Investments in a Combined Energy Network Model: Substitution between Natural Gas and Electricity?

Jan Abrell* and Hannes Weigt†

Swiss Federal Institute of Technology Zürich, Center for Energy Policy and Economics at ETH Zurich, Zürichbergstrasse 18, CH-8032 Zürich, Switzerland. jabrell@ethz.ch

†Corresponding author. Forschungsstelle Nachaltige Energie- und Wasserversorgung, Wirtschaftswissenschaftliche
Fakultät der Universität Basel, Peter Merian-Weg 6, Ch-4002 Basel, Switzerland.
hannes.weigt@unibas.ch

Executive Summary

There is a large need for investments in global energy markets due to the desired transformation towards a low carbon renewable system in the industrialized countries and a general need for energy infrastructure in emerging countries. The questions where and in what technology to invest are therefore of high importance for many energy markets in the world.
Optimal investment decisions have to take the high interlinkage of energy markets into account. The different energy fuels are either competing for the same consumers (e.g. oil and gas in the heat market) or are direct inputs (e.g. oil, gas and coal as input for electricity generation). This interaction of energy markets is particularly relevant for natural gas and electricity systems. The increasing importance of emission reductions raises the need for a shift from coal-based to natural gas-fired power plants. Similarly, the expanding utilization of intermittent renewable generation units raises the need for more flexible plants as back-up capacities which are mainly believed to be gas-fired. At the same time the gas supply side is becoming more dynamic with the 'fracking boom' in the United States, the general global prospects for unconventional gas, the further increases in the LNG infrastructure, and security of supply concerns in Europe fueled by the conflict between Russia and the Ukraine.

In this paper we analyze the interaction of natural gas and electricity investments. As natural gas is a fuel input for electricity generation the basic question is whether to generate electricity close to consumption and transport natural gas or to generate electricity close to gas supply and transport electricity. The answer to this question is made more complicated due to the network structure on both markets. Consequently, existing and potential new linkages as well as feedback effects throughout the networks need to be accounted when evaluating investment alternatives.
To address these challenges we develop a combined electricity and natural gas investment market model. The model accounts for the network structures in both markets and the investment options in natural gas transport, electricity generation, and electricity transport.

To highlight the interaction between both markets and show the impact of the network structure we present a simple test scenario with an increased electricity demand that needs to be satisfied by investments. The optimal alternative depends on the underlying cost structure. If electricity transmission investments are inexpensive it is economic to invest in gas fired generation close to the gas supply and extend the electricity grid. In case of high electricity transmission investment costs the optimal investment is a power plant close to the increased demand and an extension of the natural gas network.
This basic interaction is straightforward and a pure trade-off based on the cost structure. Accounting for the more complex physical properties of power flows in electricity networks the

actual investment pattern becomes harder to predict. However, the basic trade-off structure between ‘gas or electricity’ remains valid, but a proper network market model will be needed to identify the optimal line investments within the network.
We then extend the analysis to a stylized European representation. We assume an increased need for new gas fired power plants due to higher renewable production and a high emission price. The optimal investment pattern again depends on the underlying cost assumptions. In the case of low electricity transmission investment costs the new power plants are mostly constructed in East Europe and the generated electricity is transported to Central and South Europe. If electricity transmission investments become more costly, fewer plants are constructed in East Europe, the natural gas pipeline infrastructure towards Italy is extended, and new power plant capacities are constructed close to electricity demand in Central and South Europe.

Although the numerical simulations are designed to highlight the potential investment interaction and not provide an empirical estimate of Europe’s energy future, they show the strong interdependence of natural gas and electricity markets. Naturally, the complexity of real world energy system makes predictions of changing market conditions more difficult without model based-assessments.

Despite the restrictions of the underlying model, the analysis shows that the interplay of the two markets warrants a more holistic approach in their evaluation. Given the expectation that natural gas will play a major role in influencing electricity markets to adopt a high share of fluctuating renewables, policy decisions should not be solely based on an electricity market perspective. For the underlying network investments (i.e. the ENTSO-E/G Ten Year Network Development Plans) a closer collaboration seems feasible, as both transmission systems are already subject to regulation and coordination approaches.
Coordination between network investments and investments in new power plans, storage facilities, or LNG terminals is more complicated as the later are competitive market decisions and not subject to direct regulation. This aspect also extends to the ongoing debate about capacity markets in electricity markets. Whether and how coordination between production and transmission can be achieved is a still open research question.