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Forecasting peak-day consumption for year-ahead management of natural gas networks

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ABSTRACT

Security of supply is at the forefront of energy policy in the EU and elsewhere. This paper develops a methodology to forecast peak-day gas consumption for the consideration of gas transmission system operators. It is developed for the domestic and small-to-medium enterprise (SME) gas market, based on a review of current practice. From this assessment, a climate-adjusted network degree day (NDD_{CA}) variable is developed to estimate the weather-dependent gas consumption of such markets. We show that solar radiation significantly affects gas consumption and should be considered in consumption models. The study also quantifies the difference in capacity required under alternative gas supply standards.

1. Introduction

For many countries, the natural gas network forms a key component of their energy supply infrastructure, delivering gas to power stations, industry, small-to-medium enterprises (SMEs), and domestic dwellings. The management and delivery of this infrastructure is provided by transmission system operators (TSOs, or network operators) that must ensure the safety and security of gas supply to the consumer.

To provide this service, TSOs must make network planning decisions to safeguard against diminished supply capacity under extreme cold weather conditions. Of primary concern in this process is the requirement to maintain supplies to domestic consumers and essential social service providers, including childcare, healthcare and educational facilities whose occupants may be at risk during these events. Indeed, European Union (EU) member states are required to prioritize gas supply for these consumers (and for a limited proportion of SMEs) during periods of extreme weather (Official Journal of the European Union, 2010).

In advance of each winter, TSOs develop peak-consumption estimates for their population of domestic and SME consumers. These estimates are used by TSOs to assess the adequacy of their network for possible future extreme cold weather periods in order to inform year-ahead network operations and to fulfil regulatory requirements such as 'winter outlook' reports to the energy regulator, energy suppliers, and other stakeholders. In addition, the estimates can be used by the TSO to determine network capacity bookings and charges to energy suppliers, for planning the gas network infrastructure used to supply their customers and to calculate network maintenance and development costs for approval by the regulator. This is particularly relevant since significant investments in gas network infrastructure are planned in order to increase security of gas supplies to Europe (Insight_E, 2014). It is therefore important that the TSO follows an accurate and transparent peak gas consumption estimation methodology.

In general, TSOs calculate peak gas consumption to meet specified supply standards using a gas consumption model. Such standards define the extreme weather event during which the gas supply must be maintained. However, different definitions of extreme weather are used in the EU's supply standard (Official Journal of the European Union, 2010) and in European TSO supply standards (Czech Energy Regulatory Office, 2011; Energinet, 2011; FPS Economy, 2014; Gas Networks Ireland, 2007; Gas Transport Services BV, 2011; GRTgaz, 2013; National Grid, 2012) with respect to:

1. the weather variable used to estimate peak-gas consumption;

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2. the return level of the weather variable used to quantify extreme weather (typically a 1-in-20 or 1-in-50 year return event); and
3. the duration of the extreme weather event to be managed by the TSO.

With regard to weather variables, some supply standards specify temperature while others apply a 'composite weather variable' (CWV) that accounts for additional effects (such as wind speed) on gas consumption (see Table 1). None consider solar radiation, which recent research suggests may be an important factor in heating demand in domestic buildings (Soldo et al., 2014). For example, solar heat gains in buildings can have a significant impact on internal temperatures and, consequently, on the need for space heating and gas consumption.

This study assesses the impacts of differences in supply standards and new forecasting models on peak network demand forecasting. The specific objectives of the study are:

1. to review the supply standards and the modelling methods used by European TSOs to estimate peak gas consumption;
2. to develop a new CWV to model gas consumption, which accounts for a more weather effects than currently used, including solar radiation;
3. to apply the new approach to model gas consumption in a European country and quantify the resulting improvement in accuracy compared to existing approaches; and
4. to investigate the relative difference in the peak gas consumption required by alternative supply standards for this country, based on the new CWV.

Any resulting improvement in modelling accuracy can help TSOs reduce the error of peak gas consumption estimates, thus allowing them to develop more efficient network development plans. This would help in avoiding either under- or over-investment in the gas network. In the former case, security of supply is enhanced. In the latter case, excessive investment in infrastructure such as pipelines, compressors, and/or gas storage facilities is avoided and energy costs to the consumer are minimised.

2. Current practice

In this section, the methods applied by European TSOs to quantify peak gas consumption are investigated. A review of a sample of supply standards is presented, followed by a description of current peak gas consumption modelling methods.

2.1. Supply standards

In Table 1, the EU's supply standard and a sample of European TSOs supply standards are summarised with respect to the criteria used to describe a peak consumption event, the weather variable used to quantify this event, and additional information in relation to the methodology used to create the relevant weather variable's

Table 1
European peak natural gas supply standards.

Region	Consumption Criteria	Notes
European Union (Official Journal of the European Union, 2010)	Extreme temperatures during a 7 day peak period occurring with a 1-in-20 year probability.	These extreme temperatures have been quantified for the Belgian market as a 7-day average temperature that is equivalent to the 1-in-20 year 7-day heating degree day total (FPS Economy, 2014).
Belgium (FPS Economy, 2014)	5 consecutive days between −10 and −11 °C.	–
Czech Republic (Czech Energy Regulatory Office, 2011)	5 consecutive days when the average daily temperature does not rise above −14 °C	–
Denmark (Energinet, 2011)	3 consecutive days with a daily average temperature of down to −13 °C i.e. the 1-in-20 year event	–
France (GRTgaz, 2013)	Very low temperatures over 3 consecutive days with a 1-in-50 year probability	These very low temperatures have been quantified by an effective daily temperature as follows (GRTgaz, 2009): $T_{EFF,D} = 0.64T_{AVG,D}+0.24T_{AVG,D-1}+0.12T_{AVG,D-2}$ where: $T_{EFF,D}$ is the effective temperature for a given day (D); and $T_{AVG,D}$, $T_{AVG,D-1}$ and $T_{AVG,D-2}$ are the average temperatures for day (D), and the preceding days (D-1 and D-2), respectively. This effective daily temperature accounts for the network's consumption response lag to the current and preceding days' temperature. A 1-in-50 year estimate of this effective temperature is provided by Météo France, which also accounts for climate change, using 30 years of temperature data (GRTgaz, 2009).
Ireland (Gas Networks Ireland, 2007)	Peak daily consumption is estimated for a weekday by the 1-in-50 year value of a CWV.	This CWV accounts for the network's consumption response lag, temperature, seasonal consumption, wind chill and exceptionally cold temperatures; in addition to heating degree day transformations to linearity. The 1-in-50 year value of this CWV is estimated using a generalised extreme value model.
The Netherlands (Gas Transport Services BV, 2011)	Average daily temperature of −17 °C i.e. the 1-in-50 year event	–
The United Kingdom (National Grid, 2012)	Peak consumption is forecast as the mean of multiple 1-in-20 year return levels estimated from simulated long-term gas consumption series generated using a CWV.	This CWV accounts for the network's consumption response lag (using the following effective temperature), seasonal consumption and wind chill; and utilises a four case transformation to linearity. The effective daily temperature in this CWV is calculated using an exponential filter function as follows: $T_{EFF,D} = 0.5T_{AVG,D} + 0.5T_{EFF,D-1}$ where: $T_{EFF,D}$ is the effective temperature for a given (gas) day (D); $T_{AVG,D}$ is the (weighted) average temperature for the day; and $T_{EFF,D-1}$ is the effective temperature for the previous day (D-1)

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