The German Gas Supply System*)

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Abstract

In 1993 gas accounted for 18 % of primary energy consumption in western Germany and 14 % in eastern Germany.

The technical prerequisite for gas being able to achieve this high market share has been the availability of a nationwide transmission and distribution system through which the gas can be moved from the production fields or border delivery points to the end consumer in a safe, environmentally compatible and economic manner.

Germany's energy consumers receive their gas through a ramified 280,000 km pipeline system, 44,000 km of which are operated by gas merchant companies and 236,000 km by regional and local distribution companies.

In the gas transmission system it is not only the pipelines but also the compressor stations and underground storage facilities which play an important role.

In 1993 the mainline compressor stations had an installed capacity of approx. 850 MW and the useful working gas volume of the underground storage facilities was roughly 10.3 billion m^3. The gas is stored in both salt cavities and storage reservoirs depending on the geological conditions prevailing and the supply requirements. Storage capacities are being continually increased to cover the increasing demand for peak shaving.

The transmission system is also in a phase of dynamic expansion. Construction work is concentrated in the north German region where high-capacity pipelines are being built to carry the increasing quantities of Norwegian gas from the Troll project from the North Sea coast to the consumption centres in the Ruhr area and eastern Germany.

Ruhrgas AG is playing a major role both in the existing system and in the new northern system which is to be built up.

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The German Gas Supply System

by R. Beyer

1. Introduction

Gas has now taken second place among the primary energies in Germany - after oil and before hard coal.

In 1993 the share of gas in primary energy consumption in Germany was approximately 18 %, corresponding to a consumption of approximately 62.26 MTOE (**Fig. 1**).

There are still marked differences between western Germany (gas's share of primary energy consumption: > 18 %) and eastern Germany (gas's share of primary energy consumption: ~ 14 %) but these differences will level out in the next few years.

The strong position which gas holds on the energy market has been achieved in the comparatively short space of two to three decades. Such a development was only possible at all because gas fulfilled the major requirements which are nowadays placed on a source of energy: security of supplies, environmental compatibility, energy conservation and competitiveness.

With the introduction of natural gas in the mid-60s the German gas industry experienced an upswing of hitherto unknown dimensions.

The prelude to this expansion was the discovery and development of major gas fields in the Netherlands (Slochteren) and in the north German plains.

Supplies of the environmentally compatible and efficient energy were increased in the 70s as imports started to come from the then Soviet Union and the Norwegian North Sea.

The natural gas used in western Germany in 1993 came from the following sources (**c.f. Fig. 2**)

- 22 % from indigenous fields
- 27 % from Russia
- 34 % from the Netherlands.
- and 17 % from Norway and Denmark.

The share of Norwegian natural gas will rise steadily in the years to come and should make up nearly 30 % of supplies by the middle of the next decade.

70 % of the natural gas used in eastern Germany in 1993 came from Russia and 30 % from indigenous fields or from deliveries from western Germany.

When the contracted Norwegian gas starts flowing to eastern Germany, a balanced gas purchase structure will be achieved by the middle to the end of this decade.

A highly developed industrial country such as Germany will continue to have to import energy and import gas. To ensure long-term supply security, a strategy of diversification is being pursued: The energies are to come from as large a number of sources in as balanced a proportion as possible.

Gas makes a substantial contribution towards secure energy supplies and the outlook for the German gas industry shows that this will continue in future.

2. The Existing Gas Transmission and Distribution System in the Federal Republic of Germany

2.1 Description of the Pipeline Network - Functions of the Subsystems

The technical prerequisite for natural gas fulfilling the main requirements placed on a modern energy supply system is the availability of a nationwide transmission and distribution system through which the natural gas can be moved from the production fields or border delivery points to the end consumer in a safe, environmentally compatible and economic fashion (**Fig. 3**). Measured against this technical requirement, natural gas did not start from zero when it was launched onto the market but was able to make use of a town gas and coking gas transportation and distribution system which had been developed over several decades [1].

The German gas supply system had an overall length of approx. 280,000 km in 1993. **Table 1** gives a breakdown of the network lengths according to pressure stages.

These are networks belonging to regional and local distribution companies as well as gas merchant companies and gas producers.

Reflecting the history of the German gas industry, this gas supply network is a pipeline system consisting of different pressure stages, diameters and pipe materials. The age of the different subsystems varies greatly; the older pipelines (built before 1965) were originally used to carry coking gas and town gas whilst the pipelines built more recently have always been used to distribute natural gas.

This pipeline system serves three main functions:

- combined transmission and distribution throughout the Federal Republic of Germany,
- general distribution at the regional and local levels,
- specific distribution, i.e. provision of supplies to residential and commercial customers at the local level.

The diagram in **Fig. 4** shows natural gas supplies and the hierarchical structure of the three supply functions described. In Germany these functions are performed by about 600 gas companies of different types.

The function of combined transmission and distribution to be fulfilled by the German transmission system means that the gas is moved from the producer, from the border delivery point or from the indigenous fields to the consumption centres. To be precise, the gas is carried from the producer or supreregional supplier to the major industrial customers and power stations and to the delivery stations of the local and regional supply companies.

Whilst the older transportation systems - dating back to before the dawn of the natural gas age - were originally used to carry coking gas, the transmission pipelines built more recently are and have always been used to move natural gas. This transmission system can technically speaking be characterised by diameters $\geq$ 600 mm and by admissible operating pressures $\geq$ 60 bar. It has an overall length of 10,000 km.

The main gas trunklines in Germany tie in with each other at their intersections (**Fig 5**). The fact that this transmission system which covers the entire Federal Republic of Germany forms a grid is - together with the consequent possibility to diversify supply sources - a major contributory factor towards the security of gas supplies in Germany.

Apart from the transmission and distribution functions, these transmission pipelines have another important task, that of short-term load matching using the pipeline inventory. Short-term fluctuations in demand can be offset by using the line inventory provided that overall the gas available for distribution in a day or week remains more or less constant. However, this is only possible to the extent that the pressure differential between feed pressure and admissible minimum pressure is not used for transportation purposes; i.e. part of the pressure gradient which otherwise determines the transportation capacity of pipeline is used for load matching.

Downstream of the main transmission network comes a ramified and intermeshed high-pressure pipeline network (**c.f. Fig. 3**) of widely differing dimensions. This system performs transportation functions over shorter distances ($\leq$ 100 km) and general distribution functions at regional and local

levels. This system can be used to supply industrial customers and the power stations with gas direct, to deliver gas to the local consumption centres and also to feed gas into the local distribution networks. This high-pressure general distribution system is operated by gas merchant companies and by regional and local distribution companies.

The medium-pressure network operated almost exclusively by regional and local distribution companies is partly to be classified as a general distribution system and partly as a specific distribution system.

The low-pressure distribution network, on the other hand, performs solely specific distribution tasks at local level.
The geometric structure of this closely intermeshed network is due to the fact that it follows the layout of the roads and streets in a town.
The capacity reserves of this supply network, which are latently available or which can be mobilised at comparatively little extra cost, are considerable.
In particular, substantial increases in capacity (up to + 1000 %) can be achieved by increasing the operating pressure until it is in the medium-pressure range.

When such measures to raise the pressure are implemented, certain safety requirements must be met (network rehabilitation; installation of service governors, safety shut-off valves, low-pressure cut-off valves, etc.). Measured against the network capacities available, there are still a large number of ways of further increasing the number of residential and commercial customers connected to the mains in a particular area at favourable economic conditions.

2.2 Elements of the Gas Transportation and Distribution System

The most important elements of the gas supply system are: Pipeline, compressor station and storage facility.

The paramount importance of the pipeline, which has a dual function as both the transportation and packaging medium for gas becomes self-evident when the overall length of the German gas pipeline network of approximately 280,000 km and the fact that it is growing every year by a further 7,000 km are considered. At the gas transmission level another important component is the compressor station, which is designed to compensate pressure losses caused by external and internal friction during pipeline transportation. Such pressure compensation generally becomes necessary after every 100 to 250 km. The technically and economically optimum number of compressor stations and hence the average spacing of compressor stations are determined during system design [2].

To compress large quantities of gas, use is generally made of turbocompressors with an upstream gas turbine (aircraft-derivative or industrial-type turbine) as prime mover. In special cases, reciprocal compressors are employed with a gas engine (spark or compression ignition) as prime mover. One of the rules of pipeline transmission is that the fuel needed for driving the compressors is obtained from the pipeline itself - a principle that makes for greater cost effectiveness and supply security. The fuel gas consumption is governed by machinery data (efficiencies), the distance over which the gas has to be transported and by the structure of the quantity of gas to be transported (load factor).

Fuel gas consumption figures of 0.5 % of the throughput can be expected to cover typical central European transport distances of approximately 250 to 500 km.

In the Federal Republic of Germany a total of 37 mainline compressor stations are currently being operated by various gas merchant companies using a variety of compressors of different design and rating. The installed capacity is around 850 MW.

The third system element mentioned, the gas storage facility, is also gaining increasing significance. It is the storage facility which balances out differences between supply and demand - **c.f. Fig. 6**.

Special mention should be made here of seasonal load matching through which the seasonal temperature-induced fluctuations in sales are matched to the differing supply patterns. To carry out this load matching it may be necessary to use working gas volumes of up to 15 - 20 % of annual gas demand to obtain a balance between supply and demand. The storage facilities required are mainly operated by gas merchant companies so that the storage function is to be allocated to the supraregional supply level.

The main underground storage facilities are large storage caverns (cavities leached into salt domes) and storage reservoirs (aquifer horizons, depleted oil and gas deposits) - **c.f. Fig. 7**.

Storage caverns and storage reservoirs complement each other in their functions as large volumes can be withdrawn from storage reservoirs and high withdrawal rates can be achieved with storage caverns. The ideal case from the technical and economic aspects is a combination of storage types. The location of storage caverns and storage reservoirs depends on geological conditions and therefore cannot always be chosen solely according to supply requirements (**Fig 8**); apart from the expenditure on storage, there is the cost of connecting the storage facility to the transportation network.

At the end of 1993 32 underground storage facilities with a maximum working gas volume of approx. 10.3 billion m^3 were in operation in the Federal Republic of Germany [3]; in the final phase of expansion the working gas volume of these existing storage facilities can be raised by a further 1.1 billion m^3. Furthermore, an additional working gas volume of approx. 8.6 billion m^3 could be provided by theseexisting storage facilities which are either already under construction or in the planning stage so that an overall working gas volume of 20 billion m^3 can be expected towards the end of the next decade.

It should be noted that the total amount of gas stored in underground storage facilities is roughly twice the amount of working gas which can be used for load matching. Half of the total amount of gas held in the storage facilities remains there as so-called cushion gas.

2.3 The Ruhrgas Network as Part of the German Gas Supply System

The natural gas transmission and supply system operated by Ruhrgas AG, Essen, forms the backbone of the German pipeline system (**Fig. 9**).

In line with Ruhrgas's function as an importing gas merchant company the transmission systems operated by Ruhrgas connect the trunklines of foreign and domestic suppliers with the main consumption centres in Germany and form a grid with the systems of neighbouring countries (France, Switzerland, Italy) to fulfil transit functions.

Today, the length of the Ruhrgas network is approx. 9,316 km (as at December 1993) (**Table 2**).

The pipeline diameters of this system range from 150 mm to 1,200 mm, approx. 70 % of the pipelines having a diameter of more than 500 mm.

The operating pressures range between 1 bar and 84 bar; only approx. 10 % of the pipelines are operated at pressures below 16 bar.

The system components are:

- 22 mainline compressor stations with a total installed capacity of approx. 660 MW.
- 6 storage facility compressor stations with a total installed capacity of 50 MW.
- 12 underground storage facilities (7 storage reservoirs, 5 storage caverns) currently holding a total of approx. 3.5 billion m^3 of working gas.
- approx. 150 metering and regulating stations in the network to regulate pressure and gas quantities and to meter the gas flows.

- approx. 1,600 metering stations metering points on the customers' side.

The length of the Ruhrgas network has grown by approx. 15 % in the last 10 years.
It is foreseeable that the system will have to be extended by just after the turn of the century by:

- approx. 1,000 km of pipelines (+10 %)
- by a compressor capacity of approx. 140 MW (+20 %)
- by storage capacities of approx. 1.8 billion m^3 of working gas (+50 %).

The projects being implemented or planned concentrate on North Sea gas - in anticipation of the additional contracted quantities of Norwegian gas from the Sleipner and Troll fields.

The investments made and to be made in this connection are (**Fig. 10**):

- Ruhrgas stake in the EGL (Erdgas-Lager-Etzel) with usufructuary rights in the existing Emden-to-Etzel pipeline and the Etzel underground storage facility.

- Ruhrgas stake in the NETRA pipeline system from Etzel via Wardenburg to Salzwedel, which is nearing completion (approx. 290 km DN 1200/PN 84) and through which Norwegian natural gas is to be moved towards Berlin and eastern Germany.

- Ruhrgas stake in the Salzwedel-to-Berlin pipeline, which was put into service in the autumn of 1994 (180 km DN 1100/PN 84).

- Construction of the second Ruhrgas northern line from Wardenburg via Drohne to Werne (approx. 200 km DN 1200/PN 84) to carry the additional quantities of Norwegian gas expected from the Troll sales agreement to the consumption centres of Rhine/Ruhr/Westphalia, Saxony/Thuringia and southern Germany.

- Expansion of the DEUDAN pipeline system (Ellund - Quarnstedt) to permit additional gas to be purchased from the Danish North Sea.

Once these projects have been completed, the offshore systems (EUROPIPE, etc.) connected to the fields to be developed, and production from the Troll field commenced, the technical prerequisites for the long-term placing of additional Norwegian and Danish natural gas on the German and European markets will have been created.

3. The German Gas Transportation System as an Integral Part of the European Gas Transmission Grid

The main trunklines of the German natural gas transmission system are - due to tie-ins with the pipeline systems of neighbouring gas supplier and consumer countries - integral parts of a crossborder European transmission grid which has now assumed the character of a transcontinental gas transmission system interconnecting three continents since the east European/Siberian transportation systems and the south Italian/north African systems have been linked up (**Fig. 11**).

The MEGAL pipeline system from Waidhaus/Bavaria to Medelsheim/Saar is the direct continuation of the gas transmission systems coming from Siberia and passing through the European parts of Russia, the Ukraine, Slovakia and the Czech Republic.
The distance between the west Siberian fields near Urengoy and the Franco-German border at Medelsheim is approx. 6.000 km.

The transport system leading from the Netherlands through the Federal Republic of Germany and Switzerland to Italy (TENP, TRANSGAS) has established the connection to the Algerian gas fields near Hassi R'Mel through the pipeline which crosses the Mediterranean from Sicily to Tunisia (TRANSMED).

The northern pipeline from Emden to Werne, which is currently under construction, and the second northern pipeline, which is scheduled to go into service in autumn 1995, together with NETRA will connect the gas fields in the Norwegian and Danish North Sea with the central European centres of consumption as continuations of the North Sea offshore pipeline systems.

The links with the gas producing regions in the North Sea, the Netherlands, northern Germany, Russia and north Africa created by this and other systems are the technical prerequisite for the present diversification of gas purchase sources, which has made a substantial contribution towards the security of energy supplies in the Federal Republic of Germany and western Europe.

4. Conclusion/Outlook

The existing and expanding gas transportation network in German enables the gas industry to ensure that natural gas, a high-grade and environmentally compatible energy source, can be transported from the various supply sources to the consumption centres reliably well into the next century.

Despite all scepticism about energy forecasts, it can be assumed that the underlying trend is correct: natural gas will be the fastest growing energy in western Europe in the next 20 years. However, this development will not come about automatically. It calls for major efforts in the technical and commercial fields by the gas industries concerned. The staff must continue to contribute their technical and commercial skills and experience, and the companies must devote huge capital expenditure to the construction of new pipelines within and outside gas-consuming countries. This will make it possible to maintain the supply level reached and to handle anticipated increases in demand with the aid of long-term contracts for the purchase of natural gas, a fuel with a promising future.

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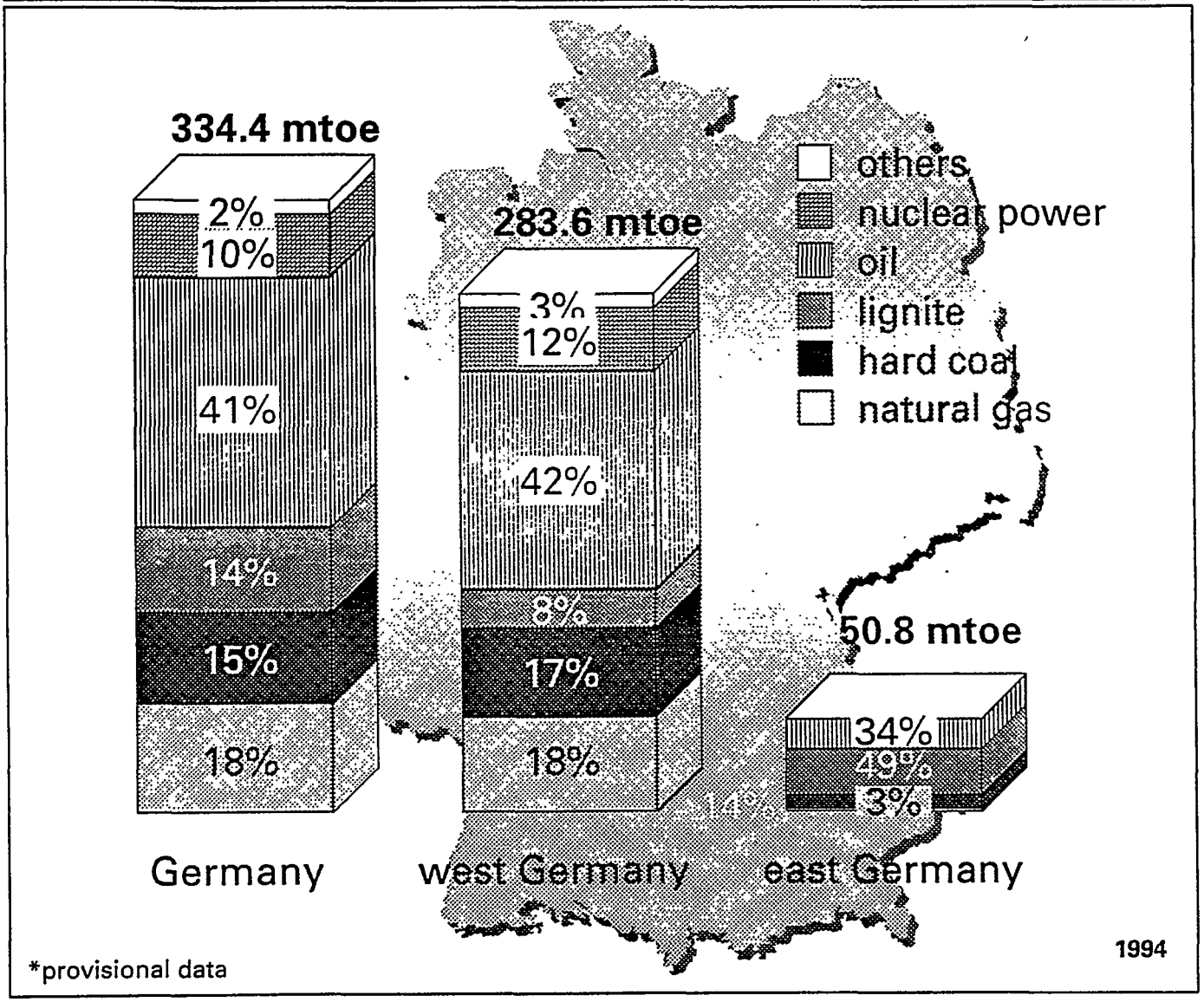
6. List of Figures/Tables

Figure 1

1993 German Primary Energy Consumption by Sources of Energy*

ruhrgas



*provisional data

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Figure 2

1993 German Natural Gas Supplies*

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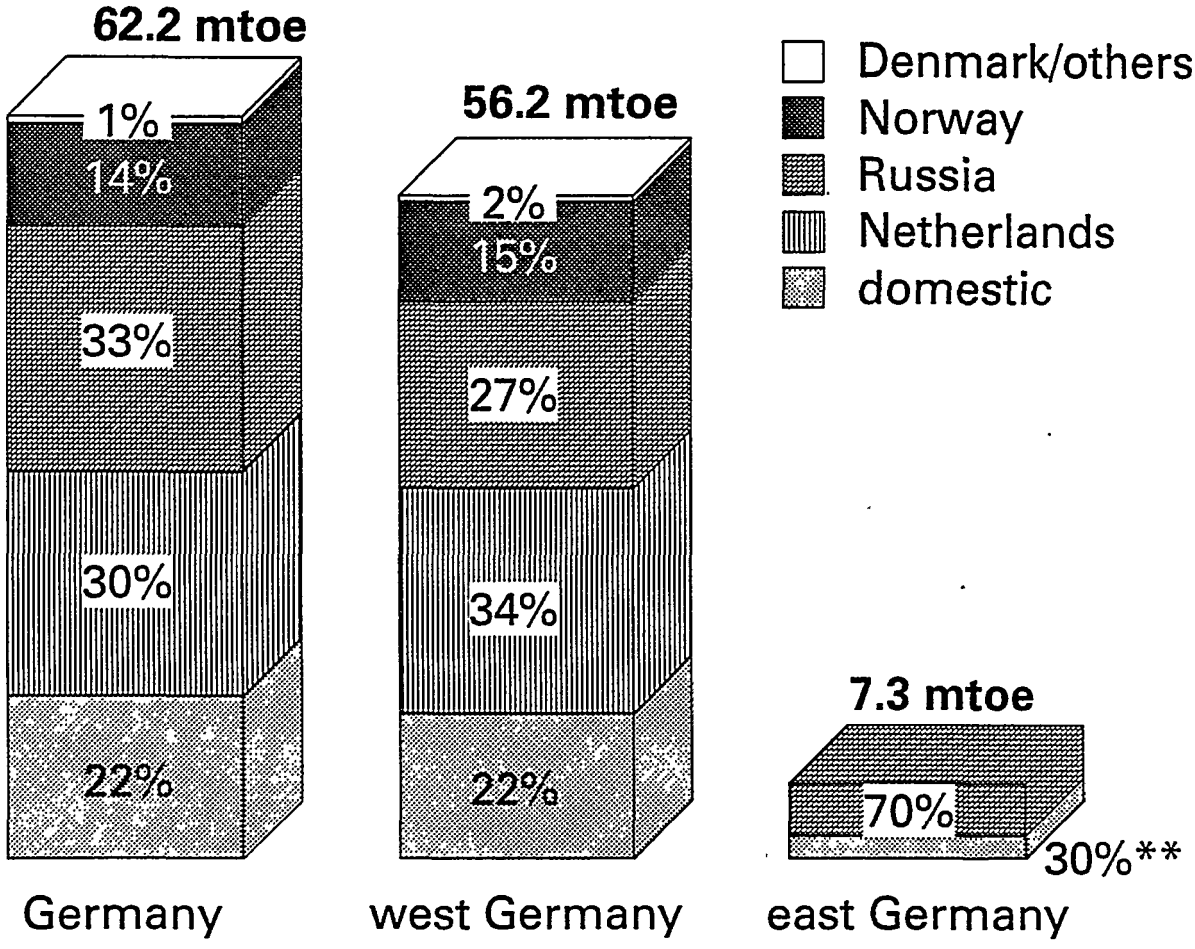

* provisional data
** incl. west-east deliveries

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Figure 3

Gas Lines in Germany

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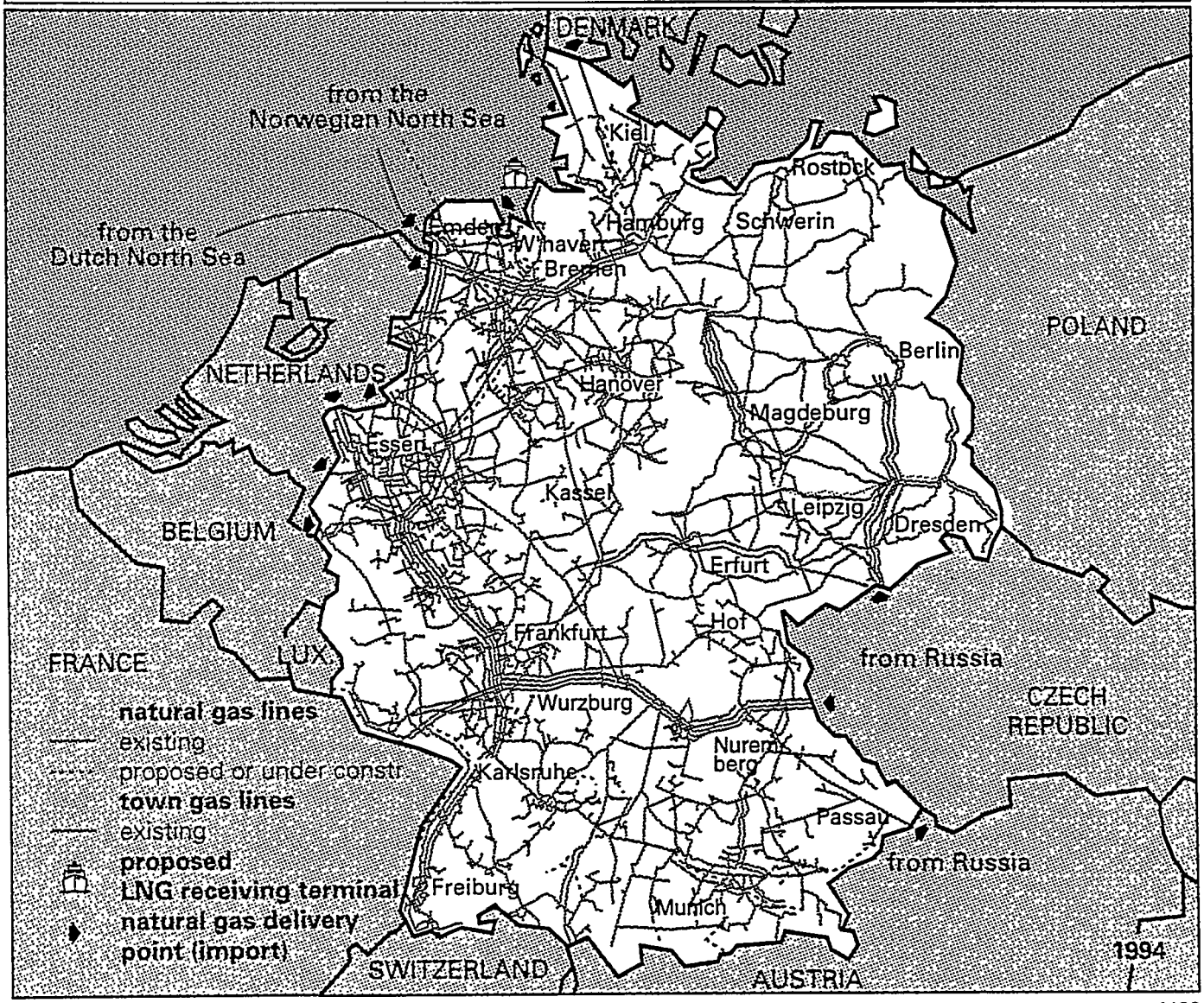

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The German Supply Network: Network Length

(Western and eastern Germany in 1993)

Pressure stage	Network length in km
Low-pressure network[1]	approx. 118,000
Medium-pressure network[2]	approx. 80,000
High-pressure network[3]	approx. 82,000[4]
Total network	approx. 280,000

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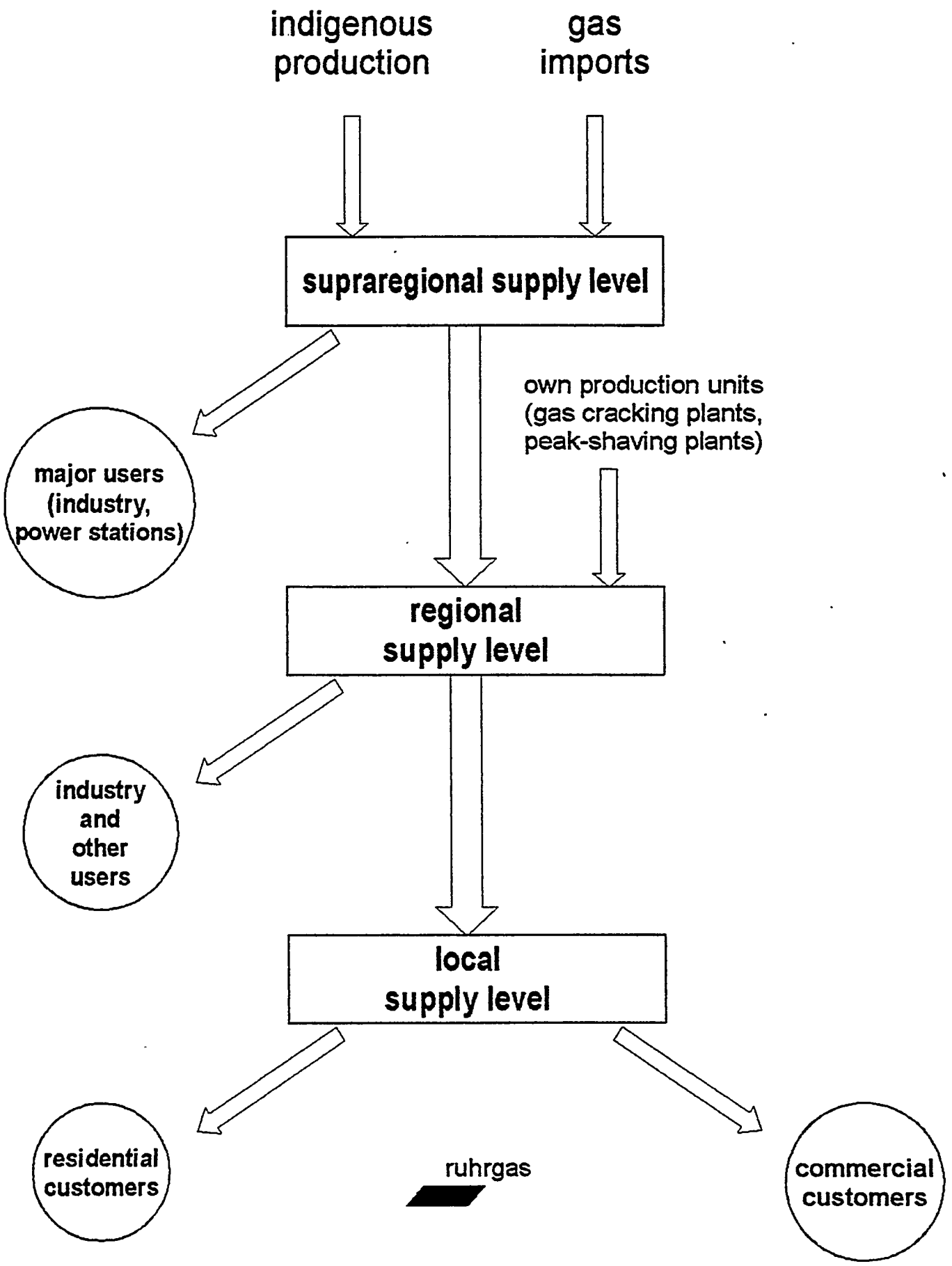
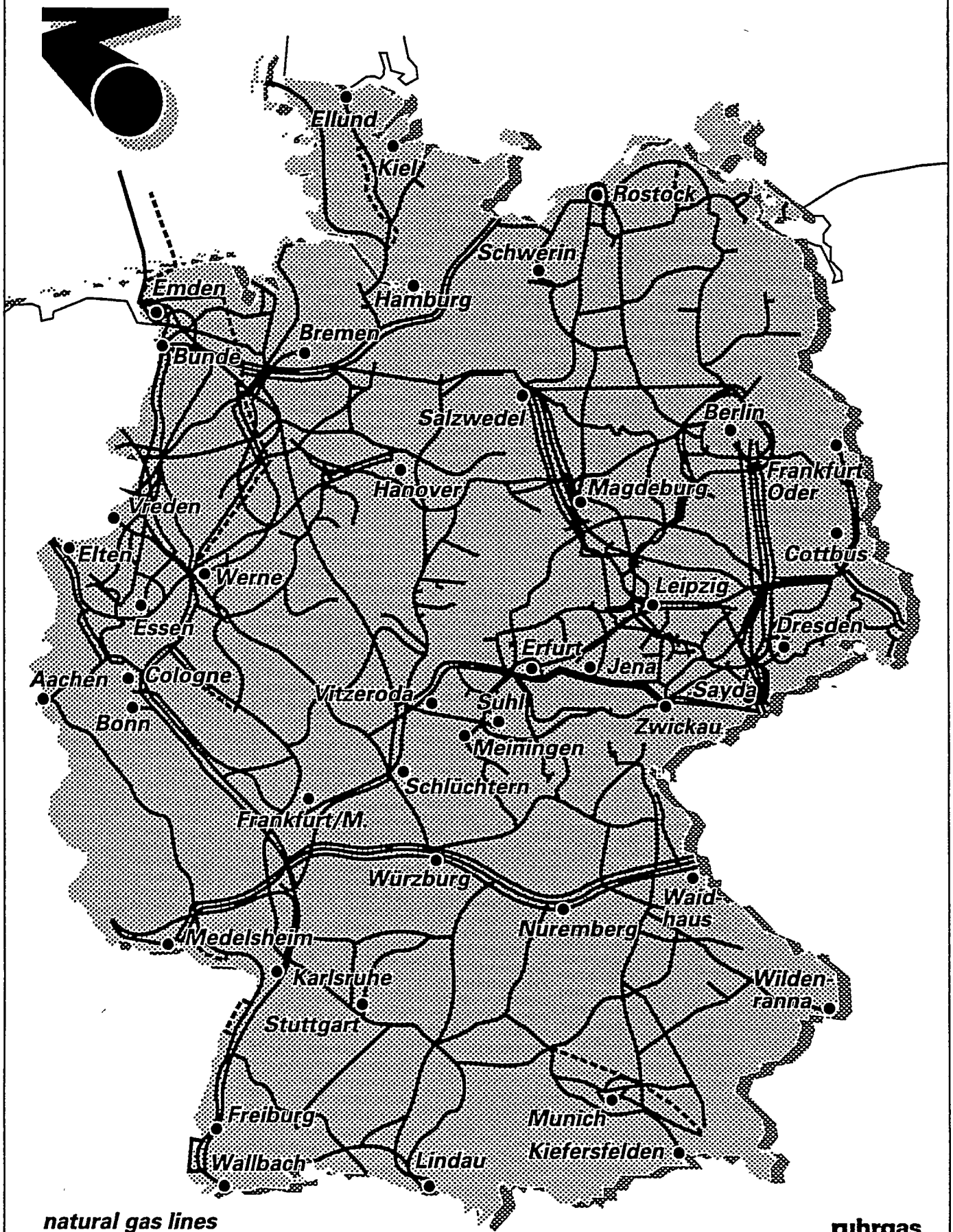
[1] 25 - 100 mbar (gauge pressure)
[2] 0,1 - 1 bar (gauge pressure)
[3] > 1 bar (gauge pressure)
[4] approx. 44,000 km of which belonging to gas merchant companies and gas producers

Figure 4

Natural gas supplies



Gas Pipelines in Germany



natural gas lines
—— existing
---- under construction/planned

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Figure 6

Deployment of underground storage facilities

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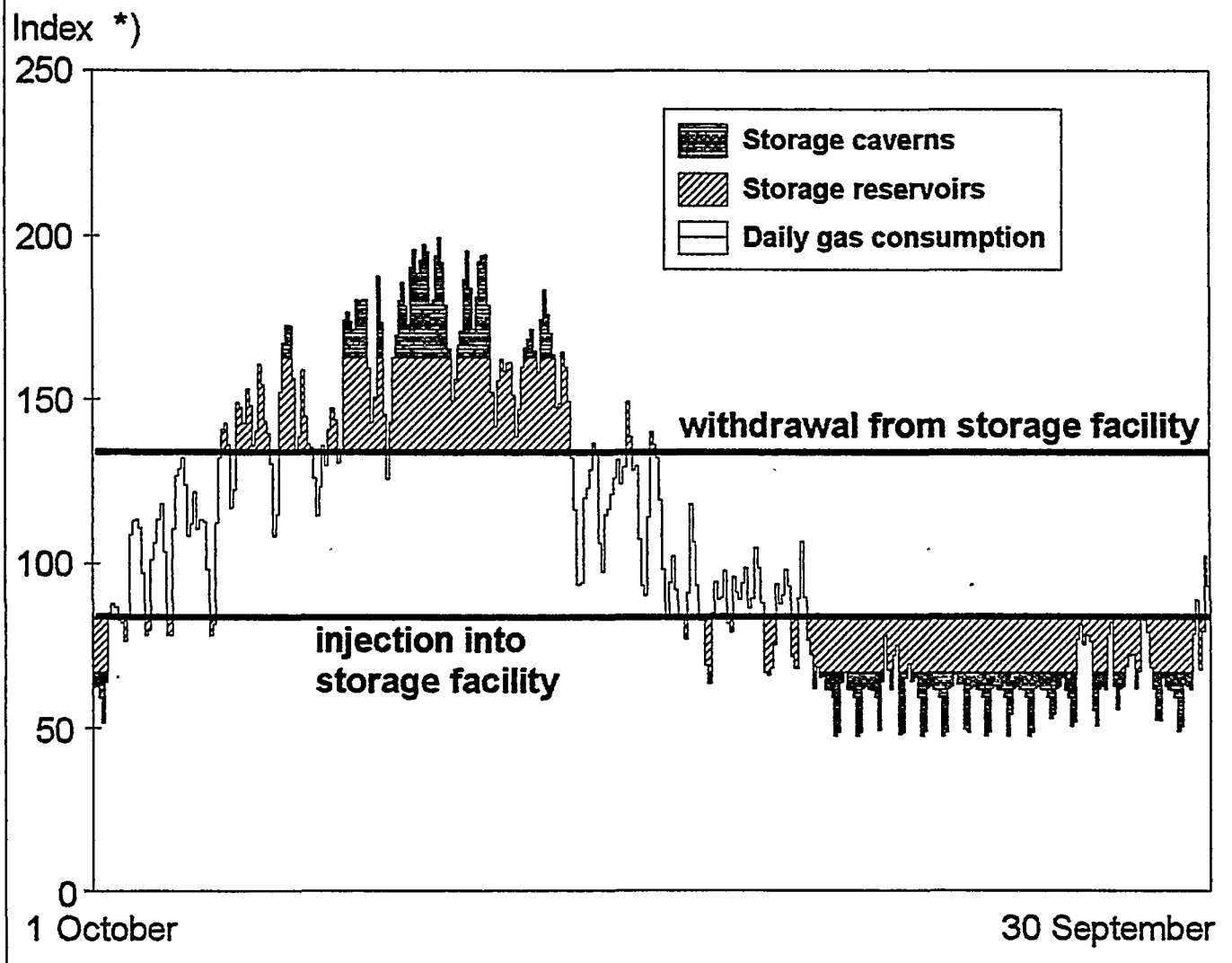

*) 100 = average daily consumption given average annual temperatures

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Figure 7

Natural Gas Storage

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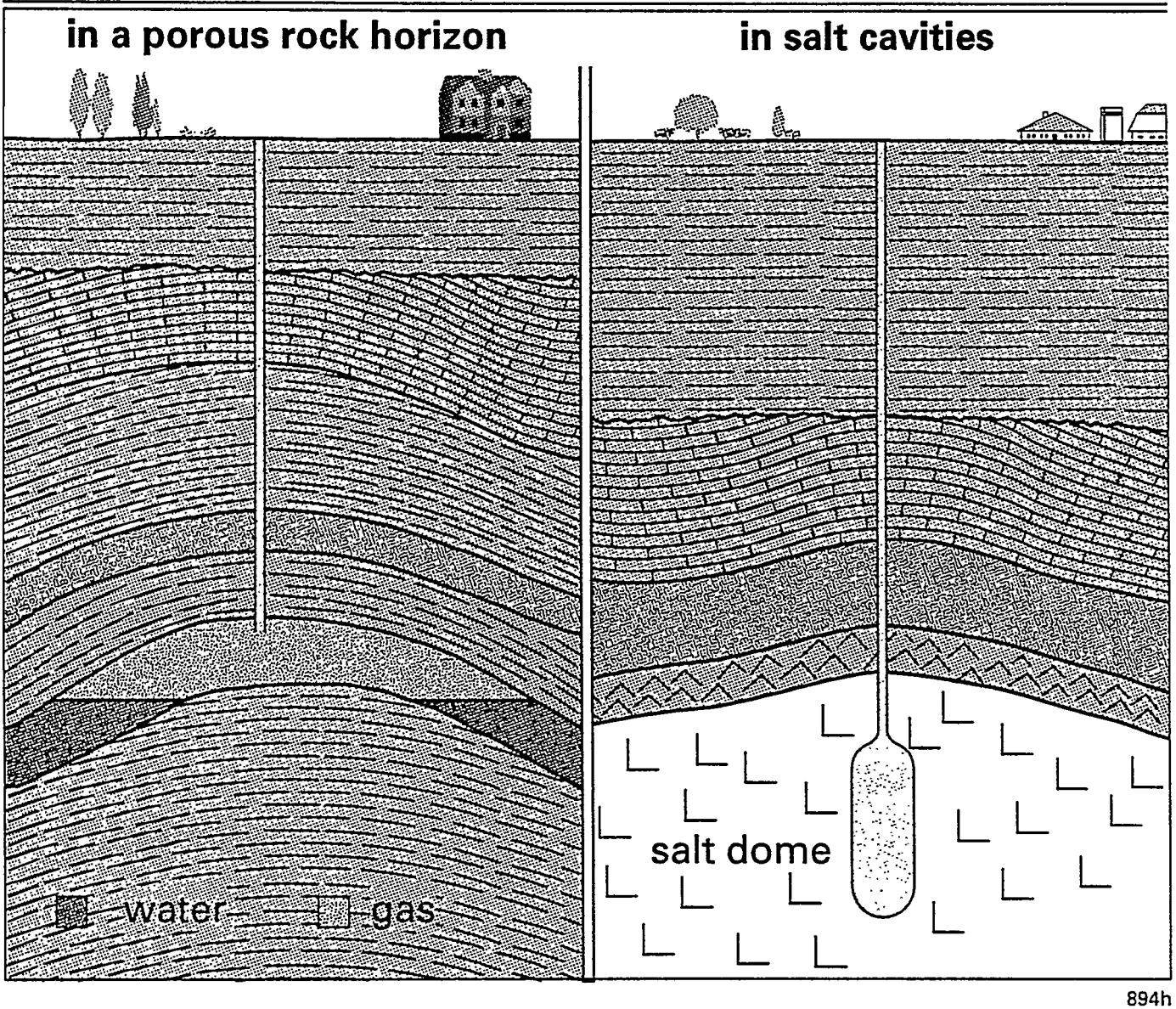

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Figure 8

Facilities for the Underground Storage of Natural Gas in Germany

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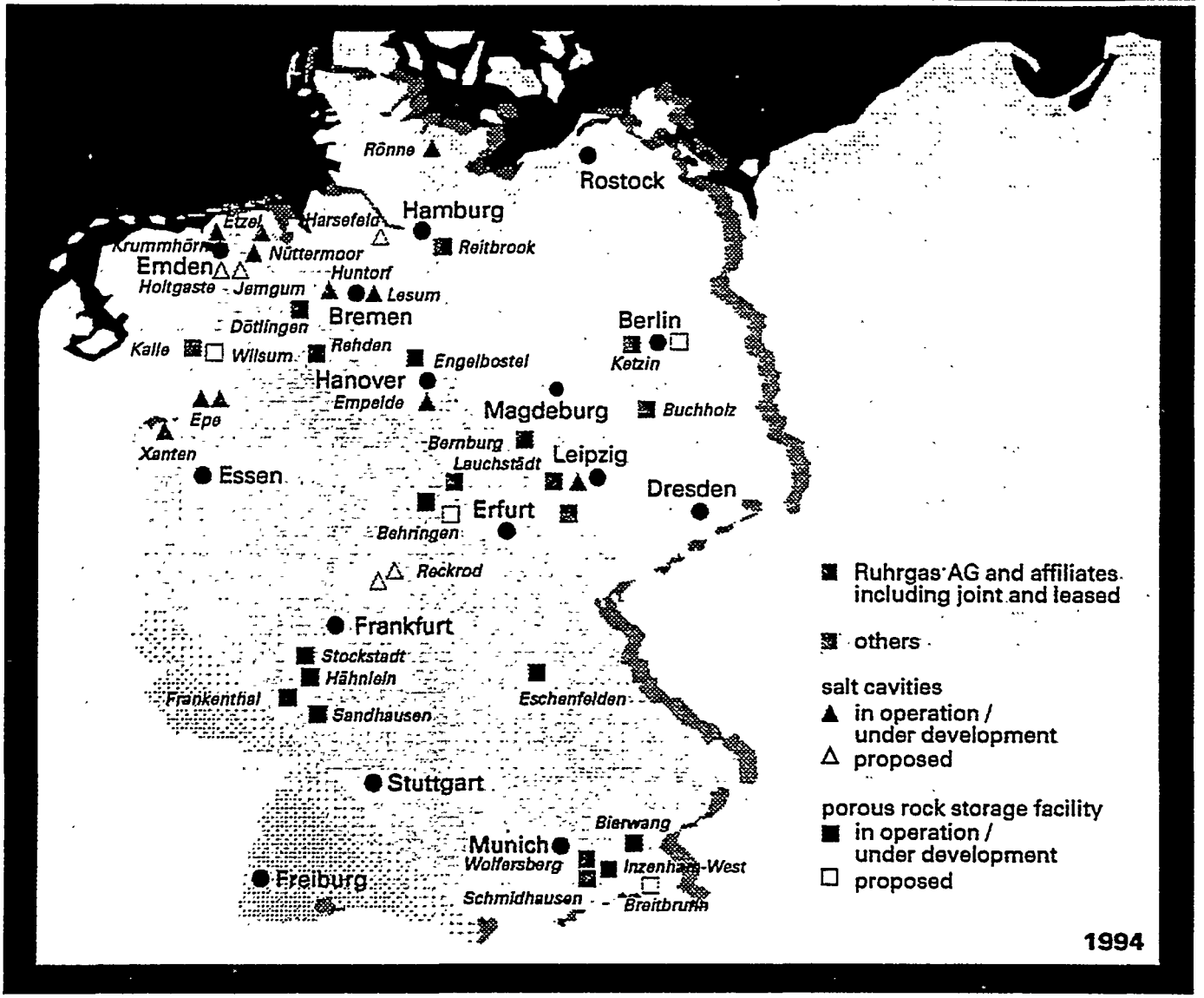

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Elements of the Ruhrgas Network

Pipelines	Length : 9.316 km
	Diameter : 150 - 1200 mm
	Pressure : 1 - 84 bar
Metering and regulating stations	150 Metering and regulating stations
	1600 Customer Stations
Compressor stations	22 Main line stations with a capacity of 660 MW
Underground storage facilities	7 Storage reservoirs with 2.1 billion m^3 of working gas
	5 Storage caverns with 1.4 billion m^3 of working gas

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Figure 9

The Ruhrgas Pipeline System

including joint, leased and joint-venture facilities

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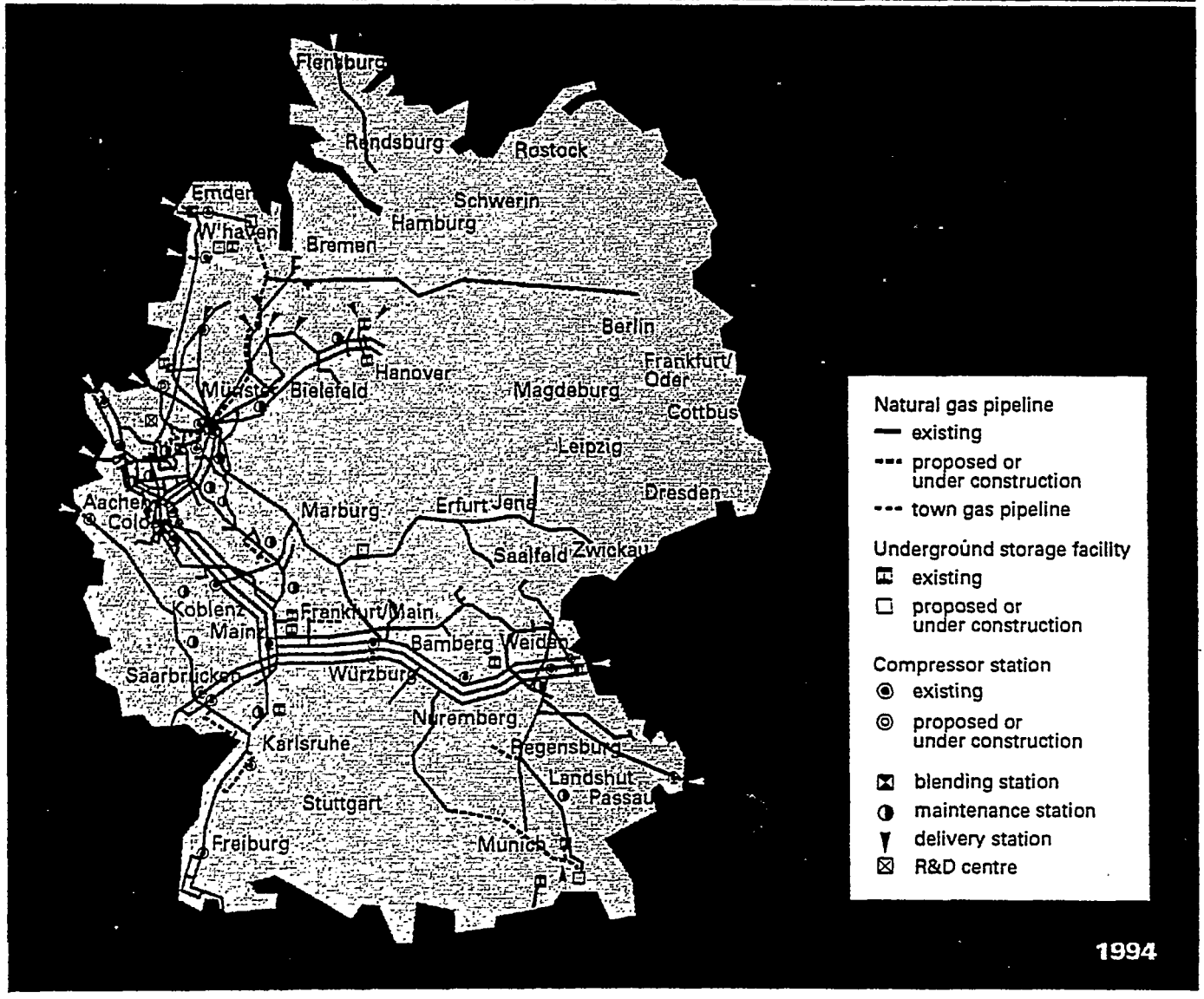

Figure 10

Pipeline Projects in Northern Germany with Ruhrgas Participation

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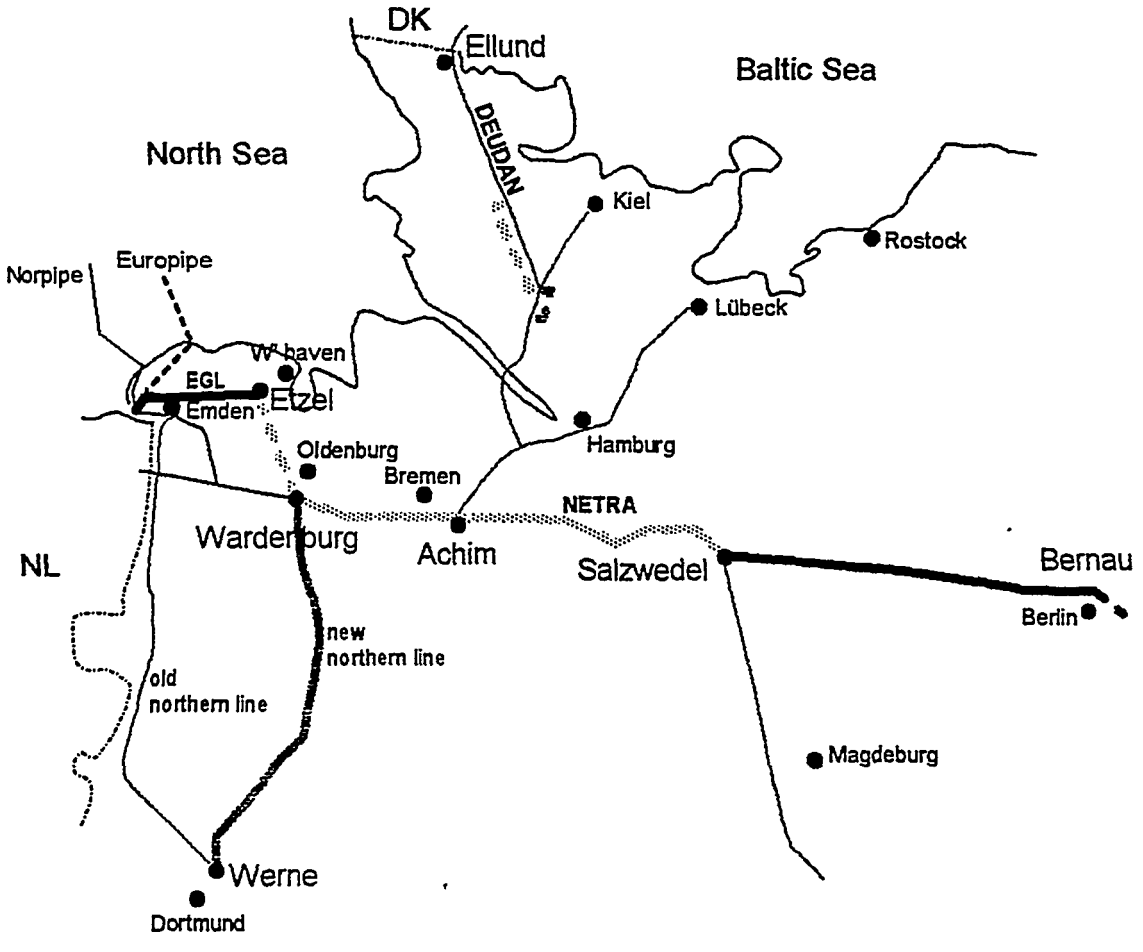

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Figure 11

European Natural Gas Transmission System

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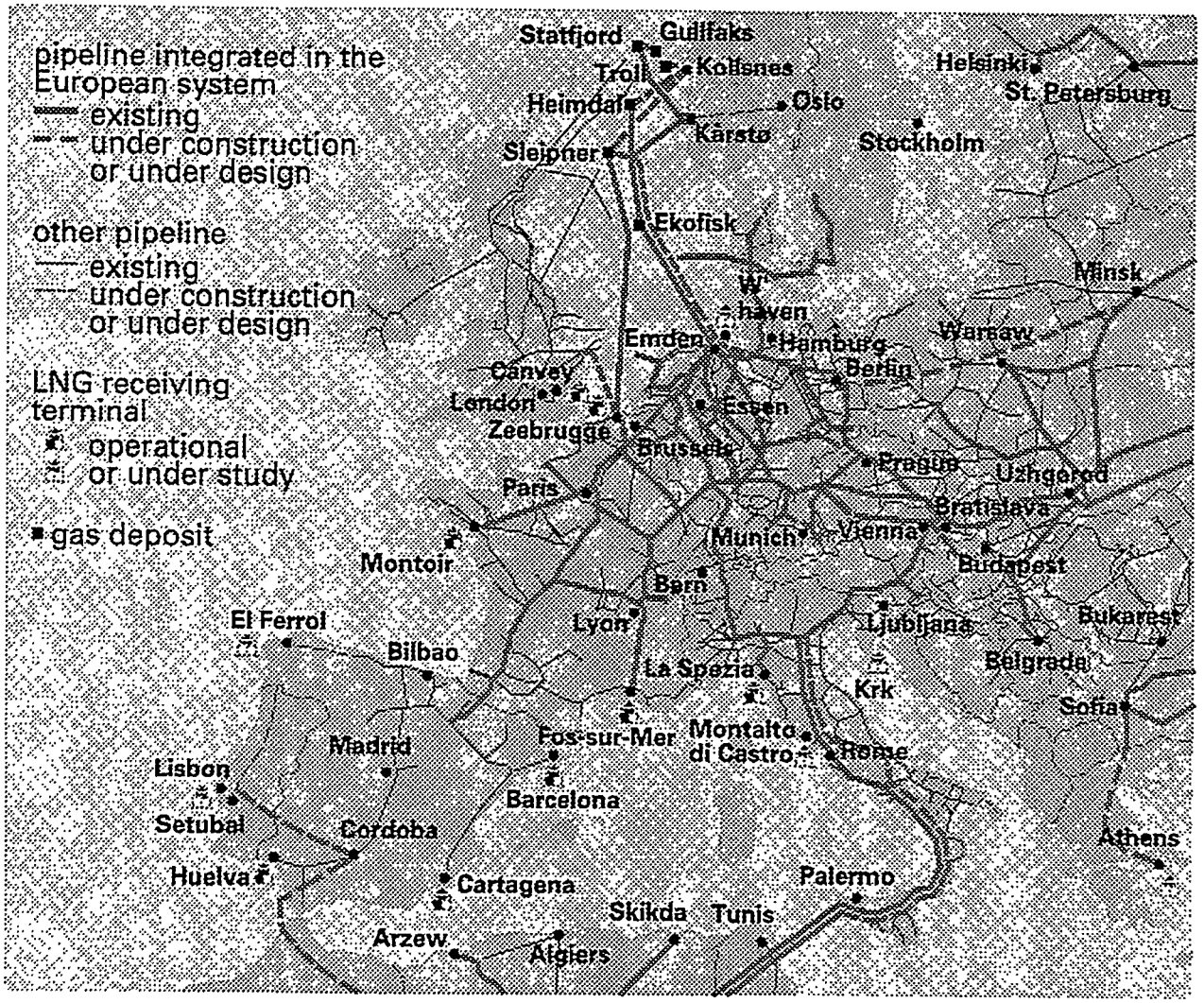

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