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# Exploring the feasibility of low-carbon fuel blends in CCGTs for deep decarbonization of power systems

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In many power systems, gas-fired power plants are the largest source of flexibility in today's electricity systems and are seen as a bridge tool offering short- to medium-term benefits in the energy transition. In this context, an ever-increasing number of studies are viewing low-carbon fuels as a promising solution for substituting fossil-based generation.

This study provides a comprehensive techno-economic assessment of low-carbon fuel options for gas-fired power plants, focusing on their role in supporting decarbonized electricity systems through fuel flexibility and blending strategies. The analysis also estimates the capital requirements for future CCGT fleet in the UK and Germany to accommodate low-carbon fuels, with a case study on Keadby2, Europe's newest and most efficient CCGT plant. A major advantage of the use of low carbon gases in CCGTs is the maintenance of the current manufacturing supply chain for CCGTs and all the equipment export opportunities this provides.

Our results show that retrofitting CCGTs to accommodate single or blends of low-carbon fuels increases the LCOE by 6-12.7 €/MWh. Interestingly, the storage cost shows a more nuanced impact on LCOE. This underscores the need for coordinated infrastructure development. National and regional energy planners should identify suitable storage sites and invest in infrastructure for cost-effective fuel storage and transport. Policy design should incorporate proximity to fuel supply and storage as part of the retrofitting decision. Plants near ports or ammonia production sites might be ideal for ammonia retrofits, while those in rural areas with access to biogas or biomethane could opt for those fuels with simpler configurations. Importantly, retrofitting CCGTs must go hand in hand with strategies to scale up infrastructure and fuel supply.

Our study reveals that the marginal costs of electricity using hydrogen, ammonia, or biomethane exceed 120 €/MWh even under the most favorable circumstances, and typically far exceed 150 €/MWh. Natural gas remains the lowest-cost option under currently foreseeable carbon prices. However, natural gas price volatility and carbon price exposure suggest that there could be a role for low carbon gases under future deep decarbonization.

Biomethane can offer a more stable but expensive alternative, however, competition with other sectors might increase its costs further. Hydrogen-based pathways represent flexible but costly options, even with high-cost reduction in the future, their viability will largely depend on infrastructure development, technological maturity, and regulatory support. Retrofitting for ammonia cracking requires fewer capital investments yet has the highest marginal cost.

Biomethane stands out among the other low-carbon fuels as a promising solution. It is costly to produce and its supply chain is underdeveloped, but it can run in existing CCGTs without modification and uses the current gas infrastructure. Our analysis suggests using biomethane as a reserve fuel could cut capital investment needs by up to €12 billion in the UK and €16.5 billion in Germany compared to using hydrogen or ammonia blends. Therefore, policymakers should seriously consider locally produced biomethane for peak electricity use in a decarbonized energy system rather than let it be consumed in sectors where electrification or efficiency could achieve decarbonization at lower costs. A policy framework that guarantees biomethane for dispatchable generation could improve cost-efficiency and reduce the risk of stranded assets.

Fuel blending emerges as a crucial strategy for enhancing the flexibility of low-carbon CCGTs. By enabling the use of multiple fuels in varying proportions, operators can optimize fuel supply based on cost, availability, and infrastructure constraints. This flexibility can reduce reliance on a single fuel source, mitigate supply risks, and improve overall system reliability. Our results show that the marginal cost of electricity for fuel blending ranges from 152 to 183 €/MWh depending on the blend. Moreover, accommodating a higher degree of fuel flexibility leads to increased capital for retrofitting, with an LCOE of 101-116 €/MWh. Strategic decisions on retrofitting the CCGT fleet for blending should be tailored to each specific plant, taking into account proximity to fuel supplies, storage infrastructure, and plant's remaining lifetime, rather than applying a uniform high fuel-flexibility retrofit across the entire fleet.

Long-term energy sovereignty security may become a stronger policy driver. This suggests that using a locally (European) produced low-carbon solution – both in terms of fuel and equipment – may be attractive. Our solution allows flexibility with respect to how, when, and if, low carbon gases are utilized. Achieving the "last mile" of power sector decarbonization requires targeted and pragmatic solutions. Our results show that low-carbon fuels and CCGTs retrofitting is a currently expensive solution but is worth investigating more carefully for deep decarbonization.

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