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A review of national gas emergency plans in the European Union

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HIGHLIGHTS

- National gas emergency plans in the EU comprehensively assessed.
- Template for gas emergencies is created to measure conformity to Regulation 994/2010.
- Gas emergency measures are related to regional cooperation and liberal markets.

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ABSTRACT

The purpose of this paper is to document and review existing national gas emergency plans in the European Union, following the guidelines and requirements set out by the EU's Regulation 994/2010 concerning measures to safeguard security of gas supply. Despite the great deal of attention paid to questions of natural gas security in an increasingly import-dependent European Union, the contingency plans of most of its member states have not been widely published or scrutinized. By reviewing TSO network codes and national legal and regulatory acts, this paper teases out the key similarities and differences between member states' emergency planning frameworks, tools and methods. A gas emergency operational template is subsequently proposed that conforms to EU legislation. This is followed by a discussion of emergency planning in the context of regional cooperation and the liberalizing European gas market. The paper concludes by advocating gas emergency measures which are proportionate to the crisis level, sensitive to the gas demand profile, aware of the regional context, inconsequential to normal market operation, transparent and non-discriminatory during implementation and verifiable during emergencies as well as under normal conditions.

1. Introduction

According to the UK network code, a gas emergency is "the occurrence of an event or existence of circumstances which has resulted in, or gives rise to a significant risk of, a loss of pressure in the total system or a part of the total system which itself has resulted in or might result in a supply emergency" (UK, Uniform Network Code, 2010). Despite the great deal of attention paid to questions of natural gas security in an increasingly import-dependent European Union, the contingency plans of most of its member states have not been widely published or scrutinized. The work that has been carried out has been largely confined to the national level or to isolated incidents (notably the Russia-Ukraine gas crisis in early 2009). To plug this analytical gap, the first part of this paper will review existing gas emergency planning frameworks, tools and methods, as far as they can be extracted from TSO network codes, legal and regulatory acts, as well as independent research such as that found in relevant EU-FP7 projects and international institutions (e.g. the International Energy Agency, IEA).

This review has been conducted for the purposes of gaining a clearer insight into the status of the implementation of Regulation 994/2010, a key piece of legislation affecting the gas security of supply of EU member states. Due account has also been taken of related EU legislation (e.g. Directive 2009/73/EC; Regulation 2009/715/EC) as well as their respective predecessors (in particular, Directive 2004/67/EC concerning measures to safeguard security of gas supply, which explicitly mentions the need to publish national emergency measures). This information has been buttressed by a survey aimed at 'Competent Authorities' of EU member states designated by EC/994/2010. Circulated by the JRC-IET in July 2011, this questionnaire was an instrumental part of the review process.

A report by the European Commission on the January 2009 Russia-Ukraine gas crisis provided a sobering assessment of EU member state emergency response

"Emergency planning was greatly hampered by a lack of consistency, coherence and comparability between the various

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definitions and measures which exist in the different Member States. Where measures were in place, their effectiveness was curbed by the narrow and localized approach to tackling supply difficulties, a lack of options to diversify supplies, and by a lack of access to up-to-date and complete information on supply, storage and demand. The EU needs to have common criteria on which Member States can base their emergency planning, and these need to be developed not just at the national level, but also at a regional and EU level with a view to the EU internal market dimension. Reactions based on national markets risk hampering the ability of gas traders to keep gas flowing efficiently in the internal market and thus exacerbate the situation for the EU as a whole" (European Commission, SEC, 2009).

It is with this in mind that the paper will seek to review existing emergency measures and subsequently propose an emergency planning operational framework to guide competent authorities in their implementation of Regulation 994/2010.

2. Defining crisis levels

There is considerable variety amongst EU member states in terms of both the procedures and criteria under which crisis levels are declared. In fact, the number of crisis levels themselves range from one (France) to five (UK and Ireland), although the Regulation mandates three main crisis levels according to Article 10. Moreover, the declaration of the first phase of a crisis (usually some form of 'early warning') is sometimes made by a government actor (France), a transmission system operator (Belgium), a designated crisis manager (Ireland) or a regulator (Germany) (Germany, Gassicherungsverordnung, 1982).

Few emergency plans offer concrete criteria or thresholds for initiating successive stages of a crisis. In most cases crisis levels are set out in qualitative terms, describing situations where supply is unable to meet demand under various conditions (e.g., when market measures alone are insufficient and intervention in the form of demand restraint or stock withdrawal are necessary). There are, of course, exceptions to this trend; the UK has defined a series of 'triggers' which activate the so-called Joint Response Team. For example, a Gas Balancing Alert (GBA) mechanism provides an early warning to the market when demand-side response or additional supplies are anticipated by National Grid Gas to ensure the physical balance and the future safety of the network. This alert occurs when the forecast day-ahead demand is above a certain 'trigger level', which is based on current capacity and recent reliability of supplies (See Poyry Consulting, 2010). Thresholds are in place in other countries, as well; for example, Romania defines an urgent situation at the national level if the country loses 20% of gas volumes from import or internal production failure (European Commission, SEC, 2009). In the majority of cases, however, the determination of crisis levels are subject to the discretion of the operational actor or competent authority; in case of the latter this is stated explicitly in French legislation, which eschews the use of strict criteria to set crisis levels in favor of modularity, meaning that measures to manage an emergency can be applied without the formal initiation of an emergency plan (France, Directive interministerielle sur les plans ressources, 2001). This lends a certain degree of flexibility in deciding on what actions to take during a gas supply crisis.

Regulation 994/2010 contains provisions for declaring a Union-wide or regional emergency for a specifically affected geographical region (this declaration is made by the Commission following requests from at least two Competent Authorities). The matter is then referred to the Gas Coordination Group, and the Commission can coordinate the actions of Competent Authorities to ensure the exchange of information, the consistency and effectiveness of MS responses in relation to the Union level, as well as action with regard to third countries. To assist in preparing for Union- and regional-level emergencies, there are a number of European bodies that focus on gas emergency planning. Most visibly, the European Network of Transmission System Operators for Gas (ENTSO-G) has set itself the task of adopting common tools to ensure coordination of network operation in normal and emergency conditions, including a common incidents classification scale (ENTSO-G, Annual Work Programme, 2011).

3. Clarifying actor roles, relationships and responsibilities

According to the Regulation, gas emergency plans must define the roles and responsibilities of gas undertakings, industrial consumers (including electricity producers) and their interaction with competent/regulatory authorities during each crisis level (Regulation, 994/2010). One of the most important aspects of a sound emergency procedure is the ability to monitor the supply situation from the top down in order to make appropriate decisions about allocations. Regulation 994/2010 states that, during an emergency, natural gas undertakings must inform competent authorities of daily flows for entry/exit points as well as for production, storage and LNG, in addition to three-day gas demand/supply forecasts that include the projected capability to supply protected customers (Article 13).

At the industry level, gas network codes are the first point of reference in ascertaining such roles and responsibilities of network users and operators during abnormal conditions; these codes contain information sharing and notification procedures as well as obligations to comply with various instructions – such as storage withdrawal or modification of shipping schedules – conferred by the TSO. Network codes become less pertinent as the crisis reaches higher stages of criticality, when government bodies are activated and/or are accorded greater powers of delegation and oversight over the management of national gas supplies. National regulations and legislation provide information on government actors' competencies, and a number of legal acts are usually relevant to the safe operation of natural gas systems.

The IEA has encouraged its member states to produce a publicly available handbook detailing the operational procedures to be taken in the event of a gas supply disruption. Such measures, it has observed, are useful for ensuring an efficient and streamlined decision-making process in the event of a crisis. In a few cases, such as the UK and Ireland, publicly-available gas emergency plans extensively set out the roles and responsibilities of the whole range of actors involved in an emergency situation. In the case of Ireland, for example, the Gas Emergency Planning Group and the Gas Emergencies Response Team (GERT), both overseen by the National Gas Emergency Manager (NGEM), are collectively responsible for Ireland's Natural Gas Emergency Plan. The GERT is composed of Gaslink, Bord Gais, EirGrid and the Irish energy regulator (CER); this body can additionally create an industry-wide consultation group to provide support to the core group when it is required (Ireland, Gaslink, Natural Gas Emergency Plan, 2009). In the UK, emergency planning and operational response is primarily guided by the Energy Emergencies Executive, which consists of experts drawn from a cross section representing the gas and electricity industries as well as government, agencies, regulators, trade associations and industry bodies. In both the UK and Irish NEPs, the concrete roles and responsibilities of these entities are set out in organigrammes and accompanying tables (see Figures 1 and 2). The UK report provides further details of the composition of each body as well

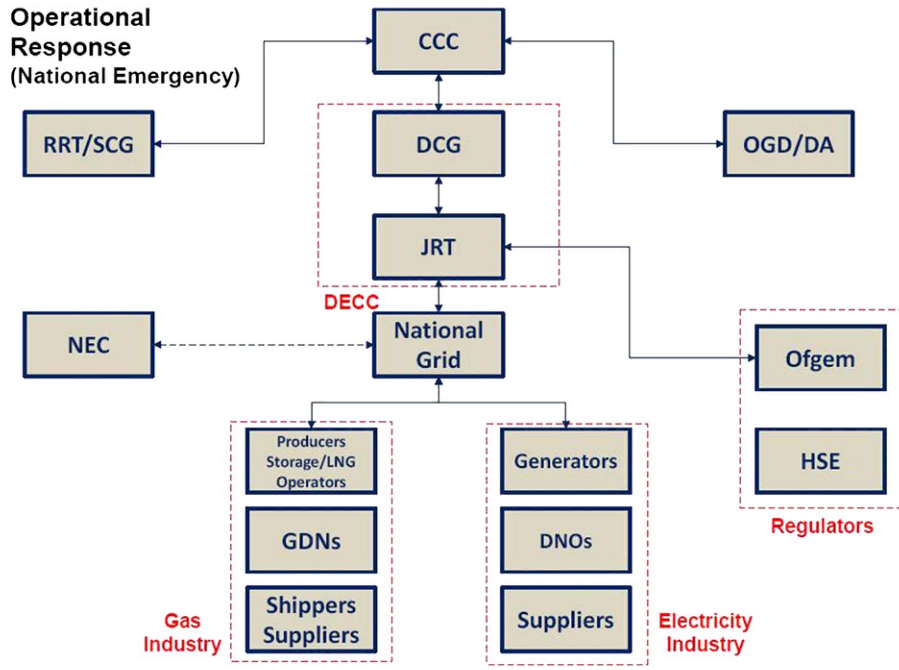

Fig. 1. The UK's 'Horizontal' Emergency Framework (UK, DECC, National Emergency Plan for Gas and Electricity, 2010).

as their operational responsibilities and lines of communication during each alert level and emergency 'trigger' (UK, DECC, National Emergency Plan for Gas and Electricity, 2010). (Fig. 1)

While a clear lead actor is normally identifiable during a gas crisis, there are at least three different ways in which stakeholders can be organized. In 'bottom-up' cases the main gas transmission system operator plays the leading role in managing a crisis and takes on most of the responsibilities for keeping network users and government actors up to date on the emergency measures taken. This is true in the case of Belgium, where Fluxys is responsible for declaring crisis levels and takes on a proactive role in both market and non-market interventions (the latter involving enforced storage withdrawal during the third and final crisis level in order to supply gas to protected customers). In other cases, the TSO is part of a wider crisis management structure that is set up in a 'horizontal' framework incorporating a range of stakeholders from government, regulators, industry and end-users. This type of arrangement is captured by the UK example above. Finally, there are 'top-down' frameworks whereby considerable powers of delegation and oversight are given to a single, usually governmental actor. The French and Irish emergency planning procedures follow this type; the former vests authority in the Ministry of Energy, which helms a Crisis Unit that can decide on emergency measures according to the degree of urgency, level of stress (based on the social or political context) and the nature of the measure itself. Similarly, Ireland's Natural Gas Emergency Manager (NGEM) plays the lead role in declaring an emergency, forming the response team and deciding on the appropriate measures in response to a crisis Figs. 2.

Frequently national emergency plans contain provisions to exchange contact details and for individual parties to be nominated to represent key actors in the gas emergency supply chain. This facilitates information sharing and encourages collaborative efforts among industry, government and end users in tackling gas supply interruptions. These bodies, in turn, are typically under various obligations to report and/or manage the incident. In this context it is usually the main transmission system operator that has the greatest operational role to play during a crisis. The TSO is responsible for informing government actors and crisis management bodies (often in real-time) of developments during an

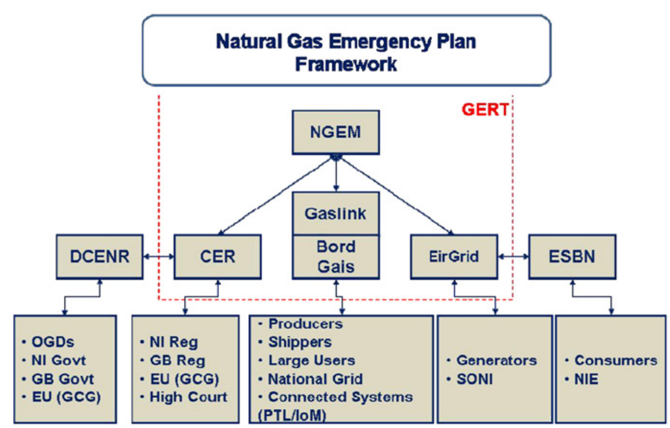

Fig. 2. Ireland's 'Top-Down' Emergency Framework Ireland, 2009.

interruption, and must coordinate most downstream activities in the supply chain (e.g., supply- and demand-side responses entailing storage withdrawal, fuel-switching, reverse flows, etc.). Moreover, TSOs are responsible for informing market players and network users (often in advance) of available capacities and interruption schedules, including their duration. These actors, in turn, are obliged to heed instructions from the TSO as it attempts to balance the network in exceptional circumstances.

In this context, gas market players (suppliers, shippers, traders, etc.) operate under increasingly restrictive rules during each successive crisis level; it is common that certain user rights to access the pipeline network or booked storage capacity are curtailed or suspended in order to effectively allocate network capacity. Outside of normal operating conditions, market players must orient themselves around such new rules, some of which require cooperation in place of competitive activities. In the second crisis management phase in Germany, for example, a 'clearing mechanism' between several energy companies and the Ministry of Economy can be initiated. This mechanism is based on a voluntary agreement between the German government and the gas industry which allows coordinated action and mutual assistance between companies, such as redirecting gas flows, freeing transport capacities and making gas swaps (Germany, Gas Emergency measures, 2009).

The suspension of commercial capacity allocation by operators is often legally mandated by public service obligations (PSOs) that set out security of supply standards. According to Article 13 of the Regulation, EU member states are obliged to make these standards public (in addition to formulating them as set out in Article 3 of Regulation 2009/73/EC). In some cases these obligations are extensive. In France, for example, Decree No. 2004-251 of 19 March 2004 requires operators to ensure continuity of supply for households in case of a) six months of an interruption to the main source of gas supply, b) a 1-in-50 winter or c) extremely low temperature for a period of up to three days statistically occurring once every fifty years (France, Arrêté du, 2006). Similar provisions exist in Denmark, where Energinet.dk must ensure gas to protected customers (designated as 'primary energy supply') when the largest gas supply source is interrupted either for 3 consecutive days of $-13\,^{\circ}$C or 60 days of normal winter conditions (DenmarkEnerginet.dk, 2011). Other standards are less demanding; Annex 1 below indicates some of the differences between member states' security of supply standards. More generally, Regulation 994/2010 provides both the Infrastructure and Supply Standards as minimum benchmarks for complying with security of supply norms (Articles 6 and 8). These obligations are usually met through gas stocks (discussed below).

Occasionally, member states' public service obligations may not necessarily be practically effective during a gas supply emergency. For example, Estonia's obligation that heat suppliers consuming more than 500 GWh annually hold a 3 days reserve does not apply to the several hundred smaller heat producers in that country. The exemption of these producers from back-up supply obligations may have important implications for heating services in several municipalities during a crisis (Sachi Findlater and Pierre Noel, 2010). Regulation 994/2010 imposes the obligation that competent authorities indicate how the supply standards or any related obligations imposed on natural gas undertakings may be temporarily reduced in case of a wider Union or regional emergency (EC/994/2010, Article 8.2).

4. Designing emergency measures

The most comprehensive emergency plans clearly set out which emergency measures are used under what conditions. Backed by obligations for continuous monitoring and information sharing amongst a wide range of market and non-market actors, an emergency plan optimizes the measures deployed to countenance a gas supply shortfall according to clear guidelines, thresholds and assumptions. It is important to state at the outset that the measures taken often reflect the particular characteristics of the natural gas supply system in each respective country. In this context there are no 'one-size-fits-all' approaches. Nonetheless it is possible to extrapolate from an analysis of these various measures the over-riding importance of maintaining an adequate level of system *flexibility* in case of a disruption. This flexibility is contingent not only on supply diversity and spare capacity but also on the management of demand-side response and the regulatory framework in which both forms of emergency measures are housed. Table 1 summarizes the emergency measures available in selected member states as per the results of the JRC questionnaire (in addition to information given by IEA reviews). The following sections discuss some of the supply- and demand-side tools available to MS for responding to natural gas supply emergencies.

4.1. Supply side flexibility

4.1.1. Gas storage and stocks

In managing national storage options, the IEA recommends that countries adopt clear provisions and regulations that distinguish in a transparent manner the relevant volumes reserved for stock obligations from the capacities available for commercial and operational purposes (International Energy Agency, 2000). The circumstances, conditions and objectives for their handling, building-up and release should also be clearly set out in an emergency plan.

There are several different arrangements in member states concerning the use of storage capacity for purposes of security of supply. Often storage capacity may be allocated automatically based on the public service obligations mentioned above, where operators, shippers and suppliers must conform to defined levels of gas in storage to meet the demands of their customer portfolio under various weather severity levels. In such cases the obligations for maintaining minimum stockpiles of gas can be variably conferred on TSOs (Denmark, Czech Republic, Bulgaria, and Belgium), shippers (Italy and Poland, for non-EU imports) and suppliers (France, Spain and Hungary) (Poyry 2010, [p. 14]).

One example of good practice in handling storage for the purpose of emergency preparedness is the UK's publication of storage monitor curves. These describe the minimum volumes of gas that need to be stored during a particularly severe winter, for both protected (the safety monitor) and firm customers (the firm monitor). National Grid for Gas provides this information in three categories-short range storage (less than 5 days at max deliverability), medium range (5–70 days) and long range (over 70 days). One of the initial 'triggers' in the UK's emergency plan is a breach of the gas storage safety monitor (http://www.nationalgrid.com/uk/Gas/Data/storage/).

Not all compulsory stockholding arrangements are managed with clear conditions regarding their release. For example, Portugal has a robust stockholding obligation whereby gas importers are mandated to hold gas reserves equivalent to 15 days consumption of non-interruptible gas-fired power plants (i.e., electricity producers) and 20 days consumption of non-interruptible customers (particularly households) in the remaining market (Portugal, Decree Law 140/2006) However, Portugal does not have automatic triggers under which the use of these stocks can be authorized. This is a contrast to countries such as Spain or Poland. In the former, Enagas and the Ministry of Trade, Industry and Tourism can authorize the use of compulsory stocks under declared emergency levels. Similarly, Poland's system of compulsory gas stocks can only be mobilized in "Phase II" of a gas emergency, after approval from the Minister of Economy. Instructions are then given by the TSO to the storage system operator that specifies the required hourly quantities that need to be delivered to the transmission system (Poland Gaz-System).

There are alternatives to minimum stockholding obligations for designated customers; some countries set national-level standards applicable to the whole country. Like Hungary's obligation to keep 45 days of strategic storage in reserve, Greece has set aside a quarter of the existing storage space at Revithoussa LNG terminal for the purpose of maintaining the security of natural gas supply on a short-term basis. LNG storage also accounts for a large share of national storage capacity in Spain (33%) and Belgium (25%).

The relative contribution of storage in dealing with an emergency may be indicated by plotting the ratio of storage capacity to peak demand against the percentage of total gas demand serviced by imports. Of course, this only provides an indication of how much stored gas is available to honor contracted demand during an emergency. In practice, it is necessary to buttress this analysis

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Table 1
Gas emergency measures in selected EU member states.

		AT	BE	DK	EE	FI	IE	EL	ES	FR	IT	HU	NL	PL	PT	SK	UK
Market measures-supply	**Production flexibility**	x		x			x						x				
	Import flexibility		x		x				x	x	x		x	x	x		
	Storage	x	x	x			x		x	x	x	x	x	x	x		
	Diversification	x	x						x	x	x			x	x		
	Reverse flows/bi-directional capacity	x	x						x					x	x	x	
	TSO coordinated dispatching		x		x		x		x					x			
	Short/long-term contracts/arrangements	x			x				x	x	x			x			
	Regional cooperation measures		x						x	x				x	x		
	Other																
Market measures-demand	**Interruptible contracts**	x		x			x	x	x	x	x			x			x**
	Fuel switching + backup fuels	x			x		x		x	x	x	x			x		
	Voluntary firm load shedding						x				x						
	Increased efficiency/RES								x	x					x		
	Stocks / drawdown						x		x	x	x			x			
	Pricing mechanism								x						x		
	Other																
Non-market measures-supply	**Strategic storage**								x		x	x		x	x		
	Enforced use of stocks	x					x										
	Enforced use of electricity substitution	x					x				x						
	Enforced gas production	x					x										
	Enforced storage	x	x	x			x			x	x	x		x		x	
	Alternative fuel obligation				x	x	x	x						x	x		
Non-market measures-demand	**Enforced fuel switching**	x			x		x				x						x
	Enforced interruptible contracts	x									x						
	Enforced firm load shedding	x					x			x	x						
	Price regulation																
	Other													x*			

* Restricting gas off-takes.
** Shortly to change due to new legislation.

by analyzing daily storage withdrawal rates as well as the available capacities of transmission lines to carry this gas to the required exit point. An illustrative example is the pipeline connection providing Lithuania with stored gas in Latvia; it has a technical capacity of approximately 5MCM/day but, due to limitations on the Latvian transmission network structure and the amount of storage withdrawal capacity available to Lithuania in winter, can only ship 1MCM/day (Findlater and Noel, 2010). By contrast, E-Control in Austria managed the January 2009 Russia–Ukraine gas crisis by drawing on unused Haidach storage capacity that was located within the territory of Austria and could be transited through the German gas grid. Equally, the increase in imports from Germany three days later was possible because of E-Control's reserved feed-in capacity on the Oberkappel interconnection point. (Austria, E-Control, 2009) The lesson here is that the degree of redundancy built into gas storage, production and transport facilities along the *whole of the supply chain* is an important factor determining the degree of flexibility during a crisis. This is all the more pertinent for Czech Republic, Estonia, Luxembourg, Slovak Republic, Slovenia, Sweden and Switzerland, all of which are connected to storage sites located in neighboring countries (IEA, Gas Emergency Policy, 2011).

Besides drawing on strategic storage and stocks, there are residual balancing tools available to TSOs that may double as emergency measures. These include the use of linepack, operational storage or LNG peak shaving facilities. The latter, usually situated in strategic locations close to areas of densest demand, provide a high level of deliverability that can supplement transmission network capacity. An example is Dudzele in Belgium, which has a relatively small working capacity of 59 mcm but can ensure a high degree of deliverability in the short term. Equivalent regional tools may include those market-based harmonization measures promulgated by ACER and ENTSO-G, namely the use of operational balancing agreements, cross-border congestion management and interconnection agreements.

4.1.2. *Spare capacity on interconnection points*

A diversity of entry points can be considered a source of resilience because they increase the total spread under which natural gas supply enters the system. However, diversification's effect on system resilience can vary depending on whether the cross-border entry/exit points are operating to their maximum capacity, as well as the extent to which their flows can be redirected. Indeed, spare capacity on interconnection points is a necessary accompaniment to an analysis of the degree of entry point diversification. Moreover, spare capacity is only beneficial during an emergency if associated supply contracts permit their use. An instructive example is the case of Poland during the 2009 gas crisis, which had spare capacity on the Drozdowicze entry point that could not be utilized due to contractual constraints with Central Asian gas suppliers (Poland, National Energy Regulatory Report to the European Commission, 2009).

4.1.3. *LNG*

Liquefied natural gas (LNG) is often considered one of the primary solutions for attaining a diversified gas supply balance. LNG terminals provide a valuable source of flexibility to meet peak/seasonal demand periods in addition to contributing to security of supply. In most cases, LNG's contribution to emergency response is as an initial capacity-increasing measure in the early stages of a supply interruption, and is hence synonymous with options to maximize imports or increase production. In order for LNG to serve as an effective supply-side buffer during an emergency situation, it is necessary to ensure a high degree of short-term deliverability. This requires, inter alia, sufficient spare import capacity and a diversified supplier portfolio with built-in flexibility enabled by spot/short-term purchases and sufficient arbitrage possibilities (i.e. stakeholder agreement to redirect LNG cargoes). Once these prerequisites are in place, the daily send-out capacity (possibly expressed as % of peak demand) is an important indicator of LNG's effectiveness as an emergency measure.

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4.2. Demand-side flexibility

The demand-side profile is an important determinant of the degree to which the gas system is able to adequately respond to an emergency situation. It is not within the remit of this paper to provide a detailed survey of the various ways in which gas is utilized, but suffice to say there are some types of facilities, e.g. combined cycle gas turbines (CCGT) and some cogeneration plants (CHP) which are more amenable to the use of back-up fuels than facilities where gas is directly used in process applications (such as furnaces, metal smelting, heat treatment, etc.) (Poyry Consulting, 2010). Hence, an emergency plan must reflect as well as adapt to such differences in end uses for natural gas. In Estonia, for example, gas supplies are important for district heating (DH) purposes. Therefore, the disconnection order is predominately related to the contingency measures available to the DH sector; for example, lowering water temperature supplied for space heating is one of the primary demand-side measures used in Estonia, in addition to the obligation that heat supply undertakings maintain a reserve fuel (Republic of Estonia, 2009). In other countries where gas may be predominately used to produce industrial chemicals such as fertilizer, there is the option of temporarily suspending local production and opting for imports (the costs of doing so being determined by the prevailing market conditions).

4.2.1. Firm load shedding and disconnection order

Many emergency plans commingle supply and demand side measures, imposing a combination of demand restraint and supply-side options. In the case of the former, there are several measures available, principal among which are fuel-switching capabilities, interruptible contracts and associated TSO disconnection orders, as well as firm load shedding in the electricity sector (whereby grid operators remove or lower pre-selected loads from a power system, either automatically by SCADA relays or manually carried out by personnel).

Some countries have opted for alternative fuel obligations to bolster demand-side response. This is the case in Greece, Ireland, Portugal, the UK and Finland. The latter requires all non-industrial players to hold three months of alternative fuels and as a corollary can lay claim to the largest proportion of interruptible capacity in the EU (IEA, 2011). Of course, in some cases fuel switching may not be considered a priority tool to face disruptions if the supply system is designed to be highly flexible (e.g., through substantial LNG supplies or a high degree of diversification). In other cases the quantity of fuel stocks are not linked to a predetermined number of days. This is the case in Italy, where switching can only occur following a specific governmental request (given the high costs involved) (International Energy Agency, 2010).

Once it is clear that available supply is no longer capable of meeting contracted demand, the first line of defense is usually to cease delivery to industrial customers with interruptible contracts (in most cases these apply to facilities with dual-fuel installations). Interruptible contracts may be mandatory, as is the case with Greek electricity producers with units that have fuel-switching capabilities (Greece, Law 3428/2005). In other cases they are voluntary, as in Romania where customers consuming less than 30,000 m3/h can opt for a 24-hour interruption provision (EC SEC, 2009). In more mature gas markets with advanced market pricing regimes, large gas consumers can enter into commercially advantageous contracts where supplies can be interrupted under certain conditions (e.g., via a price cap). These customers can also receive a discount on their energy prices in return for accepting less secure supplies (UK DECC, 2010).

In most cases the order of disconnection begins with interruptible contracts, but thereafter there is variation among member states in the way the procedure is carried out. In the UK, for example, there are five types of supply points that follow a strict order of disconnection (interruptible; supply points; large firm supply points; firm supply points; priority supply points). Where an emergency calls for reduction at firm supply points, consumers at ‘large’ firm supply points are required to reduce demand before other categories of consumer (UK National Grid for Gas, 2010). The disconnection order or ‘shut-off plan’ for Belgium is more network-oriented (a likely by-product of the bottom-up TSO-led emergency planning framework mentioned above). Interruptible capacity commences first with all exit interconnection points, followed by quality conversion points and then domestic exit points. Nominated exit quantities at interconnection points are limited before firm capacity at quality conversion points is constrained. The final step before curtailing end users involves the enforced use of commercial storage (Belgium, JRC-IET Questionnaire to Competent Authorities, 2011).

There are also differences between member states in terms of the ratio of interruptible contracts to total demand. Poland’s state-owned gas monopoly, PGNiG, has six major gas consumers with interruptible contracts, which can be notified 8 hours in advance of a suspension to their supplies. Together, these consumers constitute around 10% of industrial gas demand, thus serving as an equivalent buffer against short-term supply shocks. Denmark has an even greater proportion of interruptible capacity; Energinet.dk has arrangements with around 40 major gas consumers which can have their supplies partially or in some cases fully suspended. According to the IEA, these arrangements amount to around 20% of total Danish winter gas consumption (International Energy Agency, 2011). In other cases regulatory reforms may reduce the proportion of interruptible contracts. The UK in 2010 had around 1,000 end users with interruptible contracts but, due to the adoption of a more restrictive auction-based system for distribution network operators, has significantly reduced this number (UK, Ofgem, Interruptible to Firm-Supply Point Transition, 2011).

Interruptible contracts are closely related to load shedding strategies in the electricity sector. Indeed, natural gas is increasingly used as a primary fuel for electricity generation. In this context it is important to recognize that lack of gas supply may contribute to a lack of generating capacity in the electricity grid. Measures in place to handle such shortfalls, such as load shedding for firm and interruptible customers, voltage reduction, energy purchasing, and eventual rolling blackouts should ideally be integrated into a gas emergency plan. The UK has done so by creating a Gas & Electricity Industry Emergency Committee (GEIEC) which is made up of a number of industry and regulatory bodies from both sectors. Similarly, Ireland has integrated interruptible contracts and load shedding in its gas emergency plan. Accordingly, the country’s strategy rests on three customer categories – large daily metered (LDM, annually consuming over 57 GWh), daily metered (DM, 5.55–57 GWh) and non-daily metered (NDM, <5.55 GWh). In order to ensure more flexibility in matching the load shedding to the amount of gas required to rebalance the network, the LDM category is further sub-divided into three consumption categories ($>$ 1.500 GWh; 260–1.500 GWh; or 57–260 GWh). After all three of these loads have been reduced to zero, the NGEM progresses to any daily metered offtake, followed by two categories of non-daily metered end users (non-household/ household) (Ireland, Gaslink, Natural Gas Emergency Plan, 2009).

Disconnection orders are determined according to various criteria set out in relevant legal acts and emergency plans. The order of curtailment and suspension is primarily driven by the requirement to shed load at the fastest possible rate and, in practical terms, this means that the largest loads are shed first. Of course, to supplement this largest-to-smallest approach, criteria are in place to set an order that minimizes the socio-economic impact of a disruption. For

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example, E-Control's Energy Emergency Order takes into account the degree of urgency, substitution possibilities, macroeconomic impacts and effects on the district heating supply (Austria, E-Control, 2009). In the case of load shedding strategy, the Spanish TSO Enagas, in consultation with the electricity sector, allocates interruptible contracts according to the peak demand coverage ratio (International Energy Agency, 2011).

Whatever criteria are adopted, it is considered good practice to involve stakeholders. For example, French industrial authorities, in cooperation with gas system operators, circulated a questionnaire in 2009 for all industrial customers connected to the natural gas transmission system (France, GRT Gaz, 2009). Based on the results of the survey, 4 load-shedding criteria were defined to establish the order of priority for a reduction/suspension of natural gas to these customers. The criteria was based on a series of questions, including whether the industrial user performed a public interest role, whether suspending gas would cause public health or environmental risks, and finally whether a loss of supply would cause an immediate risk of damage to the customer's production facility. In addition to involving stakeholders, transparency is also an important part of a disconnection strategy. For example, Hungary's TSO, FGSZ, has published a detailed order of restriction for large end users, including quantities of gas consumed and the amount restricted for each crisis phase. This provides a transparent and useful reference document for Hungary's demand-side response capabilities (Hungary, FGSZ, 2011).

5. Gas emergency operational framework template

Extrapolating from a review of emergency measures available to EU member states, it is clear that an operational template should be constructed for measures which can be ordered and linked to crisis levels and be categorized according to the various actors responsible for their implementation. One possible framework structuring this information is set out below. Not all the measures listed may be available to a given member state and the order provided is merely indicative of what may be considered common emergency planning procedures. For example, the initiation of interruptible contracts by network operators is normally followed by the use of stocks or back-up fuels held by large industrial customers and power generators. The depletion of these stocks, in turn, usually results in strategic storage withdrawal or, if unavailable, the implementation of a disconnection plan. It must be stressed, however, that this framework is indicative and that actual allocations made using supply-side options such as storage may differ depending on the nature of the crisis and the available capacities to service various demand points Fig. 3.

6. The importance of regional cooperation

In most cases, emergency plans treat external supply disruptions as exogenous and focus primarily on domestic response capabilities. While the latter form the key to an effective emergency plan, engaging with partners beyond borders to better manage cross-border interdependencies and associated risks is thus far a largely untapped source of resilience during a supply emergency. Indeed, only a few national emergency plans cite an increase in import as an effective solution for coping with a gas supply deficit. Moreover, there is far less emphasis on building resilient networks capable of balancing *regional*, rather than national, gas markets. As a corollary, bi-directional capacity on cross-border entry/exit points are rarely mentioned in conjunction with other emergency response measures such as strategic stocks or interruptible contracts, even though they have been used during crises – e.g. flow lines from Belgium–UK, Bulgaria–Greece and Slovakia–Czech Republic were among those reversed in January 2009.

Thus, coordination amongst TSOs at a regional level could be strengthened and better developed in national emergency plans. The scope for cooperation can manifest itself in commercial terms through swap and short term contracts, OBAs, standby agreements in cases of emergency, and so on. Cooperation between market players can also be encouraged at the political level, a good example of which is Irish-UK cooperation. Given the former's high degree of dependence on UK gas imports, both countries have initiated a Joint Gas Emergency Planning working group and have conducted joint emergency exercises (Gaslink, Network Development Statement, 2011). On the level of information sharing, Bord Gais Networks has clarified with the Network Emergency Coordinator (NEC) in Great Britain the arrangements that will apply in the event of a gas supply emergency in the latter. Aside from bilateral arrangements, steps are being taken to strengthen regional forums; one example of which is the Declaration by the Visegrad Group's energy ministers, which mentions the need to coordinate emergency planning in accordance with Regulation 994/2010 (http://www.visegradgroup.eu/2011/declaration-of-v4-energy). Such cooperation could help streamline the conditions under which cross-border interconnections are utilized (or possibly reversed), which would significantly improve flexibility during a supply crisis; this is apparent from the experience of the January 2009 gas crisis, where many reverse flows took more than 10 days to arrive (European Regulator Group for Electricity and Gas (ERGEG), 2009).

Despite these examples of cross-border cooperation, there are also instances where existing rules contained within national emergency plans potentially conflict with provisions in Regulation 994/2010 to maintain transnational access to infrastructure (EC/994/2010). For example, Slovak law obliges storage system

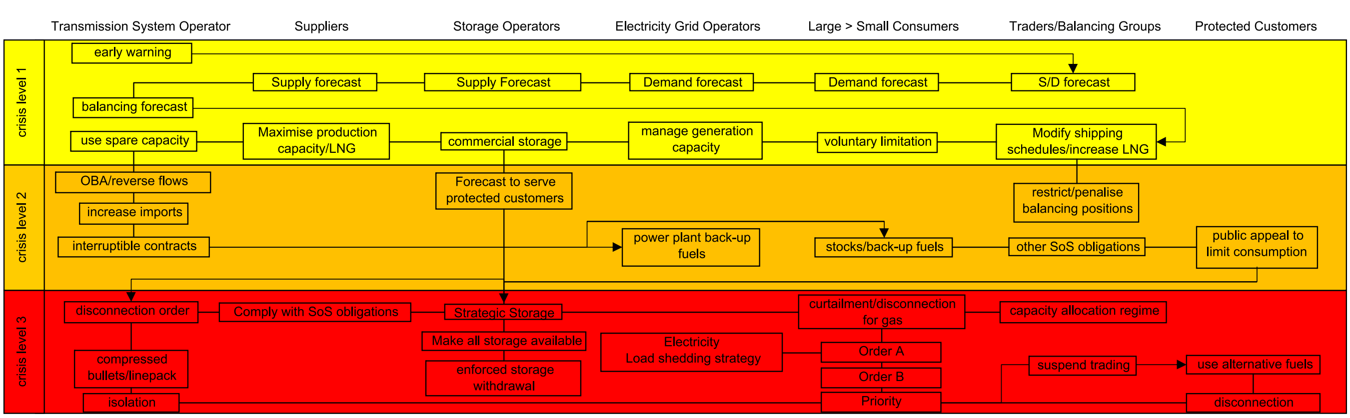

Fig. 3. Gas emergency framework template.

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operators to stop deliveries to companies supplying foreign customers during emergency situations (ERGEG, GRI-SSE achievements and bottlenecks, 2009). Similarly, the shut off plan in Belgium first suspends gas flows to interruptible exit interconnectors before doing so on domestic entry points (regardless of the quantities contracted by either point) (Belgium, JRC-IET Questionnaire to Competent Authorities, 2011). Moreover, several disconnection protocols mandate a suspension of supplies secured via third party access regimes before equivalent domestic supplies are curtailed. This is the case in the UK and Spain (United Kingdom, National Grid, 2011). Of course, there may be justifiable reasons to withhold gas to a given exit point; in case of an emergency situation in Polandthe TSO has the discretionary right to 'not accept gaseous fuel for transmission or not deliver gaseous fuel to an exit point if this could result in a threat to security of the transmission system operations, human health or lives or the environment, or could cause damage to property' (Poland, Gaz System, 2011).

7. Emergency plans in liberalizing markets

As a corollary to recognizing the necessity for enhanced regional cooperation, gas emergency plans should also adjust to the demands of a liberalizing gas market. Indeed, in several of the more mature gas markets, security of supply is a responsibility increasingly shared between a large number of market players – suppliers, operators and consumers alike. The latter may opt for back-up solutions to cope with interruptions or make contractual provisions for ensuring a given level of security from the supplier. In the transportation sector in particular, security of supply may be delivered via incentives for market participants to balance their inputs to and off-takes from the gas pipeline system (UK, OFGEM, 2011). In this context, capacity allocation and third party access have considerable importance for emergency response. Where most of the capacity on gas transmission pipelines is booked on a long-term basis by incumbents (whether it is used or not), the system flexibility during a crisis will be limited. By contrast, TSOs providing short-term 'on-demand' services under the 'use it or lose it' principle may be better equipped to source requisite capacities in case of shortfalls on the secondary market.

In a centrally cleared within-day trading market, the responsibility for balancing the system then becomes shared between TSOs and shippers, which interact to ensure physical and commercial balancing obligations are met. Imbalances, which occur when network users' injections into the balancing zone differ from their off-takes, can potentially be addressed through cross-border balancing zones – either between TSOs or led by shippers (ACER, Framework Guidelines on Gas Balancing in Transmission Systems, 2011). This can enable TSOs to act as intermediaries to facilitate access to flexible gas in neighboring markets, an arrangement that can be built into an emergency plan. For example, Belgium's Fluxys has an operational balancing agreement (OBA) with adjacent TSOs, enabling collaboration in order to meet residual balancing needs as well as the possibility of coordinated dispatching (Belgium, JRC-IET Questionnaire to Competent Authorities, 2011).

Thus, in many ways the development of regional emergency plans hinge on functional and integrated gas markets. As the EU's third energy package is progressively implemented there are increasingly visible signs of market players engaging in regional cooperation, through the creation of hub-to-hub trading, regional balancing zones, and so on. These actions create the corresponding need to develop tools to collectively manage not only system balancing needs but also short-term supply shocks, as well as to better monitor cross-border entry/exit flows. For instance, operational balancing agreements between TSOs can ensure collective balancing through coordinated dispatching (in addition to the recent OBA between Slovakia and Czech Republic, (Slovakia, EUStream, 2010) observe the example of Belgium above); this can also serve as a powerful tool to coordinate reverse flows.

7.1. Prices and compensation

In addition to adapting to changing market conditions, there is also an obligation to clarify the mechanisms for compensation to natural gas undertakings that make gas available during a supply disruption (994/2010 (36) and Article 10(l)). This provision is predominately related to the regime in place by which gas is priced during an emergency. The various methods used can be categorized according to whether

- Prices are "administered" (i.e. they are centrally determined) ex ante (in advance) with the prices either being a single price, or a price cap
- Prices are determined on an indemnity basis ex post, or
- Prices are determined through some market mechanism (Farrier Swier Consulting, 2006).

In the first category, the simplest option would be a single posted price that applies regardless of the loads curtailed. A more complex variation would be to install multi-tier posted prices linked to the order of curtailment and suspension, with "the posted price depending on an assessment of the value of gas associated with the marginal category of load curtailed during each balancing period" (Farrier Swier Consulting, 2006, p. 33). In either case, price caps would provide a means to manage risk in emergency situations and limit windfall profits and/or losses. In the case of prices being determined ex post, or after the crisis, the price/compensation amounts would be based on the insurance principle of indemnification, and likely determined by the independent system operator.

Options also exist for market pricing mechanisms to be used during an emergency situation. Demand side bidding, for example, involves shippers establishing a price at which each gas user is prepared to have a defined volume of their nominated gas load curtailed. The emergency balancing price would be determined based on the marginal load curtailed and would be recovered from shippers in negative imbalance (Farrier Swier Consulting, 2006, p. 35). Another option, assuming a liberalized gas market with third party access and trading, would be to implement wholesale market arrangements whereby gas supply injections and withdrawals by controllable loads are managed in response to market clearing prices (Farrier Swier Consulting, 2006, p. 62). Indeed, a centralized trading arrangement carrying up-to-date information on bids and offers responding to market clearing processes and price signals should be able to balance the network in the short term.

However, it should be noted that the fundamental method behind market-based strategies to resolve supply deficits is essentially by incentivising large consumers to make their reserve fuels and firm capacities available on the (spot) market; if large consumers are willing to pay the price, they can avoid having their demand curtailed. If the purpose of emergency arrangements is to conserve gas for protected customers, this can be considered counterproductive. But, if emergency arrangements are meant to allocate available gas most efficiently (regardless of what sectors actually end up consuming the gas), then market arrangements are useful. This is a socio-economic dilemma whereby the incentive to supply gas to the highest bidder must be balanced against the need to serve protected customers (which can essentially be considered 'free-riders' as they have no incentive or obligation to conserve gas).

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In the UK, frozen cash-out during an emergency and lack of compensation for firm customers are considered important gaps in emergency arrangements. The former may lead to instances where the cash-out price is below the price that customers without interruptible contracts would be willing to pay, which may lead to a disconnection despite the end user attributing a higher value to security of supply. Options to address these issues are compensation at the value of lost load (VoLL) for disconnected firm customers and more dynamic price signals in the event of an emergency, in order to better reflect the value that different customers assign to security of supply whilst ensuring that the GB market is able to attract gas imports during an emergency (UK, OFGEM,Gas Security of Supply SCR Initial Consultation 2011).

On the other side of compensation issues are penalty charges during emergencies. The Austrian TSO E-Control can impose penalties on end users consuming natural gas above the restriction measures; these charges are then used to implement future security of supply measures (Austria, Energielenkungsgesetz, 1982/2006). Similarly, during an emergency the Italian operator can impose fines for non-compliance with the full use of booked import capacity (International Energy Agency, 2010). More generally, companies with firm capacities usually pay more for gas deliveries than interruptible customers; the proceeds from these charges are usually fed into improving system balancing or, in the case of Greece, security of supply levies are used by the TSO to fulfill its obligation to compensate interrupted supplies to customers with more flexible arrangements.

The pricing options and associated issues reviewed here assume a liberalised gas market which is not necessarily the case in several member states. In fact, as a Commission impact assessment of the January 2009 gas crisis observes, "direct and indirect subsidies or price distortions, either at the public level or through commercial policies, were identified as reducing the capacity for markets to deal with supply emergencies by removing incentives for investment in new infrastructure and for greater efficiency in energy use" (European Commission, SEC, 2009).

8. Conclusions

The impact of a disruption to gas supplies varies considerably amongst EU member states. This is not only due to differences in supply/demand balances and associated infrastructural constraints but also the regulatory framework governing the management of emergency situations. The tools available to market players also vary depending on the extent to which the national gas market is sufficiently competitive and liquid. Where the market is concentrated and dominated by single vertically-integrated players, the extent of government intervention to meet security of supply standards is usually more substantial.

Having reviewed the state of play in several EU member states as well as the EC Regulation 994/2010 requirements for emergency plans, this paper concludes that the key requirements for a gas emergency plan are

- Clarity on the obligations of all players for each defined crisis level.
- Clear communication in emergency situations, including all relevant reporting, monitoring and notification procedures.
- Measures which are proportionate to the crisis level, sensitive to the gas demand profile, aware of the regional context, inconsequential to normal market operation, transparent and non-discriminatory during implementation and verifiable during emergencies as well as under normal conditions.
- Clearly understood and impartial order of disconnection and the associated classification of gas users (e.g., interruptible/ non-interruptible/ protected).
- Clear regulatory, legal and operational provisions applicable during each defined crisis level, including compensation arrangements as well as penalties on players which fail to fulfill their operational or security of supply obligations.
- Coordinated planning with third countries (e.g., suppliers, transit/neighboring countries, non-domestic players).

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Annex 1. Security of supply standards and public services obligations in EU MS.

See Table A1.

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Table A1

Austria	No specific obligations (e.g., days/volumes) found[a].
Belgium	The TSO, Fluxys, has a mandated public service obligation to be able to supply all uninterruptible customers in the case of severe temperatures that would occur based on the winter of 1962/3 or 5 consecutive days with temperature $< -11\,^{\circ}$C. For this purpose Fluxys maintains reserved strategic storage, which are charged to users through transmission tariffs.
Bulgaria	No specific obligations (e.g., days/volumes) found[b].
Czech Republic	Producers and traders must ensure supply to customers with annual consumption lower than 400,000 cu m in case of a) partial (20%) disruption of the total daily volume for a period of 8 weeks in the winter season; b) five days of an average temperature of -14 °C and c) a 1-in-20 winter[c].
Denmark	TSO is obliged to procure storage capacity to meet demand of non-interruptible customers for 60-days at normal winter temperature, 3 day at $-14\,^{\circ}$C (equivalent to 1 in 50 peak days). Shippers are required to keep a certain percentage of gas storage during winter months to meet demand of non-interruptible customers.

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Estonia	A heat supply undertaking with an annual estimated production volume over 500,000 MWh per network area is required to hold enough reserve fuel to generate heat supply for a duration of three days[d].
Finland	All non-industrial players must hold three months of alternative fuels [e].
France	Shippers supplying domestic & public interest customers are required to withstand a loss of main supply for a 6-month period under normal weather conditions, to ensure supplies for both a 1-in-50 winter and a 3-day 1-in-50 period of extreme winter conditions.
Germany	Suppliers have a legal requirement to take reasonable steps as prudent operators to ensure security of supply for their customers under normal and exceptional conditions, with severe penalties for failure. This obligation is discharged via contracts with TSOs and storage operators/providers.
Greece	New gas-fired power producers are obliged to hold at least five days of back-up reserves of dual fuel (i.e. either diesel at a storage facility on the power plant's premises, or LNG reserves at the Revithoussa LNG Terminal)[f].
Hungary	Natural gas must be strategically stored at a UGS facility that has a daily withdrawal capacity of 20 million m3 for at least 45 day[g].
Ireland	Power generators are separated into two categories—high and low merit. These must hold stocks equivalent to five days (high merit units) or three days (low merit units) continuous operation at 90% of the unit's normal fuel capacity. CHP units with a capacity greater than 10 MW are required to hold stocks equivalent to one day of continuous running on the unit's rated capacity on its primary fuel. These stocks must be held on site or in close vicinity connected by a dedicated supply line and pump[h].
Italy	Approx 40% of storage is reserved for Strategic Storage, whose release is controlled by the government. This should cover for 60 day a 50% disruption of peak capacity at the main national entry point. Additionally there is a legal obligation on each importer to maintain 10% of its import requirements in storage (minimum quantity specified by Ministry for Industry each year).
Latvia	No specific obligations (e.g., days/volumes) found[i].
Lithuania	Gas reserves accumulated for household consumers must be sufficient to meet demand for a period of 30 day (a schedule is in place for an additional 10 day each year until the level of 60 days is reached.) Non-household consumers using gas for the purpose of production of energy to be sold or consumed for covering public demand shall hold reserves equaling the demand of 1 month[j].
Luxembourg	No specific obligations (e.g., days/volumes) found[k].
Netherlands	Shippers must have contracts in place to meet demand of small customers down to -9°C. The TSO, GTS, is required to protect supplies to small customers during extremely cold winters. It procures storage gas to meet their increased demand when temperatures drop below -9°C (down to -17°C). Shippers pay for the above arrangements through a PSO tariff[l].
Poland	Companies engaging in international gas trade must maintain compulsory gas stocks equivalent to 30 days of the total average daily amount of gas brought in by suppliers of the Polish market. These mandatory stocks of natural gas are required to be stored in installations that enable delivery of the entire stocks to the gas transmission system within 40 days [m].
Portugal	Gas importers are mandated to hold gas reserves equivalent to 15 days consumption of non-interruptible gas-fired power plants (i.e., electricity producers) and 20 days consumption of non-interruptible customers (particularly households) in the remaining market.
Romania	The minimum gas stock is determined by the Market Operator of the Gas National Dispatcher, for each supplier, so that it covers about 12.5% of the volume of gas to be supplied to captive customers[n].
Slovak Republic	TSOs are obligated to supply gas to final customers in case of a) a 10-week long suspension of 30% of total gas supply, b) gas consumption for five consecutive days of -12 °C during this scenario, c) a 1-in-20 winter, d) a complete suspension of supplies for 30 consecutive days[o].
Slovenia	Gas suppliers are required to have reserve supplies equivalent to 20% of demand from 'special customers' for a period of 14 days during the average monthly temperature in the last 20 years. Additionally, suppliers must reserve 40% of supplies to special customers for a period of 5 days during the average January temperature in the last 20 years[p].
Spain	Shippers cannot source >50% of portfolio from any one country. The TSO must hold 20 days of total non-interruptible sales (10 of which are reserved for strategic purposes, the other 10 available for commercial use).
Sweden	No specific obligations (e.g., days/volumes) found.
UK	Operators must ensure supply to domestic customers in a 1-in-20 peak demand day and a 1-in-50 winter period[q].
	Sources: Poyry 2010, as footnoted, EC SEC 2009

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