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## A holistic framework for the study of interdependence between electricity and gas sectors

*Executive Summary*

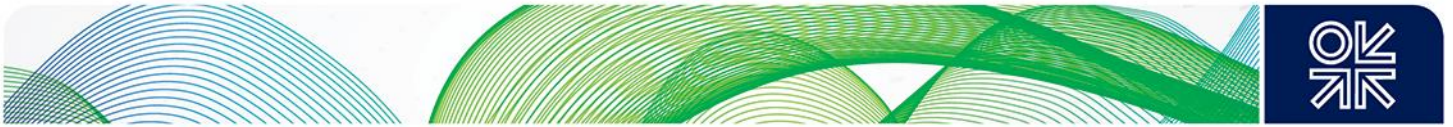
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In the last two decades, there has been important convergence between the previously parallel electricity and natural gas industries in a number of countries – the key connector between the industries being the use of gas-fired generators for power generation. As this convergence continues, the power industry effectively becomes the downstream industry of the natural gas sector, and coordination across this extended supply chain becomes important. The operational flexibility for which natural gas generators are prized is conditional upon the availability and flexibility of their input fuel. As the IEEE (Institute of Electrical and Electronics Engineers) *Power and Energy* magazine highlighted in its issue dedicated to interdependence between the power and gas sectors, it becomes important to understand both the new risks to which the power sector is exposed via natural gas, and the challenges that the gas sector needs to overcome in supplying the extremely dynamic power sector (Henderson & Shahidehpour, 2014).

The interdependence of power and gas in regional energy systems is of interest to industry agents, power and gas system operators or integrated utilities, regulators, and government bodies responsible for overall energy policy. This paper seeks to align the study of gas and power industries by providing a holistic framework for the thorough identification and discussion of power and gas sector structure, infrastructure, markets, and regulatory drivers. For any given country, this framework allows the rapid building of a comprehensive joint profile of the power and gas industries in the country/region of interest, acting as a lens through which the complex system of the gas-to-power supply chain can be observed and understood, providing diagnostic-level intelligence. The analytical framework proposed extends the Structure–Conduct–Performance (SCP) paradigm commonly used in industrial organization studies by integrating the fundamental principles of System Dynamics – a new structural theory for operations management that is grounded in system thinking and intensifies the perception of feedback, accumulation, and delays.

The Structure–Conduct–Performance–Regulation (SCPR) framework, proposed in this paper, provides a holistic ensemble view of the complex system that is the gas and power sectors. The key concepts covered include industry structure (which influences agents' participation and their motivation), the infrastructure in place and the mechanism employed to coordinate its use (which influences investment and operational decisions of industry agents), and the dynamic interaction of the above via governmental and industry self-regulation. Contextual information, important for the application of the SCPR framework to the specificities of the gas and power sectors, is also provided.

As an example, the SCPR framework is used to build a comprehensive joint profile of the power and gas industries in the United Kingdom. The structural, infrastructure, operational, and regulatory interdependencies of the UK gas and power sectors have been identified on the basis of information gathered using the SCPR framework. Also, the potential evolution of the extended gas-to-power supply chain is synthesized, from two perspectives: the likely development of gas-fired generation



with respect to the overall energy system, and the likely development of self-sufficiency with respect to natural gas.

The results of our case study shows that aside from structural changes in economic composition and fluctuations such as global economic recessions, the future demand of electricity in the UK is dependent upon the uptake of efficient energy practices and electric vehicles by end-users, which is incentivized by certain government programmes. The future demand for gas, other than the same consumer-driven change in the form of adoption of biomass heating systems via the Renewable Heat Incentive, will be significantly influenced by the interaction between major power producers' investment decisions and power generation-specific regulatory measures, which makes the power sector's demand for gas more uncertain. A wave of power interconnector projects, expected to come online by 2020, might also affect the use of flexible generation supply such as natural gas, depending on the prevailing market prices in the UK and in the interconnected country. Unless plentiful new reserves are discovered in the UKCS, which is unlikely as it is a mature basin, the UK's domestic production of natural gas is expected to decrease. The government's implementation of a recovery maximization strategy might slow the decline, but it is thwarted by the low oil price environment that has reduced global oil and gas investments.

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