SIMPLIFICATION OF THE EUROPEAN GAS NETWORK

by

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1. Introduction

As energy sources and their transformation shifts towards low carbon systems, natural gas is expected to bridge the transition pathway in the near and mid-term[1]. In comparison to coal and oil, natural gas offers lower environmental impact, higher efficiency and flexibility as back-up capacity for variable renewable power generation. However, the resource is predominately concentrated in a few global sites far from large demand centres with the consequent risk of supply insecurity[2].

Declining indigenous gas production in the European Union (EU) amid future demand uncertainty would lead to higher dependency on natural gas imports[3]. Similarly in the UK, indigenous production has declined at an annual rate of 7% since 2000[4]. The vulnerability of gas supply in the EU is intensified by increasing gas demand from emerging economies, large capacity of grid connected renewable power generation and pipeline import through multiple transit countries[3].

Consequently, the European gas grid should become increasingly flexible to incorporate diverse supply modes (pipeline and liquefied natural gas - LNG), alternative supply routes and diversify source of supply to enhance security of gas supply. Furthermore, upgrade and expansion of cross border capacity will eliminate the single input sources of some member states, improve energy security and contribute to achieve the single internal energy market objective of the EU energy policy[2].

However, the impact of these development schemes differs significantly across member states. The UK gas network links the European gas grid via interconnectors to Belgium, Netherland and Norway. These interconnectors account for around 65% of total gas import capacity to the UK in 2011 [4]. Therefore, we seek to access the impact of the integrated EU gas network on the operation of the GB gas system. In this report, we focus on the simplification of the existing European gas grid.

2. The European Gas Transmission Network

The European gas transmission grid comprises the natural gas transmission infrastructure of individual countries integrated as a single entity for delivery and transport of natural gas supplies across Europe. The transmission networks transport large flow capacities of gas (at pressures in excess of 40 bar) between nodes (supply terminals, storage and compression stations). Major network infrastructure includes pipelines, gas storage and LNG facilities.

The European Network of Transmission System Operators for Gas (ENTSOG) is tasked with responsibility to facilitate the operation and delivery of the interconnected and integrated internal gas market and ensure development of natural gas transmission network to deliver adequate, reliable, safe and secure gas transport within the EU. [2]. The ENTSOG also works closely with regional regulators bodies Agency for the Cooperation of Energy Regulators (ACER), European Regulator Group for Electricity and Gas (ERGEG) and other stakeholders such as the Gas Infrastructure Europe (GIE).

The ENSTOG system development map shown in Fig 1 was our detailed network information source.

The European gas grid has been segmented into gas priority corridors for detailed assessment of location specific challenges and proposed solutions toward gas supply security. LNG shipment and pipeline transport are the modes of natural gas import to the network. Therefore these corridors include both pipeline networks and LNG facilities. In 2011, 76% of total natural gas imported into the EU was made up of pipeline imports from Norway, Russia, Algeria and Libya while the remaining 24% capacity was LNG import sourced mainly from Qatar and other countries [5]

The corridors created through the EU- energy infrastructure framework are [6]:

- North – South gas interconnector in Central Eastern and Eastern Europe: The gas delivery in this region is limited by unidirectional gas transmission and reliance on a single supply source. Proposed gas infrastructure projects aim to improve free gas flow through reverse flow capacity, alternative supply modes and routes and market integration.
- North – South gas interconnection within Western Europe: Here the priority action is to improve short term gas supply and eliminate gas flow restriction by additional interconnector capacity in the region. This should also enhance available LNG infrastructure and provide support capacity for grid integrated renewable electricity in the region.
- South Corridor: This corridor creates opportunities for development of new import capacity to the EU gas market from diverse supply sources and routes. For instance, large natural gas deposit in the Caspian region and Middle East can be accessed through flexible supply modes (i.e. LNG and pipeline).
- Baltic Energy Market Integration Plan: The main objective is to integrate the isolated countries in Baltic region with the rest of the EU gas grid in the bid to minimize gas supply reliance on Russia.

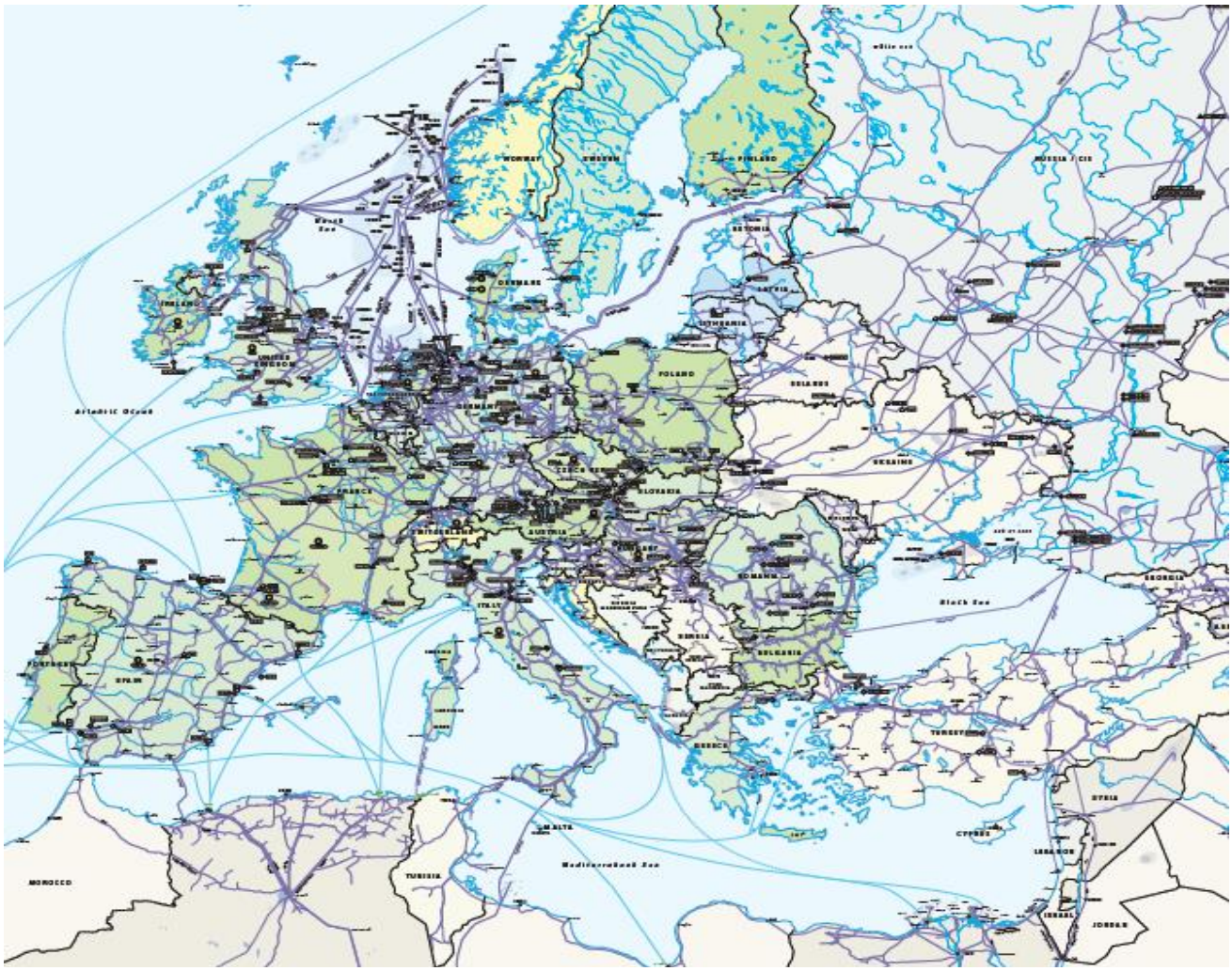


Figure 1 The European gas network [5]

3. Network Simplification

The European gas network map of Fig. 1 shows the existing gas transmission infrastructure as well as the status of the proposed development projects in 2011. The purple lines denote gas pipeline transport routes within countries and across borders while the blue lines represent LNG transport routes. The LNG terminals and storage facilities are shown by the black points clustered around country outlines. The network topology is well interconnected but most data required for detailed analysis of integrated system is inaccessible. Moreover, the focus of this study is to investigate the gas flow capacities across country borders. These are the reasons for the network simplification.

3.1 Assumptions

The following assumptions were made for the development of this simplified EU gas network model:

- The aim of this study is a high level (i.e. transmission) gas flow analysis within the European territory with focus on net flow capacities across country borders.

- Only available (i.e. in operation) natural gas infrastructure: pipelines, storage and LNG facilities in 2011 were considered. Not yet completed infrastructural developments are currently excluded from the simplified model but would be included where appropriate in future time scales towards 2020.
- Each country is represented as one node in the simplified model.
- Units of gas capacity are presented as million cubic metres at standard conditions of temperature 15^{o}C and pressure 101.325 kPa. Conversion factors are: 1 m^{3} of natural gas = 39.6 MJ Gross Calorific Value (GCV) = 11 kWh (GCV) [4].

3.2 Network Components

The simplified network model consists of 37 nodes and 57 cross border transmission links between nodes. The red coloured nodes represent European countries while non-EU transit countries and gas pipeline import sources are denoted by purple nodes. The purple lines show the direction of gas flow to the EU from pipeline import and red lines represent cross border transport among EU member states.

Countries are designated on our map by country code names as shown in Table 1.

Nodes

The primary natural gas data is denoted as nodal parameters. The presented dataset encompasses national aggregates of demand, supply and storage capacity of each country. In Table 1, the nodal parameters are classified as:

- Annual Demand - Annual natural gas demand in million cubic metres (mcm).
- Supply – Maximum gas production capacity, maximum LNG import capacity and maximum pipeline import capacity. All units are given in million cubic metres per day (mcm/d).
- Storage – Maximum storage capacity which herein is the working gas volume capacity(WGV) excluding cushion gas volume in million cubic metres (mcm).

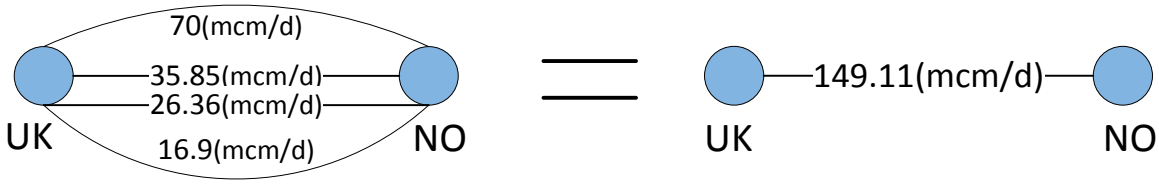
Cross border pipeline capacity

The line linking any two nodes represents the aggregated maximum flow capacity between two countries. Where multiple pipe lines occur between countries, an equivalent single pipe line was modelled and its capacity was calculated using Eq. 1.

$$Q_{eq} = \sum_{i=1}^{n} Q_i \qquad (1)$$

where Q_{eq} is the equivalent flow capacity in the single equivalent pipeline and Q_i are original individual pipeline capacities.

An example of pipeline link between the United Kingdom and Norway is given below



The maximum cross -border capacities between different countries are shown in Table 2.

4.3 Data Source

The Data sources are from the following studies: [5,7, 8]

- ENTSOG- The European natural gas network map updated version May 2012
- ENTSOG/GIE System development map 2011
- Gas LNG Europe (GLE)
- Gas Storage Europe (GSE)

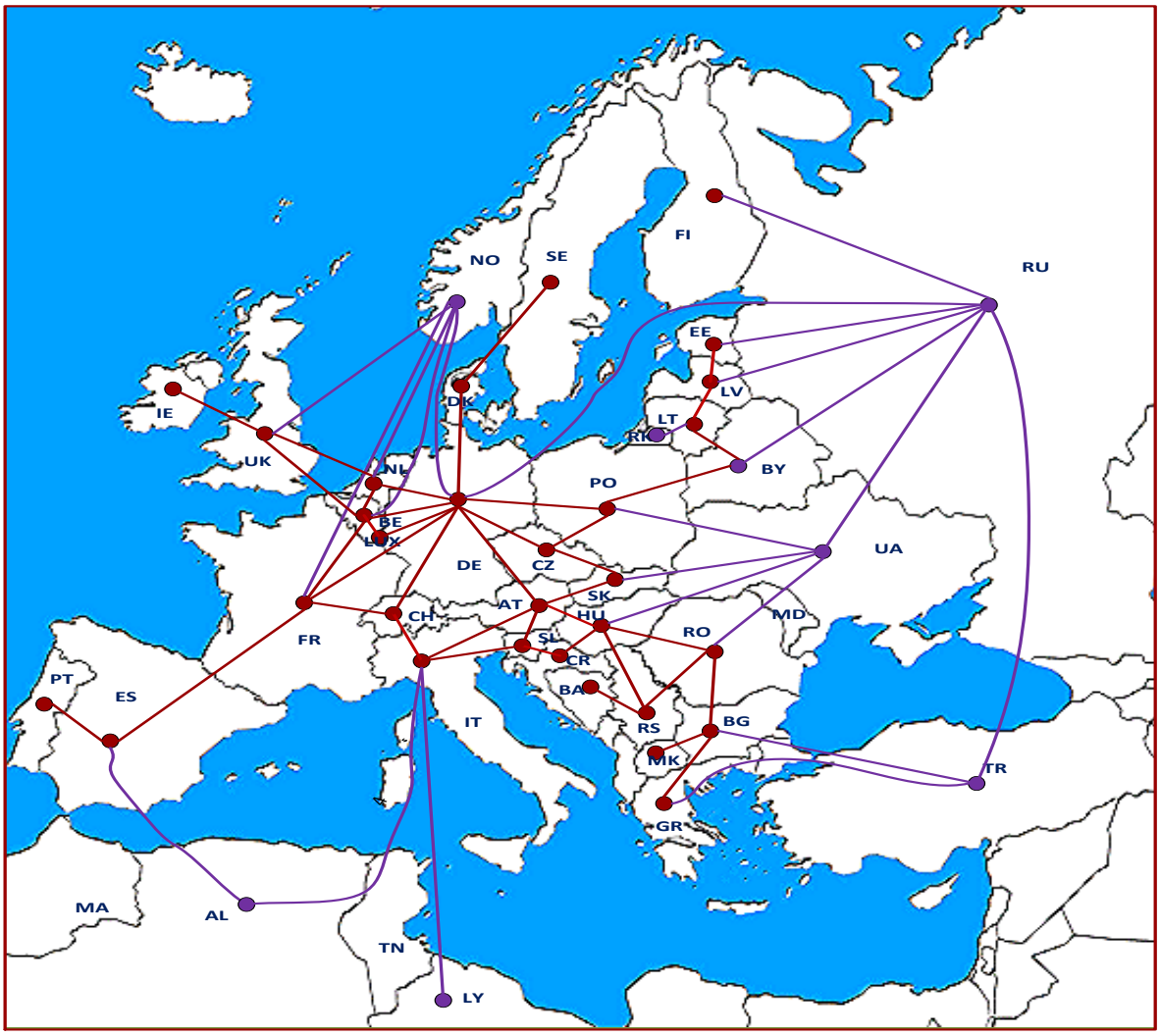


Figure 2 The Simplified EU Gas Network

Table 1 Country Nodal Parameters [5, 7]

Country Nodal Parameters (2011)					
Country	Maximum Production Capacity (mcm/d)	Maximum LNG Import Capacity(mcm/d)	Maximum Pipeline Import Capacity (mcm/d)	Annual Demand (mcm)	Maximum Storage Capacity (WGV) (mcm)
Algeria (AL)	n.a	-	-	-	-
Austria (**AT)**	5.18	-	159.73	8538	7451
Belgium (**BE**)	-	40.80	244.55	15826	700
Bulgaria (**BG**)	1.25	-	73.45	2788	450
Croatia**HR**	5.64	-	23.27	2774	550
Czech Republic **CZ**	0.54	-	191.91	7647	3432
Denmark **DK**	21.52	-	0.00	3326	0
Estonia **EE**	-	-	10.91	579	1025
Finland **FI**	-	-	22.64	3867	0
France **FR**	1.88	3.5	185.45	41584	12700
Germany **DE**	39.46	-	556.18	74423	20455
Greece **GR**	-	39	12.64	4575	n.a
Hungary **HU**	11.52	-	65.73	10368	6130
Ireland **IE**	-	-	32.09	4583	230
Italy **IT**	23.48	-	291.73	71088	16487
Latvia **LV**	-	-	20.09	1405	2320
Libya **LY**	n.a	-	-	-	-
Lithuania **LT**	-	-	37.36	3144	n.a
Luxembourg **LUX**	-	-	7.00	1150	n.a
Macedonia **MK**	-	-	0.00	58	n.a
Netherlands **NL**	326.07	-	135.27	33826	5258
Norway **NO**	n.a	-	-	-	-
Poland **PO**	8.66	-	121.82	14617	2052
Portugal **PT**	-	-	14.91	4773	171
Romania **RO**	27.05	-	96.45	12381	2684
Russia **RU**	1663	-	-	-	-
Serbia **RS**	-	-	12.45	-	
Slovakia **SK**	0.27	-	319.64	5028	2905
Slovenia **SI**	-	-	9.36	852	n.a
Spain **ES**	-	132	79.09	32070	4620
Sweden **SE**	-	-	6.55	1214	8.5
Switzerland **CH**	-	-	69.55	2385	n.a
Turkey **TR**	-	-	0.00	0	n.a
United Kingdom **UK**	134.55	153	245.00	75968	4319

Table 2 Maximum Cross-border Capacities [8]

S/N	Linking Countries		Maximum Cross - border Capacity(mcm/d)
1	UK	IE	39.25
2	UK	BE	130.65
3	NO	UK	133.93
4	UK	NL	211.96
5	BE	NL	149.77
6	BE	FR	72.73
7	BE	DE	64.73
8	BE	LUX	4.56
9	LUX	DE	2.43
10	FR	DE	105.70
11	FR	CH	20.27
12	FR	ES	18.55
13	FR	NO	53.18
14	ES	PT	30.36
15	ES	MA/AL	56.45
16	IT	AT	120.54
17	IT	SI	2.54
18	IT	CH	58.07
19	IT	LY	31.67
20	IT	TN/AL	99.40
21	AT	DE	56.34
22	AT	SK	163.50
23	AT	HU	11.68
24	SI	HR	4.85
25	HU	HR	9.27
26	HU	RO	4.63
27	HU	UA	54.25
28	BG	GR	12.17
29	BG	MK	3.04
30	BG	RO	74.57
31	BG	TK	42.47
32	GR	TK	2.75
33	RO	UA	32.73
34	SK	UA	277.89
35	SK	CZ	94.85
36	PO	CZ	0.38
37	PO	DE	88.55
38	PO	BY	109.08
40	LT	RU-KAL	9.87
41	LT	LV	4.96
42	LT	BY	29.33
43	LV	RU	15.05
44	LV	EE	6.61
45	EE	RU	3.79
46	FI	RU	20.45

S/N	Linking Countries		Maximum Cross-border Capacity (mcm/d)
47	DE	CZ	217.66
48	DE	RU	79.24
49	DE	NO	137.40
50	DE	DK	6.25
51	DE	CH	53.25
52	DE	NL	187.66
53	AT	SI	8.20
54	DK	SE	9.64
55	HU	RS	12.71
56	NL	NO	92.60
57	RS	BA	-

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