Stochastic Modeling of Natural Gas Infrastructure Development in Europe under Demand Uncertainty

Marte Fodstad[*]*, Ruud Egging*[†]*, Kjetil Midthun*[‡]*, and Asgeir Tomasgard*[§]

Executive summary

The Energy Union strategy of the European Union has the ambition to create a fully integrated internal energy market. This shall be achieved by strengthening interconnectors to allow energy to flow freely across the EU. In addition to capacity extensions, technical and regulatory barriers must be overcome. For natural gas, the steps towards a fully integrated market have been laid out in three gas directives: 98/30/EC, 2003/55/EC, and 2009/73/EC. These directives establish rules for natural gas transmission, distribution, supply and storage, which include rules for market access, authorizations for transmission, distribution, supply and storage of natural gas, and for the operation of systems. The motivation for the directive is a full opening up of national gas markets (including LNG) to achieve higher service quality, universal service levels, consumer protection, security of supply, as well as climate change mitigation. The objective is to increase competition in national markets and integration into regional and, eventually, a single EU-wide market for natural gas.

Mid- to long-term outlooks for natural gas consumption vary tremendously, both in Europe and globally. It is highly uncertain which role natural gas will play in an energy system transitioning to a sustainable, renewable energy supply. Will natural gas, as a relatively clean fossil fuel, provide a higher base load, or will it primarily act as a flexible backup fuel for intermittent renewables? Either way, the infrastructure must be in place to accommodate the higher and / or changing consumption levels and patterns over time. A reliable and competitive gas supply benefits from a fully integrated market. To achieve this integrated market, a strengthened cross-border gas transportation network in Europe is necessary. Cost-effective capacity expansion should consider uncertainty in future developments, specifically in natural gas production and consumption trends.

We present an analysis of the optimal development of the natural gas infrastructure in Europe based on the scenario studies of Holz and Von Hirschhausen (2013). In our analysis, we consider eight predefined technology and policy scenarios. We use input from PRIMES as a starting point

[*] Corresponding author: SINTEF Technology and Society, Department of Applied Economics and Operations Research, 7465 Trondheim, Norway; Marte.Fodstad@sintef.no, +47 926 16 498

[†] SINTEF Technology and Society, Department of Applied Economics and Operations Research, 7465 Trondheim, Norway; and Norwegian University of Science and Technology, Department of Industrial Economics and Technology Management, Alfred Getz veg 3, 7491, Trondheim, Norway

[‡] SINTEF Technology and Society, Department of Applied Economics and Operations Research, 7465 Trondheim, Norway

[§] SINTEF Technology and Society, Department of Applied Economics and Operations Research, 7465 Trondheim, Norway; and Norwegian University of Science and Technology, Department of Industrial Economics and Technology Management, Alfred Getz veg 3, 7491, Trondheim, Norway

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for the demand functions in the different regions in the model and supplement these with additional data where available. We consider both individual scenarios as well as a stochastic two-stage approach to find the potential value of options in the system. We use a stochastic mixed integer quadratic model to analyze the impact of uncertainty about future natural gas consumption in Europe on optimal investments in pipelines. The basis for our data is the results from the PRIMES model for natural gas demand and technology scenarios discussed in Knopf et al. (2013).

We present a comparison between the results from the stochastic model and the expected value model, as well as an analysis of the individual scenarios. We also performed a sensitivity analysis on the probabilities of the future scenarios. Comparison of results from the stochastic model with those from the deterministic expected value model indicates a negligible value of the stochastic solution. We do, however, find structurally different infrastructure solutions in the stochastic and the deterministic models.

Regarding infrastructure expansions, we find that 1) the largest pipeline investments will be towards Asia, 2) there is a trend towards a larger gas supply from Africa to Europe, and 3) within Europe, eastward connections will be strengthened. Our main finding using the stochastic approach is that there is limited *option value* in delaying investments in natural gas infrastructure, until more information is available regarding policy and technology in 2020, due to the low costs of overcapacity.

Our results imply that in the global competition for natural gas supplies and to facilitate the European transition to a sustainable, renewable energy supply, it is important to develop the necessary infrastructure for supply and distribution of gas to and within Europe, including West-East connections for economic as well as solidarity reasons.

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