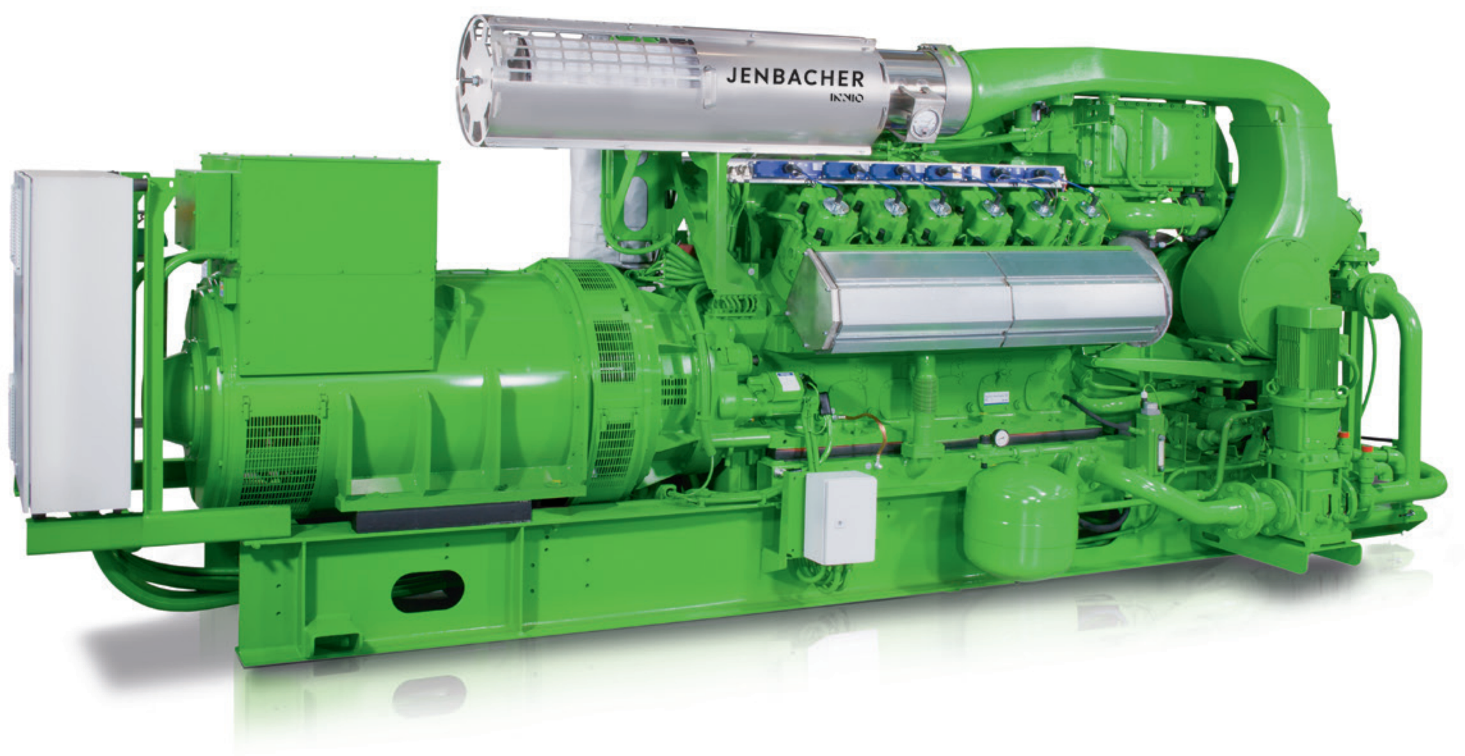

GAS ENGINES

Hydrogen as Future Fuel for Gas Engines

Hydrogen as Future Fuel for Gas Engines

Europe is aiming for a carbon-neutral energy system by 2050. In the future, synthetic fuels such as synthetic methane, methanol and hydrogen – in addition to biogas – could drive gas engines and thus accelerate the transformation from fossil to renewable energy sources. Right now nearly 55 % of the active Innio Jenbacher gas engine fleet in Europe is running on biogas or biomethane.

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THE CHALLENGES OF DECARBONIZATION

The world and its climate are changing faster than ever before; the 400 ppm CO_2 mark in the atmosphere has already been passed. Different scenarios detail how global warming can be slowed, but what they all have in common is the demand for a drastic reduction or a complete phasing out of fossil fuels. The EU Parliament has formulated a "European Green Deal" to turn the current challenge into an opportunity for Europe.

Stepping away from fossil fuels will be the challenge for the next years and decades. Traffic, as one of the main contributors to CO_2 emissions, is moving in the direction of electric mobility. Because batteries need instantaneous electric power when they are recharged, electric energy needs to always be available. This implies strong growth of the well-known renewable energy systems such as the wind and solar energy sources. Since wind and solar power are not available all the time, a key for sustaining decarbonization is storage of electrical energy. Solving the storage challenge is an essential part of the energy transformation from fossil to renewable energy. This makes the solution of the storage problem an essential part of the energy revolution. In order to implement decarbonization sensibly, storage facilities are needed on a large scale. Hydrogen (H_2) and synthetic fuels are a potential solution because they can be stored for longer periods. [1]

KEY CHALLENGE ENERGY STORAGE

Due to the volatility of renewable energy sources like wind and solar, energy storage is a key challenge. On the one hand, a short-term solution is needed to balance fluctuations within a day. On the other hand, seasonal fluctuations demand storage of several TWh over a half-year period, **FIGURE 1**. It shows that energy storage with batteries is a viable option for only a few hours. Seasonal storage of a carbon-free fuel must follow the H_2 route. Hydrogen can be stored directly or stored in hydrogen carriers, as synthetic fuels.

All storage options in which energy is stored in a chemical form start with H_2 produced via electrolysis of water as a first step. H_2 can be stored directly in underground caverns or it can be fed into the natural gas pipeline, leading to a blend of natural gas and H_2. If H_2 is fed into a pipeline, different blending rates are possible, a situation that is currently allowed. As an alternative solution, pure H_2 can be stored or transported in pipelines, enabling easy utilization of pure hydrogen. The very good cleanliness level of H_2 out of Power-

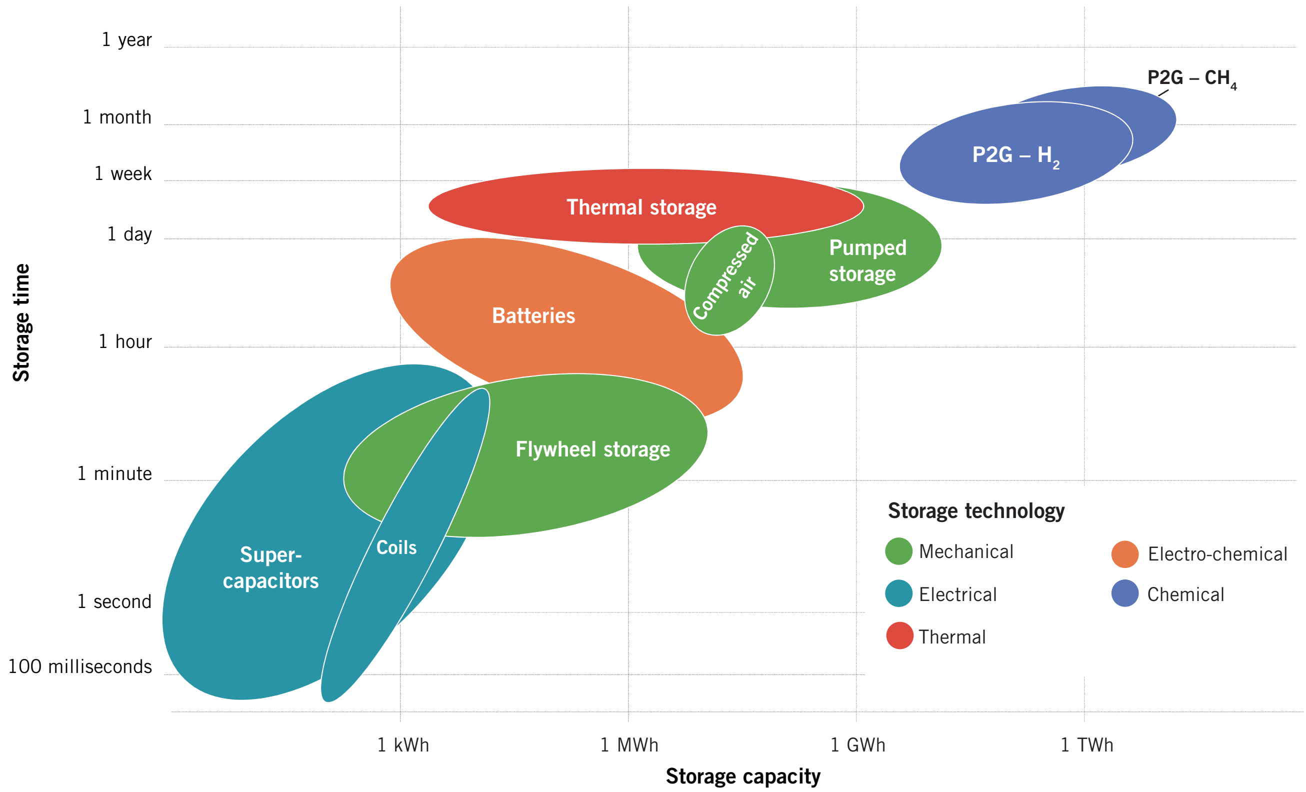

FIGURE 1 Energy storage options capacity versus duration (© Innio Jenbacher)

to-Gas (PtG) will be kept for downstream processes.

The option to process H_2 into methane (also called Synthetic Natural Gas, SNG) or other e-fuels has many advantages. These fuels can be used in the existing infrastructure without much modification, so a change to a fossil-free energy infrastructure would be easy, at least from the end user's point of view. But there is a downside to this process, the need for CO_2. Despite the new record

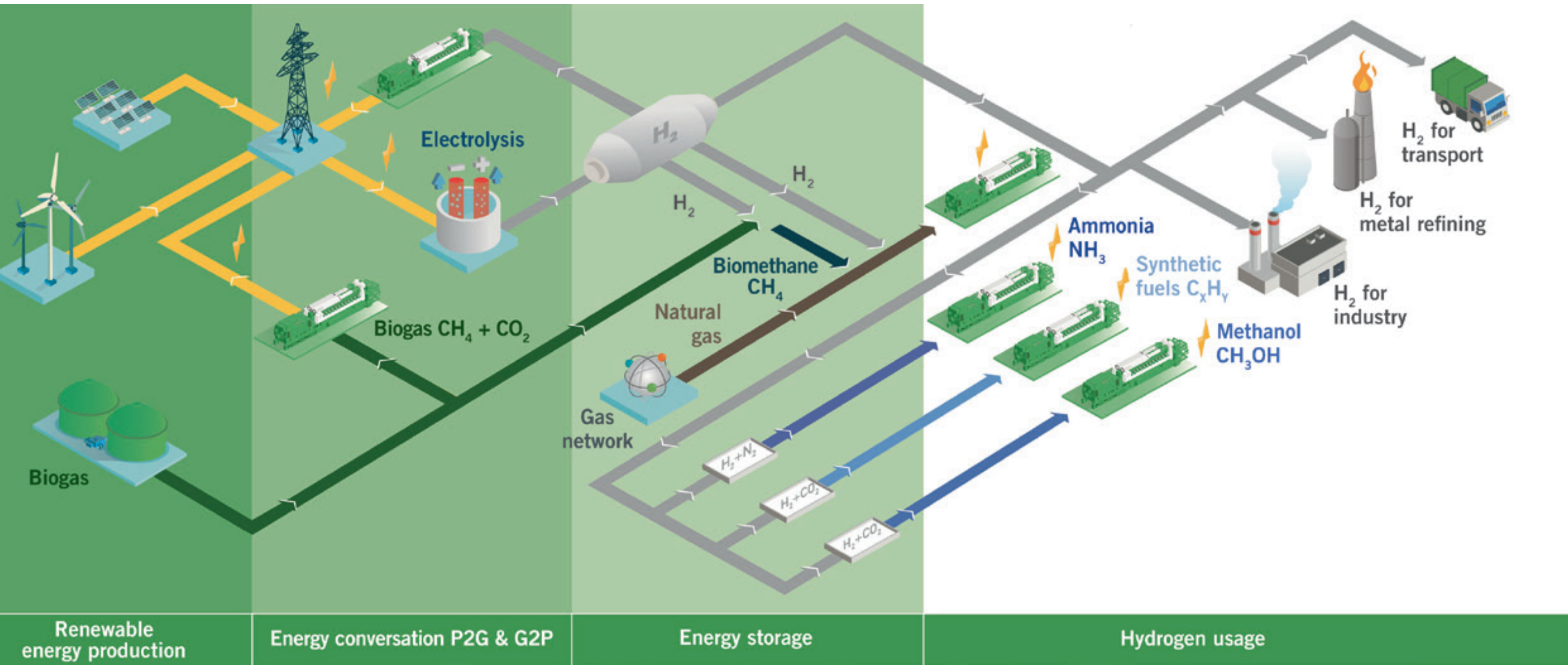

FIGURE 2 Future role of Jenbacher gas engines (© Innio Jenbacher)

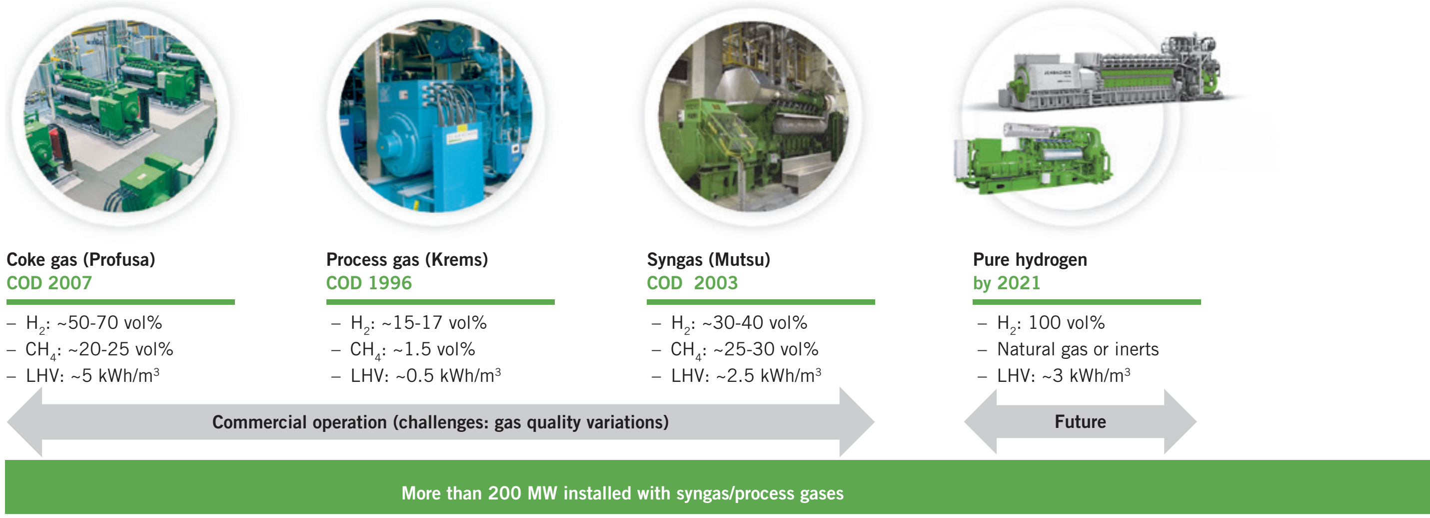

FIGURE 3 Projects with different gas qualities (H_2 content) (© Innio Jenbacher)

high of CO_2 in the atmosphere, for this separate process the concentration in the atmosphere is too low. Another option is to separate the CO_2 from the exhaust of a power plant and to use it for the production of synthetic fuels, **FIGURE 2**.

If it would become possible to produce a cost-effective synthetic fuel, quitting fossil fuels would be relatively easy, as the end user would need to make no changes – or only minor ones – to its assets. Right now, demonstration plants are in place, the technology is reliable and working – but it is too expensive compared to using fossil fuels.

FUELS FOR GAS ENGINES

“Green” synthetic methane is an excellent addition and replacement for natural gas. Synthetic methane is produced using methanization from hydrogen. This synthetic methane has the same physical properties as natural gas and therefore can be injected into the natural gas system without limitations and modifications to the gas infrastructure. All end consumers of gas, including gas engines, can continue to run reliably with current optimized performance and emission standards.

Hydrogen can play an important role in replacing fossil natural gas. It is basically carbon free and can be used as a fuel for gas engines. Over the next decades, the further growth of wind parks and photovoltaic installations could provide “green” hydrogen via P2G. Although different than natural gas, hydrogen can be transported via pipelines and tanks and, to some extent, existing natural gas infrastructure could be used. Hydrogen can be used in different sectors such as industry, heating, transportation and power generation.

Hydrogen could be injected into natural gas pipelines. In this case, it is essential to have information about the proportion of hydrogen in the natural gas. Innio Jenbacher recommends installing a hydrogen sensor to determine the H_2 content in the natural gas and to adjust the engine accordingly.

HYDROGEN AS A FUEL FOR GAS ENGINES

Gas engines are well suited to utilize a wide variety of gases, so using hydrogen and hydrogen-natural gas blends for energy generation are viable options. Depending on the composition of the gas mixture, different adjustments to the engines are necessary.

Innio Jenbacher has been operating gas engines with a high hydrogen content for many years. Waste gases from steel production and synthetic gases with high hydrogen content of up to 60 vol% are in operation. Recent projects use local hydrogen blending to natural gas up to 70 vol%. By summer 2020, the first combined heat and power plant is scheduled to be operating on a blend of 0 to 100 vol% hydrogen, **FIGURE 3**.

New engines are designed to operate on a broad range of gas qualities, although efficiency and other performance parameters may suffer. The real challenge is the existing fleet. Gas engines are designed to operate for decades, and a significant change in the boundary conditions may not compensate for replacing them. For this reason, upgrade kits must be developed to continue the operation of already existing power plants.

HYDROGEN COMBUSTION STRATEGY

Innio Jenbacher has broad experience in utilizing non-natural gases. Some of these gases, including landfill and coalmine gas, are based on CH_4, with combustion behavior that is similar to that of natural gas. The other large group, such as gasification and steel production gases, is based on H_2 and CO. The H_2 content can be as high as 70 vol% in these applications. The gas quality remains stable in normal operation, so engines can be designed to use these gases. If a large variation of gas quality is expected, for example due to the mix of several gas types, a greater effort is needed, and compromises must be accepted from the engine performance.

Innio Jenbacher gas engine versions for non-natural gas applications are different from standard natural gas engines. Just one example is the piston design of an Innio Jenbacher Type 6

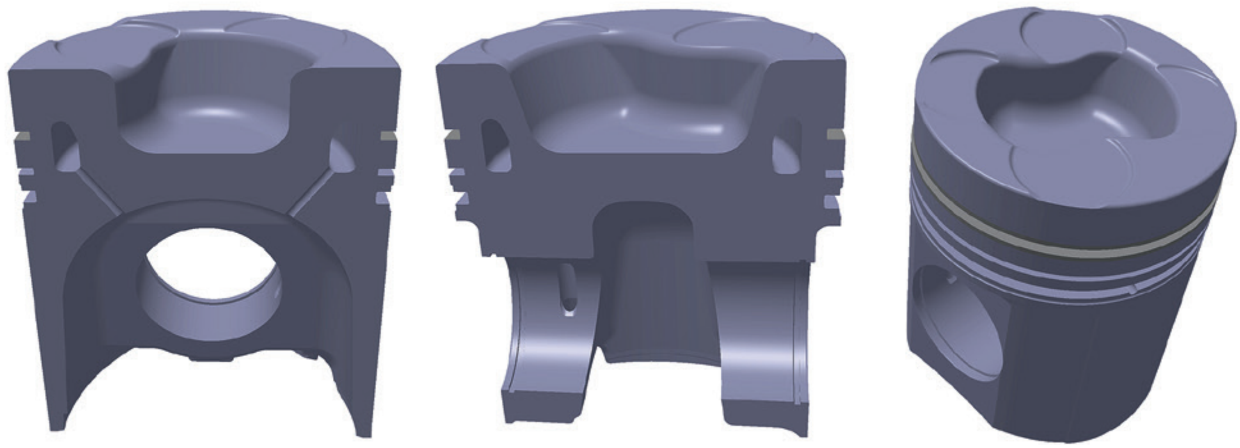

FIGURE 4 Examples of gas piston bowl shapes (© Innio Jenbacher)

engine. The standard design is a flat top or very shallow bowl design. The turbulence for rapid combustion is generated here by a gas-flushed prechamber.

Gas with a high H_2 content cannot be converted safely with a pre-chamber combustion system. A direct ignition system is the preferred route, with a defined turbulence level in the main chamber driven by an intake swirl and a specially shaped piston to break the swirl, **FIGURE 4**.

The main driver for a stable H_2 combustion is the combustion strategy, starting from the mixture preparation, charge motion, ignition of the charge to the main combustion process itself, and the charging strategy. However, particularly with gases with high H_2 and/or CO content, abnormal combustion phenomena could be observed, **FIGURE 5**. Cycles begin to accelerate the combustion and switch to self-ignition without knocking. Because there is no knocking, the standard engine control does not see these phenomena, causing heavy engine damage. With an in-cylinder pressure-based control system, these phenomena can be seen, and safe, stable engine operation is possible.

CONCLUSION

A key element of a decarbonized energy supply is efficient storage of renewable energies. A solution for effective short- and long-term storage is essential. One of the most promising solutions according to the current state

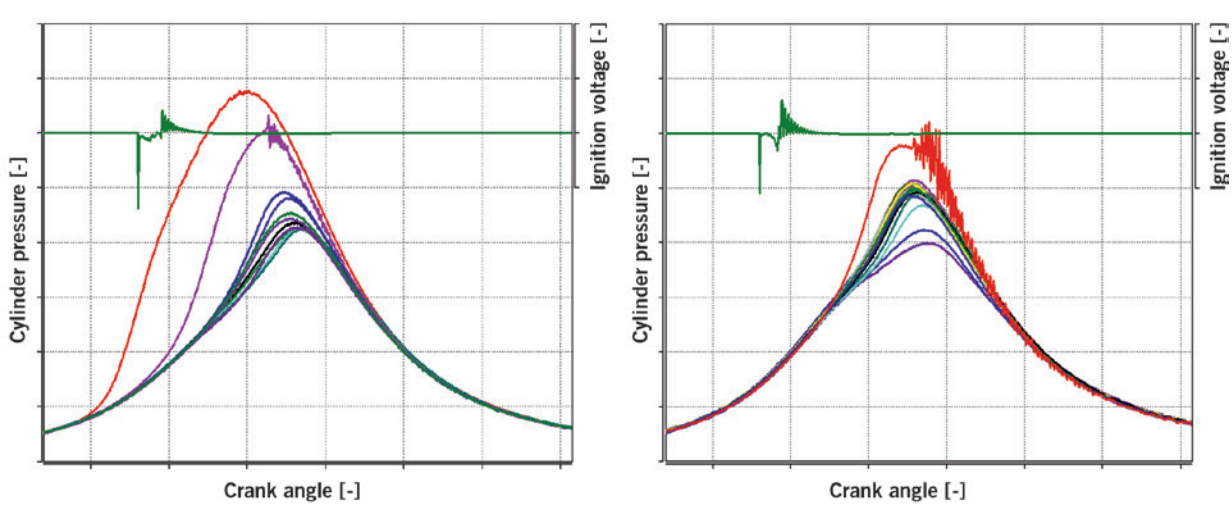

FIGURE 5 Combustion phenomena: natural gas with a knocking cycle (left) and self-ignition of H_2 (right) (schematic) (© Innio Jenbacher)

of development is hydrogen-based storage, either directly as hydrogen (under pressure in caverns or pipelines) or as synthetically produced hydrocarbons such as methane or methanol. In times of undersupply of renewable energies (wind and photovoltaic) these synthetic fuels can be converted back into heat and power.

To enable the safe utilization of various hydrogen concentrations, especially when using the existing natural gas infrastructure, Innio will continue to significantly invest in research and development. The measures aim to cover combined heat and power generation with a broad spectrum of gas mixtures – up to 100 % hydrogen – to help build up 100 % carbon-neutral and carbon-free power plants.

REFERENCE

[1] Laiminger, S.: Hydrogen as future fuel for gas Engines. 29th CIMAC Congress, Vancouver, 2019

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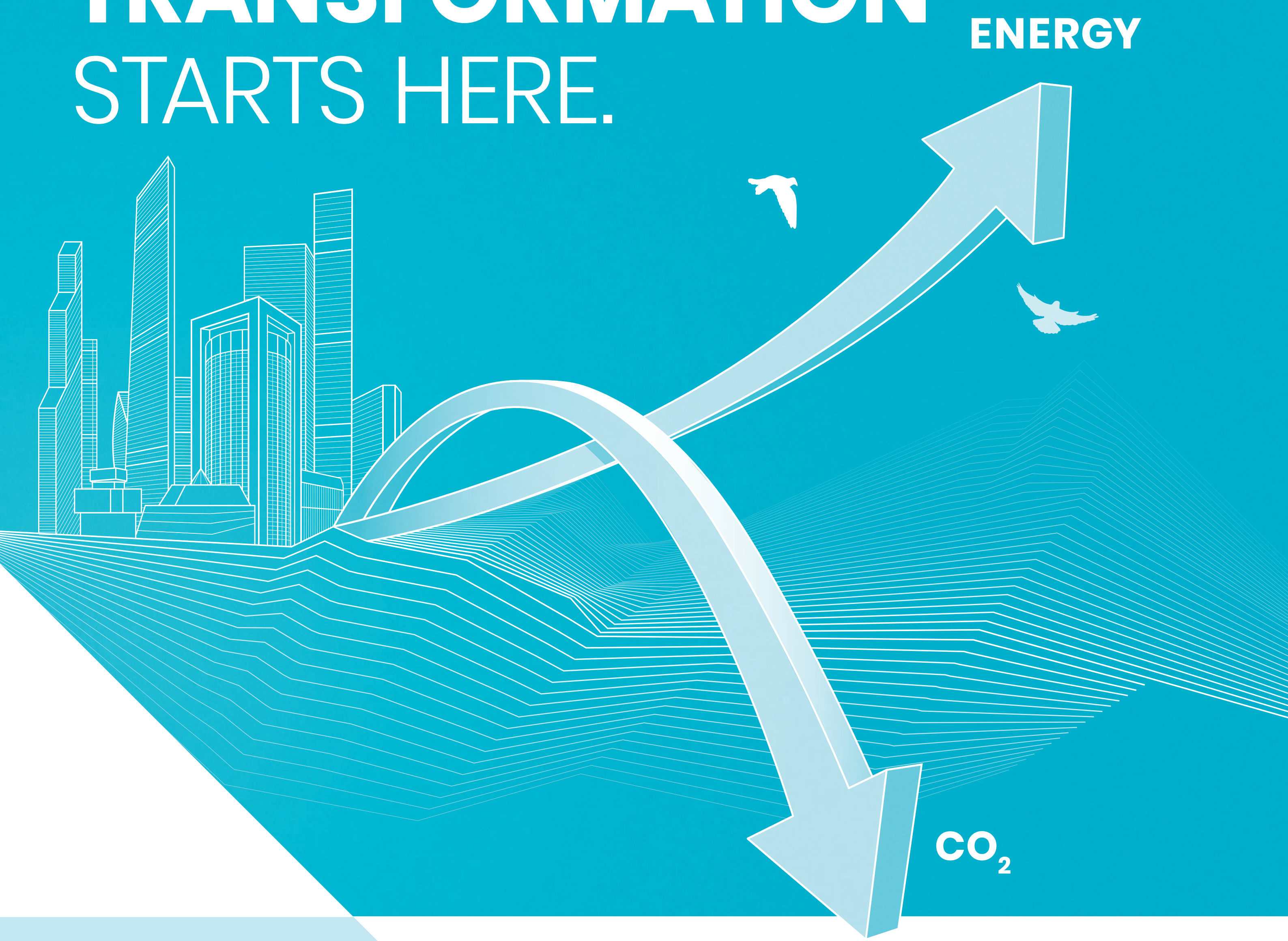

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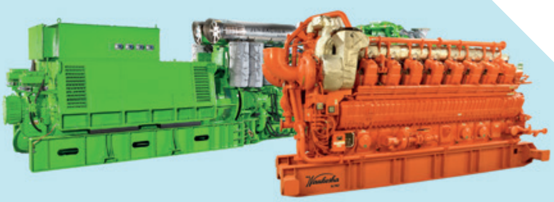

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