ELECTRICITY TRADE IN CENTRAL EUROPE

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ABSTRACT

This thesis examines the electricity supply and trading positions of the four Central European states; Poland, Hungary and the Czech and Slovak Republics. These states are situated at 'the cross-roads of Europe' and share a common history of centralised Socialist government. The unprecedented events of 1989 allowed them to contemplate a common goal of achieving membership of the wider European community and its institutions, following the example of their former ally, East Germany. This process of shaking off the legacy of the Communist past and looking towards the West extends to the field of connection of electricity supply networks.

Throughout the history of electricity supply, the trend has been to connect regional supply networks together into larger national or international grids. This provides for many advantages in terms of reduced costs and increased security of supply, detailed in this thesis. Interconnection also requires significant investment, in both transmission equipment and grid control measures, and this investment must be recovered. Methods for recovering this investment and correctly allocating the costs and benefits of interconnection are detailed in this thesis.

In Europe the process of grid connection has reached the present state of four international 'supergrids', each with different characteristics. The removal of the barrier of mutual suspicion between East and West has allowed consideration to be made of increasing the degree of connection between these networks and the volume of power traded across these connections. In order for this to take place a number of technical problems must be overcome and a clear economic case for the benefits must be made. To build such a case, a detailed examination is made of the energy supply position of each of the states, the structure and capacity of their electricity supply industries and the historic level of electricity traded between them.

The Central European states common desire to join the European Union will have a significant impact on their electricity supply industries, particularly with regard to their environmental problems, but also provides access to sources of finance for investment in improving their systems. The study assesses the implications of the European Internal Energy Market and the effects it will have on the four states. An examination will be made of planned and projected interconnections in Europe and the benefits that these will bring.

The thesis ends with some conclusions on the likely course that expansion of the European power system into Central Europe will take. This includes analysis of future electricity trade patterns and their impact on electricity supply development in Poland, Hungary and the Czech and Slovak Republics.

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Abbreviations and Acronyms

EBRD - European Bank for Reconstruction and Development

EFTA - European Free Trade Association

EIB - European Investment Bank

ESI - Electricity Supply Industry

EU - European Union

HVDC - High Voltage Direct Current

IEM - Internal Energy Market (of the European Commmunity)

IPS - Integrated Power System (of Central and Eastern Europe)

PHARE - Poland and Hungary Aid for Economic Restructuring

UCPTE - Union for the Co-ordination of Production and Transport of Electricity

UPS - Unified Power System (of the Soviet Union)

Conversion Factors

		To:					
	Multiply By:	MJ	kWh	Btu	therm	tce	toe
To Convert:	Megajoule MJ	1	0.278	947.9	9.48E-03	3.80E-05	2.20E-05
	kilowatt hours kWh	3.6	1	3412	3.41E-02	1.37E-04	8.00E-05
	British Thermal Units Btu	1.06E-03	2.93E-04	1	1.00E-06	4.00E-08	2.34E-02
	therm	105.5	29.3	1.00E+06	1	4.00E-03	2.34E-03
	tonne coal equivalent tce	2.64E+04	7.33E+03	2.50E+07	250	1	0.588
	tonne oil equivalent toe	4.48E+04	1.25E+04	4.25E+07	425	1.7	1

1 million toe = 1.11E+09 cubic metres natural gas

Heat Content of Fuels

	MJ	Per Unit
Anthracite	26797	ton
Bituminous Coal	27641	ton
Briquettes	29540	ton
Coke	26164	ton
Lignite	14770	ton
Coal Tar	42	litre
Butane	4520	bbl
Propane	4054	bbl
Diesel	6125	bbl
Distillate	6145	bbl
Gasoline	5542	bbl
Shale oil	6119	bbl
Blast Furnace Gas	4	cubic metre
Coke-oven gas	20	cubic metre
Natural Gas	39	cubic metre

SI Unit Multipliers

Exa	E	1.00E+18
Peta	P	1.00E+15
Tera	T	1.00E+12
Giga	G	1.00E+09
Mega	M	1.00E+06
Kilo	k	1.00E+03

For my wife, Moira, and my son, Samuel.

"Knowledge can be communicated, but not wisdom."

Herman Hesse, (1877-1962)

CHAPTER 1: INTRODUCTION AND BACKGROUND.

1.1 Introduction

This thesis examines electricity supply and international trade of electric energy in Central Europe; Poland, Hungary and the Czech and Slovak Republics (Figure 1.1.1). For many centuries this area was the 'cross-roads of Europe', until the division of Europe into a Socialist Eastern Bloc and a democratic Western Bloc following the end of the Second World War. The division that was the 'Iron Curtain' fell at the end of 1989, ending over 40 years of an uneasy peace known as the Cold War. These events have allowed the Central European states to become more Western oriented and to regain their position at the heart of Europe, providing an interface between the economically powerful nations of the European Union and the new states created by the dissolution of the Soviet Union.

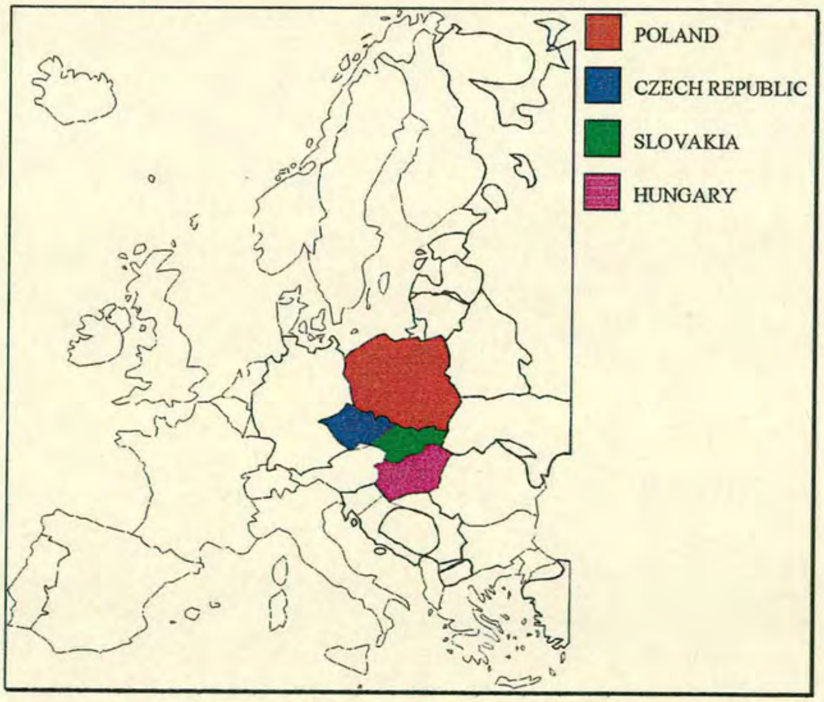


Figure 1.1.1 Central Europe

In addition to their geographical location, the four states of Central Europe share a common recent history of Socialist government and central planning. While each state had a slightly different experience under this system, its removal has left them with some common problems in the establishment of democratic government and economic reform. These reforms have proceeded at different rates in each of the states, but they have all advanced further towards these goals than their neighbours to the South (Romania, Bulgaria and the former-Yugoslavia) and East (Russia, Ukraine and Belarus). Their shared aim of full membership of the European Union now seems likely to be achieved by the end of the decade.

In the field of energy supply, the system of central-planning and the international Socialist trading organisation, the Council for Mutual Economic Assistance (CMEA), produced a dependency on cheap energy supplies from the Soviet Union and insulated their economies from the effects of the 1970s oil price shocks. The hangover from this addiction is now apparent in the environmental damage caused by large-scale inefficient energy use with little or no attempt made to control pollution. With the exception of Poland, these states have also inherited a stock of Soviet designed nuclear reactors which fall well short of Western safety standards.

Under Socialist government, the Electricity Supply Industries suffered from under-investment in new generation, network improvement and the rehabilitation or replacement of ageing equipment. The fall in demand precipitated by the economic recession following removal of the communist governments has provided a breathing space to address these problems, and all four states intend privatisation and restructuring of their ESIs to aid in their solution. However, with electricity supplied at well below cost, and with resistance to price rises for social and anti-inflationary reasons, foreign capital and investors may prove wary of entering these new markets. One potential solution to this would be to allow new entrants and existing capacity in the generation sector to sell part of their output to the West at the higher price levels prevailing there.

This leads to the main focus of this thesis; the interconnection of the Central European's electricity supply network to facilitate the trading of electric power. The motivations for, and benefits derived from, interconnection are examined further in this chapter. The second chapter provides an account of the existing interconnected networks in Europe. Both Western and Eastern Europe possess a high degree of interconnection between their national networks with significant volumes of power traded within these systems, but the years of mutual suspicion during the Cold War resulted in a very low level of connection between the two halves of Europe. The removal of political barriers to increased trading of electric power allows the technical and economic issues behind increased trading to be examined.

Each of the four states examined in detail in the following three chapters have greatly varying energy and electricity supply positions; ranging from an abundance of coal in Poland, to a high degree of import reliance for primary fuel supply in Hungary. These chapters examine the historic, current and projected primary energy and electricity supplies in Central Europe and proceed to cover the structure of the Electricity Supply Industries and their future prospects. In addition, the four states' historic and current volumes of traded electric power and associated contracts are detailed.

The process of achieving membership of the European Union involves acceptance of European legislation into national law. EU law already impacts heavily on the ESIs of its current members and EU plans for increased liberalisation of energy markets will increase this impact. These plans and their impact on the Central European states are described in Chapter 6. Details of planned and projected interconnections across Europe are described, along with some of the possible problems which must be overcome before the Central Europeans may become full members of the wider European electric power trading organisation.

1.2 Objectives of Thesis

This thesis aims to demonstrate that the direction of Electric Power Networks has historically been to increase in geographical extent and installed capacity, and that there is no overriding reason for this process not to continue in Europe in the future. The first chapter of the thesis will argue that -

- Interconnection has not always occurred for purely economic reasons but has often been driven by political considerations.
- Investment in interconnection of networks may be recovered equitably from the parties benefiting from the services provided by the interconnector. This process

can be greatly improved by the fair and transparent pricing of electric power and network services.

- The structure of the Electricity Supply Industries co-operating in interconnector projects affects the importance of demonstrating the economic benefits of interconnection and the systems developed to govern their use.

The second chapter provides supporting evidence for these claims through a high level examination of the development and current state of the four major interconnected networks in Europe. The different potentials for growth in the demand and supply sides of these markets provides the initial justification of an economic case for greater interconnection between them. Their existing and historic patterns of power trade and methods for managing this trade will provide an indication of the likely direction of future development across the continent.

The following three chapters provide a more detailed examination of the four countries which form the focus of the thesis. Their individual energy balances and fuel resources show how they might benefit from an increased ability to trade with their neighbours in the West. As the development of the electricity supply industries does not occur in isolation, the wider political and economic framework of these states is first examined. The existing and planned assets and structures of the Electricity Supply Industries are detailed to support the conclusions on the benefits of trade and the different strategies for interconnection.

As stated above, political, as well as strictly economic, motivations have governed the development of interconnected electric power networks. Chapter six examines the wider political situation which will govern future developments; specifically the role of the European Union in the arena of electricity and energy supply and trading. It is argued that this role is likely to increase in scope and to have a profound effect on the development of pan-European electric power trade.

Finally, the arguments developed above will be drawn together to provide some conclusions on the current plans for the development of interconnections between Western and Central Europe and how they might be extended without incurring excessive costs. This includes an assessment of where the initial investment capital may come from, who the beneficiaries of increased power trade will be and where the costs should be allocated to provide an equitable sharing of the benefits.

1.3 Development of Electric Power Networks.

Electric power supply networks as we know them today can trace their roots back to the pioneering work of Thomas Edison in the 1880s. Edison developed a system of D.C. generators coupled to a distribution system for supplying incandescent lights in town centres. This system was steadily developed and improved to increase economy and encompass the supply of motive power. The use of direct current, however, meant that effective and economical transmission of power was not possible, and the resulting system was tied to centres of significant load.

In 1884, an A.C. system of transmission designed to overcome this inadequacy was demonstrated in Italy inspiring subsequent development of A.C. systems. The invention and development of practical A.C. motors ensured the eventual primacy of this system over D.C., using transformers to step-up voltage to reduce transmission costs. This allowed the development of central generating stations removed from the centres of demand, such as the exploitation of hydro-electric power at Niagara, Canada and its utilisation at Buffalo, twenty miles away. However, a barrier still existed to the connection of systems in neighbouring utilities; the problem of differing frequency standards adopted by the manufacturers and owners of systems.

The imperatives of increased production forced by the First World War resulted in the construction of large scale power plants. Many regional power systems became connected to take advantage of resulting economies of scale and this began to solve the problem of standardisation of frequency and voltage. Following the war, in 1919 Germany passed an electrification law designed to nationalise electricity supply and create an integrated grid system. Despite extensive debate and planning studies, this act was never implemented, but it did identify many of the benefits of interconnection and inspired further ideas.

One such idea was that proposed by Oskar Oliven at the Berlin Power Conference in 1930. He envisaged a high voltage grid stretching from the Ukraine and Norway in the East and North to Portugal and Italy in the West and South. Such a grid would allow the hydro-power resources of the Alps and Scandinavia and the coal resources

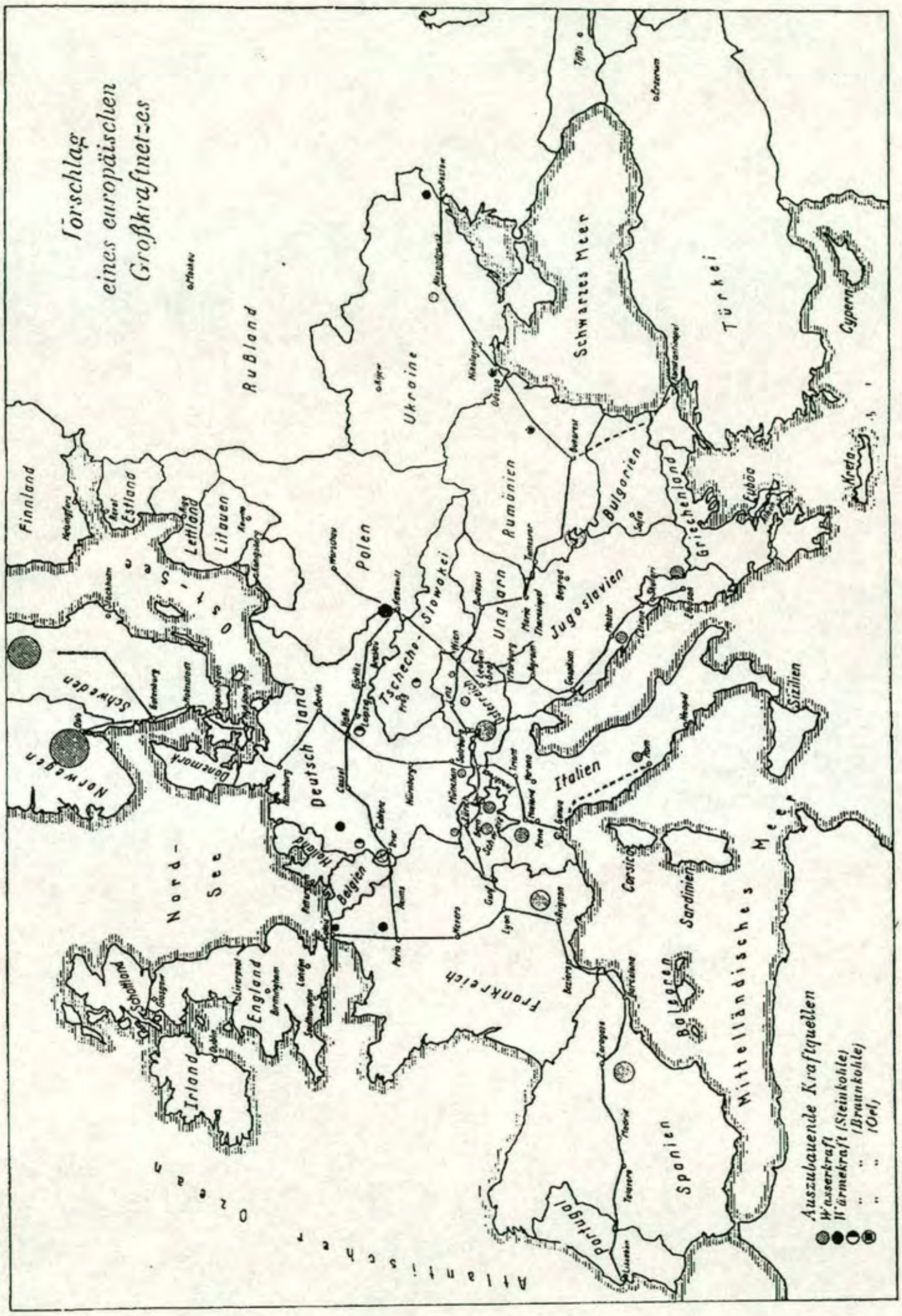


Figure 1.3.1 Oliven's Proposed European Grid System

of Central and Eastern Europe to supply the growing industrial and urban centres. (Figure 1.3.1) However, the organisation of this grid system would have to overcome not only the local and parochial interests which held back interconnection in Germany, but the international mistrust in Europe at that time. While Oliven believed that his goal of increased interconnection and efficiency was not political, he was realistic enough to recognise that his proposed grid would only come about by small incremental steps. In this he was correct, but it would not be until after the Second World War that his vision would begin to form in reality.

1.4 Motivations for Network Interconnection.

As mentioned above, it took some time before the benefits of interconnection, even within countries, began to become apparent. Although many of the arguments set against the formation of grids were spurious, some disbenefits of this process may be recognised. Plant supplying high load factor industrial demand may have to operate more flexibly when interconnection encompasses lower load factor rural and urban demand, with a reduction in efficiency. Less efficient plant and plant with low load factors supplying local grids may become stranded assets on connection with larger systems and the resulting competition. Although the formation of grids should result in lower average costs across the system, consumers who previously benefited from low cost locally generated power are likely to see an increase in costs.

Political pressure for increased electrification of rural areas and the commercial desire of low-cost generators to increase their revenue have generally been sufficient to overcome these objections on a national level, especially when weighed against the advantages of interconnection. Connecting grids to enlarge total consumption allows economies of scale and greater efficiency to be achieved by the increased capacity of generation plant. Higher transmission voltages may also be justified in a larger grid, reducing network losses. An interconnected system standardising to the same frequency and voltages also forms a larger and more open market for electrical equipment manufacturers.

An interconnected system provides a diversity of demand, tending to smooth variations in aggregate load across days and seasons. An illustration of this is the UCPTE system of Western Europe (see Chapter 2.1) where the system peak load was 241.7GW in 1994. The individual member's peak demands, however, occurred at different times across the winter and totalled 251.4GW. Supplying these twelve system demands individually would therefore require nearly 10GW of extra plant to be available, before accounting for any reserve requirements.

The formation of grid systems also allows for diversity of supply, with generation plant using different primary fuels connected in parallel. This shows particular benefit in systems with a good mixture of hydro and thermal plant (e.g. Nordel, Chapter 2.2) where the marginal cost advantage of hydro plant may be exploited at times of good water availability and at times of drought the thermal plant may be used to cover demand. A system with a mixture of different primary fuels also provides a degree of insurance against extreme price movements in individual fuel supplies, such as the oil price shocks of the 1970s. Sources of primary fuel which are removed from load centres and are site specific (e.g. hydro) or uneconomic to transport (e.g. brown coal) are also better exploited in interconnected systems.

Requirements for reserve capacity are also lower in an interconnected system resulting in significant system cost reductions. The advantages deriving from the formation of interconnected systems may be summarised into two broad categories. The increase in fuel diversity, sharing of reserve and increase in number of sources of generation in the system contribute to increased security of supply, a factor of great importance to consumers. The improved load factor of the system, economies of scale in plant construction and the reduction in marginal production cost produce a more economically efficient system.

These factors apply not only to the formation of interconnected grids within countries, but also to the connection of these national grids into larger systems. However, these advantages must be considered against government's desires to be self sufficient in energy supply and electricity supply in particular. Mistrust between the nations of Europe between the wars dictated that mutual dependency in the field of electricity supply could not be considered and that Oliven's vision of a pan-European grid would remain just a vision.

The recognition that continued peace within Western Europe could be guaranteed by increasing economic co-operation and interdependence led to the formation of the

European Economic Community. The success of this organisation sowed the seeds which allowed Western European grid utilities to co-operate and connect their grids leading ultimately to the UCPTE system. In Eastern and Central Europe, the dictates of central planning and the Council for Mutual Economic Assistance (CMEA) achieved similar results in the formation of the UPS and IPS grids.

The benefits of economic co-operation and free trade are well recognised today and have led to the formation of many regional free-trade blocs. The benefits of co-operation in the electricity supply field and of international interconnection described above have also led to the formation of international grid networks, often following the groupings of nations into free trade areas. Regional grids currently exist or are being considered or developed in the following regions -

- Western Europe (UCPTE Chapter 2.1)
- Scandinavia (Nordel Chapter 2.2)
- Former Soviet Union (UPS Chapter (2.3)
- Central and Eastern Europe (IPS/CENTREL Chapter 2.4)
- Southern Africa (South Africa, Botswana, Zimbabwe, Mozambique)
- South America - CIER (Argentina, Brazil, Paraguay, Uruguay, Bolivia, Peru, Chile) [Kurtz 1995]
- Central America, CEAC (Honduras, Nicaragua, Costa Rica, Panama, Guatemala, El Salavador) [Nordel Annual Report, 1989]
- South East Asia (ASEAN), (Laos, Vietnam, Thailand, China) [FT, 1995]
- Mashreq (Turkey, Syria, Jordan, Iraq, Egypt) [Mackie, 1995]

- Gulf Co-operation Council (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, the UAE)
- Maghreb (Morocco, Algeria, Tunisia) [FT, 1994]

Studies by UNIPEDE [UNIPEDE, 1993] and others [Müller et al, 1992] have shown that there is no technical limit to the size of interconnected synchronous grid systems. Several of the organisations mentioned above are now considering the next step in the growth of interconnection - that of synchronously connecting their systems.

1.5 Methods of Interconnection

As regional grids began to be connected into larger networks solutions were found for the various problems of connecting grids with different frequency or voltage standards or as the cost of converting an existing system to another standard would have outweighed the benefits of interconnection. The formation of international groupings such as Nordel and the UCPTE allowed international standards for grids, with respect to frequency, voltage and control to be agreed, which in turn paved the way for synchronous interconnection of neighbouring systems - generally the least-cost option.

There still existed, however, technical and political reasons why synchronous interconnection between systems in Europe was not possible. In the Nordel system, use of High Voltage Direct Current (HVDC) conversion was justified between mainland Denmark (Jutland) and Norway and Sweden due to the length of the undersea cables, allowing the grid in Jutland to be synchronously linked to the UCPTE system. In this situation, HVDC is used due to the operational limitations of A.C. cables and the reduced cost of using two constant potential cables rather than a three phase system.

Mutual suspicion between the political systems in Europe dictated that synchronous connection was not possible between East and West. Technically, lower frequency and voltage control standards in the East meant that despite operating at the same frequency, the networks were not suitable for direct connection. Trade between the systems was still desirable for many of the reasons described above and several strategies developed to allow this despite the lack of synchronous connection as illustrated in Figure 1.5.1.

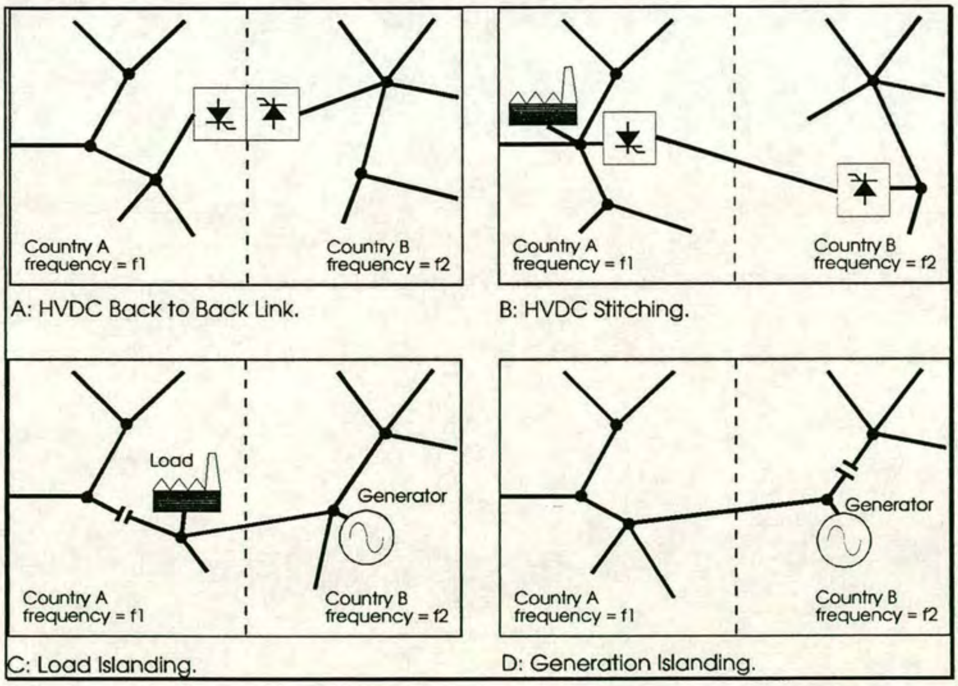


Figure 1.5.1 Methods of System Interconnection

A. HVDC back to back links are used where the asynchronous grids are adjacent. Transmission lines in each system are connected to a substation housing rectifier and inverter equipment for converting AC to DC and then back to AC at the frequency and phase of the other system.

B. Where the grids are not adjacent or the power flow is intended to supply a load centre embedded within a grid, the use of HVDC 'stitching' may be economically attractive.

C. In cases where traded power may be used by a single user or load centre, and this load is near the system border, a load 'island' may be created. Here the load is disconnected from its own grid network and connected synchronously to the neighbouring system. This technique may also be used to supply load in areas not connected to their domestic grid for geographical or economic reasons.

D. Where surplus generation capacity exists in a grid and the topography of the networks allows, a generation 'island' may be formed. Here, the generator is disconnected from its own grid and synchronised with the grid it is to supply.

1.6 Industry Structures

Local power networks were either formed by entrepreneurs and privately owned or publicly owned by municipal organisations. The extension and interconnection of these local networks towards national grids drove most countries to consider nationalisation, either of the high-voltage transmission grid or the whole Electricity Supply Industry. Electricity Supply was regarded as a 'Natural Monopoly', where competition was impossible and would lead to increased costs through the duplication of network investments. Governments often regard one of their roles as the protector of the public interest against monopoly exploitation, and nationalisation appeared to be a means to ensure this in the supply of an 'essential' service. Countries with a strong tradition of private industry, notably Switzerland and Germany, have, however, successfully co-ordinated the development of national grids without recourse to nationalisation, although regional networks still exist as 'natural monopolies'.

Following the Second World War, the provision of secure electricity supplies was seen as vital to economic re-development, and many countries chose to nationalise their ESIs to co-ordinate the development of their networks. In Central and Eastern Europe, the strictures of socialism dictated that all industry should be centrally owned and controlled and the ESIs were no exception. Government owned ESIs generally adopted vertically integrated structures, similar to that in England pre-1989, with generation and transmission controlled by one organisation supplying power under a bulk tariff to local distribution utilities and large customers.

Government owned or controlled ESIs suffered from being used as tools for political policy or were engineering driven, with investment decisions not made on economic grounds. Examples of these include France's nuclear expansion to reduce reliance on foreign energy and the UKs AGR programme where a lack of standardisation in design increased construction costs. It has been argued [Evans, 1986] that the shielding of ESIs from the discipline of the market has led to inefficient over-investment and over-capacity, with utilities making large losses and accumulating massive debt.

In the market or mixed economies of the West, even nationalised utilities were exposed to some market discipline where the cost of their inputs, particularly capital, labour and certain primary fuels were set by free markets. In the command economies of East and Central Europe, the problems described above were exaggerated by the perverse incentives, misallocation of resources and under-valuation of energy inherent in the system [Gustafson, 1989]. In this system, growth of production became the driving force in the economy and led to unsustainable growth in demand for energy from a grossly inefficient and polluting supply.

Market based industry structures can avoid many of these problems associated with central planning and control. Private companies make more rational economic decisions on investment, fuel source and maintenance when exposed to market driven prices. Competition between suppliers drives unit costs down and consumers benefit from reduced prices and a greater choice of supplier price structures. [Primeaux, 1986] While arguments over the existence of 'natural monopolies' and public service obligations held sway, little interest was shown to the application of competition in electricity supply.

The privatisation of the ESI in the UK and political forces in the EU demanding greater liberalisation of markets has led to an increase in interest in new structures for industry and the introduction of competition. It has been suggested [Holmes, 1991] that restructuring in the UK succeeded only because of the robustness of the CEGB network, and would not be copied elsewhere and was inappropriate for developing countries. This has not been supported by the fact of the creation of an electric power market in Scandinavia and the continued interest in privatisation in Europe and world-wide. For the transition economies of Central Europe, privatisation of the ESI has been regarded as the best solution to raising capital for the required investment in new generation. The introduction of cost-reflective tariffs encourages rational and efficient use of power in the recovering economy. [Schweppe, 1987] Privatisation and restructuring, often along the 'British model', is proceeding in this region and will be examined in section 6.1.

The structure of individual countries ESIs makes little difference to the formation of international interconnected networks. The UCPTE developed (see Ch 2.2) with a mix of privately owned (e.g. Germany, Switzerland) and public monopoly (e.g. EdF in France, ENEL in Italy) networks. Similarly, Nordel developed with a mixture of industry structures, and recent re-structuring of the ESIs in the Nordel countries has done nothing to diminish the advantages and importance of interconnected operation in this region. The IPS and UPS were formed from homogenous networks due to the political structure of the member countries. While different industry structures have not proved a barrier to interconnection, the methods of charging for power trades, the recovery of interconnector investment and level of access to electricity consumers have all been heavily influenced by the industry structures present in the interconnected countries.

1.7 Electricity Pricing

Traditionally, the pricing of electricity has involved the calculation of historic costs of supply and their division by the energy supplied (kWh) to customers or class of customers, reflecting the different costs of supply at different voltage levels. Fixed costs of investment in new generation plant and supply networks may be recovered through a fixed capacity or standing charge [Berrie, 1992]. This method of pricing has the disadvantages of not being cost reflective, as the costs of supply vary with a continuously changing demand, and disguising cross-subsidies between customers and classes of customers. Furthermore, where publicly owned, monopoly supply industries exist, political resistance to any rise in tariffs to cover increased costs may be applied for reasons of government fiscal policy or simply to prevent public dissatisfaction. This was particularly true of the Central European states under socialist government, where provision of electricity at low cost was seen as an integral part of the centrally planned system. Table 1.7.1 details the price of electricity in these states in 1993, where even after several years of economic reform, prices to domestic customers (generally high cost to supply through low voltage networks) were still not significantly higher than lower cost industrial supplies, and the change between 1989 and 1992. The falls in Hungarian industrial and Czechoslovak domestic prices are due to the effects of high inflation over these periods.

US $/kWh	Domestic US $/kWh	Industrial US $/kWh	Domestic Price Change 1989-92	Industrial Change 1989-92
USA	0.15	0.08		
Poland	0.08	0.07	467%	70%
Hungary	0.07	0.08	46%	-4%
Czech Republic	0.05	0.07	-31%*	30%*
Slovakia	0.03	0.04		

Table 1.7.1 Domestic and Industrial Electricity Prices 1993 [IEA, 1994]
*Refers to Czechoslovakia

Despite increasing in most cases, these prices are still generally somewhere between 20% and 50% of the OECD Europe average and further rises are expected [IEA World Energy Outlook, 1994]. This consistent under-valuing of electricity has encouraged inefficient and wasteful use, under-investment in new technology and supply improvements and led to some of the highest energy intensities in the world, 4-6 times higher than the OECD average.

Time of day or seasonal tariffs (e.g. peak/off-peak rates) encourage users to reduce demand at times of high demand and price and increase energy use at times of low price and demand. This results in a flattening of the load curve, an increase in load factor, and a greater utilisation of low cost plant, resulting in lower average system cost. This method of setting tariffs had some success in Czechoslovakia, where the resulting growth in night-storage heating demand boosted the system load factor above 70% [Unipede 1994]. However, load factors in all the Central European states have fallen due to the loss of large industrial customers during the economic recession of the early 1990s.

Following the removal of the socialist governments in Central Europe in 1989, the creation of free-market mechanisms was regarded as the best solution to the problems of the previously centrally planned economies; namely, the inefficient allocation of resources, cross-subsidisation and lack of consumer choice. Electric energy is an ideal commodity for trading via a market mechanism, with supply and demand varying in costs relative to each other and no monopsonistic purchaser of end-use energy [Schweppe, 1988]. The final requirements for economic trade in electricity are the provision of a market mechanism for trading and the removal of monopolistic behaviour on the supply side. This removal of monopolistic behaviour may be brought about by the introduction of competition (as in the UK) or by regulation (as in the US). The restructuring and privatisation of the ESIs in Central Europe has provided an ideal opportunity to remove supply side monopoly power and to introduce efficient market mechanisms.

1.8 Electricity Markets

An efficient market mechanism may be created through contracts for energy supply or through a pooling arrangement with spot prices. The choice of mechanism will depend on the structure chosen for the industry, e.g. where distribution monopolies are created, these distributors (and possibly larger customers) may contract for power supplies from competing generation companies. The use of time varying spot prices, based on the marginal cost of supply, offers many advantages in the creation of a free-market in energy trading and has been implemented most notably in the England and

Wales Pool and the Norwegian and Swedish power bourses (stock exchange). These advantages include -

- Economic efficiency - as customers adjust their demand to reflect variations in the spot price and avoid high cost periods.
- Equity - with the spot price as a marker price, the market for power becomes more transparent and subsidies between customer classes are removed.
- Free choice - customers may make decisions about the best use of energy themselves and may choose from competing suppliers.
- Supply-side operation and planning - the supply side receives signals, via the correctly calculated spot price, which aid decision making in the operation of existing plant and investment in new plant.

It has been argued [Holmes, 1991] that such free market structures are not suitable for implementation in developing or transition economies and have only been successfully implemented in the UK due to the inherent strengths of the UK ESI. This is further supported by the premise that foreign investors in the ESI's of these countries will only be attracted if they can make a high return on their investment, returns which can only be guaranteed through the provision of a monopoly position. These arguments are disingenuous to consumers, who stand to benefit from the advantages above and to suffer in the long term from abuse of monopoly power. Creation of an open market with few barriers to entry and appropriate price messages is likely to attract at least as many investors as the granting of monopoly privileges, which may be removed by a change in government, and allows for more rational investment decisions to be made.

The ideas of transparent, marginal cost based pricing may be extended from the field of energy costs to transmission costs. This allows for recovery of costs resulting from third-parties using transmission networks for trading and is examined in the following section.

1.9 Recovery of Interconnector Investment

While significantly less costly than the construction of new generating capacity, the costs of building an interconnector must be recovered where there is a commercial motivation for the project. Historically, however, interconnector construction has not always been commercially driven. Publicly owned and financed utilities may choose to pursue interconnector projects jointly for the system security benefits or in anticipation that exchange of energy will remain roughly in balance over a year. This has led to several non-cost-reflective methods of valuing the energy exchanged and, therefore, an inequity in the share of benefits deriving from interconnection and an under-recovery of the initial investment.

One such method which is commonly used is to value each unit of 'peaking' power exchanged as double that of baseload units. This was commonly used by the CMEA countries in the UPS and IPS systems. For each interconnected party to derive equal benefits from this system two conditions must be met. Firstly, twice the number of baseload units to peak units must be delivered over the lifetime of the interconnection for the net value to remain balanced. Secondly, this system assumes that cost of generating peak units is exactly double that of baseload units. This depends critically on the relative cost of fuel and types of plant used for generating power for exchange. Pricing peak units using a highly non-linear 'Loss of Load Probability' method values these significantly higher than double the baseload value in meeting demand (see above).

The CMEA used to trade goods and services in 'transferable roubles' at rates well below prevailing world prices. Barter was also used, where energy supplied would be paid for in material output. These materials and goods supplied would often add little value to the energy input used in their manufacture. In some cases manufactured goods would even be worth significantly less than the cost of energy required to make them due to the distortions of central planning. [Winiecki, 1988].

Before moving to a competitive power 'bourse', the Nordel countries valued exchanged energy at the marginal cost of the exporting country plus half the difference between this and the cost of the next unit in the importing country. This is illustrated in Figure 1.9.1, where the exporting country, A, increases generation at a low cost, partloaded plant, allowing the importer, B, to cease production at a higher cost plant and import power at cost $£_{AB}$. Again, this assumes that trade across the interconnector will remain balanced over the lifetime of this asset to ensure an even share of benefits from a shared investment. While reflecting costs in a better manner than the systems described above, this system would be inadequate to finance an interconnector designed primarily for one-way energy flows. Here, the exporting party would not be receiving maximum possible revenue for entering the importing country's market to cover the cost of generation and make a return on the interconnector investment.

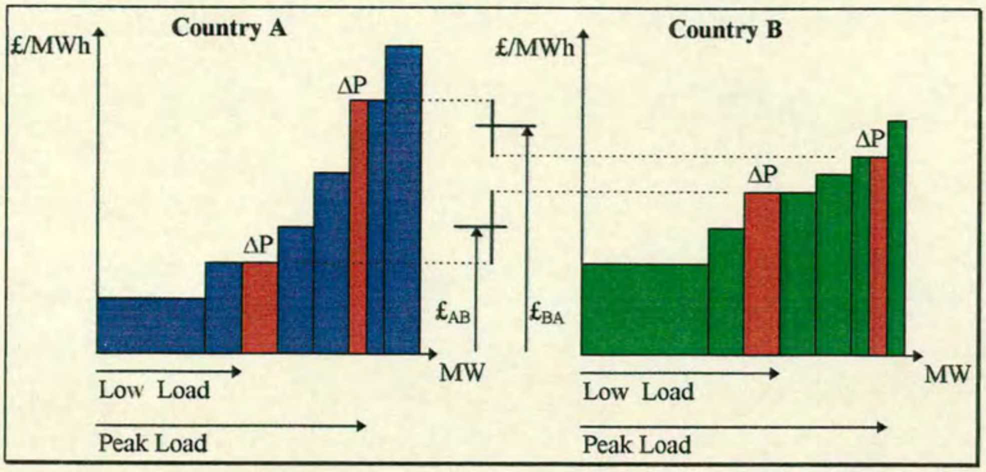


Figure 1.9.1 Nordel Valuation of Energy Exchanges

Interconnectors have historically been mainly utilised for exchanging power between the two owners/operators of the transmission systems on each side. In a more complex, deregulated system, transmission networks and interconnectors may be used increasingly by third parties. A substantial debate has taken place in both the US [OTA, 1989] and the EC (See 6.1, below) over the appropriate allocation of costs arising from the transmission of power through third-party networks or 'wheeling'[Schweppe and Merrill, 1987]. Four main types of wheeling transaction may take place -

- Utility to utility - the 'traditional' form of exchange
- Utility to customer - a utility delivers power to a large customer or distributor
- Generator to utility - an embedded generator sells power to an outside system
- Generator to customer - a generator sells power to a large customer across network

The interconnector used to facilitate these transactions across a border may be owned by either of the transmission system operators, jointly by both, or even, in a fully deregulated system, by a third party.

As wheeling transactions will, in general, be profitable to the buying and selling parties, the transmission system operator will require a share in this profit for providing the wheeling service in addition to compensation for any increase in losses arising from the transaction. Compensation for the losses incurred by wheeling may be calculated as the marginal wheeling rate, i.e. the change in costs (including transmission losses and re-despatch of generation) incurred by the party or parties providing the wheeling service for each incremental amount of energy to be wheeled [Berrie, 1992]. It should be noted that, in some cases, this will actually be negative, e.g. if the flow of power being wheeled is in the opposite direction to main grid flow and hence reduces losses. The share of profit from the wheeling transaction accruing to the wheeling utility for providing this service requires regulation to avoid abuse of monopoly power. It may be calculated in a transparent and equitable manner from the marginal cost-based spot prices at the points of entry and exit of the wheeled energy [Schweppe, 1988].

As mentioned above, some trades in energy may be beneficial in reducing system losses and therefore costs. In order to maximise use of interconnectors and revenue from the wheeling of energy, the principle of superposition may be applied. This principle allows, theoretically, unlimited trade across an interconnector, provided the net flow does not exceed the physical capability of the line. As an example, suppose an interconnector with a physical capacity of 100MW is fully utilised to transmit power from country A to country B. If a customer in country A strikes a deal with a generator in country B for the import of 10MW, the net flow across the interconnector is reduced to 90MW from A to B. Superposition allows other generators in country A to fill this 10MW 'spare' capacity on the line and the interconnector may recover its fixed costs across the full 110MW of deemed power flows.

It is unlikely that such constant counter-trade would persist in a rational market. However, the short-run costs of production of electricity vary considerably, depending on fuel costs, plant availability and demand. The superposition principle allows the delivery of time-varying 'profiled' packages of power in opposing directions without unfairly prejudicing the interests of the interconnector owner to recover his costs. The superposition principle is applied across Europe and has recently been incorporated into the rules governing the use of interconnectors in the England and Wales Pool.

In addition to recovering the investment in the interconnector through the trading of energy, financial benefit may be derived from the other benefits of interconnection listed above. Contracts may be struck with the grid operators on both sides of the connection for the provision of reserve capacity (where the full operating capacity of the interconnector is not being utilised and capacity exists in the other grid to meet these obligations) and assistance in times of abnormal operating conditions. Reactive power may also be supplied across AC interconnections or part-loaded DC links and may be of value to either grid, depending on operating conditions and interconnector site. Properly controlled and co-ordinated HVDC connections may also be used to dampen power oscillations in AC grids (e.g. the Fennoskan link between Finland and Sweden, see Ch 2.3) allowing heavier loading of the grid.

CHAPTER 2: EUROPEAN NETWORKS.

Following the destruction of the Second World War, the countries of Europe began a process of reconstruction and redevelopment of industry and commerce. Politics dictated that international co-operation would develop divided by the barrier of the 'Iron Curtain'. In the West, NATO and the bodies that would develop into the European Union formed a co-operative structure based on independent states driven by market forces. Similarly, the non-aligned Scandinavians formed the Nordic League and joined the looser European Free Trade Association (EFTA).

In the East, Stalin formed the Council for Mutual Economic Assistance (CMEA or Comecon) in 1949, as a rival to the 'Marshall Plan' for development aid from the US to Europe. Instead of a co-operative, market led structure, this organisation relied on central planning and control. The distorted incentives, such as oil priced at one fortieth of the World price [FTEE 119/16], created by this system led to many of the problems now faced by the formerly socialist countries of Eastern and Central Europe. In the field of energy, these created an 'addiction' on under valued Soviet energy supplies (mainly gas, oil and electricity), high energy intensity per unit of production and an under investment in infrastructure and modernisation. [Gustafson, 1989]

The events of 1989 which resulted in the removal of socialist, centrally planned governments across Central and Eastern Europe have created a regime of 'conservation by economic depression', where the decline of heavy industry has reduced energy demand. This has allowed energy and electricity supply industries across the region a breathing space, with the significant fall in demand allowing old, inefficient plant to be retired and improvements in supply efficiency and pollution reduction to be made. The Central European states have also made efforts to improve both the security and diversity of supply by seeking connection to Western energy supply networks.

This chapter examines the existing international electricity supply networks in both East and West Europe in terms of structure, capacity and production. Later chapters will discuss some of the proposals for further interconnection.

2.1 The IPS

The IPS (Interconnected Power System) is the synchronous power system of Central and Eastern Europe. Although some of the European members of the CMEA had begun to connect their systems in the 1950s, it was the construction of a 400kV supergrid in the 1960s that really marked the beginning of the IPS. This grid covered Poland, Czechoslovakia, Hungary, Bulgaria, Romania and the German Democratic Republic (East Germany), and included a variable part of the Southern Power System of the UPS (Moldova and the Ukraine), as shown in Figure 2.1.1. In 1967 the Central Despatch Office (CDO) was established in Prague to operate the grid and in 1974 a 750kV link was established between Hungary and the Ukraine. Future development of the grid was to be covered by two long term plans, the first formulated in 1976, to run to 1990, and the second in 1982 to cover the period to 2000 [Lévai and Jászany, 1991].

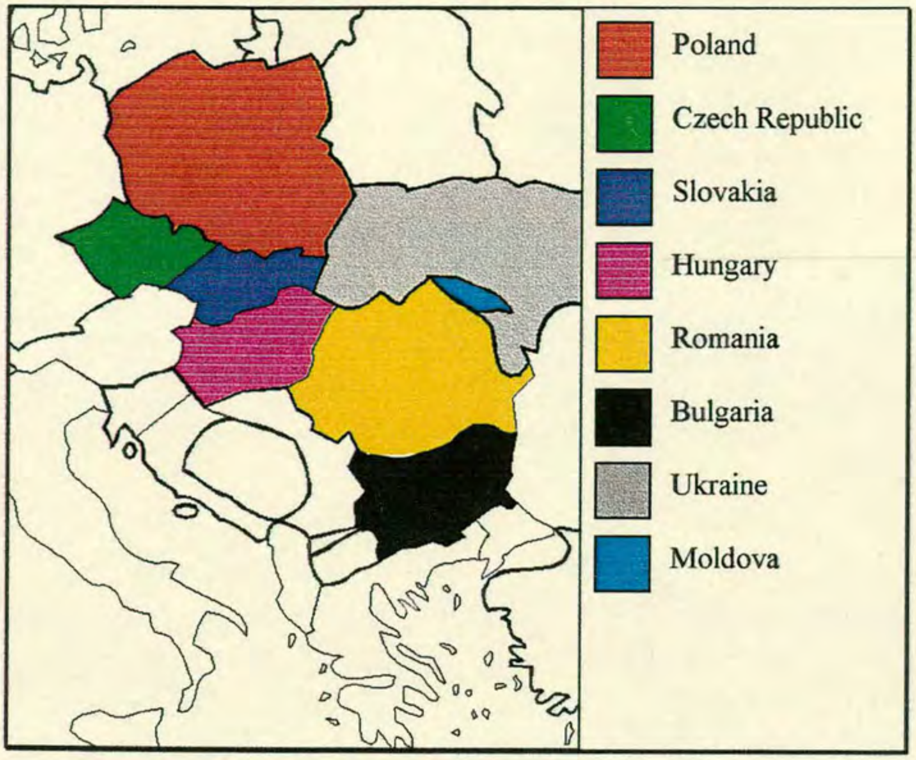


Figure 2.1.1: The Members of the IPS

Central planning has a tendency to set ambitious development targets which remain unfulfilled with an attendant under-investment in operation and maintenance. This was no less true of the IPS. Plans for large coal, nuclear and hydro generation and EHV transmission links co-existed with obsolete, polluting plant, high network losses and inadequate frequency and voltage control. Primary frequency control was wholly lacking in the IPS grid and, in addition, there was no automatic secondary control. Frequency variations of up to one Hertz were not uncommon and the IPS relied on power imported from the UPS system to regulate frequency. Inadequate reserve capacity in the UPS resulted in a strategy of disconnection of the IPS system, by the use of two large breakers, if this power flow increased above certain pre-agreed limits.

With the unprecedented political events of 1989, resulting in the removal of communist governments across East and Central Europe and the dissolution of the CMEA, there remained little motivation for the continuation of the IPS system. Newly independent governments sought greater autonomy in the planning and operation of networks. The economic recession and the closure of the most innefficient end-users, largely heavy industry and chemical production, increased capacity margins, reducing the motivation for power exchange. A lack of hard currency and the introduction of 'world' prices for fuel and electricity forced governments to adopt policies of reducing imports and self-sufficiency.

The re-unification of Germany in 1990 paved the way for the break-up of the IPS system. The generation and transmission system in the former-DDR, or the new Länder of the Federal Republic, was organised into a single body, VEAG, in 1991 which is now owned by the nine major utilities of West Germany. These new owners naturally wished to integrate the Eastern grid into their own transmission system and begin a programme of refurbishment and investment. The two systems are scheduled to be integrated in late 1995, necessitating disconnection from the remainder of the IPS grid.

Having removed forty years of socialist rule, the new governments of Central and Eastern Europe began a process of economic and political reform and expressed a desire to become more 'Western', through membership of the EU and NATO. Reform has proceeded at different rates, but the four Central European states of

Poland, Hungary and the Czech and Slovak Republics seem likely to attain these goals by the end of the century. In line with the spirit of these political aims, the Electricity Supply Industries in these countries have embarked on a process of reform, and share an objective of integration with the Western UCPTE system.

In order to achieve this objective, the electricity supply industries in these four countries formed CENTREL on October 12th 1992. Rather than a centrally controlled operation and despatch organisation, CENTREL is more a co-operative body between independent members to co-ordinate meeting the standards for integration ('catalogue of measures') agreed with the UCPTE and UNIPEDE.[Halzl, Budapest 1994] Romania and Bulgaria were rejected for membership of this organisation as it was felt that the poor state of their grids would hold back integration of the other members. A more detailed examination of the conditions of the Electricity Supply systems in the CENTREL countries and the requirements for interconnection with the West will be made in the following chapters.

2.2 The UCPTE

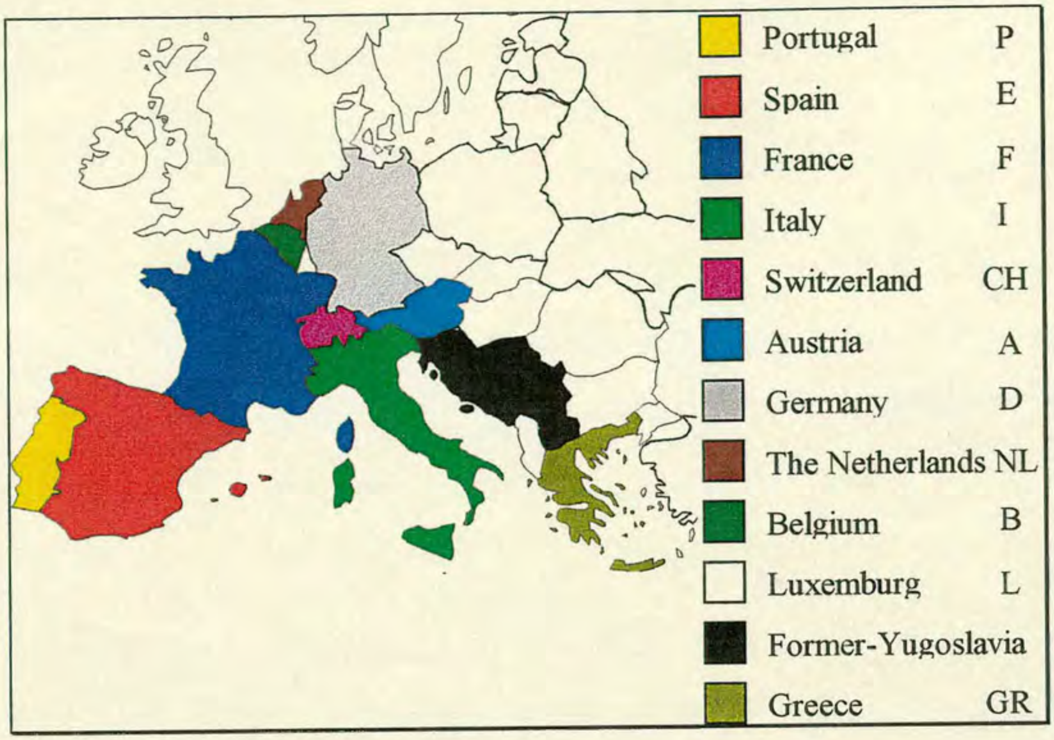


Figure 2.2.1: The UCPTE Members.

The UCPTE (Union for the Co-ordination of Production and Transmission of Electricity) was set up in 1951, after a proposal from the OECD, by representatives of the electricity supply industries in West Germany, France, Italy, Belgium, Luxembourg and the Netherlands. Prior to this, there had been no co-ordinating body for interconnected operation in Western Europe.[Strauss, 1992]

> "The UCPTE aims to achieve the most efficient utilisation of power generating facilities and transmission systems currently in existence or likely to be created. It endeavours to facilitate and promote the international exchange of electric power between the various grid-connected participants to enable each company to function with optimal conditions for supplying its clients in the most economic way possible."
> - UCPTE Annual Reports, Title Page.

In 1955, five asynchronous regions still existed in the UCPTE system-

- Germany, Austria, Belgium and Luxembourg
- France, Northern Italy and parts of Switzerland
- The remainder of Switzerland, Southern Italy and the Netherlands formed separate regions

By 1958, the grids of all the members were fully synchronised, with the exception of parts of Italy and The Netherlands. The Balkan system (Greece and Yugoslavia) and Iberia (Spain and Portugal) were accepted as full UCPTE members in 1987, once they had satisfied the condition that trade must occur with more than one member. (It is for this reason that the UK is not a member)

The UCPTE maintains no central despatcher or grid controller, although system frequency is monitored at Laufenburg in Switzerland. Members maintain control of their own internal networks, exchange operational information with other members and organise exchange of power on a bi-lateral basis. In addition, each interconnected member must satisfy the following conditions [UCPTE, 1990] -

- Demand must be met at all times by the country's own power stations, shared power stations or supply contracts.
- Each member must operate a primary reserve not less than 2.5% of installed capacity, operable within seconds.
- Each grid must have adequate frequency control (secondary reserve).
- 'n-1' security standard must be maintained under all operating conditions, i.e. the failure of a single piece of transmission equipment or loss of a large generation set must not prejudice interconnected operation of the system.

Albania and mainland Denmark (Jutland) operate synchronously with the UCPTE system, although they are not members. The IPS of Central Europe and the UK National Grid are connected by DC links. The new Länder of Germany are currently still operating in parallel with Central Europe, although completion of a new double circuit 380kV line in mid-1995 was intended to allow full synchronous operation to take place in this area.

The war in Yugoslavia has resulted in major damage to the grid in this area and caused its separation into a Northern and Southern area. Slovenia and Croatia are currently operating synchronously with the main UCPTE network, but the remainder of the former-Jugel system, Greece and Albania are operating as an asynchronous 'island'. In April 1994, Romania began operating in synchronism with this system, resulting in improved frequency stability. The damage to the former-Yugoslav system will take several years to repair, and the separated section may first become re-connected to the UCPTE by a proposed DC link with Southern Italy or via Bulgaria.

2.2.1 Capacity and Demand

The maximum simultaneous demand on the UCPTE system in 1994 was 249.2GW and occurred in January. Individual member's peak loads occurred at different times due to different climatic conditions, but most fell between December and March, the winter months, with the exception of Greece. The UCPTE determines power demand and power flows on the third Wednesday of each month. The annual maximum of these system demands (including mainland Denmark) grew from 140GW in 1975 to

249.2GW in 1990. Maximum system demand has remained nearly constant since this date as any load growth in the main UCPTE system is offset by the loss of synchronous load in the separated Greek and Southern Yugoslav system.

Table 2.2.1 details maximum demand in each UCPTE country, load factor and installed capacity in 1994. Figure 2.2.1 illustrates the division of this capacity by type.

	B	D	E	F	GR	I	SL/C*	J*	L	NL	A	P	CH
Peak Load GW	11.2	61.1	24.3	57.8	5.6	41.3	3.5	6.5	0.8	10.7	7.1	4.7	8.2
load factor %	73	73	69	75	70	70	67	71	68	75	69	68	70
Capacity GW	14.9	88.2	42.4	104.7	7.9	64.2	5.6	13.2	1.3	15.0	15.6	7.6	15.6

*SL/C - Slovenia and Croatia, J - Remainder of Former-Yugoslavian System.

Table 2.2.1: Peak Load and Total Capacity in the UCPTE.

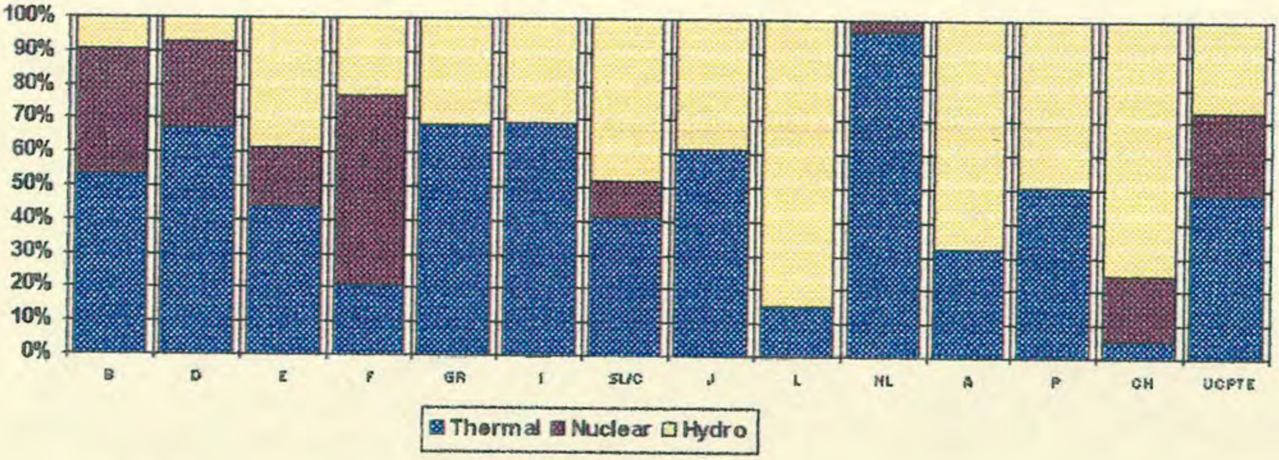


Figure 2.2.1: UCPTE Capacity by Type.

Total installed capacity in the UCPTE system in 1994 was 396GW, with nearly half of this as conventional thermal plant, and nuclear plant and hydro plant capacities making

Total installed capacity in the UCPTE system in 1994 was 396GW, with nearly half of this as conventional thermal plant, and nuclear plant and hydro plant capacities making up around one quarter each. An examination of figure 2 reveals that this division of capacity varies widely between states. Hydro capacity depends on geographical conditions, with Austria and Switzerland having large proportions of hydro plant. Several states have moratoria on nuclear plant (The Netherlands, Austria, Switzerland, Spain and Italy) [FTBI, 1992] and plan to close existing stations or build no further plant of this type. In contrast, Belgium and France rely heavily on this source of power, with France possessing an installed nuclear capacity of 58.6GW (56% of total) and with four further 1450MW reactors under construction for commissioning by the end of the century.

2.2.2 Production and Consumption

In 1994, the UCPTE countries consumed a total of 1531TWh, an increase of 1.7% over 1993, when overall growth was poor due to economic conditions. Individual countries demand growth rates vary according to economic and climatic conditions and the level of consumption already reached. Consumption growth in Western Germany shows signs of saturation, with consumption per unit GDP expected to fall in future. Southern UCPTE countries have experienced increased consumption in the summer months due to air-conditioning load, but Switzerland and Austria actually recorded a fall in consumption, possibly due to environmental regulation and the comparatively high price of power [PiE 159/8] forcing greater efficiency in users.

Total UCPTE production of electricity in 1994 reached 1557.8TWh. Table 2.2.2 details consumption, consumption growth and total production for the UCPTE countries in 1994 and figure 2.2.2 shows production by type. As might be expected, countries with nuclear plant utilise these at a high load factor to maximise energy production from plant with low marginal costs. Volumes of production from hydro-electric plant vary according to the pattern of rainfall in each country, but, as a whole, the UCPTE has maintained production of over 200TWh/year from this source since 1975.

	B	D	E	F	GR	I	SL/C*
Total Consumption TWh	71.4	388.1	146.0	381.1	34.1	253.4	20.5
% Growth 93/94	4.6	0.7	0.1	0.7	5.4	2.8	3.3
Gross Production TWh	68.6	385.8	145.5	447.7	34.0	219.9	18.9

	J*	L	NL	A	P	CH	UCPTE
Total Consumption TWh	40.3	4.7	70.3	42.6	27.9	50.6	1531.1
% Growth 93/94	5.2	6.2	1.5	-0.3	2.8	-0.7	1.73
Gross Production TWh	41.1	1.2	59.5	44.9	27.1	63.7	1557.8

*SL/C - Slovenia and Croatia, J - Remainder of Former-Yugoslavian System.

Table 2.2.2: Consumption, Growth and Production in the UCPTE 1994.

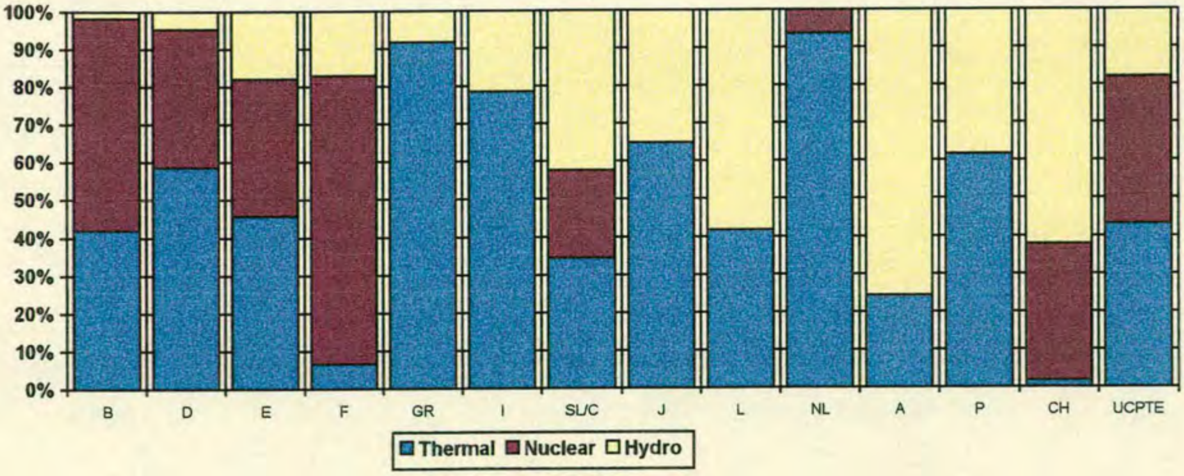


Figure 2.2.2: UCPTE Production by Type, 1994.

An examination of table 2.2.1 shows that all UCPTE members have more than adequate capacity to meet demand, but table 2.2.2 shows that many do not cover consumption from domestic production. Several reasons can account for this. In countries with large hydro-capacity, such as Switzerland, availability may vary from year to year and month to month, depending on climatic conditions. Countries with large thermal capacities, such as Italy, may have much of their stock of plant fuelled by oil, making operation extremely expensive. Local and national emissions regulations may also constrain the utilisation of thermal plant. In addition, countries may have contracts for the output of plant in neighbouring countries or simply choose to make judicious use of imported power to meet demand at the lowest possible cost.

2.2.3 Trade

For the reasons mentioned above, the exchange of electric power is extremely important within the UCPTE, on top of the other benefits of interconnected operation, such as reduced reserve requirements. The volume of electricity traded within the UCPTE has grown from just under 50TWh in 1975 to 129.6TWh in 1994, and to 155.7TWh when trade with countries outside the UCPTE is taken into account. Growth has occurred not only in volume terms, but the share of trade in consumption has increased from 6% in 1975 to 10.2% in 1994 (including trade with third parties).

The UCPTE operates no central despatch of generation plant or overall merit-order by cost. All trade is organised around bi-lateral contracts between members, although detailed information on system states and availability is shared between members. In 1994, peak simultaneous power flow summed across the UCPTE borders reached

13.9GW at night (December) and 14.7GW during the day (September). The 126 interconnections operated by the UCPTE members have a total transmission capacity of 93.5GVA (thermal rating of the transmission lines).[UCPTE, 1992]

Table 2.2.3 details cross-border energy flows in the UCPTE in 1994. Overall, the UCPTE was a net exporter of electricity, with third parties taking over 18TWh from the UCPTE system and supplying only 8TWh. Over 90% of this export is accounted for by French exports to the England and Wales Pool. Germany took the largest share of third party imports and, although some of this power flow is from the new Länder in the East, most of these imports came from Denmark. The German utility Preussenelktra has a share in a 600MW plant in Denmark and the Danish system is used to wheel exports from Norway and Sweden. Apart from some small trading in the Balkan Region, the remaining imports from third parties were made by Austria, through its two HVDC links with Hungary and the Czech Republic.

Internally, France is the UCPTE's largest single trader, with energy flows across French borders making up 53% of total internal trade in the UCPTE. France has a large over-capacity of more than 80% of peak demand and, with 56% of this capacity in nuclear plant, must export significant volumes of power to maintain reasonable levels of plant utilisation. Apart from the export to England mentioned above, France's largest export is supplied to Italy, which has a large stock of oil fired plant (42% of Italian thermal capacity is oil fired) and finds it more economic to meet demand from French imports. Much of the 7.8TWh exported by France to

GWh	Import to													
Export from	B	D	E	F	GR	I	SL/C	J	L	NL	A	P	CH	TP
Belgium	•	-	-	1419	-	-	-	-	990	2654	-	-	-	-
Germany (D)	-	•	-	35	-	-	-	-	3849	13027	4873	-	6087	216
Spain (E)	-	-	•	885	-	-	-	-	-	-	-	2198	-	82
France	4693	14944	3733	•	-	17354	-	-	-	-	-	-	7763	16939
Greece	-	-	-	-	•	-	-	276	-	-	-	-	-	235
Italy	-	-	-	265	-	•	-	797	-	-	0	-	21	-
Slovenia/Croatia	-	-	-	-	-	702	•	0	-	-	83	-	-	0
Yugoslavia (J)	-	-	-	-	140	-	0	•	-	-	-	-	-	78
Luxembourg	0	564	-	-	-	-	-	-	•	-	-	-	-	-
Netherlands	4239	687	-	-	-	-	-	-	-	•	-	-	-	-
Austria	-	4853	-	-	-	1538	1697	-	-	-	•	-	1200	829
Portugal	-	-	1369	-	-	-	-	-	-	-	-	•	-	-
Switzerland	-	6012	-	617	-	19079	-	-	-	-	972	-	•	-
Third Parties	-	4043	-	-	623	-	108	60	-	-	3159	-	-	•
Total Import	8932	31103	5102	3221	763	38673	2602	336	4839	15681	9087	2198	15071	18378
Total Export	5063	28087	3165	65426	511	1083	785	218	564	4926	10117	1369	26680	7993
Balance	-3869	-3016	-1937	62205	-252	-37590	-1817	-118	-4275	-10755	1030	-829	11609	10385

Balance - Imports negative.
TP- Third Parties (Albania, Andorra, Bulgaria, Czech Republic, Denmark, asynchronous region of Germany, Great Britain, Hungary, Romania, Slovakia and Sweden)

Table 2.2.3 UCPTE Electricity Trade.

Switzerland is also transmitted onwards to Italy, although the Swiss system is often used to add value to this by using French imports at night to drive pumped storage plant and exporting during the day at a premium. With 5.8GW of nuclear plant due to be commissioned in France by 1998, an Italian moratorium on domestic nuclear plant and tight emissions limits on thermal plant, this trade flow is likely to continue far into the future.

Germany's exchanges with other countries vary quite widely on a year to year basis (e.g. 3.7TWh export in 1992 and 3TWh import in 1994), depending on plant availability and demand levels. Trade with Austria and Switzerland generally balances in most years, but with a change in the direction of power flows between day and night as German nuclear and thermal baseload power is used in pumped storage plant. The expansion of interconnections with Scandinavia is intended to allow this type of trade to increase in the North as well.

The UCPTE operates the earliest formally established interconnected network in Europe, with a large and increasing volume of energy traded through it. It should be re-stated, however, that this is organised on a bilateral contract basis by grid operators in member countries. Regional distributors and large industrial consumers are excluded from this trade and this has led to calls, within the European Union especially, for increased liberalisation of trade in electricity. (See section 6.1, below)

2.3 Nordel

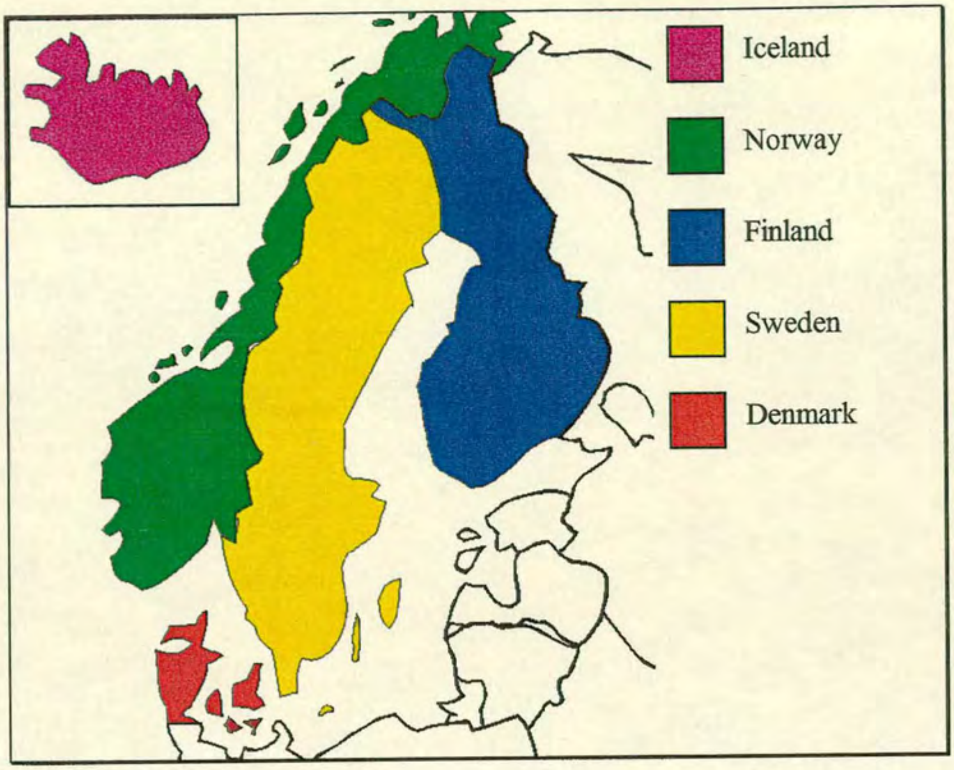


Figure 2.3: The Nordel Members

The Scandinavian countries have a long history of trade and co-operation in the field of electricity supply. Starting with links between regional grids in 1915, this co-operation has evolved to produce one of the most highly interconnected grid systems in the World, with large volumes of energy exchanged between member states. Recent domestic and international political developments have changed the emphasis on trade in the region from a co-operative to a more commercial basis, but this has not diminished the inherent advantages of interconnection in the region.

Co-operation in the utilisation of electric power resources began in Scandinavia in 1915, with the completion of a 6MW, 25kV undersea link between Denmark and Sweden. The economic benefits of this project were clear, and of great benefit to both parties. The small storage capacity of the Swedish hydro schemes resulted in the spilling of large quantities of water during summer when demand was low. The cable allowed this water to be used to generate power for export to Denmark, where it would displace power generated by expensive imported coal. This also proved highly useful during its first five years of operation when coal was scarce due to the first world war.

As the size of national grid systems, and the capacity of individual generating plants embedded in them, increased to realise economies of scale, the benefits of increased interconnection and co-operation became more apparent. The Norwegians had initially been reluctant to share the benefits of their hydro-electric resources, preferring to use this electricity for their own industrialisation, and low coal prices between the two World Wars had reduced interest in importing power. The need for large plant sizes to efficiently exploit large hydro-electric resources could only be met if power in excess of local demand could be exported. Increased utilisation of resources also offset the large capital cost of hydro schemes and, as security of supply became more important, the disadvantages of total reliance on this source of power became clear. Interconnection and co-operation allowed for the creation of a balanced mix of capacity and decrease the risk of power shortages in dry years.

In 1963, 12 years after the formation of the UCPTE in Western Europe, representatives from the ESIs in Sweden, Norway, Denmark and Finland formed Nordel to promote co-operation in the development of their power systems and in the field of power exchange. (Iceland also became a member, but for the reason of its geographic isolation from the other members does not take part in any power exchange.) The terms 'co-operation' and 'exchange' are important and characterised Nordel until recently. Members of Nordel did not seek to exploit any commercial advantages over their neighbours, with the price paid for imported power set at half the difference between the costs of each system's marginal plant (see earlier section on methods of exchange).

This almost wholly co-operative system of exchange has now begun to move to a more commercial trading arrangement. This development is driven by two important factors; European Union (EU) plans for market liberalisation, and internal re-structuring in the Electricity Supply Industries of Nordel members. Denmark has been a member of the EU, or the European Economic Community (EEC) as it was, since 1973, while Sweden and Finland recently became members in 1995. These countries will, therefore, be subject to all EU plans for increased liberalisation of international electricity trade. Although Norway rejected full membership of the EU in a referendum, the EU's plans for energy markets are almost certain to have a large impact on a nation which already derives a large proportion of its wealth from energy exports.

Structural changes within the ESI's have also driven changes in the role of Nordel. State-owned National monopolies, the founders of Nordel, have been transformed into market based competitive systems in order to achieve greater efficiency. This process began in Norway in 1991, when the state-owned company Statskraftverkene was divided into separate generation and transmission arms and a pool-based trading system was set-up. It has been estimated that competition has delivered a reduction in final electricity prices of 15% in the two years to 1993 [Nordel 1993], although a price has been paid in reduced co-operation between generators.

Sweden and Finland have not yet grasped the nettle of a fully competitive ESI, but are making firm moves in this direction. Sweden converted its state utility, Vatenfall, into a limited company with its transmission activities divested into a separate company. International trade will become unregulated and two structures for a power pool are under consideration; a national pool or an operating protocol with the Norwegian pool. [WEFA 1995]. Re-structuring in Finland may almost be considered to have followed an opposite course to that of its neighbours. Here, the many industrially-owned generation plants and municipally owned distribution companies have begun a process of consolidation into larger bodies better able to withstand the rigours of competition. The state utility Imatran Voima Oy (IVO) has been split into transmission and generation subsidiaries, and it is proposed that international trade will become an unregulated activity.

2.3.1 Capacity and Demand

With a total capacity of 86GW [Nordel 1993] and an aggregate peak demand[1] of 53GW, the Nordel System is less than one quarter of the size of the neighbouring UCPTE. The distribution of this capacity between the member states and across plant type has, however, produced a system almost uniquely favourable to international exchange of electric power. Table 2.3.1 illustrates this distribution.

	Denmark	Finland	Norway	Sweden	Nordel
Hydro-electric	10	2802	27013	16451	46276
Nuclear	0	2310	0	10000	12310
Conventional Thermal	9794	9200	278	8354	27626
Total	9804	14312	27291	34805	86212
Peak Demand[1]	5378	9712	16534	21004	52628

[1] Peak demand on 3rd Wednesday in January 1993 (times of peak not co-incident).

Table 2.3.1: Capacity and Demand in Nordel, 1994.

Sweden and Finland maintain a balanced portfolio of plant, while the Norwegian and Danish systems are almost wholly reliant on hydro and conventional thermal power respectively. This adds up to a mix of plant across Nordel with a large share of hydro plant and a large margin between peak demand and capacity. As expected from these Northern European countries, peak demand occurs over the winter period, and generally coincides with high levels of capacity from hydro-electric reservoirs.

Capacity is projected to grow to 91 GW by 2000, with the largest growth in Finland. Demand is expected to increase at a higher rate, rising to 73.5GW at the end of the century, with this increase fairly evenly distributed across Nordel members. Sweden remains committed to the result of a referendum held in 1980 on the future of nuclear plant which resulted in the decision to close all 12 nuclear stations (10 GW capacity) by 2010. CCGT plant burning Norwegian gas will probably be the favoured choice for replacing this, although there is some potential for increasing hydro-electric capacity.

2.3.2 Production and Consumption

Gross consumption in Nordel in 1994 stood at 358TWh. Electric boilers for industry and district heating are used within the Nordel system for smoothing demand and consumed 9.7TWh, with losses and pumped storage demand using a further 24TWh. Net consumption in the Nordel system was 324TWh, with 43% consumed by industry, 1% by transport (trams and railways) and the remainder by domestic and commercial premises. A notable feature of Nordel consumption is the high level of consumption per head of population due to the prevelance of electric storage heating and the high level of lighting demand through the winter. Consumption per inhabitant averaged 14.6MWh in 1994, ranging from 6.4MWh in Denmark to 25MWh in Norway, the highest in the World. Gross consumption in Nordel is projected to grow to 378TWh by the end of the century.

Total generation in Nordel in 1994 reached 356TWh, with a 2TWh net import making up the balance of consumption. Over half of this generation was hydro-electric power, one quarter nuclear power and the remainder conventional thermal with a small proportion of wind power (1.2TWh, mainly in Denmark) and geothermal power (in Iceland). Table 2.3.2 details the distribution of this production. Total production in 1994 grew by only 0.1% over 1993, while consumption grew by 2.3%. Hydro-electric production fell by 13% overall, with reductions of 15TWh in Sweden and 6.7TWh in

Norway. This was due to low levels of inflow into reservoirs, with capacity in Swedish reservoirs falling to their lowest levels for 14 years over the Winter. Sweden was able to match consumption by increasing Nuclear output by 11TWh from the 1993 level when much of the stock of nuclear plant had extended outages for work on emergency cooling systems. The poor level of hydro production resulted in atypical patterns of exchange, which will be examined in the next section.

GWh	Denmark	Finland	Iceland	Norway	Sweden
Hydro	28	11669	4510	112908	57883
Nuclear		18337			70151
Thermal	36933	32095	4	613	9547
Renewables	1083	7	260	7	75
Total Production	38044	62108	4774	113528	137656
Gross Consumption	33201	68211	4774	113612	137909

Table 2.3.2: Production and Consumption in Nordel, 1994.

2.3.3 Electricity Trade

The Nordel countries are interconnected by 22 cross-border links, totalling 5.6GW of transfer capacity, including 4 HVDC undersea links. A further 500-600MW HVDC link is planned for 1998 between mainland Denmark (Jutland, which operates in synchronism with the UCPTE) and the Danish Island network (Funen, which is synchronously connected to Sweden). Finland and Sweden are synchronously connected by 400kV lines over their border in the North and by a DC link across the Baltic. Due to the topography of their grids, with hydro generation concentrated in the North and population and load concentrated in the South, instabilities in power flow occur. The fast operation of the DC link allows power oscillations around the grid to smoothed out, contributing greatly to grid security in addition to its role in power transfer.[Nordel, 1989]

As mentioned, Denmark is connected to Germany in the South by 2×400kV and 2×220kV synchronous links with a capacity of 1.4GW and a 600MW HVDC link is planned for commissioning in 1995 between the Danish Island grid and Rostock in Germany. In 1994, a 600MW HVDC link between Sweden and Germany was commissioned and two 600MW HVDC links are planned between Norway and Germany and The Netherlands, to be commissioned in 2001 and 2003 respectively. A 900MW back to back DC link connects Finland to Russia and Russia is also connected to three isolated asynchronous grid 'islands' in Northern Finland and Norway with a total transfer capacity of 210MW. Links have also been proposed across the Baltic to Estonia and Poland, but these remain uncertain. Similarly, a proposed link between Norway and East Anglia has failed to attract power purchasers in the UK, and a proposed link between Iceland and Scotland is unlikely to be built.

The development of Nordel interconnection was motivated by the desire to exploit optimally the large hydro-electric resources in the area and this is apparent from an examination of the pattern of electricity exchanges over time. The volume of electricity traded within Nordel has grown steadily over time, with Norway maintaining a net export from its hydro plant and Denmark absorbing much of this to displace fossil fuel fired plant. Sweden maintains a balance between imports and exports, except in years of particularly high hydro availability, but transfers large amounts of power through the grid between Norway and Eastern Denmark and between Norway and Finland. Finland has been a large net importer in recent years as growth in consumption has out-stripped capacity expansion, often importing over 10% of total consumption.

GWh	Imports to:				
Exports from:	**Denmark**	**Finland**	**Norway**	**Sweden**	**Others**
Denmark	•	0	2306	1933	2383
Finland	0	•	291	298	0
Norway	932	1	•	4430	0
Sweden	681	1664	2850	•	1226
Others	166	5027	0	13	•
Total Imports	1779	6692	5447	6674	3609
Total Export	6622	589	5363	6421	5206
Net Export	4843	-6103	-84	-253	1597

Table 2.3.3: Imports and Exports of Electricity in Nordel, 1994

Table 2.3.3 details electricity exchanges in Nordel in 1994. As stated above, 1994 was a year of poor hydro-electric availability compared to recent years, although annual Norwegian production was in line with its long-term average. Danish exports to Germany are mainly the production from the German utility, Preussenelektra's, 50% share in a 600 MW thermal plant. Finland's import from Russia is part of a long-term contract which has recently been re-negotiated to run until 2004.

Trade within Nordel has averaged around 6% of total consumption from 1990-1994, slightly lower than in the UCPTE. The importance of interconnected operation to member countries cannot, however, be understated. Liberalisation of both internal markets and external trade, combined with the expansion of interconnections is likely to increase the volume of electricity trade in future.

2.4 The UPS.

While the UCPTE network may be the World's largest interconnected network in terms of installed capacity, the Unified Power System is certainly the largest in area, covering 10 million km^2. Stretching across six time zones, from Belorus to Lake Baikal (some 7000km), this was the main electricity supply grid in the Soviet Union and was largely constructed in the sixties. (Two smaller area grids existed in Soviet Central Asia and the Far East). To transmit power over these large distances, the UPS contained several AC lines operating at 750kV and one DC link running from Siberia to the Urals at over 1000kV. Some of the World's largest power plants are in the UPS and, in keeping with the Soviet doctrine of central planning and control, the grid was controlled by a central despatcher in Moscow, with nine regional grids operating under his instruction.

In 1989, the UPS system had an installed capacity of 287GW, a peak load of 230GW and a total production of over 1500TWh. Since the break-up of the Soviet Union, the lack of investment inherent in the centrally planned economies has become apparent, with the majority of capacity in need of rehabilitation or replacement [Pockney, 1990] and achieving poor levels of availability, and much of the transmission system in a similarly poor condition.

The UPS is still described as being in operation, but links have weakened. Azerbaijan has been disconnected, due to its inability to pay for power imports, and the link to Georgia has been severed due to damage. The Baltic Republics, Belorus, Ukraine, trans-Caucasus and North Kazakhstan still operate in synchronism with the Russian grid, but have developed much higher levels of autonomy. Power transfers between the grids have also generally declined as many of these states have insufficient funds to purchase large volumes of power from Russia with hard currency. The UPS has external connections to Finland (via a 900MW DC link), Norway (40MW) and Mongolia (30MW) and can transfer power to the IPS/CENTREL system via the Ukrainian power system.

2.4.1 Russia

The Russian grid still forms the backbone of the UPS. The Russian grid is owned and managed by a joint stock company, RAO-EES Rossii formed in March 1993, 20% of which is now in public ownership. Thermal and hydro plant is operated by Mintopenergo (Ministry of Fuel and Power) and nuclear plant is operated by Minatomenergo (Ministry of Atomic Power). In addition there are 72 local companies controlling distribution and smaller thermal (<1000MW) and hydro (<300MW) plant. The Russian electricity supply industry is scheduled to be fully privatised but faces severe problems. Rehabilitation of ageing, inefficient plant is a priority, with 60-70% of plant described as being at the end of its rated life, but it is difficult to take plant out of service for this process due to acute power shortages. Increasing capacity through new build is also difficult due to a lack of funds and, following the Chernobyl accident, there is a moratorium on the completion of nuclear plant.

Total installed capacity in the Russian system was 212GW, at 580 power stations, in 1994, with an additional 18GW at industrial complexes. 27GW of capacity is hydro-electric plant, 12GW of which is sited in Siberia, East of the Ural mountains

[Whittington, 1990]. Russia has a huge hydro-electric potential, with only 20% of this currently exploited, and, in 1992 generated 186TWh [BP, 1995] from this source. Russia also has 29 operational nuclear reactors, with a combined capacity of 19GW [Greenpeace, 1992] at 9 sites; 13 PWRs, 11 RBMK reactors of the type at Chernobyl, one fast breeder and four small combined heat and power reactors. In 1992, these generated 385TWh of electric energy. Construction at four other sites has been abandoned due to a government decree cancelling all future nuclear plans.

The remaining capacity is made up of conventional thermal plant; primarily coal fired, with gas and oil used in CHP plant sited in cities. Russia has huge reserves of fossil fuels, 241Gt of coal (23% of the world total), 48100Gm^3 of natural gas (34% of world total) and 6700Mt of oil (5% of world total). [BP, 1995] Table 2.4.1 summarises gross production and consumption in Russia in 1980, 1990 and 1992, the last year for which figures are available.

TWh	1980	1990	1992
Production	804.9	1082.2	1008.5
Consumption	697.96	1077.6	992.2

Source: MDIS

Table 2.4.1 Russian Production and Consumption

2.4.2 The Ukraine

The Ukrainian and Moldovan grids together formed the Southern Power system of the Soviet Union, despatched from Kiev. This system played a pivotal role in executing transfer of power and regulating frequency in the IPS system of Central and Eastern Europe, as described below. The Ukrainian system continues to operate synchronously with the remainder of the UPS system, but longer term electricity policy has not yet been finalised. Electricity supply is operated by a single vertically integrated utility owned by Minenergo, the Ministry of Power and Electricity, with nuclear plant operated by Ukratomenergoprom. Privatisation of Minenergo as six generation companies has been proposed, but the energy crisis in the Ukraine is so acute that this seems unlikely in the immediate future.

The Ukraine shares many of the problems of Russia in its electricity supply industry, caused by under-investment in the past. Most of its thermal plant is over 20 years old and the grid network is in poor condition. Installed capacity in the Ukraine totalled 45.7GW in 1992, 4.7GW of which was hydro plant, mainly sited along the Dnepr, and 28.2GW was conventional thermal plant, 90% of which has dual-firing capability. The Ukraine has its own coal, producing 24% of the former-Soviet Union total in 1992, and its own oil, accounting for 12.4% of former Soviet Union (FSU) production in 1992, but must import most of its gas from Russia.

The remaining 12.8 GW of installed capacity is nuclear plant at five sites, including the remaining operational reactors at Chernobyl. Following the dissolution of the Soviet Union, the newly independent Ukrainian government planned to halt all further nuclear expansion and to close completely the Chernobyl RBMK reactors. Electricity shortages, and the Ukraine's inability to pay for any energy imports have forced these plans to be abandoned. Units 1 and 2 at Chernobyl remain in operation. Three near-complete stations are planned to be commissioned in 1996 and two further partially built plant by 1999, although these are all of the more modern VVER-1000 design. It is anticipated that this will bring the share of nuclear generation up to 40% of electricity produced in the Ukraine.

TWh	1985	1990	1992
Production	272.2	298.8	253.5
Import	10.3	15.6	11.5
Export	34.2	43.9	21.0
Consumption	203	223.6	202.8

Source: MDIS

Table 2.4.2 Ukrainian Electricity Balance

Table 2.4.2 details production, trade and consumption in the Ukraine, illustrating how these increased in the late 1980s and have since dropped due to the current economic situation. In 1992, the Ukraine's largest trade in electric power took place with Russia, importing 7.4TWh and making 9.2TWh of exports. Apart from this, both Romania and Hungary made significant imports of 5TWh and 2.7TWh respectively, and small exchanges took place with Slovakia, Poland and Belorus. A government forecast made in 1993 anticipated that consumption would recover to 1990 levels by 1995 and increase by 10TWh every five years after this, a high growth rate even in a healthy economy.

2.4.3 Belorus

The Belorussian grid formed the UPS' Western border with Poland but had only one connection with this country's isolated North-Eastern region. Belorus currently has one state-owned utility, Minenergo, and six regional distributors. Installed capacity comprises 22 thermal plant totalling 7010MW and 7MW of hydro plant. Peak demand in 1990 was 8566MW and Belorus relied heavily on plant elsewhere in the UPS, particularly Lithuania's Ignalina nuclear plant, to meet demand. Belorus has a total capacity of 2800MVA of interconnections with Russia and 1500MVA with Lithuania at 750kV and 330kV.

Heavy Fuel Oil (Mazut) and gas are the primary fuels in Belorus' thermal plant, 82% of which is dual fired, and must be imported from Russia. Table 2.4.2 details production, consumption and trade of electric power by Belorus from 1980 to 1992. Despite a steep fall in consumption between 1991 and 1992, shortages have continued due to poor plant maintenance and fuel shortages. Minenergo projects that 1990 levels of consumption will be regained by 2000 and, following this, consumption will grow by 5TWh every five years. It is also hoped that self-sufficiency in electricity production will be achieved by 2005, through a programme of CCGT construction, and that Belorus can be linked to the UCPTE with the Baltic republics. Given the current state of the economy, this seems rather ambitious.

TWh	1980	1985	1990	1991	1992
Production	34.1	33.2	39.5	38.7	37.4
Consumption	31.97	39.48	48.96	49.14	43.90
Import	3.9	9.8	14.2	14.2	9.9
Export	6.0	3.5	4.7	3.8	3.4

Source: MDIS

Table 2.4.2 Belorussian Electricity Balance

In summary, the short-term outlook for the Unified Power System appears to be one of crisis management. The pressing problems of plant obsolescence, environmental pollution and nuclear safety will require considerable investment to solve. The severe climate of this region and lack of alternative fuels allows little room for compromise on security of supply. The reduced import dependence of the Eastern Europeans and declining industrial demand provides some breathing space for tackling these problems but also reduces sources of revenue to pay for this. In the medium to long-term, the UPS area should develop clean-coal and CCGT generating plant to increase the benefits derived from the large fossil fuel reserves in this region [Marder, 1994].

CHAPTER 3: POLAND

3.1 Overview

Area: 312 690 km^2 , 60% agricultural
28% forested

Population: 38.6 million (December 1994)

Capital: Warsaw (Population - 1.65 million)

Language: Polish

Climate: Temperate, Max. Temp. 24°C, July
Min Temp. -5°C, Jan.

Currency: Zloty Zl 22,723:$1 (1994)

Foreign Debt: $44.1 billion (1994)

Unemployment: 16% (1994)

GDP

	1989-91	1992	1993	1994	1995	1996	1997	1998	1999	2000
GDP Growth	-17.7	2.6	3.8	5.0	5.9	5.0	5.5	3.9	4.5	4.7

(% Change at constant prices) Economist Intelligence Unit Forecast, 1995 onwards

Inflation

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Consumer Prices	585.8	70.4	43	35.3	32.2	28.3	22.2	20.9	15.6	12.5	9.0

(% Change) Economist Intelligence Unit Forecast, 1995 onwards

3.2 History

The peak of Poland's power and influence in Europe occurred during the 15th and 16th centuries. During this period the Commonwealth of Poland and Lithuania controlled large areas of Central Europe from the Baltic to the Black Sea and was the grain production centre of Europe. In the 17th and 18th centuries, due to internal governmental weakness and the expansion of neighbouring powers, the Commonwealth suffered a steady decline. By 1795, Poland had ceased to exist as an independent state and was partitioned between Prussia, Russia and Austria.

Despite attempting three uprisings, the Poles remained divided until the end of the First World War, with conditions varying greatly between the three partitions. In the final days of the war, Poles in the Russian, Prussian and Austrian armies were mobilised under Josef Pilsudski and the Second Republic was declared. The early years of the Republic were marked by conflict as the new state sought to stabilise its borders. The second republic stretched considerably further East than present day Poland and almost one third of the population were from differing ethnic backgrounds. The fledgling democracy was overthrown by a coup in 1926 led by Marshal Pilsudski.

This new regime grew increasingly authoritarian and fearful of its neighbours. The Polish economy, however, proved inadequate to support a program of military modernisation and expansion and the state was again partitioned by the invading Germans and Russians in 1939.

As a result of the Potsdam talks following the end of the Second World War, and the mass exterminations and forced migrations perpetrated by both Stalin and Hitler, the modern state of Poland emerged, comprising over 97% ethnic Poles. In 1948 the Polish United Workers Party took power, which it would retain until 1989. A Stalinist program of industrialisation and the collectivisation of agriculture was undertaken, and Poland joined the CMEA in 1949 and the Warsaw Pact military alliance in 1951. Central control was never as repressive as in neighbouring states and collectivisation of agriculture did not proceed as far. Riots in Poznan in 1956 caused a change of leader, but the communists maintained power and the economy continued to stagnate. Again, in 1970, food riots brought a change in leadership, with the new first secretary Edward Gierek attempting to stimulate the economy with heavy foreign borrowing.

In 1980, a rise in food prices led to widespread strikes and the formation of an independent trade union, Solidarity. By 1982 membership of Solidarity had risen to ten million and its leaders demanded free elections. Martial Law was declared by the authorities, General Jaruzelski became First Secretary, and many Solidarity activists were imprisoned. By 1988, however, the Polish economy had stagnated due to foreign debt of $43bn, and labour unrest forced the government to begin negotiations with Solidarity. Semi-free elections were held in June 1989 and in September a new government was formed under the leadership of Tadeusz Mazowiecki, a Solidarity member.

3.3 Events Post-1989

The Mazowiecki government faced a conflicting set of challenges. Whilst maintaining national stability and unity they had to reform the ailing centrally-planned system. On 1 January 1990 an economic reform plan was introduced, named after finance minister Balcerowicz, that freed prices, cut subsidies, allowed for private enterprise and planned the privatisation of state industry.

Within six months inflation was under control, 90% of prices were free and food queues eliminated and 70 000 private firms established. The cost of these reforms was high with rising unemployment, falling industrial output and a substantial drop in real income for many Poles.

Free presidential elections in November 1990 resulted in victory for Lech Walesa, the Solidarity leader. The first free parliamentary elections on October 1991 resulted in 18 major parliamentary groupings and consequentially weak coalition government. The result of this was a slowing in the pace of reform through 1991 and 1992.

3.4 Economy

Poland's economy traditionally relied on agriculture and mining. Industrialisation began in the 18th Century but was severely curtailed by war and the depression of the 1930s. What industry remained was nationalised by the communist government to the extent that, by 1949, 90% of the workforce was employed by the state. Priority industries for investment were heavy industry, chemical refining and machinery, with production geared towards trade with the Soviet Union. A modernisation programme for industry was attempted in the 1970s, financed by Western credit, but this failed , due to the problems inherent in a centrally planned economy, and left the nation bankrupt.

Following the 1990 economic reform package, industrial output fell by 40% compared to 1989 levels and GDP fell by 12% and 9% in 1990 and 1991 respectively. However, 1992 saw the beginnings of a recovery with industrial output growing by 4.2%, GDP by 1% and inflation falling from 586% in 1990 to 43%. Providing political stability at home continues and the international economic climate remains fair, Polish GDP is set to grow by 2-3% per annum for the next few years. Poland quickly signed trade and association agreements with the European Community and has formally submitted an application for full membership of this organisation.

3.5 Domestic Energy Resources

3.5.1 Hard Coal

The importance of the hard coal industry in Poland cannot be understated. Hard coal production peaked in 1987 at 193Mt/yr, 6% of the world total, placing Poland as the world's fourth largest producer. The total sector provided 11% of industrial employment, accounted for 9% of total Polish exports and provided nearly 70% of primary energy in 1987. Proven reserves of hard coal are put at 65Gt, with a further 'probable' reserve of 100Gt, nearly half of which is recoverable.

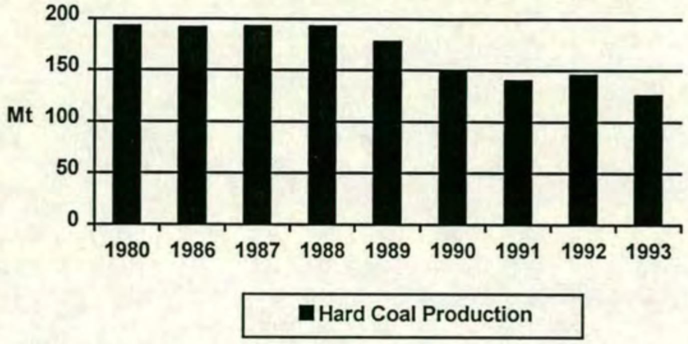


Figure 3.5.1 Polish Hard Coal Production

Since 1989, Hard coal production has fallen dramatically due to recession and the closure of uneconomic mines, as illustrated in Figure 3.5.1. Production is also heavily influenced by demand for export, which has fallen heavily in recent years due to increasing foreign competition and the imposition of hard currency dealings with the former CMEA area. Coal exports peaked at 43Mt in 1984 but reached only 19Mt in 1992, with the largest markets in Western Europe.

Hard coal is currently produced at 63 mines, organised into 7 holding companies and employing some 311 000 workers, nearly 25% fewer than in 1986. These mines are situated in the Upper Silesian and Lower Silesian basins in the South, with one in the largely unexploited Lublin basin in the East of the country. Colliery debt (Zl 28913bn in 1993) and falling exports have starved the coal industry of funds for investment in new production equipment, although industry plans to regain 1992 production levels and maintain them into the next century through productivity gains.

3.5.2 Brown Coal

The production of hard coal remained constant through the 1980s and began to fall in the early 1990s. In contrast, the importance of brown coal has increased. Annual production of 36.9Mt in 1980 had doubled by 1988, but fell slightly in 1991 to 69.4Mt. Currently worked reserves stand at 3.5Gt and total reserves are estimated at 30-40Gt.

Brown coal is considerably cheaper than hard coal as it is exclusively extracted from open-cast mines and transported, by conveyor belts, to neighbouring power stations. Demand is therefore heavily influenced by overall demand for electricity as transport costs make it economically valueless for any other use. Brown coal is produced at four sites: the largest, Belchatow, accounts for almost half of total production, 37.5Mt in 1989, followed by Turow in South-West Poland and Konin and Patnow in Central Poland.

3.5.3 Oil Sector

Poland has negligible reserves of oil (around 4Mt) and production in 1993 was only 227kt. Oil and oil products account for 13% of primary energy demand and 11.45Mt was imported in 1991. Poland was able to supply all its oil import requirements, before 1989, via the 'Friendship' pipeline from the Soviet Union. The introduction of world prices for this oil in 1990 has forced the Poles to look at diversification of supply sources, with a growing share of imports coming from OPEC and North Sea sources. In December 1991, the main Polish importer signed a deal with Iran for 7Mt of imports, spread over two years, in return for the purchase of Polish ships. The expansion of import facilities at Gdansk to 15Mt/year allows Poland to obtain all her import requirements from non-Russian sources.

Poland has enough refinery capacity (16.5Mt/year) to cover current domestic demand but the needs of modernisation and an expanding motor fuels market will require the production of new facilities. Current consumption is dominated by the transport sector, and an almost total lack of fuel oil use for domestic heating means that Poland is a net-exporter of fuel-oil.

3.5.4 Gas Sector

Gas supplied 8% of primary energy in Poland in 1991, a small increase from its 1970 share of around 6%. 30% of gas is supplied by domestic production, around 4Gm^3, in 1991. Total domestic reserves of methane are estimated at around 3000Gm^3 and it is hoped that production will be increased to around 5.5Gm^3 from its 1993 level of 4Gm^3.

Poland relies heavily on the former Soviet Union for imports of natural gas. The former Soviet Union has vast reserves of gas and willingly supplied its CMEA trading partners with natural gas in return for material input into the construction of pipelines and other bartered goods. After January 1992 the new Russian administration refused to honour previous gas supply agreements causing acute shortages in Poland and, in future, gas must be paid for in hard currency at World prices.

Poland anticipates an almost three-fold increase in gas consumption by 2010 to $37Gm^3$/year as natural gas penetrates the domestic heating and service sectors. In order to reduce dependence on the former-Soviet Union, the Poles are looking to import gas from West Germany and, possibly, the North Sea; however, more ambitious plans to import from Algeria or Turkey are unlikely to come to fruition as new pipelines will require large capital investment.

3.5.5 Other Energy Sources.

In addition to the fossil fuel energy sources covered above, Poland produces 400 000 tonnes of peat annually, from reserves of 890Mt, and 1.8Mt of fuel wood was produced in 1990. Poland also has 10-50kt of uranium reserves, although little is known about production costs. Reserves of 33Mt of oil shales are not described as suitable for energy production.[Russell, 1989] The Industry Ministry estimates that 12 000 Gwh/yr of hydro-electric power may be produced, in economically viable sites of greater than 1MW capacity, from a theoretical total potential of 23 000 Gwh/yr.

Figure 3.5.5 summarises Poland's overall energy position in 1993, showing the importance of coal in the Polish economy and the reliance on foreign oil imports.

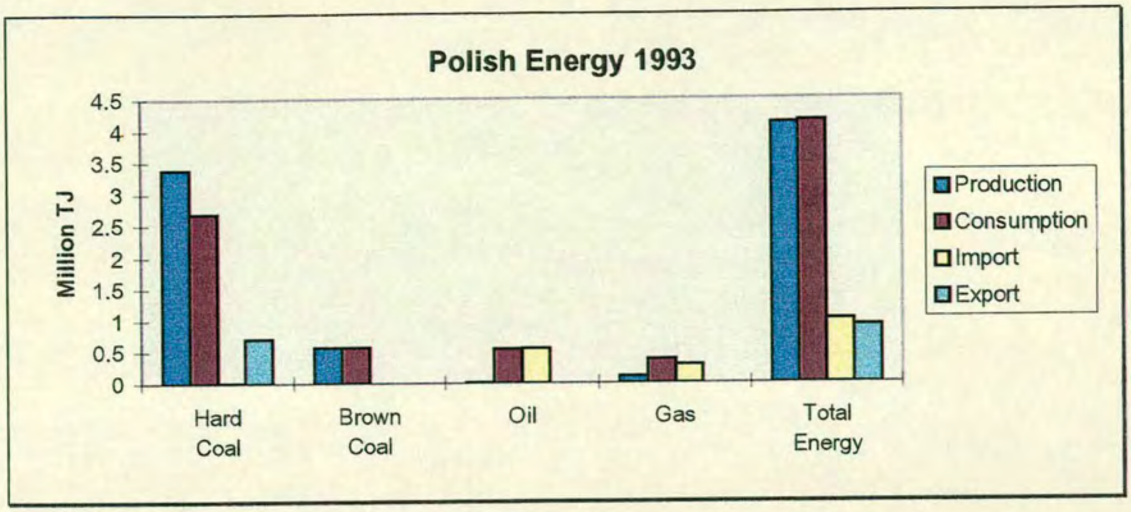


Figure 3.5.5 Polish Energy 1993

3.6 Electricity Sector

3.6.1 Structure

Before the Second World War the Electricity Supply Industry in Poland was characterised by separate plants supplying local area grids. Following the destruction caused by the War, a co-ordinated effort began to create a national power grid with a standard frequency of 50Hz and a nominal voltage of 110kV. By the mid-fifties almost all large power stations were connected to the grid and, by the sixties, construction had begun on a 400kV network. Since 1946, production of electricity has increased by a factor of 25, with over 90% of production in 1989 coming from centrally controlled plant.

Until September 1990, the responsibility for production resided with the Union of Brown Coal and Power Industry, a subsidiary organisation of the Ministry of Industry. This controlled the national despatch centre, the 33 regional boards, 56 thermal power plants and 119 hydro-electric plants.

Since 1990, government aims in the energy sector have included restructuring of energy industries and removal of state controls with a progression towards market pricing for energy. The goal of restructuring is privatisation, to allow for industry improvements by raising external capital, and an appropriate regulatory structure would be developed concurrently. Electricity costs to industry had been heavily subsidised in the past, and as the price of electricity had a significant impact on overall industry costs, a phased restructuring of this sector towards the British model was favoured. Generators will become progressively holding companies, treasury-owned joint-stock companies and, finally, private companies. Competition would deliver market prices without subsidies, with regulation maintaining security of supply and reductions in environmental impact.

In September 1990, the Union of Brown Coal and Power Industry was dissolved and the Treasury owned Polish Power Grid Company (PPGC) formed. The first stage of restructuring allows the PPGC to maintain a monopoly on purchasing power from the 34 generating companies, despatch of their plant and international trading of electric power. The 33 regional distribution companies are allowed to enter into contracts for the purchase of electric power with local auto-producers but must purchase all other requirements from the PPGC. The PPGC purchases power from the generators through annual contracts, with prices paid reflecting costs of generation plus a margin, while distribution companies pay a tariff based on PPGC average purchase costs. This system allows stable prices to be delivered through the transition to a more efficient, competitive system, by subsidising smaller, less efficient plant which would be expensive to decommission and which may be required as demand increases. In order to facilitate investment in new replacement capacity, the PPGC may also enter into longer term power purchase contracts. All contracts entered into by the PPGC are regulated by the Ministry of Finance.

The second stage of restructuring, scheduled for 1998 and currently envisaged as lasting ten years, would allow greater competition in contracting for generator output. Uncontracted output would be bought by the PPGC through a pool at Pool Purchase Price, set in a similar manner to the England and Wales Pool. Large consumers would be allowed to buy from local distributors or direct from the PPGC at a bulk supply tariff.

The final phase of restructuring would allow complete competition in generation and possibly also in supply, with the ending of the Bulk Supply Tariff and Wholesale contracts. Generators would trade directly with suppliers or customers with uncontracted energy sold through the pool.

3.6.2 Capacity and Demand

Before the Second World War, there were over 3000 electric power plants in Poland, with the total capacity of 1.7 GW split equally between public suppliers and industrial autoproducers. The war resulted in the destruction of nearly all of this capacity, but reconstruction to pre-war levels was achieved relatively quickly. Capacity expanded almost exponentially from 1950 to 1980, while the share of autoproducers fell from nearly 50% to around 10%.(Figure 3.6.2) Most of this expansion comprised of hard coal plant, much of it producing heat for local district heating schemes in addition to its generation capacity, but hydro-power also expanded from 200 MW to 2 GW installed capacity over the same period.

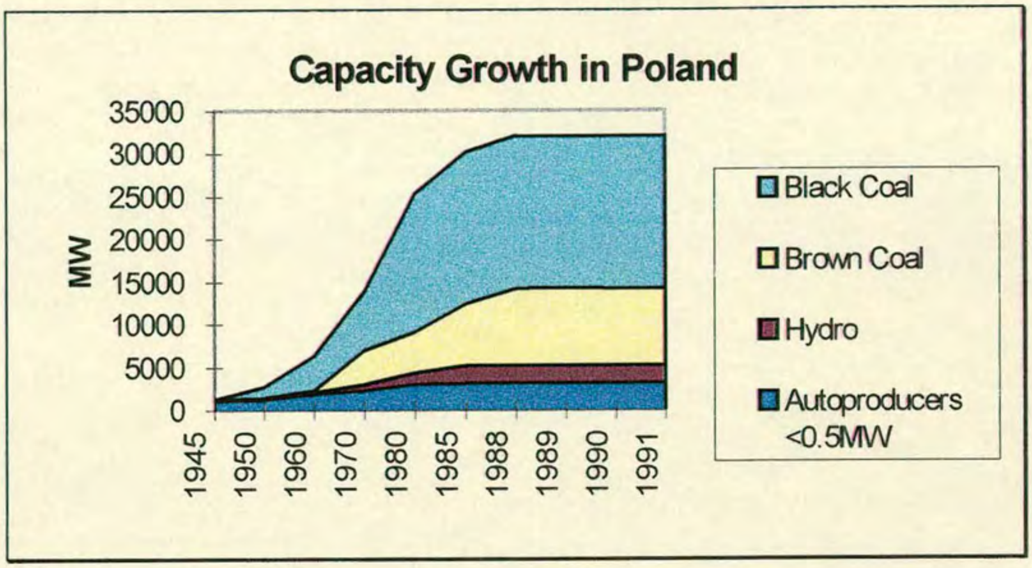


Figure 3.6.2.1 Capacity Growth in Poland.

Growth in capacity slowed through the 1980s as the economy stagnated and capital for new investments grew scarce. Although some 6 GW was added over the decade, this consisted largely of the commissioning of the Belchatow brown coal plant (at 4320 MW, Europe's largest single power station) and the Zarnowiec pumped storage plant (680 MW). In 1982, construction commenced on a 2 GW pressurised water reactor plant, also at Zarnowiec. This was part of a plan to build up to 10GW of nuclear plant to cover a perceived capacity shortage of 14-18 GW by the year 2000. Construction of this plant proceeded fitfully due to lack of funds and was dogged by poor quality construction and materials. The project has since been abandoned and, unlike its central European neighbours, Poland has no plans for new nuclear capacity.

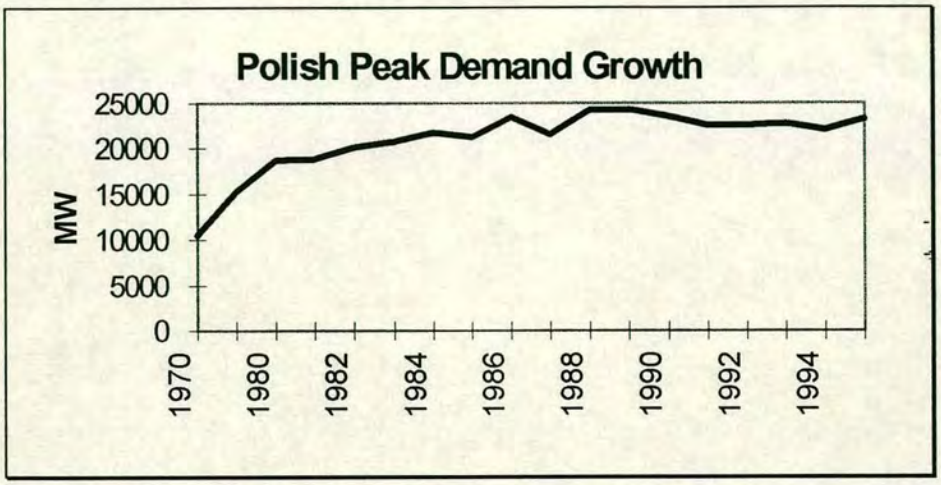


Figure 3.6.2.2 Polish Peak Demand Growth

Peak demand grew by only 10% between 1980 and 1994 from 20 to 22 GW. (Figure 3.6.2.2) Peak demand is driven by temperature and occurs around 17:00 hrs on a winter evening in a similar fashion to the UK. While the margin between peak demand and generating capacity would appear comfortable at 11GW (50% of peak demand), over

50% of this capacity is over 20 years old, inefficient and grossly polluting. Peak demand is forecast to grow to 26 GW by 2000 and 30GW by 2010 in the industry's 'stagnation' scenario, and to 30GW and 40GW, respectively, in its' 'prosperity' scenario. Although these projections may be somewhat over-estimated, and there is certainly some scope for demand management, it is clear that construction of new capacity will be required soon.

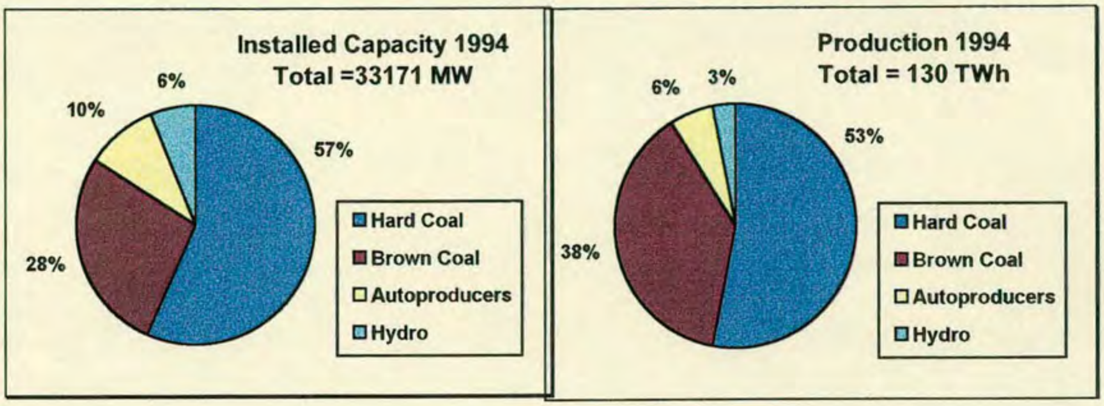
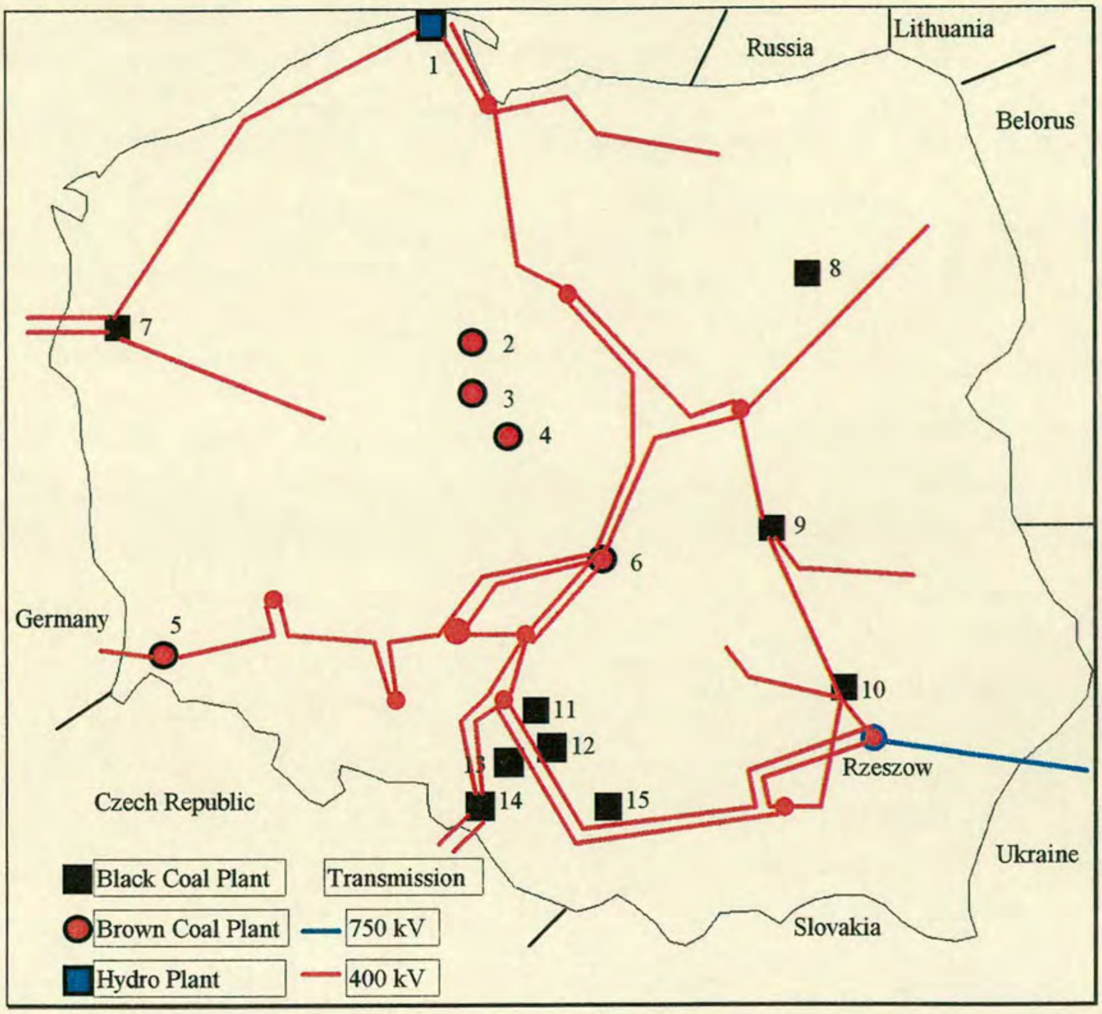


Figure 3.6.2.3 Polish Capacity and Production, 1994

Current capacity is dominated by hard coal plant. Individual plant capacities and locations are detailed in Figure 3.6.2.4, over. Of a total installed capacity of 33.2 GW in 1994, 56.6 % was hard coal, and 27.5% brown coal. Much of the autoproduction capacity is also fired by coal, although some uses local waste fuels such as coke oven gas. While some expansion of the hard coal sector is projected, it is likely that capacity growth will be in the gas-fired sector. As mentioned above, there are plans to expand domestic production of gas and to seek alternative sources of supply. While some small peaking plant will be required to cover peak demand growth, most of the projected 9 GW of gas-fired plant projected for 2010 will be baseload CCGTs.



	Name	Fuel	Capacitry MW
1	Zarnowiec	Hydro (pumped storage)	680
2	Patnow	Brown Coal	1600
3	Konin	Brown Coal	583
4	Adamow	Brown Coal	600
5	Turow	Brown Coal	2000
6	Belchatow	Brown Coal	4320
7	Dolna Odra	Black Coal	1600
8	Ostroleka	Black Coal	600
9	Kozienice	Black Coal	2600
10	Polaniec	Black Coal	1600
11	Lagisza	Black Coal	840
12	Jaworno	Black Coal	1697
13	Laziska	Black Coal	1040
14	Rybnik	Black Coal	1600
15	Skawina	Black Coal	740

Figure 3.6.2.4 Polish Generation Plant.

3.6.3 Production and Consumption

Gross production of power in Poland grew by around 30 GWh each decade between 1960 and 1989, with the only slow -down in growth occuring in the early 1980s when the economy went into recession. Following the removal of central-planning in 1989 production fell by almost 10% from 145 TWh in 1989 to 133 TWh in 1993 as many larger industrial consumers closed. This decline has now stabilised and production increased by around 1% per year in 1994 and 1995.

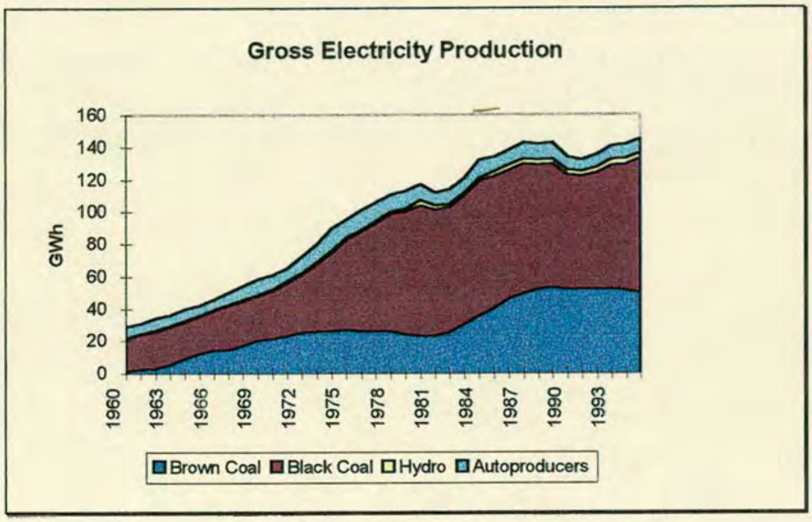


Figure 3.6.3 Polish Gross Electricity Production

Black coal plant dominates production of electric power in Poland as might be expected. As can be seen from the above graph, brown coal and hydro production increased their level of production significantly in the mid-1980s with the opening of Belchatow and Zarnowiec stations. Brown coal plant has historically operated at baseload (around 75% load factors), reflecting its low fuel costs and the large size of the units installed. Since 1989, the older, less efficient brown coal plant has operated at lower load factors of around 50%. The load factor of the larger black coal plant fell through the 1980s with the increase in brown coal-fired production and much now operates in a mid-merit role. Hydro production generally has a variable share of production, reflecting annual rainfall patterns. In Poland, however, as 70% of capacity is pumped storage plant, hydro plant maintains a relatively stable share of production of around 3.3 TWh p.a. Pumped storage and hydro is used for providing peak cover as there are few alternative sources of generation for this role in Poland.

Of the 135 TWh gross production in 1994, 3 TWh was consumed in water pumping in pumped storage stations, net exports totalled 2.5TWh, and power stations consumed 10 TWh. Transmission and distribution losses are extremely high and accounted for 17 TWh (14%) due to continual underinvestment in these networks.

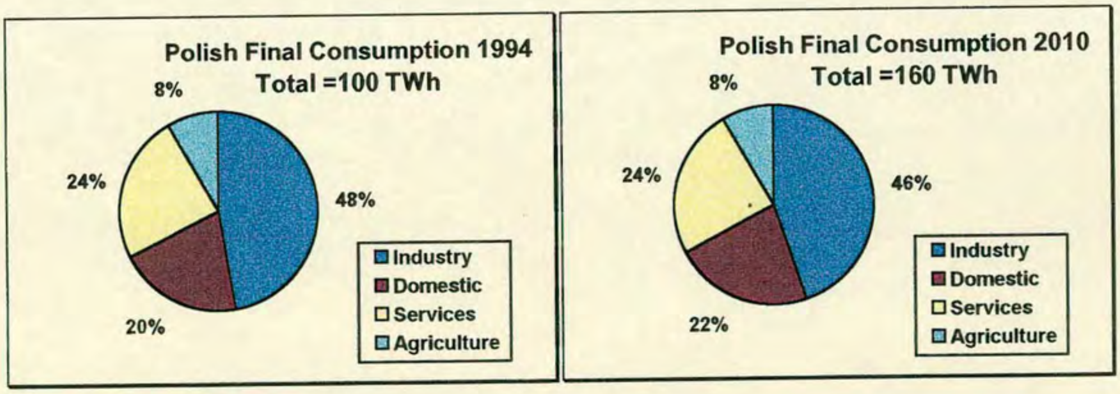


Figure 3.6.3.2 Polish Final Consumption, 1994 and 2010

Figure 3.6.3.2 illustrates the shares of consumption by sector.

Total consumption is projected to grow to 117 TWh by 2000 and 160 TWh by 2010. Between 1990 and 1995, consumption in the industrial sector declined as large, inefficient users closed. This is projected to recover to 1990 levels by the end of the decade. Domestic consumption is projected to increase by 25% over the same period as access to consumer electrical goods and the buying power of the population increases. Similarly, the underdeveloped service sector is set to increase its consumption by almost 20%. Growth in all sectors is expected to continue to 2010, such that relative shares remain little different from 1994 levels.

3.6.4 Electricity Trade

Poland currently has one 750kV interconnection with the Ukraine, terminating at Rzeszow in South Eastern Poland. The Polish grid system is weak in the North East and is supported by a 220kV link with Belarus. In addition, Poland has one single and one double circuit synchronous connections with the VEAG grid in Eastern Germany at 400kV, one double circuit 400kV and one double circuit 220kV connections with the Czech Republic in the south.

A link has been proposed from Bialystock in North-East Poland to Lithuania, allowing trade with the Baltic Republics. The cost of this link is estimated at $85m and would allow the Baltic states to reduce their dependence on imports from the former Soviet Union. In November 1992, a letter of intent was signed by the PPGC concerning construction of a high capacity 4000 MW link running East-West across Poland. [Hammons, 1994] Other partners in the project are Preussenelektra and VEAG of

Germany, the Russian Energy Ministry and the Belarus Ministry of Energy.[OXERA, 1994] Commissioning of the link is projected by 2010 and several schemes, including a new 1700km, 600kV DC line.

Through the 1980s the volume of electricity traded by Poland grew steadily. However, imports grew at a greater rate than exports so that, from a balanced position in 1980, Poland ran an import deficit of 4.5TWh in 1988.(Figure 3.6.4) More than half of the volume of trade was managed on a non-remunerative basis with the neighbouring states by the Elektrim agency of the Foreign Trade office. Exchanges were co-ordinated by the Central Dispatcher in Prague and were largely used for peak lopping. Commercial exports totalled 2.6TWh in 1988 and included 1.4TWh sold to Austria on a long term contract. This contract has recently been re-negotiated at 1.6TWh p.a. and is reported to be worth $55 million p.a. [IEA 1994].

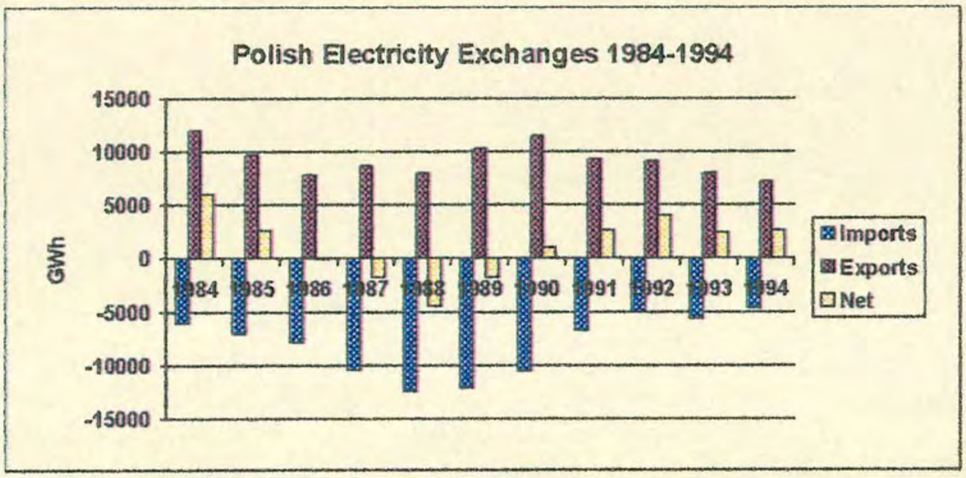


Figure 3.6.4 Polish Electricity Exchanges 1984-1994

Since 1988, Poland has moved from being a net importer to being a net exporter, although the overall volume of trade has declined to 60% of its 1989 level. Small imports of 168GWh/year from Belarus stopped in mid 1993 when North-East Poland was integrated with the national grid system.

Polish net electricity trade from 1992 to 1994 is detailed in Table 3.6.4.1. Figures for 1992 and 1993 are taken from UNECE reports and are simply the net flows across borders. 1994 figures, from the PPGC annual accounts provide information on the final destination of these net exports. The large net exports to the Czech Republic in 1992 and 93 therefore account for volumes of power wheeled to Austria, Switzerland, and Slovakia. CEZ's accounts detail imports for the Czech republic of only 1000GWh in 1992 and 885GWh in 1993. The total net import from Germany accounts for only around one eighth of the total volume of power traded between Poland and the VEAG system in 1992 and 1993, suggesting a significant level of spot trading for sytem support. PPGC's figures suggest that this trade remained in balance in 1994 and the integration of the former East -German VEAG network with the UCPTE system in 1995 effectively ended this trade until the CENTREL grid can be synchronously connected to the UCPTE.

Partner	1992	1993	1994
Belarus	-168	-125	
Czech Rep.	5552	4591	362
Germany	-1381	-1132	
Ukraine	29	-923	
Slovakia			37
Hungary			300
Austria			1796
Switzerland			122
Total	4032	2411	2618

Table 3.6.4.1 Polish Net Electricity Trade 1992-1994

Although currently constrained by the heavy environmental burden of emissions from coal fired plant (particularly brown-coal plant), Poland has a promising position as a net exporter of power in future, providing it can deliver its power system expansion and emissions reductions programmes. The lack of import dependence on the former-Soviet Union allows for decoupling of the Eastern links with a minimum of problems. Continued synchronous connection to the West, rather than an extended period of disconnection from the former-East German network, would allow for significant exports to be made to Germany, where high prices prevail. Without synchronous connection to the UCPTE grid, exports will be constrained by the DC converter stations linked to the Czech Republic and the Czech grid's ability to wheel energy to them. An inability to export power would also have a detrimental effect on revenue and funding for improvements in the Polish Grid system.

3.7 Future Developments

As reported above, much of Poland's current generating stock is aging, inefficient and grossly polluting. The fall in demand due to recession has presented an opportunity to rectify these problems and the industry has plans to refit 4GW of coal plant with FGD equipment by 2000 and a further 8GW by 2010. From 1 January 1998, generators must comply with Polish air emissions regulations and the cost of compliance has been estimated at $6-8bn. Of particular concern are smaller CHP plants sited in towns which present an opportunity for conversion to gas firing. Funding has been forthcoming from the World Bank and the EBRD for efficiency improvements and projects are currently taking place at the Dolna Odra, Laziska and Patnow plants. The PPGC has made committments to sign 20-25 year power purchase contracts with plant undergoing modernisation programmes. The problem of transmission and distribution losses (as high as 14%) also needs to be addressed and may add up to $7bn to the cost of improving the Polish power system.

To cope with projected demand growth, and potential export opportunities, the Industry Ministry has produced a number of expansion scenarios. A low-growth case projects an increase in capacity of around 12GW by 2010 to cope with demand growth. This would involve a doubling of current hydro capacity with the remainder of the expansion made up of gas-fired CCGT plant. A 'high' growth scenario projects a further 10GW on top of this, mainly in hard coal plant, but nuclear plant has been considered for this.

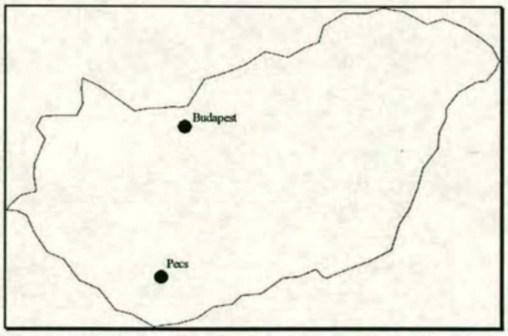
Existing projects in Poland include:

- 2160 MW hard coal plant at Opole, with 6×360MW units scheduled for completion in 1998 and due to be sold off to private investors after commissioning.
- 300 MW coal fired CHP plant at Walbrzych, costing $500 million.
- 750 MW pumped storage plant at Mloty in Silesia. Construction began in 1979 but was halted due to lack of funds. Electricité de France are reported to be interesting in funding completion of the plant, at a cost of $650 million, with power sold by direct link to Germany.

Poland remains comitted to increased trade in electric power with other countries and to increased competition in its internal power systems. This presents good opportunities for foreign investors to buy existing plant or build, own and operate new plant. Both Domestic and Industrial electricity prices are projected to rise to levels which will allow revenue to cover investment in these projects.

CHAPTER 4: HUNGARY.

4.1 Overview



Area: 93 030 km^2, 70% agricultural
18% forested

Population: 10.3 million (Jan. 1994)

Capital: Budapest (Population - 1.99 million)

Language: Magyar (Hungarian)

Climate: Continental, Maximum Temperature, 28°C, July
Minimum Temperature, -4°C, January

Currency: Forint Ft125.7:$1 (1995)

Foreign Debt: $28.5 billion (1994)

Unemployment: 10.2% (December 1995)

GDP

	1989	1990	1991	1992	1993	1994
GDP Growth	1.1	-3.5	-11.9	-3.0	-0.8	2.9

	1995	1996	1997	1998	1999	2000
GDP Growth	2.0	3.0	4.4	5.0	4.0	4.6

(% Change at constant 1991 prices) EIU Forecast, 1995 onwards

Inflation

	1990	1991	1992	1993	1994	1995
Consumer Prices	28.9	35.0	23.0	22.5	18.8	28

	1996	1997	1998	1999	2000
Consumer Prices	22.4	17.0	14.0	11.0	10.0

(% Change) EIU Forecast, 1995 onwards

4.2 History

The Magyar tribes arrived in the Danube basin in the late 9th Century. The country fell under Austrian rule in the 17th Century and remained part of the Hapsburg empire until 1867 with the establishment of a dual Austro-Hungarian monarchy. Hungary fought on the side of Austria and Germany in World War One, sustaining terrible losses. The Treaty of Trianon in 1920 cost Hungary over 50% of her territory and one third of her population to neighbouring states.

Hungary was governed by the conservative Admiral Horthy between the wars and again fought on the German side in World War 2. Hungary was liberated by the Soviet army in 1945 and, in 1948, a communist government took power. A popular uprising took place in 1956, led by Imre Nagy, but was crushed with the aid of the Soviet Army and Nagy was executed. Strict communist control of the economy was relaxed in 1968 with the introduction of the "New Economic Mechanism", allowing greater freedom for individual enterprises.

Janos Kadar, who had governed Hungary since 1956, was removed from power in 1988. The political reform in the Soviet Union and economic stagnation at home paved the way for the reforming government led by Imre Pozsgay. In October, 1989, the "Hungarian Socialist Workers Party" voted to dissolve itself and the first free elections were held, ending 40 years of communist control.

4.3 Events Post-1989

Hungary's first free elections since the end of World War 2 were held in March 1990 and resulted in a win for the Hungarian Democratic Forum and its allies, with Jozef Antall as Prime Minister. This coalition government faced serious internal tension over radical plans for free-market restructuring of the economy. Hungary has been relatively successful in stimulating private enterprise, with around 36% (OECD estimate) of its workforce employed in private and post-private firms. However, between 1990 and 1994 industrial output of large firms fell by 40% and agricultural production by 50%, causing great social hardship.

Following the death of Mr Antall, elections were held in May 1994. These were won by the former communist Hungarian Socialist Party (HSP) in a landslide victory, reflecting the populations belief that the economic hardship was a result of bad management since 1989. The HSP has, however, put its communist ideology aside and appears to be proceeding with economic reform, albeit at a slightly slower pace.

4.4 Economy

The Hungarian economy remained primarily agricultural and primitive until 1867 when industrialisation began. Manufacturing output grew at 4% p.a. to 1913 and industry expanded in sophistication as well as volume. Hungary adopted electrical technology quickly and Hungarian engineers invented the A.C. transformer allowing practical transmission of electric power.

World War 2 devastated the Hungarian economy but central planning after the war allowed the communist government quickly to nationalise industry and agriculture post 1945. Central control had some success, but by 1968 stagnation had set in and reforms allowed greater local control of industry.

Throughout the 1970s, Hungary's government attempted to finance continued investment by foreign borrowing. Hungary's foreign debt rose to $7bn by 1982 and remained at this level throughout the 1980s. Economic reform gathered pace through the 1980s as government planners sought solutions to the growing economic problems resulting from this level of indebtedness. However, these reforms were too little, too late and, following the removal of the communist government in 1989, real economic change was allowed to take place.

4.5 Energy Resources

4.5.1 Hard Coal

Hungary has reserves of hard coal totalling 714Mt, of which 100Mt is economically recoverable. Hard coal production has consistently fallen since 1980 when it reached 3.1Mt. In 1989 this had fallen to only 2.2Mt and by 1992 the decline in production had accelerated, as uneconomic mines closed, with production totalling 1.7Mt, a fall of 23% over 3 years. The Hungarian government made a strategic decision in the early 1980s not to pursue expansion of national iron and steel industries and this has had a knock-on effect into the development of hard coal resources. The cost of low-calorific value Hungarian coal is estimated as 33% higher than imports, and the government has taken a hard line on further subsidies. The main hope for continuing production of domestic coal is a policy of pairing power stations with adjacent mines. The power stations are designed to burn Hungarian coal and the cost of new capacity or conversion is likely to be greater than continuing to subsidise these mines. This policy has been successful at three sites: Matra, Pecs and Bacony, and the Hungarian government has announced its intention to introduce a similar policy at other sites.

4.5.2 Brown Coal

Hungary has extensive reserves of lower grade brown coal, estimated as totalling 5.7Gt. 3.65Gt of this are described as economically recoverable, with 780Mt in existing sites which is enough for 30 years consumption at current rates. Production of brown coal fell through the 1980s as costs rose, from 22.6Mt in 1980 to 18.6Mt in 1989. By 1991 this had fallen further to 15.2Mt production of brown coal and lignite, and in 1993 total coal production (including hard coal) in Hungary totalled only 14Mt. Production is projected to fall further, with further mine closures and falling demand, although government policy anticipates maintaining sufficient production for existing electricity generation plant. By 2000 there are expected to be only five working mines in Hungary, with the closure programme costing in the region of $122m.

4.5.3 Oil

Hungarian oil reserves are found mainly in the Alfold region in the South of the country, and estimates of their size range from 58Mt to 80Mt. Recoverable reserves are estimated between 20-40Mt with proven reserves in 1993 put at 147million barrels. Production remained constant at 2Mt/year through the 1980s, but this is unlikely to continue as current reserves are exhausted faster than new sites are brought on stream.

Hungarian oil accounts for around 25% of domestic demand. The remainder had previously been imported from the Soviet Union, under barter arrangements, through the Friendship I & II pipelines. This must now be bought with hard currency, and plans to diversify sources of supply have suffered a setback with the severing of the Adria pipeline by the war in the former -Yugoslavia. The government gas and oil monopoly OKGT has been broken up with the oil-sector company, MOL, privatised in 1994.

4.5.4 Gas

Gas reserves in the Alfold region are estimated at around 113Gm^3. Production through the 1980s averaged 6Gm^3/year but has gradually fallen to 4.9Gm^3 in 1992, with a slight recovery to 5.3Gm^3 in 1993. Output is expected to decline to 4Gm^3/year by 2000 as currently worked reserves are exhausted. The discovery of sizeable natural gas reserves in the 1960s spurred the development of an extensive pipeline network which now serves over one million customers via 5 distribution companies. Consumption climbed steadily, peaking at 12.5Gm^3 in 1989, but has declined to 9.8Gm^3 in 1992 with the closure of large industrial consumers. Consumption is expected to recover to 1989 levels by the end of the century, as the pipeline network expands to supply further towns and villages. District and residential heating accounted for 47% of consumption in 1991.

Hungary imports the balance of its gas requirements from the former-Soviet Union area via the Brotherhood pipeline. Two long-term contracts for gas supply were signed from this source in the 1980s; the Orenburg contract for 2.8Gm^3/year to 1996 and the Yamburg contract for $2Gm^3$/year to 1998. Hungary also received $2.5Gm^3$ in 1990 as compensation for past inequities in barter deals, where Hungary was judged to have received less value for the energy imports than had been delivered to the Soviet Union in agricultural produce and Hungary's contribution of construction materials for the pipelines.

Reports suggest that Hungary contracted for $2.8Gm^3$ of Orenburg gas in 1993 at prices comparable to West European levels. MOL of Hungary is also reported to have signed a deal with OMV of Austria for construction of a $4.5Gm^3$/year capacity pipeline from Austria to Gyor in North-West Hungary allowing access to the West European gas network. Completion is projected for October 1996. Hungary also has an extensive network of underground storage sites to cover seasonal peaks in demand.

4.5.5 Other Energy Sources.

Hungary has one sizeable deposit of uranium, though little is known about the production costs. 524 tonnes of uranium were produced in 1990, the last year for which figures are available. Proven reserves are estimated at 3.12kt of uranium, exploitable at costs less than $130/kg, with an additional 18.25kt exploitable above this cost. Yellowcake was previously processed into fuel by the Soviet Union under an agreement which also encompassed the return of spent fuel. Hungary's one uranium mine at Mecsek is scheduled to close due to the collapse of world uranium prices, but it may ultimately find a use as the final resting place for radioactive waste.

Hungary has a gross theoretical hydro-electric capability of 7,400GWh/year. From this upper limit, 4,000GWh/year is assessed as exploitable at sites over 2MW capacity and 500GWh/year at smaller sites. Currently only 173 GWh/year is produced in average conditions from a total of 42MW capacity.

In addition to the above energy sources, Hungary produces 100kt/year of peat for domestic consumption, from a total resource of 238Mt, and 934kt of fuel wood. Hungary has large reserves of 'Alginite' oil shale, up to 150Mt in total, in favourable mining conditions. This is described as low to medium grade by international standards but some parts of the deposit have calorific values as high as 12500-17000kJ/kg, comparable to brown coal. Sulphur content is less than 1% but the high ash content (40-60%), presence of heavy metals and other pollution problems associated with oil shale exploitation would not favour its use as an energy source in the near future. Hungarian territory falls within a region of significant seismic activity and has a geothermal potential of 2615GWh/year production from 1276MW of potential capacity.

Figure 4.5.5 summarises Hungary's energy balance in 1993, illustrating the reliance on imports of oil and gas.

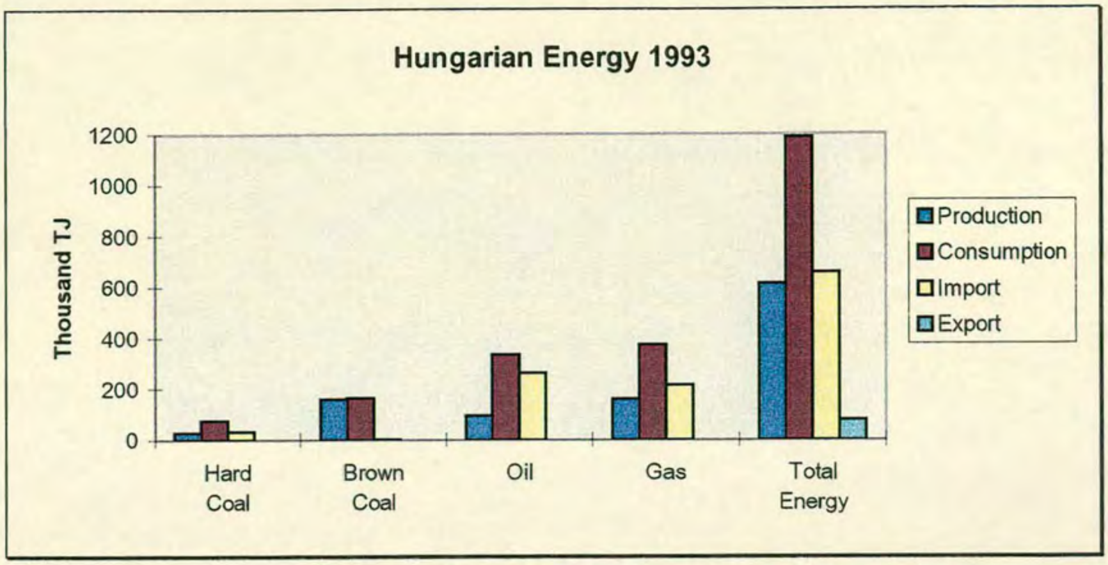


Figure 4.5.5 Hungarian Energy 1993

4.6 Electricity Sector

4.6.1 Industry Structure

In common with its central European neighbours, the structure of the Hungarian power industry under communist rule was that of a large, monolithic company controlling all aspects of electricity supply. In Hungary, however, the degree of control which this company, Magyar Villamos Müvek Troszt (MVMT), had over the power sector was much greater than in the other states. MVMT maintained a monopoly over distribution (6 subsidiary distribution companies), transmission and a near monopoly over generation, as autoproduction by large industrial concerns was almost non-existent.

On January 1 1992, this structure was unbundled into a two-layer system of public limited companies. MVM group maintains control of transmission and despatch through the subsidiary grid company MVMRt. MVM group is also a 50% stakeholder in the 6 distribution companies and 8 power plant companies, with the state property agency controlling 48% and municipalities controlling 2%. The coal-mines associated with power stations are incorporated into those power station companies. The distribution companies are in the process of being sold off by a voucher scheme, which issues shares to individual investors, and it is intended to sell off MVMRt and the power station companies by auction.

Independent power producers are allowed to construct power stations in Hungary, but must offer their production to MVMRt if their capacity is greater than 20MW. 7 applications for Independent Power Projects, totalling 1GW, have reportedly received licenses and power purchase agreements from MVMRt.[EER 49/4]. MVMRt undertakes to purchase power at least-cost but in selling to the distribution companies, a cross-subsidy from industrial to domestic consumption is made.

In addition to this cross-subsidy, a number of questions regarding the final structure and liabilities of the generation companies and MVMRt must be addressed. Foreign investors are reported to be reluctant to invest in MVMRt, despite its profitability, if it includes the Paks nuclear site. MVM group also requires investors in nine coal fired plant to upgrade to modern coal or gas over the next fifteen years at a cost of $126-371million per plant. Majority shareholdings in the Distribution companies and the Matra and Dunamenti power stations were recently sold by the state privatisation agency to, amongst others, EdF, RWE Energie and Bayernwerke.[Financial Times 13/2/96] This sale raised $868m, with an average premium of 30% paid over the list price, but interest in purchasing generators was poor due to the conditions attached, with only two plant out of seven offered sold [GPP, 7/9].

4.6.2 Capacity and Demand

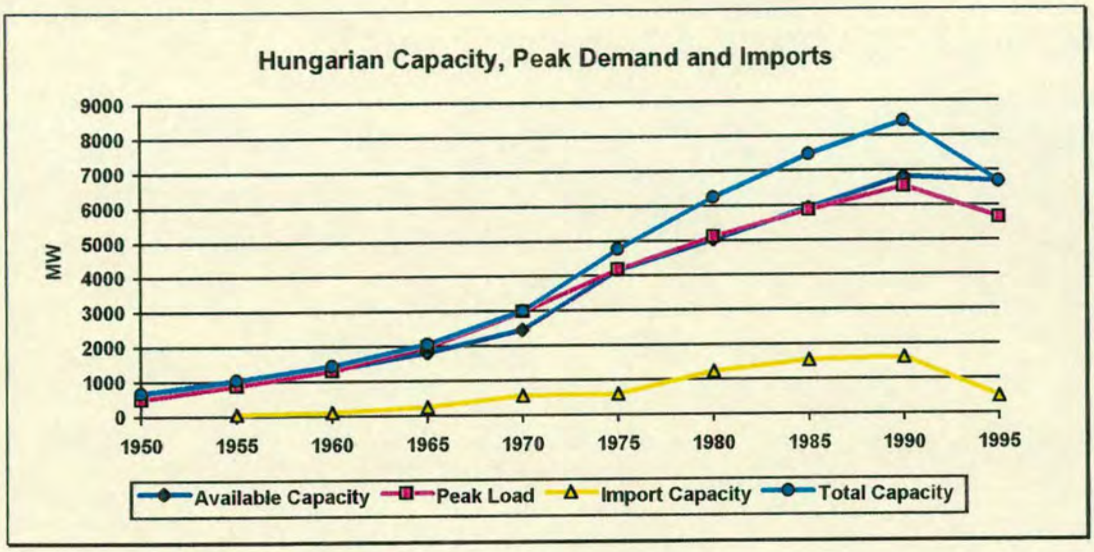


Figure 4.6.2.1 Hungarian Capacity, Demand and Imports

The capacity of the Hungarian Power System has grown steadily since 1950, from 675 MW to 7168 MW in 1989. Peak demand, however grew at a faster rate, from 486MW to 6550MW over the same period, as the level of electrification of households increased from 47% to nearly 100%. Growth in capacity stagnated from 1977 as no new plant were commissioned but picked up between 1983 and 1987 with the commissioning of the Paks nuclear units before slowing once again. In order to meet the increasing demand, Hungary increasingly grew to rely on the capacity of its interconnections, with imports required to cover demand growing from around 500MW in 1970 to nearly 2GW in 1989. Plans for further expansion of capacity after this centred around further nuclear plant and the Gabcikovo-Nagymaros hydro-scheme.

From 1988 to 1990, peak demand remained relatively constant, at around 6.5GW, but in 1991 this had fallen to 5.7 GW and it has remained at this level since. The fall in demand is due to the closure of inefficient state industry, and is not projected to recover to the 1989 level until after the turn of the century. The annual load factor of the Hungarian system has remained relatively constant since 1980 at around 65%. The load factor of business days gradually rose through the 1980s, as measures to reduce daily peaks were introduced, but this is likely to fall again as industrial demand declines and domestic and commercial loads increase.

3GW of Hungary's 5GW of conventional thermal plant is installed at four sites, (as illustrated in figure 4.6.2.2, over) constructed during the 1960s, and almost 1GW of the remainder is even older, situated in smaller combined heat and power plant. Much of the older plant was refitted during the 1980s, but must still be considered obsolete by international standards. Of Hungary's small stock of hydro-electric plant, totalling 48MW capacity, 20MW is described as 'very old', with the only exception being the 28MW Kisköre station. 26% of total capacity is sited at the 1720MW Paks nuclear station, which has strong implications for overall system security in the event of problems at this plant. Installed capacity by type is illustrated in the figure 4.6.2.3.

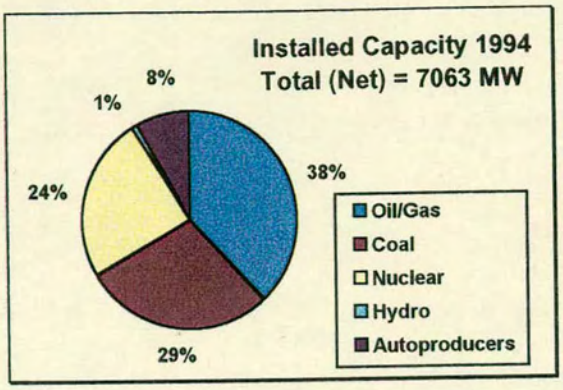
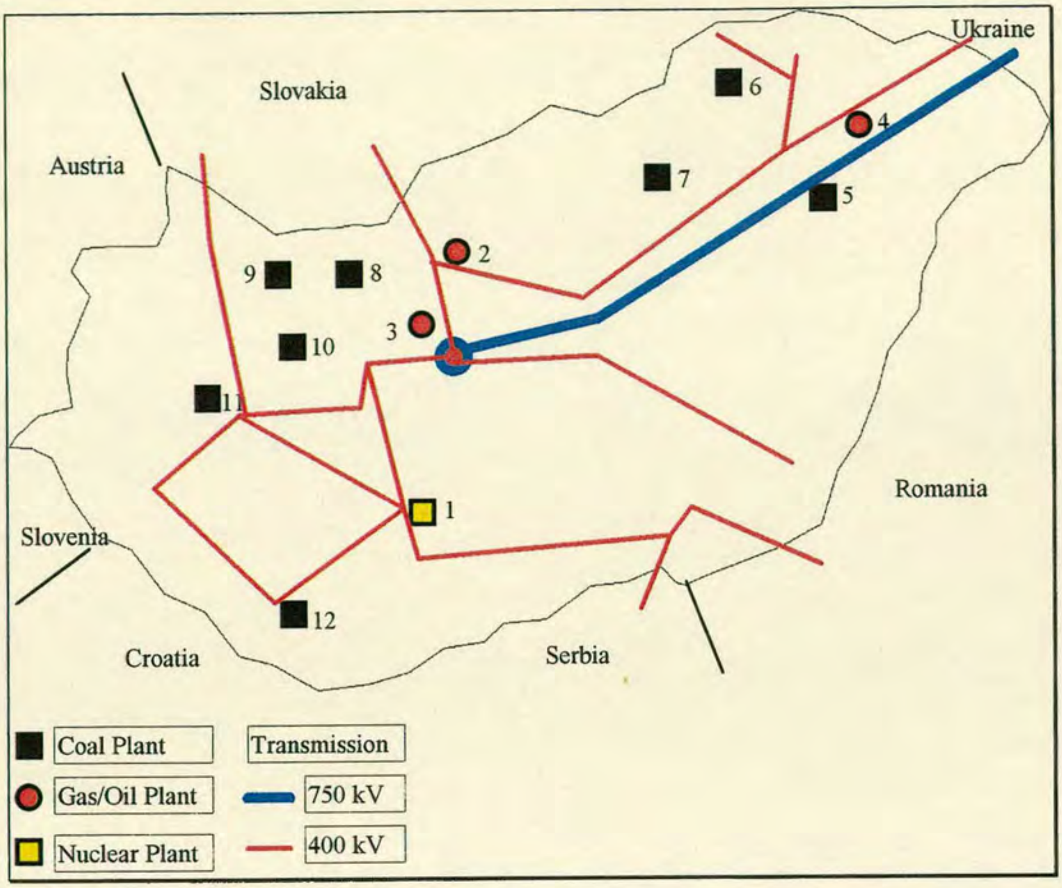


Figure 4.6.2.3 Hungarian Installed Capacity 1994



	Name	Fuel	Capacity MWe	Production GWh (1992)	Load Factor	Heat Supply TJ
1	Paks	Nuclear	1840	13964	86.63%	629
2	Budapest	Gas/Oil	163	640	44.82%	16314
3	Dunamenti	Gas/Oil	1870	4275	26.10%	7697
4	Tisza II	Gas/Oil	860	2616	34.72%	
5	Tiszapalkonya	Coal	250	932	42.56%	2422
6	Borsod	Coal	171	599	39.99%	3168
7	Mátra	Lignite	800	3798	54.20%	151
8	Bánhida	Coal	100	617	70.43%	105
9	Oroszlány	Coal	235	1436	69.76%	388
10	Inota	Coal/Oil	262	122	5.32%	680
11	Ajka	Coal	132	476	41.17%	3361
12	Pécs	Coal	250	955	43.61%	3389

Figure 4.6.2.2: Hungarian Generation Plant

4.6.3 Production and Consumption

From the end of the Second World War to 1988, consumption of electric energy grew exponentially in Hungary. However from about 1965, domestic production began to lag behind in its growth rate. Hungary was able to maintain imports at a constant level for most of the 1970s, but imports increased each year from 1977 to 1985 before flattening off again with the commissioning of the Paks nuclear plant, as illustrated in figure 4.6.3.

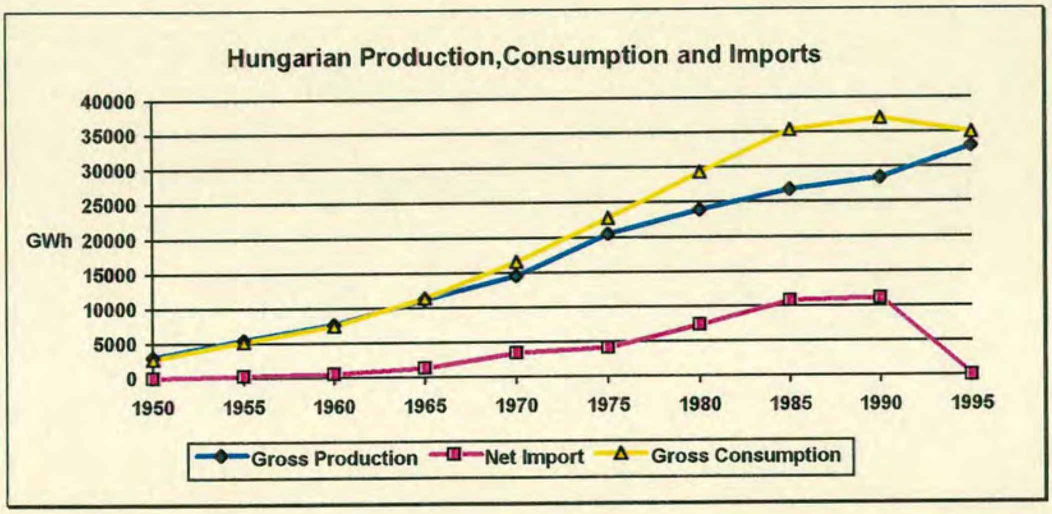


Figure 4.6.3 Hungarian Production, Consumption and Imports

Total consumption peaked in 1989 at 40.6TWh, before beginning to fall as industrial demand declined. By 1992, consumption had fallen to 34.8TWh and it has remained steady at around 35TWh per year since. Consumption is expected to make a slow recovery to its 1989 levels by 2005, but this masks a continuing increase in household consumption and decline in industrial share. The ratio of domestic to industrial consumption was 1:2.7 in 1989 and this had fallen to 1:1.84 in 1994. Domestic consumption per resident is reported to be 958kWh in 1994, an increase from 776kWh in 1988, and well above the levels in Poland and Czechoslovakia of 494kWh and

655kWh respectively. This is probably due to the greater penetration of consumer electrical goods into the Hungarian market.

Between 1980 and 1990 production by MVMT in Hungary grew by a little under 5TWh in total, from 22.8TWh to 27.4TWh. Over this period, use of oil for power generation fell from a share of 24.6% to less than 4%. The total share of fossil fuels in domestic production also fell, from 99.3% in 1980(the balance was hydro power) to slightly less than half as nuclear output increased The increase in consumption of 7.2 TWh over the same period was increasingly met by imports of energy, largely from the Soviet Union.

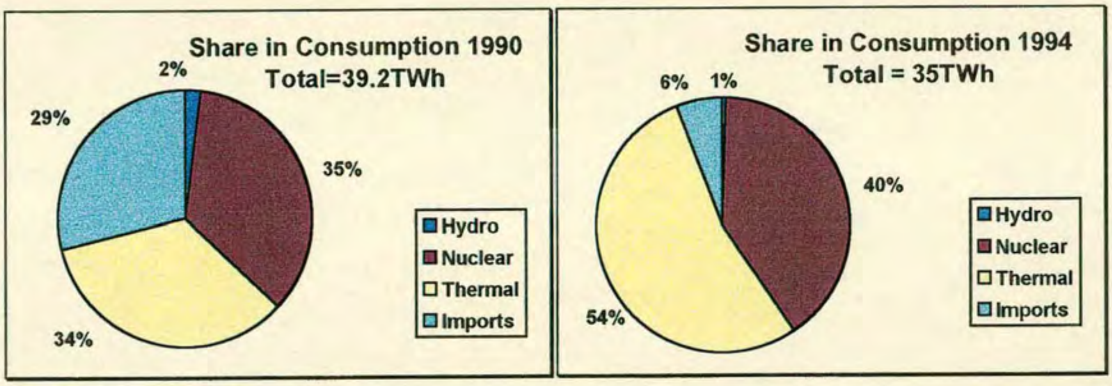


Figure 4.6.3.2 Share of Generation Sources in Meeting Consumption 1990 and 1994

Since 1990, production of electricity in Hungary has actually risen slightly and this, coupled with the large fall in demand has allowed the dependence on imports to be reduced. Figure 4.6.3.2, above, illustrate the falling share of imports in meeting overall electric energy demand. Most of the increase in thermal production has been through an increase in fuel oil and gas consumption, with the level of coal burn actually decreasing as Hungary attempts to reduce emissions from stations which are not equipped with pollution control equipment.

The Paks nuclear plant, with its high levels of availability (87%) and low marginal cost of generation, provides baseload power to the Hungarian system. The larger, more modern coal plant and a substantial fraction of imports are also utilised to cover base-load demand. Some of the operation of Hungary's gas and oil-fired units is dictated by the heat demand of customers, but with their more expensive generation costs they are generally used in a mid-merit role. Peak cover is provided by a number of open-cycle gas turbine plant and a portion of imports with some of the older small coal fired units kept as reserve.

Hungary's stock of coal fired stations are reported as not being able to readily burn imported coal. Lignite burning plants therefore have a mutual dependence on their neighbouring mines and have government regulated annual coal contracts, based on three-year inndustry plans, with set prices and volumes.[IEA, 1994] Hungarian brown coal costs $1.86-2.23/GJ, compared with the cost of hard coal at $1.49-1.86/GJ and an international hard coal marker price in 1993 of $1.29/GJ.[ICR, 1994]

4.6.4 Nuclear Power

The first two units at the Paks site in central Hungary were ordered by the government in 1971, with construction commencing in 1974. Two further units were ordered in 1977 with construction beginning two years later. Commercial power was first delivered from the first unit in 1983 and from the last unit in 1987. Although the units at Paks are of the same design as those in the Czech and Slovak republics (Russian VVER-440-213), they have a slightly higher thermal efficiency and have achieved much higher performance. The average lifetime load factor of the four units at Paks is 83%, much higher than the world PWR average of 67%.

In 1989, the Hungarian government cancelled an agreement made in 1986 for the supply of two 1000MW reactors from the Soviet Union when the required financing could not be raised. Lacking large fossil fuel and hydro resources, Hungary is reported to be considering the nuclear option for longer-term capacity expansion. In 1991 EdF offered to build two 900MW reactors, with repayment coming from electricity sold through a link to the West. Canada is also reported as having offered assistance in the construction of further reactors at the Paks site. The relatively large size of nuclear units in relation to overall demand, and the potential problems of having so much capacity at one site, do not favour the expansion of the Paks site in the short to medium term.

4.6.5 Electricity Trade

With the exception of Italy, Hungary has maintained the largest dependency on imported electric power of any European country. From the mid 1960s until 1985, net imports grew steadily as demand growth out-stripped construction of new capacity. Imports levelled off after 1985, with the comissioning of the Paks nuclear plant, but with little expansion planned for capacity within Hungary, imports would probably have begun to increase again. The reduction in demand, caused by recession after

1989, has allowed the level of imports to decline, but imports of 2TWh per annum are still planned up until 2010. [UNIPEDE, 1995]

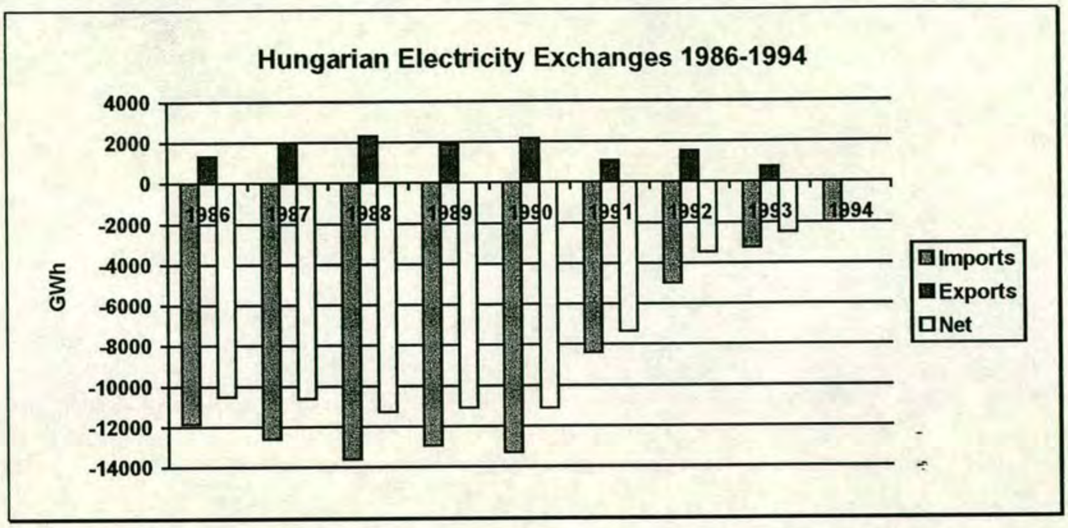


Figure 4.6.5 Hungarian Electricity Exchanges 1986-1994

Hungary's import dependency rested almost wholly on the Soviet Union, with imports from this country's Southern Power System peaking at 12TWh in 1990.(Figure 4.6.5) Hungary is connected to the Ukraine by one 220kV, one 400kV and one 750kV line with a combined capacity of 4GW. Two 400kV links with Slovakia and one 400kV link to Romania are operated synchronously. The 400kV link to the former Yugoslavia and the 400kV and 220kV links with Austria have been utilised for small exchanges in the past, with parts of the Hungarian network operating in 'island' mode.

The Hungarian network is synchronously connected to Romania at 400kV and has two 400kV and one 220kV link to Slovakia. These links were previously used mainly for small peak trades or the delivery of power wheeled across the Hungarian network. In July 1993, a 600MW back-to-back DC converter station was comissioned, linking

Gyor in North-West Hungary to Vienna South-East transformer in the Austrian system. This link will allow Hungary to trade more freely with the UCPTE system.

Contracted imports from the Soviet Union reached an annual level of 10.5TWh, pre 1990, with a maximum capacity of 1.8GW. As mentioned above, a proportion of these imports was used for load-following, with the interconnection making a contribution as flexible capacity in addition to its energy import role. With the inntroduction of hard-currency trading in 1990, the level of this contract has steadily reduced, initially to 6.5TWh in 1991, and the maximum capacity cut to 1.1GW. The contract is re-negotiated annually and is of a take-or-pay form with maximum levels of MW capacity and a minimum MWh energy take. The energy price of the contract has three levels, off-peak, normal and peak, but the contract also has a capacity element. The capacity element is quoted [IEA, 1992] as being 50% higher than that of domestic capacity and the peak price as double that of domestic production.

	Imports		Exports	
GWh	1992	1993	1992	1993
Austria	246	1705	472	273
Croatia	n.a.	n.a.	n.a.	n.a.
Romania	0	33	106	0
Slovakia	1496	696	367	23
Ukraine	2741	749	545	0
Yugoslavia	n.a.	n.a.	n.a.	n.a.
Total	4987	3230	1521	756

Table 4.6.5.1 Hungarian Electricity Trade 1992-1993

The commissioning of the Wien-Gyor interconnector in 1992 allowed Hungary to reduce the level of imports from the Ukraine and take energy from the more secure

UCPTE system, as detailed in table 4.6.5.1. Spot imports of peak power are generally cheaper than domestic production and would make up most of the trades with Croatia/Yugoslavia and Romania. Hungarian contracted trade for 1994 and 1995 consisted of 2TWh of imports, the majority of which is likely to come from the UCPTE system via Austria. The Wien-Gyor interconnector has sufficient capacity to provide for all Hungarian spot trading in addition to any contracts, but spot trading is likely to follow a similar pattern to 1993, with power delivered from Slovakia and the Ukraine albeit in smaller volumes.

Having relied heavily on imports in the past, resistance to dependence on neighbouring states for supplies is likely to be somewhat lower in Hungary than in most other countries. Improved connections and the greater grid stability resulting from synchronous connection with the UCPTE would allow for these imports to be made from the West and other Central European countries, but this would necessitate disconnection from the Ukraine, Hungary's traditional source of electricity imports. This presents a difficulty, as the Hungarian system may not meet some of the UCPTE membership requirements.

The UCPTE requires that members can operate their systems in isolation, with a margin of reserve. Hungary has clearly not met this requirement in the past, but MVMT has regarded the import contract with the UPS as firm capacity. Although the UCPTE conditions for interconnected operations allow contracted supplies to count towards a member's obligation to meet demand, whether this contract does deliver firm capacity, given the current situation in the Ukraine, is debatable. The UCPTE also requires an n-1 level of system security (that is the ability to continue to operate the power system in the event of the failure of a single large generating station or transmission line). The ability of the Hungarian system to acheive this, with Paks making up 25% of installed capacity, is also questionable.

Hungary must also find 1.2TWh per year from 1996-2015 to meet an export contract to Austria. This contract was struck in compensation for Austrian financing of the Nagymaros dam project on the Danube, which Hungary cancelled due to the perceived impact on the environment and water table of the area. Cancellation has also affected Slovakia's ability to operate the Gabcikovo dam upstream, and the Slovak government is currently pursuing a compensation claim.

4.6.6 Future Developments

Medium-term planning by MVMT projects that increases in demand and tertiary reserve requirements may be met by the construction of small gas-fired peaking plant. A total of 1270MW of gas-turbine plant is planned by the year 2000, with almost half of this covered by currently committed projects. The construction of gas-turbine plant offers advantages to Hungary of low capital costs, improved efficiency and the ability to expand incrementally. The price and availability of imported gas, however, represents a downside risk to these plans which would mean a doubling of gas consumption for power generation from its current level of 2Gm^3 per year. [IEA, 1994]

By end-1996 Hungarian tariffs should cover the cost of supply and this will aid the financing of MVMT's longer term plans. 1.2GW of plant is planned for closure by 2000, and 7GW of increased capacity will be required from new plant or the rehabilitation of older plant by 2010. Three options have been considered for a new large baseload power station in Hungary:

- A lignite burning plant at the Bukkabrany mine.
- A hard-coal burning plant on the Danube, utilising imported coal.
- A new nuclear station at the Paks site.

Both Canada and France have offered assisstance with new nuclear plant, Edf in 1991 offering to fund 70% of the construction of 1800MW with repayments made by direct electricity exports to the West. As stated above, Hungarian costs for the production of brown-coal are high in comparison to imported coal, and the construction of a large plant burning this fuel may be preferable to continued reliance on imported electricity.

CHAPTER 5: CZECH AND SLOVAK REPUBLICS

5.1.1. Czech Republic - Overview

Area: 78 864 km^2, 53% agricultural
39.9% forested

Population: 10.35 million (1994)

Capital: Prague (Population - 1.2 million)

Language: Czech

Climate: Continental, Maximum Temperature, 30°C, July
Minimum Temperature, -12°C, January

Currency: Kopek Kc28.785:$1 (1994)

Foreign Debt: $10.7 billion (1994)

Unemployment: 3.2% (1994)

GDP

	1989	1990	1991	1992	1993	1994
GDP Growth	1.4	-1.6	-14.7	-7.1	-0.9	2.6

	1995	1996	1997
GDP Growth	4.0	4.4	4.5

(% Change) Czech and Slovak Federal Republic to 1991, EIU Forecast, 1995 onwards

Inflation

	1989	1990	1991	1992	1993	1994
Consumer Prices	2.3	10.8	57.8	11.0	20.8	10.0

	1995	1996	1997
Consumer Prices	9.5	8.0	6.0

(% Change) Czech and Slovak Federal Republic to 1991, EIU Forecast, 1995 onwards

5.1.2 Slovakia - Overview

Area: 49 035 km^2

Population: 5.3 million (1994)

Capital: Bratislava (Population - 441 000)

Climate: Continental, Maximum Temperature, 30°C, July
Minimum Temperature, -12°C, January

Currency: Slovenska Koruna (Slovak Crown) Sk32:$1 (1994 average)

Foreign Debt: $4.3 billion (1994)

Unemployment: 13.7% (1994)

GDP

	1989	1990	1991	1992	1993	1994
GDP Growth	1.4	-1.6	-14.7	-7.0	-4.1	4.8

	1995	1996	1997	1998	1999	2000
GDP Growth	5.7	4.8	4.6	4.8	4.0	4.1

(% Change) Czech and Slovak Federal Republic to 1991, EIU Forecast, 1995 onwards

Inflation

	1989	1990	1991	1992	1993	1994
Consumer Prices	2.3	10.8	57.8	10.0	23.2	13.4

	1995	1996	1997	1998	1999	2000
Consumer Prices	10.6	10.0	9.0	9.0	8.0	7.5

(% Change) EIU Forecast, 1995 onwards

5.2 Czechoslovakia - History

Slavic tribes first settled in the area that is now Czechoslovakia in the sixth century and the region formed an important part of the Hapsburg empire. Following the revolutions of 1848, however, the Austro-Hungarian empire became more divided. The Czech lands in the West became increasingly industrialised and urbanised, with a powerful German aristocracy leading this development. The Slovaks fell under the Hungarian sphere of influence and remained mainly rural.

The Czechs seized independence from the Austro-Hungarian Empire in 1918, and the Treaty of Versailles created a Czechoslovak state which included significant German and Hungarian minorities. The Czech economy boomed during the 1920s, but Slovakia remained behind and the Slovaks became increasingly discontented. Despite being democratic and politically stable compared to its neighbours, Czechoslovakia was abandoned by France and Britain, her allies, and annexed by Germany in 1939.

At the end of the war, Czechoslovakia again became independent and the 3 million Germans in the West were expelled. The president, Edvard Benes, saw Czechoslovakia's position as a strong independent state in Central Europe, but the growing power of the communist party did not allow this. The communists took power in 1948 and Czechoslovakia became rigidly Soviet, with strong central planning and heavy industrialisation. Economic stagnation led to the replacement of the Stalinist leadership in 1968 and Alexander Dubcek was appointed first secretary.

Dubcek's radical political and economic reforms were unacceptable to the Soviet Union under Brezhnev. In August 1968 the Red Army invaded Czechoslovakia and removed the reformers from power. An extremely repressive Stalinist regime was put in place and remained in power until 1989, when its position became untenable in the force of growing moral opposition.

5.3 Czechoslovakia - Post 1989

Street demonstrations on November 17th 1989 resulted in police brutality against protesters and a wave of strikes and further protest followed. By December 10th the Communist President Husak had resigned and a Government of National Understanding appointed until free elections were held in June 1990. The reformers won a majority in the new federal government, but as time went on fragmentation between the various groupings increased. Coupled with this were increasing demands for greater Slovak autonomy, which resulted in a vote on termination of the federation on 1st October 1992. Although this motion did not gain the required majority, Czech politicians, who initially opposed separation, realised that integration with Europe would proceed faster for the Czech republic without the encumbrance of the Slovaks. On 25th November 1992 a vote on separation was passed, and independent Czech and Slovak republics were created on January 1st 1993.

Since separation, the two republics have followed very different paths, with the Czechs perceived as embracing the free-market and the West and the Slovaks as lagging behind. In truth, the separation has been difficult, with disagreements between the two governments over debt and trade terms. Both republics have suffered economically, but as they were going through a transition period anyway it is difficult to apportion particular problems as being due to the split. Since separation the Czech Republic has maintained greater political stability than Slovakia, stability being a keystone in their aim of membership of the EU and other Western organisations.

5.4 Czech and Slovak Energy Resources.

5.4.1 Hard Coal

Coal is even more important to the economy of the former Czechoslovakia than it is to Poland, providing over 80% of primary energy. Reserves of hard coal are estimated at around 4.5Gt, enough to last 100 years at current extraction rates. Official estimates describe 47% of these reserves as being practically recoverable, but the economics of recovery must be questionable, as the coal is not of good quality, with a calorific value of around 24.4GJ/t.

Production of hard coal peaked in 1980 at 27.71Mt, (figure 5.4.1) but declined through the 1980s as extraction became increasingly difficult. Since 1989, production has declined by 21% due to the removal of subsidies, which has led to a closure of uneconomic mines. However, production is expected to increase at three sites, Karkov producing up to 5Mt/yr from the mid 1990s, Frenstat from 1995 and Slany, a source of good quality coal, from 2000.

Hard coal is produced only in the Czech Republic, and the separation of the two Republics has caused numerous problems between government, producers and customers. In May 1993, the Czech Republic suspended deliveries to Slovakia over a payment dispute, with the Czech government requiring hard currency for all future supplies.

Since 1992, the Czech mining industry has halved its workforce to 54 000, but further cuts of up to 8000 jobs are expected. A restructuring programme has been proposed whereby economic pits would be grouped with uneconomic sites and help pay for their closure. The industry faces many challenges in the coming years, particularly from competition from Polish coal, with production projected to decline to 16Mt by 2000.

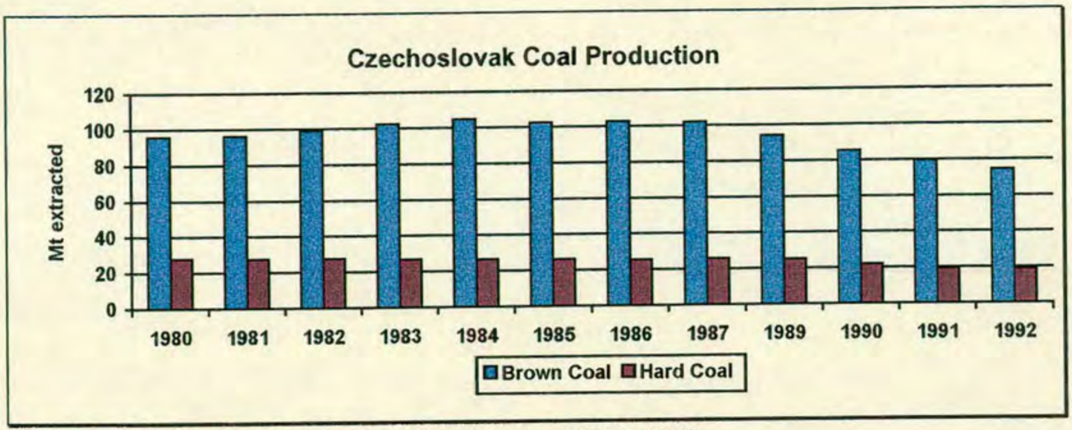


Figure 5.4.1 Czechoslovak Coal Production 1980-1992

5.4.2 Brown Coal

Czechoslovakian reserves of brown coal and lignite are even larger than their reserves of hard coal, at 5.5Gt. 3.9Gt of this are described as recoverable, but the faster rate of extraction (3% of total reserves p.a.) means that these reserves are likely to be exhausted within 30 years. Production of brown coal is exclusively from open-cast sites and reserves close to the surface are becoming exhausted, resulting in increasing production costs.

Production of brown coal peaked in 1984 at 101Mt (figure 5.4.1) but, had declined by over 25% to 74.6Mt in 1992 as consumption for electricity and heat production reduced. 96% of production takes place in the Czech Republic in Northern Bohemia, resulting in severe ecological damage to this area. Production in future is expected to decline to 49Mt/year by 2000 as grossly polluting power plant is phased out and demand falls.

5.4.3 Oil

Czechoslovakia has negligible reserves of oil, estimated at slightly more than 2Mt. Domestic production increased over the 1980s, to 150kt/yr in 1989, but has since declined to 100kt in 1992.

In 1990 Czechoslovakia imported 16.6Mt of oil, from the Soviet Union, via the Druzba pipeline. Plans to reduce this dependence in the face of increasing prices were handicapped by the closure of the Adria pipeline through Yugoslavia in 1991 due to the war. Czechoslovakia has a refinery capacity of around 10Mt/year, with most of the production consumed internally. Construction of a 2.7Mt/year pipeline from Ingolstadt in Bavaria is planned, with completion due in 1996, to reduce dependence on the former Soviet Union.

5.4.4 Gas

Czechoslovakian reserves of natural gas are also small, estimated at $64Gm^3$, with domestic production accounting for less than 10% of consumption. Production almost halved between 1988 and 1993, from $649Mm^3$ to $340Mm^3$, with around 75% of this in Slovakia.

In addition to natural gas, Czechoslovakia also produces significant quantities of gas from gasworks, coke production and blast furnaces. Gas from these sources supplies around $2.3Gm^3$ of consumption each year, with natural gas supplies totalling $11.3Gm^3$.

Czechoslovkia was regarded by the former Soviet Union as politically more stable than Poland and was therefore chosen as the route for major pipelines for transit of gas to Western Europe. Czechoslovakia received supplies of gas from this source in return for material input to the construction of these pipelines and for transit rights for gas. Their geographic position should allow both republics to negotiate strongly for future gas supplies, although reduced reliance on a single source of supply is desirable. To this end, the Czech republic has made moves to import gas from Norway and Algeria via its links to the Western European gas network.

5.4.5 Other Energy Sources

Although little is known about uranium production in Eastern Europe, the former Czechoslovakia is estimated to have produced significant amounts, at unknown production costs, from a total resource of up to 500kt. There were 11 uranium mines and three yellowcake units in Czechoslovakia prior to 1990, but the government had decided even then that these were uneconomic. Nine of the mines and two of the yellowcake units were scheduled to close leaving production centred at Hamr in Northern Bohemia. In 1991, production totalled 1760 tonnes, but the Czech government has stated that from 1995 onwards production will be made sufficient only to cover use in domestic power stations.

Czechoslovakia as a whole has a potential hydro-electric production capacity of 28600GWh/year. 9800GWh/year of this is exploitable at sites of over 2MW capacity, with 1026GWh/year at smaller sites.

In 1990, the former Czechoslovakia also produced 100kt of peat for domestic consumption from an unknown total resource, and 129kt of fuel wood. Czechoslovakia has a geothermal potential of 105MW sited in East Slovakia, and several feasibility studies are taking place into this energy source. One deposit of oil shale, with reserves of up to 6Mt, has been previously exploited as fuel for glass manufacture, but is not described as economic as a major energy source.

Figure 5.4.5 summarises the Czechoslovak energy balance in 1993, demonstrating the importance of imports of oil and gas. (Due to a lack of data, total consumption and imports are presented as the sum of coal, oil and gas consumption and imports only).

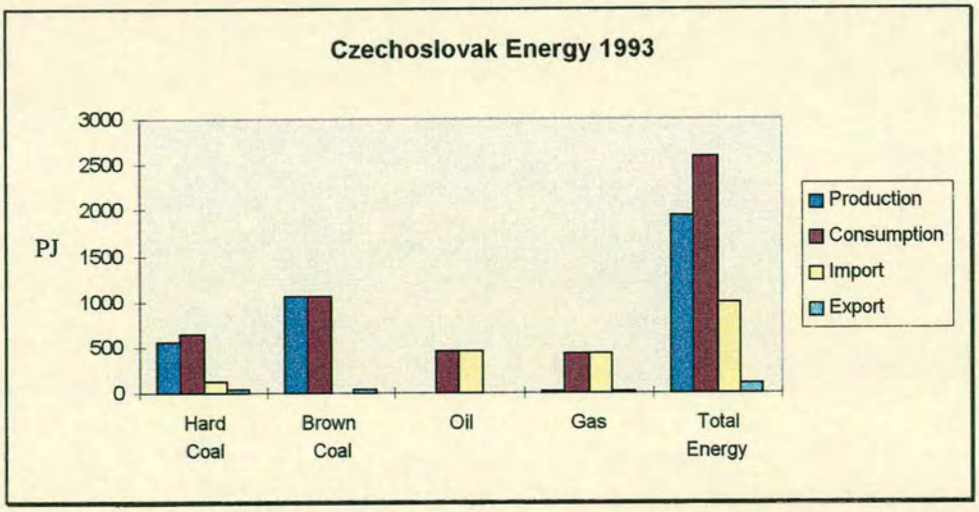


Figure 5.4.5 Czechoslovak Energy 1993

5.5 Electricity Sector

5.5.1 Czech Industry Structure

The state monopoly on the Electricity Supply Industry was broken on May 6 1992. The former Czech Power Works was divided into 8 joint-stock distribution companies and CEZ (Ceske Energeticky Zavody), which took over the generation, transmission import and export functions. CEZ remains 67% state owned but is gradually being privatised through a scheme designed to promote public share ownership.

The Czech government passed a new Energy Act on November 2nd 1994. This act provides a basis for development of competition in the electricity generation sector, through a competitive bidding process by independent power producers for construction of new capacity. This competitive bidding process is regulated by the Ministry of Industry and Trade to ensure non-discrimination. At present deals between the utilities and independent power producers and autoproducers are largely structured around one year power purchase contracts, which do not provide a strong incentive for longer term investment in capacity.

CEZ currently controls around 75% of the installed generation capacity in the Czech Republic, producing around 80% of electrical energy, with the remainder owned by industrial autoproducers. In addition to the headquarters and transmission divisions based in Prague, CEZ is subdivided into two nuclear, ten thermal and one hydro-electric generation divisions.

5.5.2 Czech Capacity and Demand.

If the Polish economy is fuelled by domestic hard coal, the Czech Republic has an overwhelming reliance on domestic brown coal. In 1980, 75% of the 10.5GW total capacity in the Czech Republic was from this source, with a further 15% fired by hard coal. Total capacity increased by 3 GW through the 1980s, largely due to the completion of two major projects, the Dukovany nuclear power station (1760 MW) in 1988 and the Melnik III brown coal station (500 MW), in 1981.

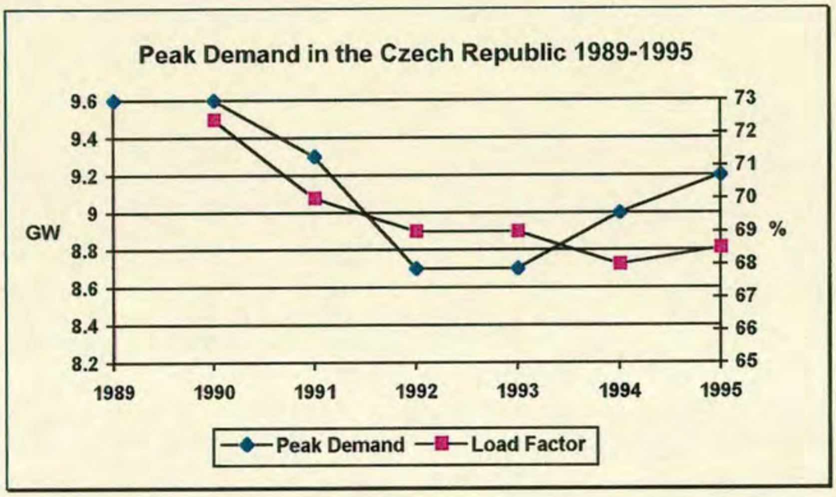


Figure 5.5.2 Czech Republic Peak Demand and Load Factor

Figure 5.5.2 illustrates the decline in peak demand from 1989 as the economy underwent its transition from central planning. Peak demand has recovered slightly and is projected to increase to 10GW in 2000 and 11.7GW in 2010. As electricity is increasingly used in domestic heating, encouraged by low cost off-peak tariffs, the temperature sensitivity of daily peak demand is expected to double from 1% per °C to 2% per °C. This effect may, however, be offset by greater demand side management by industrial consumers and centrally controlled heating loads, with an independent study by Tractabel and Ontario Hydro estimating that 270MW could be saved from peak demand by 2000 using these methods.

While peak demand has begun to recover, the load factor of the Czech system has declined by around 4%, due to the closure of large industrial users. In 1989 peak demand in a summer week was typically 8 GW, and this had declined to 6.5 to 7 GW in 1994. Load factor is unlikely to recover to its pre-1989 levels and is projected to remain around 67-68% to the end of the century and beyond.

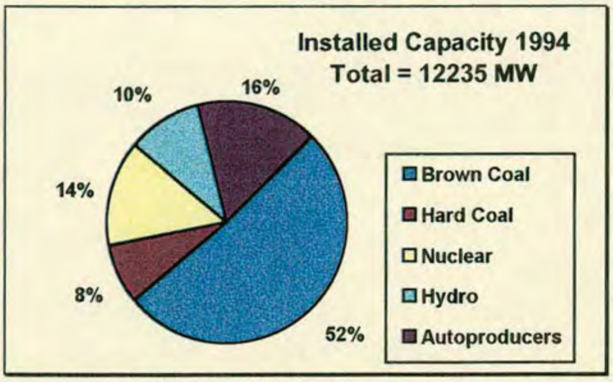
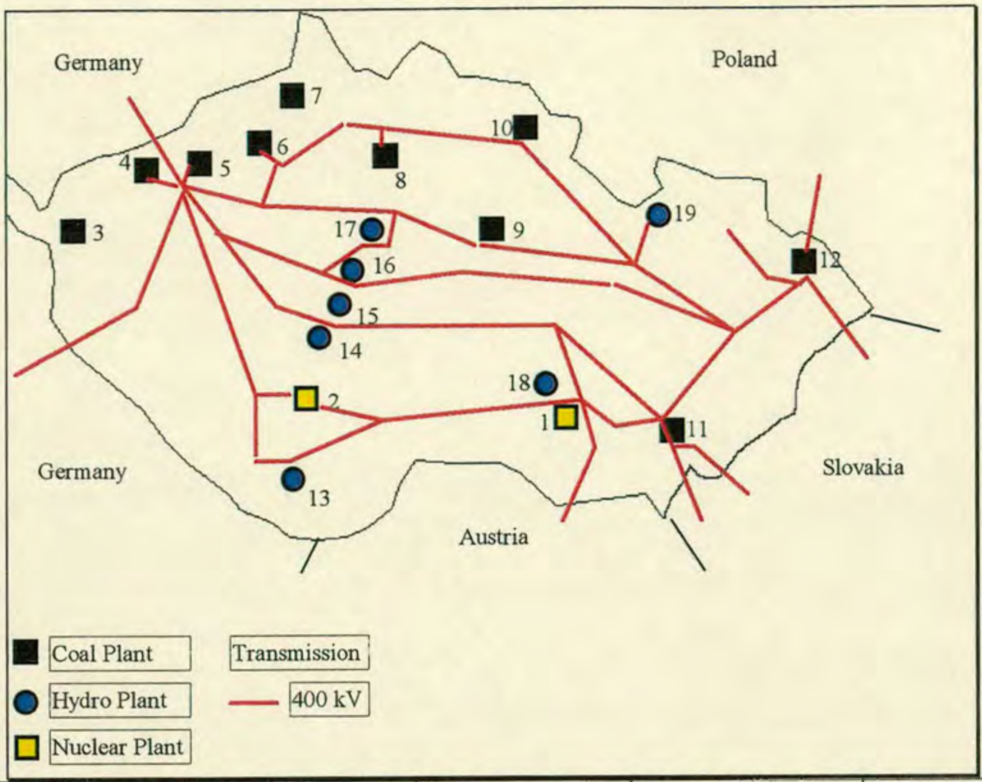


Figure 5.5.2.2 Czech Installed Capacity 1994

Capacity is still dominated by brown coal, as shown in figure 5.5.2.2 although the construction of the Dukovany nuclear power station and decommissioning of 1.2GW of plant has reduced its share somewhat. Brown coal share of capacity is projected to fall further, with a further 1GW planned for decommissioning by 1999, the completion of the Temelin nuclear plant (1962 MW) in 1997/98, and the commissioning of 2×325MW pumped storage units at Dlouhé Stráne in 1996. 50% of the autoproduction fuelled by brown coal is also projected to be closed by the end of the century, but up to 1GW of new CCGT/CHP plant is planned to replace this by 1999.



	Power Station	Type	Capacity MW	Commissioning Year
1	Dukovany	Nuclear PWR	1660	1985-1988
2	Temelin	Nuclear PWR	1962	1997-1998
3	Tisová I	Brown Coal	222	1959-1960
3	Tisová II	Brown Coal	100	1961
4	Prunérov I	Brown Coal	440	1967-1968
4	Prunérov II	Brown Coal	1050	1981-1982
5	Tusimice I	Brown Coal	220	1963-1964
5	Tusimice II	Brown Coal	800	1974-1975
6	Pocerady I	Brown Coal	600	1970-1971
6	Pocerady II	Brown Coal	400	1977
7	Ledvice I	Brown Coal	200	1967
7	Ledvice II	Brown Coal	330	1966-1969
8	Melnik II	Brown Coal	440	1971
8	Melnik III	Brown Coal	500	1981
9	Chvaletice	Brown Coal	800	1977-1978
10	Porici	Hard Coal	165	1957-1958
11	Hodonin	Lignite	155	1954-1958
12	Detmarovice	Hard Coal	800	1975-1976
13	Lipno I	Hydro	120	1959
14	Orlik	Hydro	364	1961-1962
15	Kamyk	Hydro	40	1961
16	Slapy	Hydro	144	1954-1955
17	Stechovice I	Hydro	22.5	1943-1944
17	Stechovice II (pumped storage)	Hydro	40	1947-1948
18	Dalesice (pumped storage)	Hydro	450	1978
19	Dlouhe Strane	Hydro	650	1995-96

Figure 5.5.2.3 Czech Generation Plant

5.5.3 Czech Production and Consumption

Production of electricity achieved an annual average growth rate of 1.7% between 1980 and 1990 in the Czech Republic, with consumption following a similar trend.(Figure 5.5.3) The difference between production and consumption comprises mainly of transmission losses and an internal transfer to Slovakia. Since 1990 however, this trend has been reversed and production declined by an average of 2% per annum as grossly polluting brown coal plant is closed. Production is projected to recover to 1990 levels by 2000, with the commissioning of the Temelin nuclear plant and the completion of the programme to close or fit desulphurisation equipment to brown coal plant.

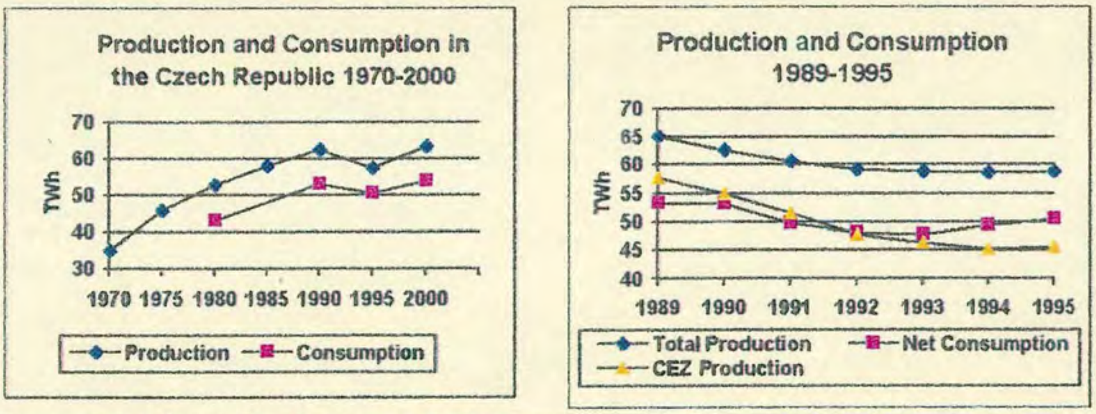


Figure 5.5.3 Czech Production and Consumption

The second chart in Figure 5.5.3 illustrates in greater detail developments in Czech production and consumption from 1989 to 1995. Consumption fell by almost 10% between 1990 and 1991 as economic restructuring began to take effect. This trend continued to 1993, but consumption recovered after this and growth is predicted to continue as the Czech economy expands. While overall consumption displays the effects of the contraction and recovery of the economy over this period, a large shift has occurred in sectoral shares of consumption. Between 1990 and 1993, industrial consumption fell by 22%, from 30.3TWh to 23.8TWh, where it has remained. Agricultural demand fell by 13% over the same period, with demand in the service sector increasing slightly by 0.2TWh. Domestic demand grew by 1.5TWh between 1990 and 1993 to 11.1TWh and increased to 12.6 TWh in 1995. The pie chart below illustrates sectoral shares in consumption in 1995. Consumption in industry is expected to increase by only 1TWh by 2000, and agricultural consumption is projected to remain constant. Growth will be accounted for in the expanding shares of domestic and service consumption.

On the production side, Figure 5.5.3 illustrates the falling margin between production and consumption as production for supply to Slovakia has been reduced. Overall, falling consumption was met by a similar decline in production between 1989 and 1993. As consumption began to increase after this date, production has remained constant. Figure 5.5.3.2 shows overall production shares in 1994. Autoproduction has a large (23%) share in Czech production and is mostly fuelled by coal, with a small amount of gas fired and hydro- plant. The remaining share in production is CEZ's plant. CEZ supplied 77% of electricity production in 1994, with the fall in its share from 1993 accounted for by the transfer of the 400MW Melnik I plant to private ownership. Overall production is projected to increase in future with the commissioning of the Temelin Nuclear plant and the Dlouhé Stráne pumped storage plant, but thermal production will fall as CEZ continues to close polluting brown coal plant.

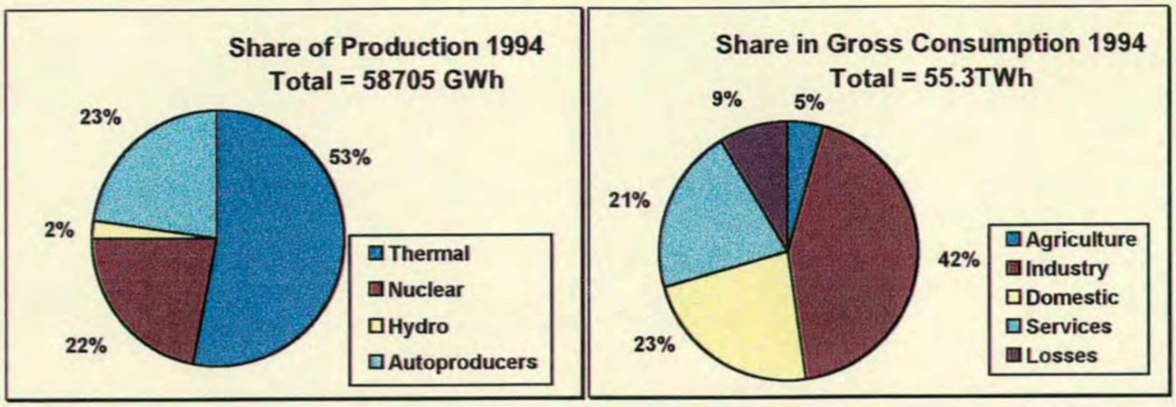


Figure 5.5.3.2 Share of Production and Consumption 1994

5.5.4 Czech Nuclear Power

Faced with increasing pollution problems from its large stock of coal-fired plant, the Czechoslovakian government placed its faith in nuclear power. In 1978, construction began on the Dukovany plant, now in the Czech Republic. This plant consisted of four 440MW pressurised water reactors of a Russian design, designated VVER-440-213, and was built by the Skoda engineering concern. Commercial operation commenced in 1985, with full output achieved by 1987. Since then, the Dukovany plant has maintained an excellent operational record, with a lifetime load factor of 77%, compared to the world average load factor for PWRs of 67%.

In 1984 construction began on a second reactor, of larger capacity, at Temelin in Southern Bohemia, with completion scheduled for 1992. This was again to be constructed by Skoda, to the Russian VVER-1000-320 design, with two units of 918 MW net capacity. Construction of the plant has been repeatedly delayed in the face of growing environmental concerns, particularly from neighbouring Austria, and a lack of funds. Environmental concerns focus on:

(a) the fact that neither plant has containment facilities in the event of a reactor accident and therefore do not meet IAEA standards

(b) the Czech republic's lack of spent fuel storage facilities.

Spent fuel is currently stored by the CIS which charges hard currency for this service at the rate of $20m per year.

The Czechs claim that both plants have been built to higher quality standards than similar plant in Russia, and the IAEA has reported a high quality of operation and maintenance at Dukovany. The Czech government also sees completion of Temelin and the continued use of nuclear plant for baseload generation as vital to reduce pollution from coal plant and maintaining long-term supply security. Contracts worth $400m have been awarded to Westinghouse of the US for completion of Temelin with Western standards of control and safety equipment. Operation is now scheduled to begin in 1996. In its business plan, CEZ has rejected the case for further nuclear plant, and plans by the former-Czechoslovakian government to build two further units at Temelin are effectively abandoned.

5.5.5 Slovak Industry Structure

Slovak Energy Policy was formulated under the national government in December 1991, and the current Slovak government continues to pursue its main aims. These include the creation of a market based structure, increased efficiency, reduced environmental impact of energy use, diversification of energy sources and reduced reliance on imports.

The Slovak Electricity Supply Industry retains most of the characteristics of a state owned monopoly, with Slovensky Energeticky Podnik responsible for 85% of generation capacity, transmission and foreign exchanges. Most of the remaining capacity is owned by industrial autoproducers, with a small share for two of the three regional distribution companies. Slovakia removed SEP's generation monopoly in 1991 in order to open investment in new power projects. A firm regulatory framework has not yet been created and, in practice, the utilities retain responsibility for planning and development. A new electricity act is currently being drafted and is expected to include 'must-take' obligations on the utilities for production from independent power producers.

Customer tariffs have been liberalised and increased towards market based prices. The Slovak government has produced a least-cost development plan for the electricity sector, but remains committed to the completion of the Mochovce nuclear plant and the Gabcikovo hydro plant due to the large amount of investment already sunk in these projects.

5.5.6 Slovak Capacity and Demand

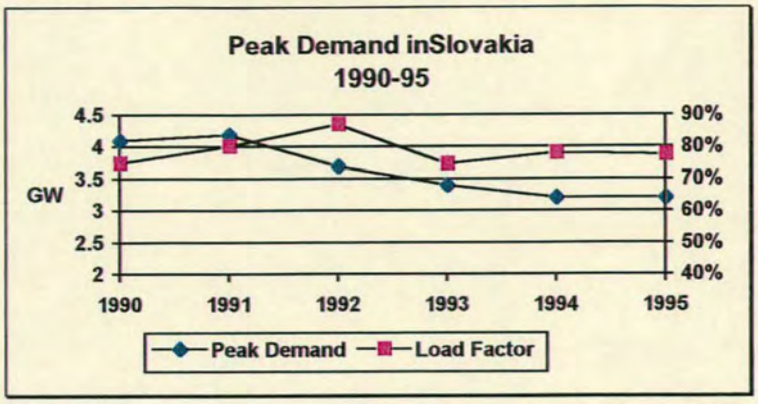


Figure 5.5.6 Slovak Peak Demand

Between 1980 and 1990, Slovakian peak demand grew by 25%. Through the same period, the load factor also improved, due to the low level of domestic consumer demand growth and also because of the increasing proportion of pumped storage capacity (the Cierny Váh pumped storage plant has a capacity of 735MW, equal to 18% of peak demand). Post-1990, peak demand growth slowed and, after 1992, began to decline, although not at as high a rate as in the Czech Republic, falling back to its 1980 level by 1994. Economic reform in Slovakia has been somewhat slower than in the neighbouring states, due to its generally lower level of heavy industrial development. Peak demand varies by about 0.5% per °C in Winter, and is projected to recover to 1990 levels some time between 2000 and 2005 as domestic demand increases. As a result, load factor is expected to fall slowly but demand management is also expected to save up to 3.6% of peak load over the period.

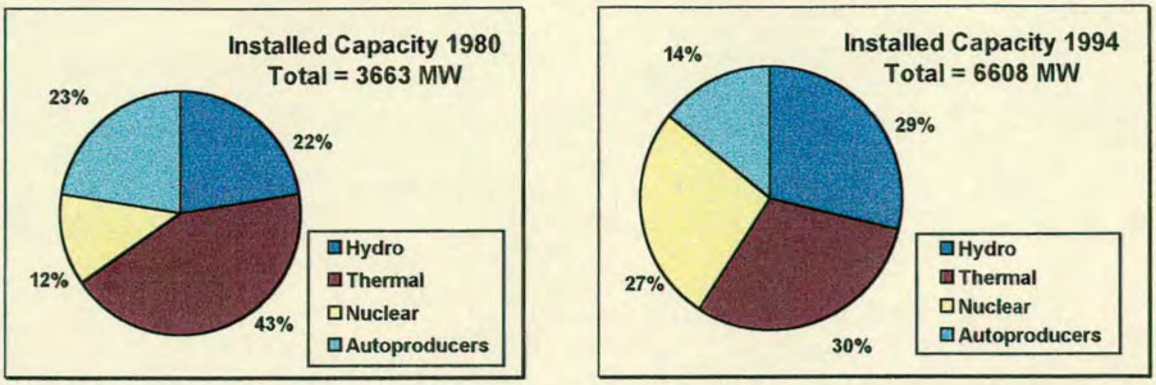
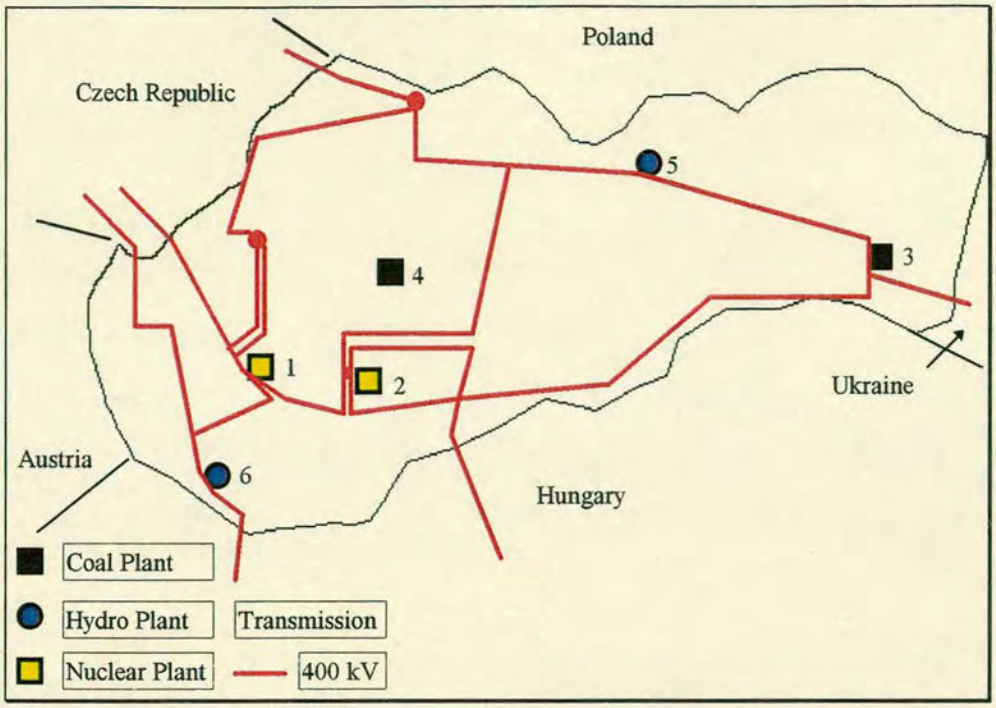


Figure 5.5.6.2 Slovak Installed Capacity 1980 and 1994

The above pie charts illustrate the development of installed capacity in the Slovak system. Between 1980 and 1994, capacity has increased by just over 80%, from 3.6GW to 6.6GW. Almost half of this increase is accounted for by the commissioning of three nuclear units at Bohunice (440 MW each). The capacity of autoproducers changed little over the period concerned, and conventional thermal capacity increased only slightly with the addition of a 66MW CHP plant burning coal and gas at Kosice. While the majority of the former Czechoslovakia's fossil fuel reserves are located in the Czech Republic, the majority of hydro-electric sites are in Slovakia. Between 1980 and 1994 Slovakia increased its exploitation of this generation source by adding over 100MW of conventional hydro plant and commissioning the 735MW Cierny Váh pumped storage plant. The 270MW Gabcíkovo hydro scheme on the Danube was also constructed during this period and is currently described as being in preliminary operation.



	Power Station	Type	Capacity MW
1	Bohunice	Nuclear PWR	1760 (4×440)
2	Mochovce	Nuclear PWR	1760 (4×440)
3	Vojany I	Black Coal	660 (6×110)
3	Vojany II	Oil, Natural Gas	660 (6×110)
4	Novaky A	Brown Coal	111 (2×22.4, 2×32)
4	Novaky B	Brown Coal	440 (4×110)
	Kosice	Coal, Natural Gas	121 (1×66, 1×55)
5	Cierny Váh (Pumped Storage)	Hydro	735
6	Gabcikovo	Hydro	270
	Orava	Hydro	28
	Liptovská Mara	Hydro	203
	Sucany	Hydro	102
	Miksová	Hydro	180
	Nosice	Hydro	68
	Dubnica	Hydro	63
	N.Mesto nad Váhom	Hydro	77
	Madunice	Hydro	88
	Dobsiná	Hydro	98

Figure 5.5.6.3: Slovak Generation Plant.

Nuclear units and the thermal plants are used as baseload due to their low marginal costs, and provide over 70% of capacity to cover peak demand. The hydro plant is used to follow peaks in the load, but for the days with highest demand, a substantial portion is met through imports in a 'mid- merit' role. Due to the large proportion of nuclear and hydro plant in its generation portfolio, Slovakia has avoided the large pollution problems of its neighbours, and has not been forced to decommission any of its thermal plant. The commissioning of the Mochovce nuclear plant (see below) would allow the lignite burning 550 MW plant at Nováky to be removed from service, or to operate at a reduced load factor, displacing imports.

5.5.7 Slovak Production and Consumption

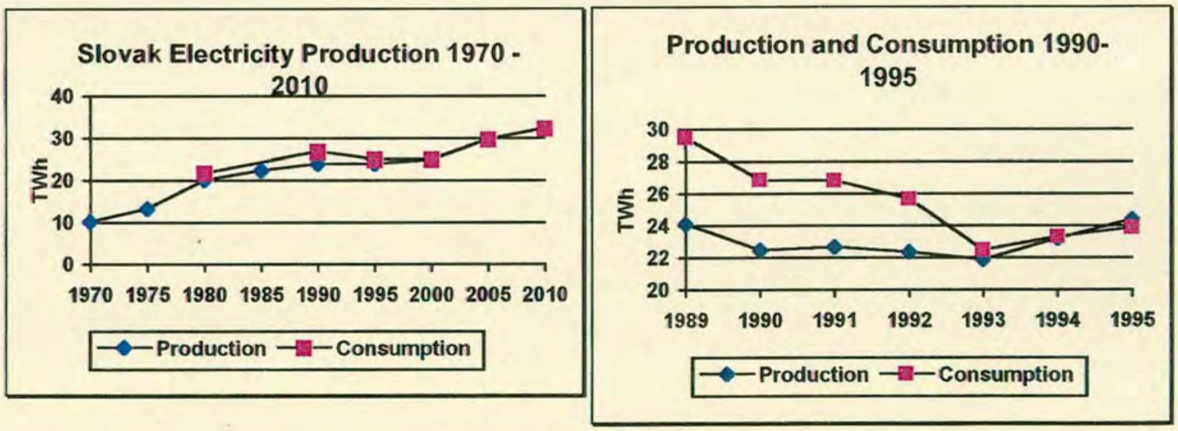


Figure 5.5.7 Slovak Production and Consumption

The above charts plot the historic patterns of electric power production and consumption in Slovakia. Production grew steadily through the 1980s, at an average rate of 1.6% per annum, as the Bohunice nuclear plant increased production. Despite this, Slovakia still depended heavily on imports from the Czech lands to cover consumption until the second nuclear station at Mochovce could be commissioned (see below). The second graph illustrates in more detail the decline in consumption as larger industrial consumers closed post-1989. This decline proceeded at a slightly slower rate than in the Czech Republic and has begun to show a recovery, although total consumption is not expected to reach 1989 levels until 2005.

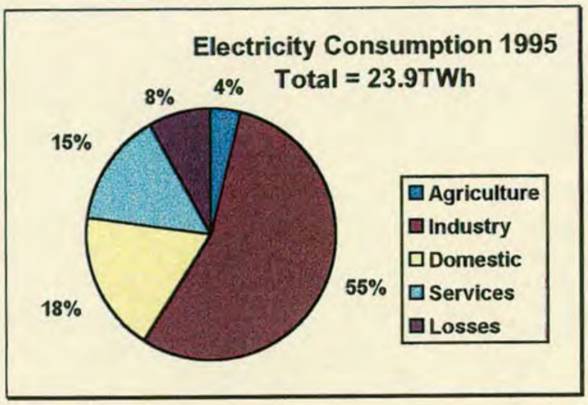


Figure 5.5.7.2 Slovak Electricity Consumption 1995

The above chart shows the share of different sectors in consumption in 1995. Between 1990 and 1994, total consumption fell by 3TWh, before recovering by 1.1TWh in 1995. This overall movement masks trends in consumption for each sector. The largest fall in consumption was in the industrial sector, whose share in total consumption fell by 7% or 3.2TWh between 1990 and 1995. Domestic consumption and the underdeveloped service sector increased their share in consumption by 0.8TWh and 0.6TWh, with the balance accounted for by a slight rise in losses and a 0.3TWh fall in agricultural demand. Growth in the domestic and service sectors is projected to continue as service industries develop and purchasing power for consumer electrical goods increases. Industrial and agricultural demands are also projected to increase, but will not regain their 1990 levels until 2010.

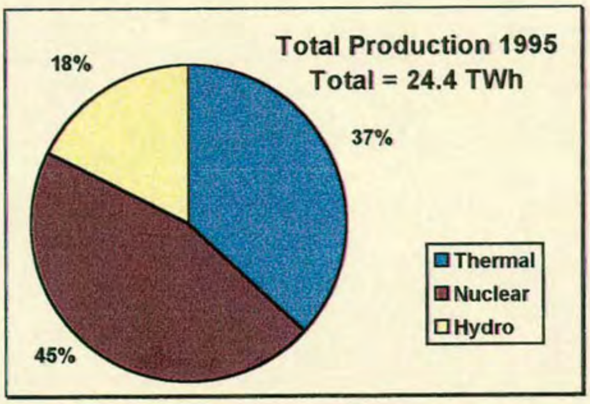


Figure 5.5.7.3 Slovak Electricity Production 1995

SEP owns 85% of the installed capacity and produces over 90% of electric power in Slovakia, including all nuclear and hydro-electric generation. Nuclear and conventional thermal plant, including that of industrial autoproducers, is used to provide baseload energy, with peaks in demand being met by hydro and pumped storage plant. Over the decade from 1980 to 1990, nuclear plant more than doubled its output to 11.2TWh, while production from hydro plant remained constant. Thermal plant output fell by 3.3TWh over the same period and continued to provide a declining share of production till 1994. Delays in commissioning the Mochovce nuclear plant (see below) have resulted in an increase in thermal production in 1995, and the opening of the Cierny Váh pumped storage and Gabcikovo hydro plants have increased hydro output.

5.5.8 Slovak Nuclear Power

The Czechoslovakian government placed orders in 1970 for four pressurised water reactor units at Jaslovske Bohunice in Slovakia to provide base load capacity in a region lacking the major fuel resources of Bohemia in the West. Construction began in 1972 on the first two units of the Russian design VVER-440-230, with construction of the second two units of the slightly later design VVER-440-213 commencing in 1976. Commercial power was produced by the units 1 and 2 in 1980 and units 3 and 4 came on stream in 1985. Individual information on the performance of these units is not available but overall figures suggest that Bohunice achieved load factors above average for PWR stations, in line with the performance of Dukovany in the Czech Republic.

As commercial operation was beginning at Bohunice, the Czechoslovak government placed an order for a further four VVER-440-213s at Mochovce, with construction beginning in 1983. Completion was scheduled for 1993 but construction halted in 1991 due to lack of funding. Units 1 and 2 are 90% and 80% completed respectively, and the Slovak government remains committed to completion of all four units to cover rising demand and to combat pollution from coal plant. Funding from the European Bank for Reconstruction and Development (EBRD) for completion of the project was rejected because of conditions on the closure of the Bohunice site and a 30% rise in electricity prices to customers. Completion of the first two units is now scheduled for 1997/98, with DM 1.2bn funding coming from Russia and Czech and Slovak banks. EdF has taken over from Skoda-Plzen as the turnkey contractor, and is reported to have agreed purchase of power from the plant at a pre-agreed price. Funding for the remaining two units is not yet secure.

5.5.9 Electricity Trade

Volumes of electricity traded by Czechoslovakia grew steadily through the 1980s following an initial drop caused by the commissioning of the Bohunice nuclear plant. The country as a whole maintained only a small net import of between 2-3TWh, mainly for peaking cover. Much of the volume of trade is accounted for by power in transit through the Czech grid, particularly exports from Poland, and this explains the step change in trade volumes in 1986, when the DC link with Austria was commissioned.

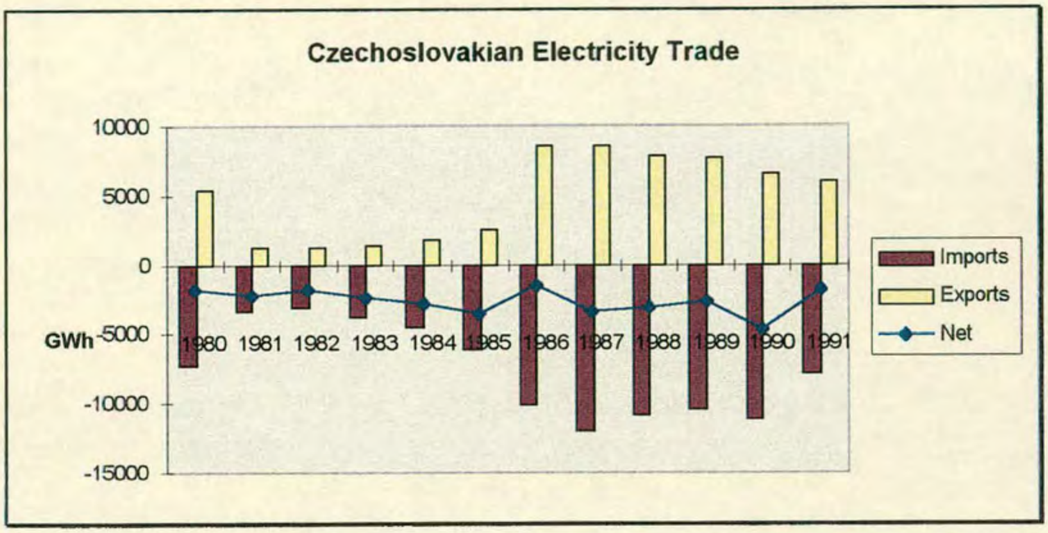


Figure 5.5.9 Czechoslovakian Electricity Trade

Little information is available on internal transfers made between CEZ in the Czech Republic and SEP in Slovakia, but there is likely to have been a significant net transfer to Slovakia to cover consumption. In 1991 this transfer stood at 6TWh, just over one fifth of supplied electricity in Slovakia. The construction of the Mochovce nuclear plant was intended to cover this shortfall and balance the power flow, but as this has been delayed, Slovakia continues to import from the Czech Republic.

Slovakia est.	Imports		Exports	
Partner	1992	1993	1992	1993
CFR	5068	3438	0	632
Hungary	367	23	1496	696
Ukraine	n.a.	n.a.	n.a.	n.a.
Total	n.a.	n.a.	n.a.	n.a.

Czech Republic	Imports		Exports	
Partner	1992	1993	1992	1993
Austria	216	201	3303	2770
Germany	317	405	779	1725
Poland	5623	4714	72	123
Slovakia	0	632	5038	3438
Total	6156	5952	9192	8056

Table 5.5.9.1 Czech and Slovak Electricity Trade, 1992 and 1993

Table 5.5.9.1 details trade flows in the two republics in 1992 and 1993, from UNECE figures which are estimates in the case of Slovakia. SEP's own figures for 1992 put total imports at 6TWh, with a slightly higher transfer from the Czech Republic, and total exports at 2.5TWh, with 0.4TWh to the Czech Republic. Falling demand has allowed Slovakia to reduce its reliance on imports slightly, but balanced trading is not likely to occurr until the first tranche of capacity at Mochovce is commissioned. Falling imports by Slovakia has allowed the volume of Czech exports to fall, in line with the Czech republics plant closure programme. In the above table, much of the import from Poland is wheeled through the Czech network to Austria, and to West Germany in increasing volumes with the commissioning of the 600 MW DC link at Etzenricht.

GWh	1994	1995	1996	1997	1998	1999	2000
Contracted Export	1624	1465	1694	1915	1695	1465	1465
Spot opportunities	400	400	400	400	400	400	400
Total Export	2024	1865	2094	2315	2095	1865	1865
Contracted Import	643	422	193	193	193	193	193
Spot opportunities	400	400	400	400	400	400	400
Total Import	1043	822	593	593	593	593	593

Table 5.5.9.2 Projected Czech Republic Electricity Trade, 1994-2000

Table 5.5.9.2 projects future trade volumes for the Czech Republic under the Power Sector Least-Cost Development Study, conducted by Tractabel in 1993, with the support of EU PHARE funding. These projections expect the Czech Republic to continue to support a net export surplus, possibly through long term contracts with Austria, although these will have to be agreed around a framework which does not contradict the Czech Republic's aim of reducing emissions from brown coal use. The overall level of trade represents a significant decrease on historic levels and the low level of 'spot opportunities' may underestimate the potential for short term exchanges with neighbouring states. The Tractabel study did assess the prospects for using the Czech grid for wheeling power but the potential revenue from this source was not considered firm enough to be incorporated in the CEZ long term business plan.

5.6 Future Developments

Geographically, both the Czech and Slovak Republics are ideally situated to take advantage of East to West energy trade. In addition the Czech grid has played a key role in transmitting power to the West and is likely to continue in this role.

Slovakia anticipates moving to a net electricity surplus sometime after 2005 when the final two units at Mochovce, 600MW of new hydro and 200MW of CCGT plant at Bratislava are commissioned. Expansion of the Gabcikovo hydro plant on the Danube from its current 540MW to 720MW is currently the subject of an international dispute with Hungary. Gabcikovo was originally designed to produce peaking power and the resulting surge waves would be absorbed by the Nagymaros dam downstream. Hungary has cancelled this part of the project for environmental reasons, imposing constraints on the operation and expansion of Gabcikovo. A claim for compensation is currently proceeding through the International Court in the Hague, with the Hungarian's reported to have concluded an agreement with Austrian contractors for compensation in exported power.

Funding for the completion of Mochovce the expansion in hydro-capacity and the rehabilitation of thermal plant at Vojany and Novaky is also reported to be uncertain. This uncertainty appears to have resulted in the postponement of plans for the privatisation of SEP. [GPP, 4/7] SEP is to remain in the state sector for five years and attempt to raise funds for its ongoing projects through the issue of bonds.

Despite the attempts of Austrian environmentalists to halt it, the Czech republic remains determined to complete the Temelin PWR by 1998. Completion was originally scheduled for 1992 but construction was slowed by lack of funds. The Czechs regard dealing with the emissions from their stock of thermal plant as of prime importance and the completion of Temelin is seen as central to the solution of this problem, attracting 42.5bn Koruny from CEZ's budget in 1994-2000. The completion of the 640MW pumped storage plant at Dlouhé Stráne in 1996 will also alleviate emissions but the largest emissions reduction spending is being targeted in the thermal plant sector.

CEZ has decommissioned 1.2GW of the worst polluting brown coal plant since 1990, with a further 1GW scheduled to close by 1999. In addition to these closures, some 21.2bn Koruny is to be spent on FGD and denitrification equipment at remaining thermal plant and 5.9 bn Koruny on construction of Fluidised bed boilers at four plant. This will further reduce total capacity and reduced availability during the programme may require increased use of spot trading to meet demand. Despite loans from the World Bank and interest from commercial lenders, CEZ's cashflow, like that of SEP, is insuffiecient to fund these developments. While industrial tariffs are now at a level sufficient to cover present costs and those of power from Temelin, domestic tariffs are still at less than half the cost of supply and will be required to increase in future years to meet CEZ's investment costs.

CHAPTER 6: FUTURE TRADING DEVELOPMENTS.

6.1 EU Impact on Electricity Markets

The current European Union has developed from the European Economic Community, an organisation, founded in 1957 by the Treaty of Rome, designed to promote European trade and co-operation and thereby guarantee peace and stability on the continent. [Leonard, 1994] This body has steadily grown, both in membership and influence in member's affairs, to its current state. On their liberation from Communism in 1989/90 the Central and Eastern European states signed trade and co-operation agreements with the European Community, and Poland, Hungary and Czechoslovakia signed association agreements in 1991. East Germany achieved full membership of the EU on unification, Poland and Hungary have formally applied for membership, and the Czech and Slovak Republics, along with the Baltic States and other Eastern European states, have stated membership as an objective in the medium term (Figure 6.1.1). The EU plays an important role in the distribution of aid and investment funds to Central Europe through its subsidiary organisations, the European Investment Bank (EIB) and European Bank for Reconstruction and Development (EBRD).

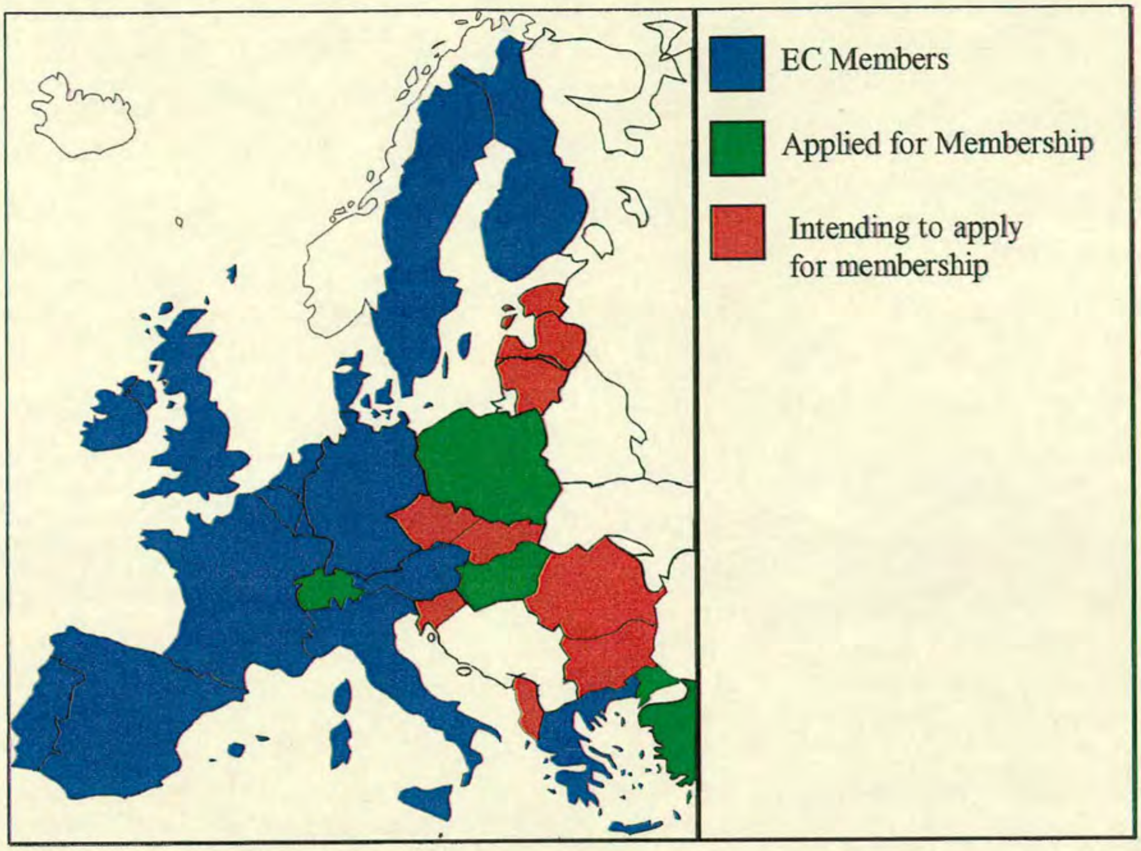


Figure 6.1.1 - The European Community

The founders of the EEC envisaged the strategically important energy sector as playing a central role in European co-operation; through the European Coal and Steel Community (ECSC) and Euratom treaties, encompassing coal and nuclear energy. However, despite its growing influence in other areas, the EC played little part in the energy policies of its members and the electricity sector in particular was afforded "30 years of benign neglect" [Hancher, in Holmes, 1990] by the EC. This changed in the late 1980s with the EC's expansion of competencies encompassed in the Single European Act of 1986, providing for increased liberalisation of the Community's internal market, and growing environmental pressure. EC energy policy currently centres on three strands; security of supply, the environment and the internal energy market (IEM). [Lyons, 1992]

6.1.1 Security of Supply

The security of supply policy stems from the oil crises of the seventies, when imported oil made up 62% of EC gross energy consumption [RIIA, 1989]. An efficiency programme and policy of diversification (mainly to coal and nuclear power) have reduced this to around one third, but this has been helped by an increase in North Sea production and it could be argued that member states would have followed these policies anyway. The EC also seeks to maximise its negotiating position as one of the world's major fuel importers, signing co-operation agreements with the Gulf states on oil and with Australia, Canada and the US on uranium. On a practical level, this policy has motivated the legislation that sufficient fuel stocks for 30 days generation be held at power stations.

The individual country surveys in earlier chapters set out the Central European states' energy supply positions. These are certainly no worse, on the primary energy front, than many of the current EU members, with Poland and the Czech Republic in strong energy reserve positions with their large coal reserves. Diversification away from their historic dependence on the Soviet Union for energy supplies will provide a major theme of future energy policy in these states, but membership of the EU will place them in a stronger negotiating position with this, and other, fuel suppliers. Their important strategic position across the transit route for gas between the vast reserves of Russia and the Western European market will also prove benefitial as natural gas becomes increasingly important in electricity generation.

6.1.2 The Environment

On the environmental front the primary article of community legislation affecting the electricity supply industry is the Large Combustion Plant Directive of 1988 [88/609/EEC]. This sets limits on sulphur dioxide, nitrogen oxides and particulate emissions from all new plant, of greater than 50MWth capacity, at levels dependent on fuel type. Existing plant are also required to make phased reductions of these emissions. [Johnson, 1990] Faced with meeting its commitment to stabilising carbon dioxide emissions by 2000, made at the UN Earth Summit in Rio de Janeiro, 1992, the European Commission has proposed a combined energy/carbon tax. This tax would be phased in to a level equivalent to $10/barrel of oil, comprising of an energy component of no more than 50% with the balance levied on carbon content of fuel. This tax has been strongly opposed by industry, who fear it will damage international competitiveness, despite assurances that it will be fiscally neutral i.e. a corresponding reduction in other components of the general tax burden would be made. With evidence to support the inelasticity of energy demand there is also doubt over the effectiveness of such a tax.

The environmental problems in Central and Eastern Europe made a significant contribution to the general unrest which ultimately resulted in the downfall of the Socialist system. The centrally-planned economic model proved unable to tackle the problems of environmental degradation caused by its industrial policies. Since 1989, economic restructuring has produced a significant reduction in overall energy demand and energy intensity in the region. On the specific issue of the environmental effects of power generation (mainly atmospheric emissions), all four states have included measures to improve the current situation in their development programmes. The EU has contributed to many projects, such as fitting electrostatic precipitators to reduce particulate emissions and flue-gas desulphurisation to power stations, via its PHARE programme.

6.1.3 The Internal Energy Market

The most influential, and controversial, components of EC energy policy in the electricity sector are those concerning the internal energy market. In 1988, the Commission published an influential paper entitled 'The Internal Energy Market' [COM/88/238] arguing that energy, particularly gas and electricity, should be included in single market measures. Achieving a liberal, internal market in energy would require action on two fronts; network development and deregulation. [MDIS, 1995] Network development was supported by a Commission decision in December 1990 [OJ/90/326] to earmark ECU300M (£230M) for energy infrastructure projects, including an HVDC link between Italy and Greece. The Maastricht Treaty, 1992, incorporates provisions for the funding of Trans-European Networks (TENS) in the fields of energy, communications and transport.

It is the proposals on deregulation that have caused the most controversy in the gas and electricity markets. The Commission has estimated [Lyons, 1992] that ECU 70G

(£54G) of total savings to 2010 could result from the establishment of an internal electricity market through greater efficiency and competition. A more detailed study by ENEL [ENEL, 1991] puts the fuel savings from greater integrated operation of the EC power system with a higher level of power exchanges as ECU 5.2G (£4G) over the same period, or 2.2% of total fuel costs, possibly a more realistic figure.

These proposals follow a three phase plan, according to former Energy Commissioner, Cardosa e Cunha, with the first stage already accomplished by the October 1991 Transit directive [90/547/EEC]. This directive provides for open access for the wheeling of electric power across internal borders by transmission grid operators, provided this does not endanger security of supply. The second phase of deregulation in establishing the IEM would involve the abolition of monopolies in generation and the construction of transmission assets, 'unbundling' of vertically integrated utilities into separately accounted generation, transmission and distribution divisions and limited third party access. The third phase was envisaged as encompassing another degree of deregulation and full third party access, but was qualified as only being developed in the light of experience gained from the second stage.

6.1.4 EU Impact on Central European Power Sector

On membership of the EU, the Central European states would be expected to adopt most of the legislation of this body. This would present a number of problems and a significant cost to these countries, and transitional arrangements would be required for compliance with the Large Combustion Plant Directive and any Energy/Carbon tax. All of the states have long term development plans for the electricity supply sector, as discussed in previous chapters, which incorporate plans for emissions reductions. A Carbon tax would have an extremely detrimental effect on economic recovery in these states, imposing an unacceptable financial burden on industry in these states. It has been suggested [Russell 1991] that the Central and Eastern European states should be the recipients of some of the revenue raised from this source in Western Europe. This is because a proportionately greater reduction in emissions may be made, per unit invested, in these countries than in many Western states where significant reductions in emissions have already been made and further improvements would face a situation of diminishing returns.

To a large degree, the Central European governments have already exhibited their willingness to accept the directives and proposals pertaining to the Internal Energy Market, by becoming signatories of the European Energy Charter. (See Appendix A for full list of signatories) This Charter was first proposed by Dutch Prime Minister and President of the Council of Ministers, Ruud Lubbers, at the Dublin Summit in May 1990, and set out to extend some of the Commission's energy plans to the EFTA states and to Eastern Europe. Protocols within the Charter encourage co-operation in technology exchange, harmonisation of technical and safety rules, energy efficiency and protection of the environment. The main objective of the Charter, however, is to promote increased trading in energy through the creation of a 'common market' in energy, with common rules on exploration, access to resources, financing of projects and infrastructure development.[OXERA, 1994]

Through their commitment to privatisation and restructuring of their previously monolithic state owned industries, the Central Europeans have signalled an acceptance of these principles. In their capital constrained economies, foreign investment has been welcomed and encouraged. Organisationally, their Electricity Supply systems are ready to accept the strictures of European Union membership. The remaining barriers to full interconnection are technological and economic: their solution will be examined in the following sections.

6.2 Planned Interconnection.

Chapters 1 and 2 plotted the development of electric power supply networks in Europe and described their current position. This development is continuous, with states constantly seeking to exploit the maximum benefits achievable by expanding existing and constructing new links. With the exception of the loss of transmission lines caused by the conflict in Yugoslavia, both Nordel and the UCPTE have expanded their internal transmission capacities since 1989 to facilitate the increased levels of energy trade. The two systems also intend to increase their capacity to exchange energy with each other. In 1989 the Nordel and UCPTE systems were only connected at the Danish-German border by one 400kV and two 220kV lines, with a capacity of 1400MW. In 1994 a 600MW DC cable was completed between Sweden and Germany, although its capacity is currently limited to 250MW due to constraints in the German network, and in 1995 a 600MW DC link was commissioned between Eastern Denmark and Germany. Two further 600MW DC links between Norway and Germany and Norway and the Netherlands are planned for commissioning in 2001 and 2003, respectively, and a 600MW DC link joining the two halves of the Danish grid, planned for 1998, should further increase the ability to exchange energy between Nordel and the UCPTE.

Nordel maintains one 900MW back-to-back DC link between Russia and Finland and a number of lower voltage local connections along this border. This situation has not changed since 1989 and, although suggestions have been made for cable links connecting Sweden with Poland, and Finland with the Baltic Republics, no firm plans for increased trading links in future have been made. In 1989, the UCPTE system was linked to the Czech, Hungarian, Romanian and Bulgarian systems along its Eastern border. The Romanian, Bulgarian and Hungarian links at 400kV with the then Yugoslavian system were all used for 'islanded' synchronous trading of limited volume, as were the 220kV links between Austria and Hungary and Czechoslovakia.

Prior to 1992, significant volumes of energy (3TWh in 1990) could only be traded between the UCPTE and Central Europe through the 550MW back-to-back DC converter station at Dürnrohr in Austria and its 400kV link to the Czechoslovak system. However, plans had already been laid for expansion of this capacity, with two 600MW back-to-back DC linking the UCPTE and IPS systems. These were commissioned in 1992; one connecting the German and Czech systems between

Etzenricht and Hradec and the other the Austrian and Hungarian Systems between South-East Vienna and Györ. Figure 6.2.1 illustrates the European interconnections (>400kV) operating in 1994.

Figure 6.2.1 European Interconnections at 400kV and above.

The re-unification of Germany in 1990 resulted in ownership of the former East-German VEAG system being transferred to the West German utilities. The new owners promptly began a programme of restructuring and grid improvement with the ultimate aim of full integration of the two countries' grids. This required the construction of four new 400kV synchronous links, as the political situation had previously meant that the two systems were not connected at all. Synchronous connection was scheduled for the beginning of 1995, but delays in commissioning one of these lines resulted in the postponement of this date to later in the year. The West Berlin electricity supply network, isolated for 40 years, was successfully connected to the East German network in 1994.

This effective loss of a member state left the remaining countries of the IPS with a choice of future possibilities for the development of their interconnected system. The status quo could be maintained, with continued connection to the former-Soviet Union area in the East and limited trade through HVDC links to the West, or they could pursue greater integration with the West. The dependency of the IPS system on the former-Soviet Union UPS for frequency control and member countries' dependence on this source for energy imports (particularly Hungary, Romania and Bulgaria) ruled out the prospect of operating an autonomous network.

The aspirations of the former Socialist states in Central and Eastern Europe to become more free-market and Western oriented extended to the field of electricity supply. The desire to diversify sources of energy supply and the perceived instability in the East effectively constrained the ESI's in Central Europe to the pursuit of greater integration with the UCPTE system. In May 1990, a UNIPEDE/UCPTE working group conceded that synchronous interconnection between the UCPTE and Central European states networks was technically possible [Twardy, 1994]. The UCPTE had previously encountered the problem of the interconnection of 'sparse' networks with the connection of the Iberian and Balkan grids in the 1980s [Asal in OECD/IEA, 1991]. Synchronous interconnection would require an assessment of the compatibility of the IPS grid with the UCPTE in the following areas:

- Network and generator voltage control and reactive power capability
- Primary governor control of generating sets to maintain frequency at 50Hz±20mHz
- Secondary reserve capacity to respond to variations in demand
- Transmission capacity and short circuit current levels across the border
- Plant and reserve margin
- Generator and network reliability

As mentioned previously, the IPS network fell short of these standards for generation reserve and control and immediate interconnection would have jeopardised security of supply in the UCPTE system. In particular, the IPS reliance on the UPS system for frequency control and poor voltage control, resulting in frequent 'brownouts', ruled out synchronous interconnection. However, on the positive side, the capacity of the IPS system, at around 144GW, was larger than either the Iberian (50GW) or Balkan (27GW) networks which had been successfully interconnected. Despite the absence of synchronous connection some 15GVA of transmission capacity exists along the

UCPTE/IPS border, [Thiry, 1991] in the three DC converter stations and high voltage transmission lines used for exchange in 'islands'. (See section 1.4)

The four ESI's in Central Europe decided to co-ordinate their efforts towards the aim of interconnection and, in October 1992, agreed a 'Catalogue of Measures' with the UCPTE, governing the requirements for synchronous connection, and formed CENTREL. Romanian and Bulgarian membership of this organisation was rejected as it was felt that the greater level of investment and time required for these countries to meet the UCPTE standards would hold back the process of network integration[Miheaileanu, 1994]. As detailed in previous chapters, the effects of economic recession and restructuring on electricity demand moved the CENTREL states towards a significantly more secure supply position and reduced reliance on imports from the former-Soviet Union. The cost of interconnection of CENTREL to the UCPTE is therefore largely restricted to investment in improved generator and grid control measures and the lost opportunity costs of trade with the other members of the IPS/UPS.

On September 29-30th 1993 the CENTREL states conducted a trial to demonstrate their ability to operate as an autonomous system. [Fremuth, 1994] The series of tests involved the four CENTREL states and the former-East German VEAG network disconnecting their links with outside systems, operating their own primary control measures and monitoring their networks. Over the two days a number of planned (and unplanned) disconnections of large generating units took place. The maximum frequency deviation due to these outages was 80mHz with nominal frequency restored after a maximum of 6 minutes and maintained under all steady-state conditions. The trial was judged to have successfully proven the CENTREL states ability to meet the UCPTE standards and to operate autonomously during the process of transferring connections from the East to the UCPTE.

6.3 Interconnection Scenarios.

Several scenarios of East-West Interconnection may be envisaged. In the short-run, simply maintaining the current status quo, with trade limited by the capacity of the HVDC links, could be considered the least-cost option. This would, however, limit options in the longer term, a severe handicap in a changing market where any increase in traded volumes of power would have to be served through dedicated links at high cost. A similar argument could be made against simple disconnection of the CENTREL system from its partners in the East, swapping dependency on one region for another and removing opportunities for conducting 'wheeling' trades between East and West.

The scenario which seems most attractive to the CENTREL states is one with three stages, moving CENTREL from synchronous connection to the East to integration with the UCPTE, but still allowing trade with the East. These three stages are as follows:

1. CENTREL disconnects its network from the UPS and remaining IPS systems (Romania and Bulgaria). A period of operating autonomously follows, but with

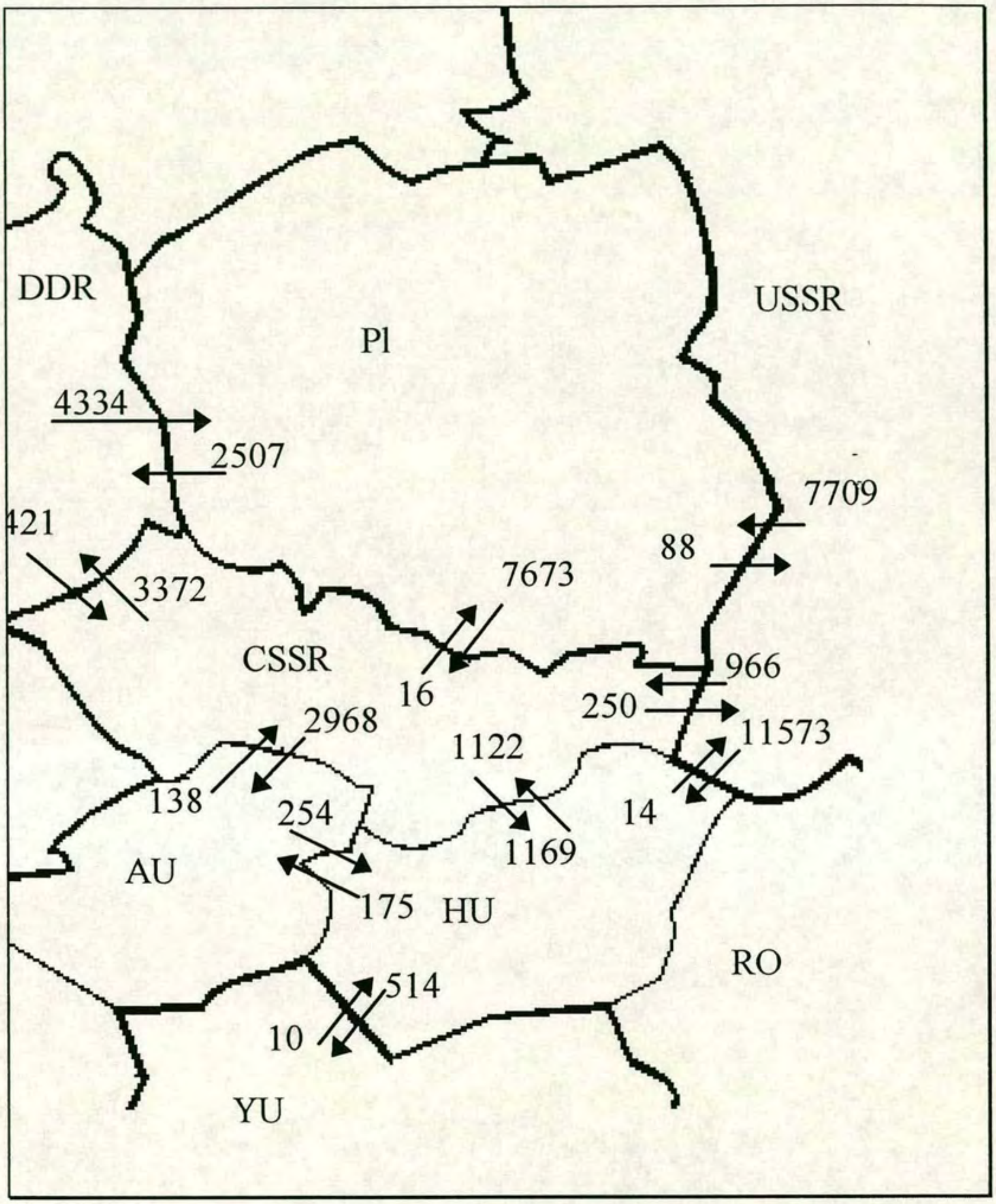
many of the advantages of wider interconnection retained through use of the HVDC links to Germany and Austria.

2. Once the UCPTE is satisfied that the CENTREL system meets its control and security standards, synchronous connection may be made between the two systems.
3. The HVDC converter stations may be removed from their current sites and moved to the Polish, Hungarian and Slovak borders with the Ukraine. This would allow a resumption of trade with the UPS system.

While a full cost-benefit analysis of this scenario is beyond the scope of this thesis, some of the issues regarding this scenario will be discussed. It may also be considered that the CENTREL countries have already made their judgement of alternative scenarios and have decided that the costs of achieving synchronous connection are outweighed by the benefits.

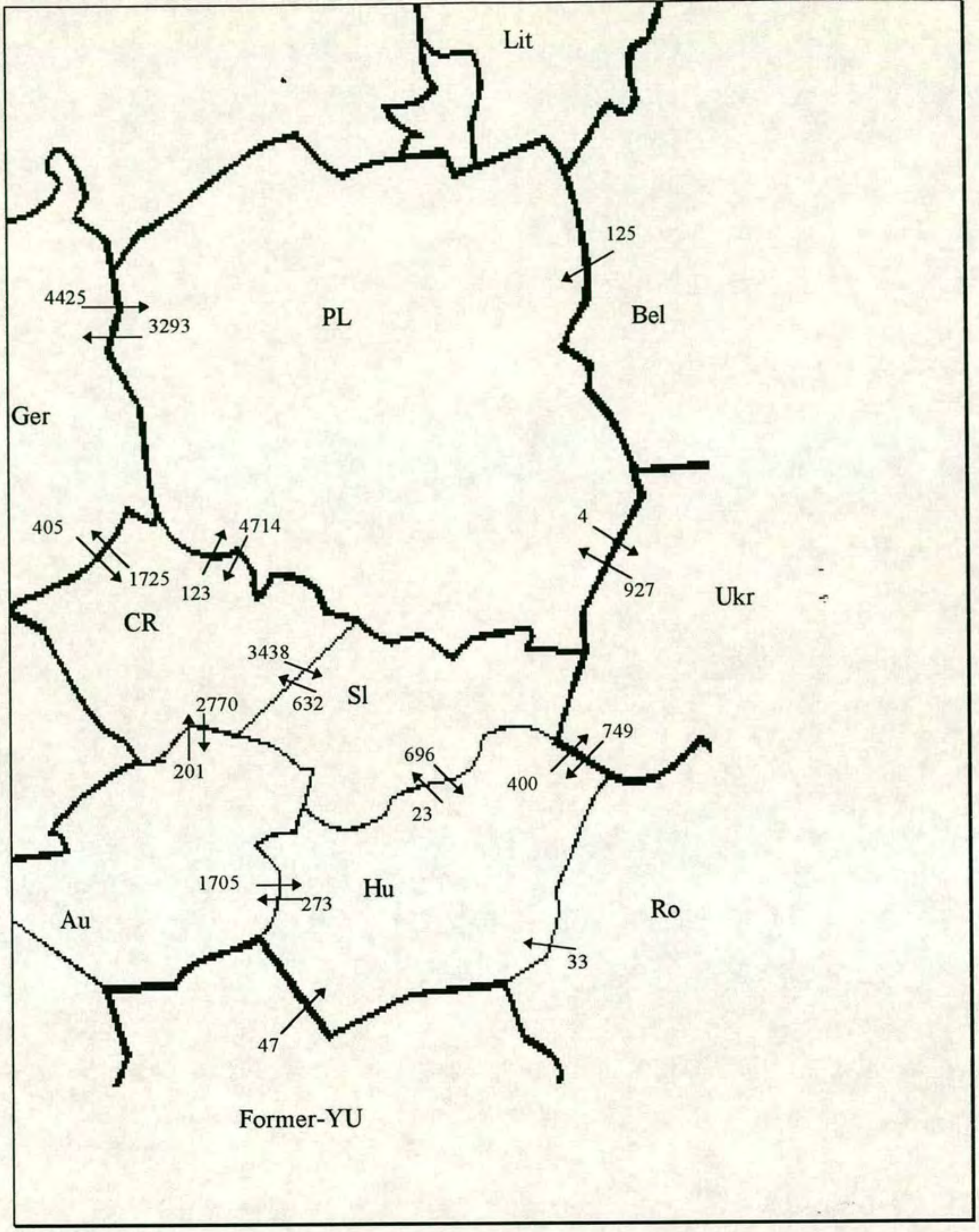
The cost of realising stage one is primarily that of the lost opportunity of trading with the UPS and Romanian and Bulgarian systems. Figures 6.3.1 and 6.3.2 on the following pages illustrate this trade in 1989, before the beginning of reform in these states, and in 1993. This trade had declined to negligible levels by 1994 due to declining demand in CENTREL and doubts over the ability of the Ukrainian system to deliver a surplus of energy for export to these states. Trade between CENTREL and its former-CMEA partners is not projected to recover in the short to medium term and, therefore, the opportunity cost of lost trade may be judged to be small.

Similarly, the benefits of reserve sharing and system support provided by interconnection may be discounted due to the problems in the UPS system.



	Import	Export
Poland	12059	10268
Czechoslovakia	10377	7728
Hungary	12959	1875

Figure 6.3.1 Central European Electricity Trade, 1989 (GWh)



	Import	Export
Poland	5600	8011
Czech Republic	5952	8056
Slovakia	3461	1328
Hungary	3230	756

Figure 6.3.2 Central European Electricity Trade, 1993 (GWh)

Stage two costs considerably more in investment in upgrading power station and transmission network control equipment to UCPTE standards. It could be argued that, due to the history of under-investment in this area and the general benefits to the economy through provision of a stable and secure electricity supply for the future, much of this cost would have been incurred without any plans for interconnection to the UCPTE. Funding for upgrading network control to provide a stable electricity supply to the growing industrial and commmercial sectors could also be considered a justifiable target for government loans or EU funding through the PHARE programme. The level of investment required for transmission lines linking CENTREL and the UCPTE is also smaller than expected, due to the significant capacity of existing synchronous links previously used for trade between network 'islands' (see section 6.2).

Further interconnection capacity may be added at low cost by removing the HVDC converter stations and synchronously connecting the lines feeding these. While this may not seem necessary immediately, leaving the HVDC converters embedded within the synchronous network requires a high degree of co-ordination and control to avoid the problem of energy circulating through the links. This manner of control imposes its own cost, reduces the flexibility of trade and is contrary to the philosophy of the UCPTE, with each member controlling their own system. Any future expansion of interconnection capacity will be via synchronous lines, avoiding the capital investment required for converter stations.

While the Dürnrohr HVDC interconnector, between the Czech Republic and Austria, is approaching 14 years of operation and would be considered almost fully written-down as an asset, the remaining two converters are only 3-4 years old. Removal of these stations from operation would be likely to require some compensation to the partners involved for the construction costs of these projects ($180M for the Etzenricht converter [PiE 156/12], $84.2M for the Wien-Südost station [PiE 162/7]). Some of this compensation might be made from European Union TENS funds (see 6.1) but the third stage described above allows for some of the costs of these assets to be recovered by their re-use farther East.

Poland and Hungary are both linked to the Ukraine by 750kV lines designed for the bulk transmission of power to the Rzeszow and Albertirsa transformers respectively. Much of the HVDC converter equipment at Etzenricht and Wien-Südost could be re-located to these sites allowing re-connection to the UPS system. A similar re-use of the Dürnrohr converter equipment might also be possible, either linking Slovakia or Hungary to the Ukraine via existing 400kV lines or re-establishing connection to the Romanian system via its existing 400kV link with Hungary. A larger proportion of the benefits of this re-connection would accrue to the Eastern networks, through provision of network support and the re-establishment of markets for any surplus energy, providing much needed revenue. However, the CENTREL countries will also benefit from diversity of supply for any import requirements.

6.4 Trading Opportunities

Electricity demand in Western Europe is projected to grow by almost 10% (200TWh) by the end of the century, with further growth of 400TWh to 2010. Much of this increased energy consumption will be met by new plant in Western Europe and increased utilisation of existing plant. Construction of new plant in Western Europe is, however, costly and attracts significant local opposition, as witnessed by the difficulties Italy has experienced in constructing new capacity to meet demand.

There exists a sizeable, and growing, market for generation plant in Central Europe to serve in the West, in addition to the local demand growth described in earlier chapters. This market opportunity can only be exploited if there exists sufficient operational generating capacity in Central Europe and transfer capacity for trade with the West.

It has been suggested that some of the benefits of generation in Central Europe (low property and labour costs, low tax regime and access to cheap fuel sources) may be realised by building export dedicated plant. In the absence of synchronism between the Central and Western European networks, this plant would require dedicated transmission links to the West, increasing construction costs and reducing the comparative advantage that such plant would have. Environmental opposition to power projects is also likely to become stronger in Central Europe in future, making plant operating mainly for the benefit of other states consumers politically unacceptable. Such plant would also not be able to exploit any relative changes in the markets for power in Central and Western Europe in the same way as plant operating in a combined synchronous network.

Chapter 2 discussed the various methods for recovering interconnector investment. In the case of connection of the Eastern European grids, however, the question remains as to who should provide the initial investment capital for funding the required interconnector capacity and who this should be recovered from. Traditionally, interconnections have been funded jointly by the connecting transmission system owners as part of their general investment programmes. The investment is recovered from all transmission system users and this is justified by the benefit of extra system security enjoyed by them. Some of the cost may also be recovered by interconnector use charges made to specific third parties who wish to trade energy over the link.

Passing on the cost of interconnector construction, linking the CENTREL systems with the UCPTE, to Western European consumers may prove difficult to justify on system security grounds, as the UCPTE already enjoys a high standard of security. In this case, a greater proportion of the initial costs must be recovered from parties using the interconnector for physical energy trades. As an alternative to building dedicated links to supply energy to the West, export dedicated plant could instead provide some of the capital for constructing synchronous links between the systems. This capital would be recovered through the exports from the plant supplied through the link and also from any other users of the link. This allows potential investors in new power plant greater freedom in choosing sites for their power stations and could provide an additional source of revenue to the project, as well as benefitting the system in general and potentially lessening opposition to externally funded power projects.

CHAPTER 7: CONCLUSIONS.

In Section 1.3 of this thesis Oskar Oliven's 1930 plan for an European Supergrid, stretching from the coast of Portugal to the Baltic Sea and from Norway to Greece. Nearly 70 years later, Europe is on the verge of achieving this far-sighted goal. However, it is important to note that this has not come about through the prescriptions of some grand strategic plan, but largely by a process of expanding and linking existing grids. In Western and Northern Europe, this has occurred initially where neighbouring regional grids have identified significant benefits, such as reserve sharing or trading a seasonal energy surplus, and have agreed an equitable settlement on meeting the costs of synchronous connections. In Central and Eastern Europe, however, the dictates of central planning and international socialism played a key role in shaping the structure of the electricity supply industries and their interconnections.

The removal of these political systems in 1989, opened the door for reform of the wider economy and the monolithic, state-owned electricity supply industries. Coupled with moves towards trade liberalisation in the West, the structure of the European power system, with its four, large asynchronous networks, could be re-examined. The geography of Northern Europe makes synchronous connection between the Scandinavian Nordel network and the Western European UCPTE impractical. Nevertheless, increased interconnection between the grids, via HVDC cables, is taking place as the independent Scandinavian generators seek to gain a share of the high cost power market in Germany.

The Unified Power System of the Soviet Union has suffered from the extreme economic conditions prevailing in this region and from the break-up of its former political master. These events have left the Central European states of Poland, Hungary, the Czech Republic and Slovakia with a unique opportunity. Economic reform has resulted in a weakening of electricity demand in these states, allowing their previous dependence on the UPS to be vastly reduced. The same reforms have broken up the vertically integrated ESIs and opened the door for foreign investment to increase and modernise generating capacity. This outside investment is projected to increase as their market evolves and better power pricing structures develop to allow recovery of investment capital. It is one of the central arguments of this thesis that this process of development will be hastened by the synchronous interconnection of the Central European states with the West European UCPTE system.

The first chapter of the thesis charted the development of international interconnected networks and described some of the motivations and problems encountered in this process. The second chapter illustrated the current state of the four large networks in Europe and their historic growth and future potential. The following three chapters moved away from the higher level view of trading networks to examine the individual Central European states in more detail. After outlining the wider political, historic and economic framework in which industry in the four states operates, the different domestic fuel resources and accessibility of fuel imports were described. This was done in order to explain the different structures and fuel choices for generation which have developed in this group of countries.

As has been shown in the individual country chapters, these states share a common history of central planning, with its attendant problems of under-investment and inappropriate allocation of resources. However, they now have quite different electricity supply positions and therefore have differing requirements in the future development of their power systems and their interconnections with their neighbours in the West.

Poland enjoys massive resources of coal; both good quality black coal and lower grade brown coal. These reserves may be exploited at lower cost than in the majority of Western Europe. The lack of regard paid to the environment by the Socialist governments of the past, however, have left Poland with high levels of environmental degradation due to the burning of coal without emissions reduction equipment. The solution of these environmental problems remains the most pressing problem for the Polish ESI. Although some retrofit of emissions reduction equipment has been funded by outside agencies, the sale of surplus Polish electricity to the West would provide a useful revenue stream to cover future costs of meeting environmental standards.

The Czech Republic shares some of Poland's problems of large-scale burning of low grade coals with little or no emissions reduction equipment. The Czechs have now made significant steps to alleviate this environmental impact through a programme of retrofitting emissions control equipment and the closure of older, inefficient plant.

Both the Czech Republic and Slovakia have ongoing nuclear power programmes the safety of which has been called into question by their neighbours in Austria. Both countries remain committed to their programmes as the only means of meeting future electricity demand with minimised environmental impact. This may lead to an internal over-supply of electricity in the near-term and both states could offset some of the massive capital costs of nuclear power and pay for increased safety standards by exporting power.

Of the four states, Hungary is the least likely to enjoy the ability to export power. Traditionally reliant on the Ukraine for over one quarter of electric energy supplied, the Hungarians will look to interconnection to provide diversity of supply from more secure sources. Economic recession has greatly reduced electricity demand in Hungary but, as in its Northern neighbours, high projected GDP growth is expected to result in increasing demand in future. Synchronous interconnection would allow some of this growth to be met by imports while investment in new capacity is made.

The newly reformed states of Central Europe have expressed their desire to form part of the European Union and it seems likely that this will take place around the turn of the century. EU regulations have significant impacts on the costs and structures of electricity supply organisations of member states and this influence is likely to increase as the EU seeks to create an Internal Energy Market. Current EU regulations and proposals for the IEM were examined in the early part of Chapter 6. The Central European's are currently in the process of privatising much of their state-owned enterprises and opening markets to outside investment. In some ways this will place them on a better footing to adhere to the EU proposals on competition and trade liberalisation in the energy sector than some existing EU members.

Chapter 6 goes on to examine the expansion in interconnection capacity which has been planned to allow for future deregulation of trade. This has primarily been located to allow trade from the Northern hydro resources in Scandinavia to demand centres in Northern Germany. While significant transmission capacity currently exists for trading asynchronously between Central and Western Europe, it is considered that asynchronism represents a barrier to increasing future trade between the two regions. To overcome this barrier, the Central European power sector has formed an umbrella organisation, CENTREL, to co-ordinate the necessary changes to allow for synchronous connection between the two regions.

The CENTREL states demonstrated in 1993 their readiness for synchronous connection by operating their system for two days independently of external connections. Since then, work has continued to bring the CENTREL system up to Western standards and allow the bypass of the current HVDC stations which form the current interface between the two systems. This thesis argues that synchronous connection will almost certainly be made in the near future, but that these plans can and should be taken a step further. The redundant HVDC converter stations may be moved to the Eastern edge of the CENTREL network where they can continue to be used for trading with the East. This move would improve diversity of supply for the

CENTREL states and continue to provide both a market and source of supply for the power systems in the East as they tackle their own problems.

Through this transition, the CENTREL states must bear certain priorities in mind. The maintenance of a secure, economic supply of electric power is the goal of any modern power system and is of extreme importance for the overall economies of these countries. The minimisation of the environmental impact of power generation is also important, as the citizens of these new democracies will no longer suffer the burden of pollution previously imposed on them by Socialist governments. Synchronous interconnection with the West will improve security of supply by linking these states to a more reliable system than that in the East. Interconnection also allows greater flexibility in meeting demand at lowest cost and reduced environmental impact as inefficient, polluting plant may be displaced by imports over the short term, until new capacity can be brought on stream.

The construction of new capacity and improvements to existing equipment requires significant levels of investment. While some of these costs will be met through the rise in prices towards a level above costs of production, these states hope to attract capital from foreign investors. The wider market for power provided by an interconnected system reduces the risks to an independent power project sited in these states and therefore the cost of capital associated with it. Competition from power supplied from neighbouring grids also protects purchasing utilities from excessive price rises by generators. It is proposed by this thesis that synchronous interconnection with the West, combined with a liberal trade regime, will lead to more stable market prices for power in Central Europe and an increased level of external investment than the continued isolation of this region's electricity supply system.

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APPENDIX A - SIGNATORIES OF THE EUROPEAN ENERGY CHARTER

On December 17 1991, the following countries had signed the European Energy Charter:

Albania
Armenia
Australia
Austria
Azerbaijan
Belarus
Bulgaria
Canada
Cyprus
Czech and Slovak Republics
Finland
Georgia
Hungary
Iceland
Japan
Kazakhstan
Latvia
Lichtenstien
Malta
Norway
Poland
Romania
Russia
Sweden
Switzerland
Tadjikistan
Turkey
Ukraine
United Kingdom
United States of America
Uzbekistan
Yugoslavia (Belgrade government)
European Community

Arrangements were made for the signing of Estonia, Kirgyzstan, Lithuania, Moldova and Turkmenistan at the earliest opportunity.

Observer status was granted to the Gulf and Maghreb states.

APPENDIX B - USEFUL ADDRESSES

Czech Republic

CEZ,
Hlavni Sprave,
Jungmannova 29,
11148 Praha 1,
CZECH REPUBLIC.

Czech Federal Statistical Office,
Federalni Statisticky urad,
Sokolovska 142,
Praha 8 - Karlin,
CZECH REPUBLIC.

Czech Ministry for Fuel and Energy,
Vinohradsk 8,
12070 Praha 2,
CZECH REPUBLIC.

Embassy of the Czech Republic,
Commercial Section,
26 Kensington Palace Gardens,
London W8 4QY

Ministerstvo Prumyslu A Obchodu
(Ministry of Industry and Trade)
Na Frantisku 32
11015 Praha 1
CZECH REPUBLIC.

Hungary

MVMRt,
Vám Utca 5-7
Levélcím,
1251 Budapest II,
HUNGARY.

Central Statistical Office,
Kozpotnti Statiszikai Hivotal,
Kelety Karoly Utca 5-7,
1024 Budapest,
HUNGARY.

Ministry of Trade and Industry
1024 Budapest II
Martirok UTJA85
HUNGARY.

Embassy of Hungary,
46 Eaton Place,
London SW1

Poland

Polish Power Grid Company,
2 Mysia Street,
00 496 Warszawa,
POLAND.

Centrum Informatyki Energetyki,
(Energy Information Centre)
skrytka pocztowa 143,
ul. Mysia 2,
00 950 Warszawa,
POLAND.

Central Statistical Office,
Al. Niepodleglosci 208,
00 925 Warszawa,
POLAND.

Polish Embassy,
15 Devonshire Street,
London W1N 2AR

Ministry of Industry and Trade
Ul Wspolna 4,
00-926 Warsaw,
POLAND.

Slovakia

Slovensky Energeticky Podnik,
Hranicna 12,
82736 Bratislava,
SLOVAK REPUBLIC

Embassy of the Slovak Federal Republic,
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Ministertuo Hospodertua,
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SLOVAK REPUBLIC.

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2 rue André Pascal,
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UCPTE
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E-28109 Madrid,
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UNIPEDE,
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(Energy Division)
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SWITZERLAND.

APPENDIX C - PUBLISHED PAPERS

1. Electricity Generation in Central Europe, Wito, A., Macpherson, D.E., and Whittington, H.W. Published in IEE Proceedings Part C - Generation, Transmission and Distribution, Volume 140, Number 5, September 1993.

2. The European Supergrid - Linking East and West, Wito, A., Macpherson, D.E., and Whittington, H.W. Published in Proceedings of the 29th Universities Power Engineering Conference, 1994, Galway, Ireland.

.G. Wito
.E. Macpherson
.W. Whittington

dexing terms: Energy economics, Power generation

Abstract: The current electricity supply position of Poland, Czechoslovakia and Hungary is reviewed, the political and economic background examined and details of primary energy sources for the three states presented. Generation capacity, production and consumption are detailed before an examination of some of the environmental consequences of past policy is made. Conclusions are made on the present problems and the possible future direction of the electricity supply industry in these states is examined.

Introduction

conomic prosperity has always been closely linked with e provision and expansion of an electricity supply. This as particularly relevant in the centrally planned econmies of the socialist states of Central and Eastern urope. Lenin himself summarised the philosophy as Communism is Soviet power plus electrification of the hole country' [1]. Growing industrial output was to be elled by growth in electricity supply and be virtually nconstrained by market disciplines or environmental onsiderations. However, the sweeping political changes f the past three years have called into question such a olicy and revealed many of its worst failings. Attempts ave been made to replace central planning and state bsidies by local management and market forces. Genertors of electricity in Eastern Europe are also becoming ccountable for any pollution they produce. These hanges have provided a new set of challenges for the lectricity supply industries of Central and Eastern urope far removed from simply matching growing emand with the construction of new capacity.

To illustrate the issues involved this paper covers the nergy supply and electricity generation situation in oland, Hungary and Czechoslovakia since geographiclly these countries lie in the area formerly known as entral Europe and share borders with the European ommunity to the West and the former Soviet Union to e East. As such, they provide a bridge between the two conomic systems and demonstrate most of the points lluded to above.

Background

olitical reform began in these countries before the urrent problems in the USSR surfaced and their democratic system and elected governments may now be regarded as stable. Economic reform in these countries is also further advanced than in Bulgaria and Romania to the South, and they are attracting progressively increasing amounts of Western aid and business interest as the process of reform continues successfully [2].

Poland, Czechoslovakia and Hungary have recently concluded free-trade agreements with both the European Free Trade Association and the EC. Associate membership of the EC is likely to be granted to the three states within the next few years, although the states themselves would probably prefer full membership. The EC itself currently favours the year 2000 as a realistic date for this to occur.

The three countries are full signatories of the European Energy Charter. This treaty concerns free trade in energy, open access to energy resources for exploration and exploitation and co-operation in nuclear safety and technology transfer. It has particular relevance to the states of East and Central Europe, both as energy producers and consumers and as transit corridors for energy trade between the former Soviet Union and Western Europe. Because of this, a study of the electricity generation and transmission systems of Poland, Hungary and Czechoslovakia is of particular relevance.

2.1 Centrally planned economies [3]

Central planning of the economic structure of Eastern Bloc countries was generally performed by unelected government officials without market discipline and gave rise to many problems. Planners reacted to real or perceived shortages of goods by ordering increases in production. These plans could generally not be met because of shortages in supply of production inputs. These shortages may have arisen because of corruption, e.g. claims were made that production figures of suppliers were 'doctored' to show higher performance to win increased bonuses. Lack of market discipline prevented producers from choosing the lowest cost or most reliable supplier. The result is that supplies were often of poor quality, the wrong type (as suppliers have no interest in upgrading goods to sell to a guaranteed market) or did not arrive at the correct time in the production process. Industries would try to meet production targets, in this climate of general shortage. To achieve this they demanded surplus inputs of material in an attempt to ensure their ability to produce their product. With every level of industry functioning in this way, a problem of excess demand was created and resulted in a general decline in the quality of the resulting goods as lower quality inputs were used to meet production quotas.

2.2 Energy

Primary energy and electrical energy are vital inputs in any industrial process. Industry demanded large supplies of both in the energy intensive processes such as steel

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gers to improve efficiency and save energy. In turn, generators were forced to accept low-grade, subsidised fuel as this was all that was available to them in the rigid supply structure that existed. Their guaranteed market and a lack of competition again provided no incentive to improve efficiency. Environmental protection legislation was generally slack, where it existed at all, and planners saw no need to invest in emissions reduction equiopment in a growing number of plants which were burning increasing amounts of low-grade fuels.

2.3 *CMEA (Comecon)*

These problems were aggravated and given an international dimension through the creation of the Council for Mutual Economic Assistance (CMEA or Comecon). This organisation was founded by Stalin in 1949 as an Eastern European 'Marshall Plan' and focused on integration of the economies of the Soviet Bloc. What resulted was a distorted trading Bloc with Eastern Europe addicted to cheap supplies of Soviet energy and raw materials. These were used to produce basic industrial inputs, such as steel or chemical products, or inferior engineering and consumer goods. Because of their inherently low quality these goods could not be sold on the World Market, but were accepted as payment by the Soviet Union. This forced increased specialisation in Eastern Europe to produce industrial goods to pay the Soviet Union for the energy and raw materials inputs on which they depended. The Soviet Union was unable to realise the full economic potential of her energy reserves because she was subsidising her partners with cheap material inputs. These could have been sold on the world market as 'hard' commodities for hard currency, but accepting inferior 'soft' goods instead often resulted in problems with her own internal indusrries. Eastern Europe is now paying the price for this system by being left with an over-large industrial sector that is inefficient, expensive, energy intensive (requiring approximately double the energy input per unit GDP as compared to the West) and environmentally hazardous [4].

The CMEA has now collapsed as an organisation. Internal problems of excess demand are being approached by attempting complete economic restructuring. This process has three main components:

(*a*) removal of price controls, so that industry and consumers must pay more realistic prices for goods

(*b*) privatisation programmes to introduce market discipline to viable industries

(*c*) removal of state subsidies to inefficient industries.

This has resulted in inflation and unemployment, two problems previously not experienced in the socialist states.

2.4 *Political changes*

Poland, Czechoslovakia and Hungary removed their communist-contolled governments peacefully and have since held free elections. Their new governments all have a strong commitment to economic reform to a Western, free-market structure and have received financial aid from the West to enable this to happen with the minimum of delay. Despite rising unemployment and inflation there is a general consensus within these countries that the reform process is vital, and there are few advocates for a return to the previous system [5, 6, 7].

fuel and for power generation formed a key of central government planning in Eastern Europe. Rising demand in the expanding industrial sector was fuelled by increased production of existing domestic coal resources and imports from the Soviet Union. Little consideration was given to the economics of production or the environmental consequences. The cost of this policy is now being paid in a blighted landscape, rising unemployment from pit closures and growing hard-currency debt to pay for both Soviet and Western imports.

Table 1 illustrates the production and import of oil, gas and coal, in million tonnes of oil equivalent, to provide an overview of their relative importance for the energy economies of the three states.

Table 1: Production and import of oil, gas and coal in million tonnes of oil equivalent

1990 Energy balances (Mtoe)			
	production	import	export
Poland			
oil	0.1	15.2	1.7
gas	2.6	6.8	—
coal	95.5	0.3	17.0
Czechoslovakia (EIU estimate)			
oil	0.1	15.6	1.0
gas	0.7	8.0	0.5
coal	38.0	3.5	2.0
Hungary			
oil	2.7	8.0	2.0
gas	3.9	4.9	—
coal	4.6	2.2	0.1

Source: Economist Intelligence Unit Country Profiles 1991/92

3.1 *Oil and gas*

3.1.1 Poland: There are almost negligible proven reserves of domestic oil, estimated at 2 Mt, but the Baltic remains largely unexplored and there are hopes of a find there. Imports from the Soviet Union totalled 15 Mt in 1989, but this was cut to 10.7 Mt in 1990 forcing an import from the West of 3.3 Mt. Poland produced nearly 28% of is domestic demand for gas in 1990. The remainder was imported from the Soviet Union via the Kobrin–Brest–Warsaw pipeline. Demand was largely split between domestic and industrial fuel use, but an important fraction was used as material input to the chemical industry. The gas distribution network supplies 490 towns and comprises 14000 km of high-pressure pipe with some 2000 km of high capacity trunk lines. Poland's import quota for the 1986–1990 five-year period was 40 Gm^3. Poland has asked the Soviet Union for an additional 11 Gm^3 for the next five-year period, claiming it had a higher than expected construction input into the gas pipeline from the Yamburg field in the Soviet Union. Industrial gas prices already refect import costs and with domestic prices rising by a factor of five in January 1990, the gas market is relatively well developed. The World Bank has lent Poland $250 M to increase gas production, and negotiations are under way for supplies from Norway and Algeria.

3.1.2 Czechoslovakia: Like Poland, Czechoslovakia has only small reserves of domestic oil, again estimated at 2 Mt, and must import 97% of her needs from the Soviet Union. This import is made via the Friendship pipeline which links Kuibyshev to Czechoslovakia, Poland, must seek other sources for oil supplies. Deliveries of 0.1 Mt per month began in January 1990 from the Middle East via the Adriatic pipeline through Yugoslavia. How reliable these will be, given the current situation in Yugoslavia, remains to be seen.

Czech engineering expertise and government money have made a large contribution to pipeline construction in Eastern Europe. In 1987, 12 Gm^3 of gas was imported in payment for work undertaken on the Orenburg pipeline. Since 1989, Czechoslovakia has received 5 Gm^3/year for work on the Progress pipeline from the Tazov peninsula. This contract will run for 20 years and Czechoslovakia also receives 5 Gm^3/year in gas supplies in return for transit of Soviet gas through to Western Europe. Czechoslovakia has 30000 km of transit pipeline with an estimated capacity of over 80 Gm^3. There is little doubt that this secure supply of gas is of great benefit to the Czech economy and use of gas is set to expand within the country. A large increase in storage capacity will be needed, however, to deal with winter peak demand which can be up to three times greater than demand in the summer months.

3.1.3 Hungary: In contrast to its northern neighbours, Hungary has significant oil reserves, estimated at 58 Mt. Production averages around 2 Mt/year, roughly one quarter of domestic requirements. The oil extracted, however, has a high sulphur content and production is likely to halve by the end of the century as extraction becomes increasingly difficult due to technical difficulties. The Soviet Union supplied 7.7 Mt in 1989 but this was cut to 5 Mt in 1990 with the introduction of hard currency payment. Supply through existing pipelines from the Soviet Union is still likely to be Hungary's cheapest source of oil in the future, even at World Market prices.

duction from 6.2 Gm^3 in 1989 to 4.95 Gm^3 in 1990 and production looks set to fall further. Hungary has two long-term supply contracts with the Soviet Union, one for 2.8 Gm^3/year of Orenburg gas till 1999 and the other for 2 Gm^3 of Yamburg gas to 2008. In 1990 Hungary also received 2.5 Gm^3 of gas from the Soviet Union in part payment of Hungary's transferable-rouble trade surplus. Consumption in Hungary is projected to reach 15 Gm^3 by 1995. A large expansion of the distribution network will be required, however, as at present only around one third of the population is connected to a gas supply.

3.2 Coal resources [9, 10, 11]

Table 2 illustrates coal reserves and annual production in 1988. Production since 1988 has fallen as uneconomic pits have been closed.

Table 2: Coal reserves and annual production in 1988

Coal reserves and production 1988 (Mt)			
	Poland	Czechoslovakia	Hungary
Hard coal			
Proven reserves	45000	1870	100
Estimated reserves	64000	9000	714
Annual production	193	25.5	2.2
Brown coal			
Proven reserves	11700	8850	780
Estimated reserves	17000	11500	3650
Annual production	73.5	98	18.6

Source: IEA

3.2.1 Hungary: The Hungarian coal sector is highly in debt and many uneconomic pits will need to be closed to comply with World Bank conditions for economic aid.

Fig. 1 *The Polish high-voltage network*
thermal ○ hydro —— 400 kV —— 750 kV

stations are situated at the pithead and configured to run on domestic coal. Adjusting these plant to run on imported coal or building new plant to run on other (also imported) fuels would be a more expensive option. Hungarian coal has very high ash and sulphur contents and it may be necessary to commit capital to the installation of emissions control equipment in the larger coal-fired power stations.

3.2.2 Czechoslovakia: At present rates of extraction, Czechoslovakian hard coal would last for 100 years, with brown coal only lasting until 2010. However, economic extraction of coal is unlikely to continue until this date as the more accessible seams are exhausted. Coal supplied 95% of Czechoslovakian primary energy needs in the early 1970s but diversification into nuclear power and gas has reduced this to around 55% at present and projections are that this will fall to 30% of primary energy in 2000. 72% of brown coal production was used for heat and power production, much of which takes place in North Bohemia where the coal has a high moisture content and is suitable only for pit-head generation. 42% of hard coal produced was suitable only for heat and power generation with 41% suitable for coking and metallurgic production.

3.2.3 Poland: The importance of coal in the Polish economy cannot be over-estimated. In 1987 Poland produced 6% of the world's hard coal, placing it as the world's fourth largest producer and third largest exporter. Hard coal accounted for 70% of Poland's primary energy requirements and brown coal for a further 15%. Production costs for Polish coal range from $10/t to $66/t, with the higher figure better than many EC pits. Despite continuing production, many mines have ceased to be economic and have recorded losses of up to $48/t. This has resulted in a subsidy requirement for the coal industry of $1 billion per year. Productivity is high despite dangerous working conditions. Average productivity in 1987 was 940t/worker–year in Poland, comparing with 983 for the UK and 797 for [West] Germany. 148 Mt of hard coal was produced in 1990, a significant fall from the 1988 production level, and brown-coal production has also fallen to 67.6 Mt. 60% of hard-coal production was used for heat and power generation within Poland. The figure for brown coal use in power stations is 96.3% and this intensive use has resulted in the highest level of SO_2 emissions per head in Europe.

3.3 Hydro power

Table 3 illustrates the total electrical power generated by hydroplants in 1989 and compares this with the theoretical exploitable potential.

Expansion in the hydroelectric generation sector may be possible, especially in Hungary where there exists a significant domestic resource. Expansion will displace polluting fossil fuel plant in the generation schedule. Construction of large-scale schemes, however, may result in strong local and environmental opposition which, with the arrival of political freedom, can no longer be ignored. An example of this is the ill-fated Gabcikovo Nagymaros project on the Danube.

Table 3: Electrical power generated by hydro plants in 1989

	Poland	Hungary	Czechosovakia
Exploitable potential GWh/yr	12000	4500	10826
Generation 1989 GWh	4053	169	4254
Total capacity MW	3460	50	3192
Pumped storage capacity MW	1460	0	1349

Source: International Water Power and Dam Construction Handbook 1990 [12]

Environmental opposition has forced the Hungarian government to abandon their part of the project over fears of pollution entering the water table and the risk of seismic activity in the area. Popular opinion in Hungary is also reported as antagonistic, viewing the vast project as a symbol of discredited central planning. Austrian contractors and the Czech government continue to seek a solution to the problem, mainly through compensation claims in the international courts. There is some hope that the Gabcikovo plant may be run at reduced power, displacing some Czechoslovakian brown-coal plant; an environmental benefit stresed by the Czech government. However, it appears that most of the billion dollars spent on the project will be lost and the massive concrete civil works already constructed will remain a silent monument to the fall of central power.

Any expansion of hydropower in Hungary must be balanced against loss of agricultural land which produces an important source of foreign income. The Polish power utility calculates that 35% of the exploitable potential allows for construction of small plants with capacities less than 10 MW. The larger rivers in Czechoslovakia have well developed cascades and any expansion is again likely to be in the form of small dams.

3.4 Nuclear power

Nuclear power generation capacity in Eastern Europe is made up exclusively of Soviet designed pressurised water reactors (PWRs, or VVERs in Russian). This reactor type is generally held to be inherently safer than the graphite-moderated RBMK reactors of the type installed at Chernobyl. There are, however, doubts as to the quality of the safety systems installed at these plants and the standard of competence of their operators. Governments in all the Eastern European states had high hopes of expanding nuclear generation to meet projected electricity demand. The Soviet Union actively encouraged this as it would reduce its own obligation to supply these countries with energy imports which could be sold to the World market for hard currency. The Chernobyl disaster and growing evidence of the uneconomic nature of the nuclear fuel cycle has largely destroyed these hopes. It now seems

Table 4: Nuclear power generation capacity in Eastern Europe

	MWe (number of reactors)		
	operating	under construction	planned
Czechoslovakia	3488 (8)	3788 (6)	6084 (6)
Hungary	1760 (4)	—	5000 (5)
Poland	—	1860 (4)	8000 (8)

Source: World Nuclear Industry Handbook 1990 [14] radiation monitoring. The Hungarian government remains the only socialist administration to compensate directly its farmers for $10 million of losses arising from the Chernobyl fallout. Eastern European governments lost a total of $300 million of foreign income due to an EC ban on imports of agricultural produce [13].

3.4.1 Poland: Ambitious plans to build 9860 MW of nuclear plant were to fill Poland's 14-18 GW projected undercapacity in the year 2000. Work began on 4 × 465 MW units at Zarnowiec in April 1982. Construction work was undertaken by Skoda Export of Prague, but Polish industry was unable to meet the standards of quality required, or maintain a reliable supply, of construction goods. As of May 1989 the project was only 35% complete and plans to have two units operating by 1992 look uncertain. The plans for a further 8000 MW of capacity at two sites have been abandoned, apparently due to a lack of capital.

3.4.2 Czechoslovakia: Commercial operation of two reactor sites at Jazlovske-Bohunice and Dukovany began in 1984 and 1985, and plant currently under construction at Mochovce and Temelin is due to come on stream in the mid-1990s. The Czechs claim their reactors are of a very high standard, having been built by Skoda of Prague rather than by Russian engineering firms. However, the two existing reactors at Jaslovske-Bohunice and Dukovany and the one under construction at Mochovce do not include protective containers for the core. The other construction site at Temelin is reported to be on a geological fault and has received strong international opposition from Austria and Germany. Czechoslovakia still favours continuing expansion of nuclear power despite receiving high levels of fallout from Chernobyl, but has promised to close its existing plants in 1995 if it has not brought them up to Western standards. Falling demand and lack of capital are likely to sink the plans for further capacity, and Austria has shown willing to provide cheap electricity in return for closure of coal plant.

3.4.3 Hungary: At present, 4 × 440 MW units at Paks on the Danube provided 20% of Hungarian total capacity and nearly 50% of internal production in 1989. Hungary has large uranium reserves and regarded nuclear power as an escape from overdependence on Soviet energy. Orders for two further 1000 MW Soviet-built plant at Paks were suspended in November 1989 when neither partner could find the necessary funding. Strong environmental opposition to nuclear power is present in Hungary, but the government still appears to be considering seriously Western (notably French) offers to build nuclear plant, paid for with electrical power exported to the West.

4 Electrical sector

Table 5 illustrates the generating capacity of the three countries, according to type of plant, in 1989.

Table 5: Generating capacity of Eastern Europe in 1989

	Generating capacity by type (MW)		
	Poland	Hungary	Czechoslovakia
Hard coal	19878	227	—
Brown coal	8896	1735	11246
Oil or gas	400	3129	—
Hydro electric	1976	48	2920
Pumped storage	1330	—	1450
Nuclear	—	1654	3226
Total	32480	6793	18842

Source: Annual Bulletin of Electric Energy Statistics for Europe 1990 [15]

4.1 Poland [16]

In 1987 the Ministry of Industry operated a subsidiary company, the Union of Brown Coal and Power Industry, responsible for generation of electrical power. This body was restructured in August 1990 when the Polish Power Grid Company was established. Thirty-three independent

Fig. 2 *The Czechoslovakian high-voltage network*
■ thermal ○ hydro ▲ nuclear —— 400 kV

sary for the transmission of power and maintaining a reliable supply.

Table 5 shows Poland's heavy reliance on coal-fired plant. According to Polish engineers, the total installed capacity is insufficient to meet the peak demand (of just over 22000 MW in 1990) owing to poor plant availability and maintenance problems. A planned output of 230 TWh in 2000 was to have been met by building a further 14–18 GW of capacity, 50% of which would be nuclear. 6800 MW extra was needed by 1990 to fulfill this plan but, of 2625 MW definitely planned for this period, only 1800 MW was actually installed at the Belchatow brown-coal site. Six 360 MW hard-coal units are under construction at Opole, due to come on stream in 1991–1995, but no other significant projects are under construction at present. Further problems are caused by the age of existing coal plant, with at least 9000 MW of capacity in plant older than 20 years, and the lack of emissions control equipment.

Polish electricity production peaked in 1987 at 146 TWh. By 1989 it had fallen slightly to 145 TWh but in 1990 it reached only 136 TWh, as seen in Table 6.

Table 6: Electricity production in 1990

Hard coal	53.3%
Brown coal	38.3%
Hydro	2.4%
Self produced	6.0%
Total	136 TWh

Source: Union of Brown Coal and Power Industry

Total electricity consumption in Poland in 1989 stood at 137 TWh, comprising of 135 TWh domestic production and 2 TWh of import deficit. Allowing for 13 TWh (nearly 10%) of network losses, 120.8 TWh was made available to consumers. Table 7 illustrates the relative shares of consumption for different types of customer.

Table 7: Electricity consumption in 1989

Industry	55%
Domestic	17%
Agriculture	8%
Public buildings	8%
Railways	4%
Other	4%
Self producers	4%

Source: Union of Brown Coal and Power Industry

Electricity supply price rises of 800% over the period 1990/91 have hit the industrial sector hard and a decline in total consumption of 8% was recorded. The IEA states that while market reforms are proceeding smoothly, further price increases of up to 270% will be required to align prices with those of the West. The Poles aim to improve their network efficiency and regain previous production levels to fuel new industrial and domestic demands following the end of economic reforms and to export power. Electricite de France has conducted a study of the Polish system and believes all Polish units can conform to EC standards by 1995 although it is difficult to see how this will be achieved.

4.2 Czechoslovakia [17, 18]

Electricity production in Czechoslovakia is overseen by the Ministry of Fuels and Energy through two utilities; it was announced that these two bodies would become limited companies in the Czechoslovakian privatisation programme although the state would maintain a major share. Nuclear plant is controlled by a separate atomic energy commission.

80% of brown-coal production and 42% of hard-coal production are used for power production, in 11 GW of utility plant and in industrial plant. The 800 MW Detmarovice plant in the Ostrava coal field accounts for most of the hard-coal use in power generation and of the remaining thermal plant 5520 MW are situated around the brown-coal fields of Northern Bohemia near the German border. Other Czechoslovakian capacity is shown in Table 5. Industrial autogeneration accounts for a significant 2800 MW of total Czechoslovakian capacity of 21700 MW. Table 8 illustrates production of electricity according to type from Czechoslovakia.

Table 8: Electricity production in 1990

Coal	55.5%
Nuclear	28.5%
Self produced	11.5%
Hydro	4.5%
Total	86 TWh

Source: Czech Power Company

Although the relative share of coal for generation has fallen by over 20% since the early 1980s due to the introduction of nuclear plant, this fuel is still used in large amounts in plant with little or no emissions control equipment. The situation is, however, likely to improve as new nuclear units come on stream and older plant is closed. Table 9 shows consumption by type and the heavy industrial demand can be expected to fall again allowing for a reduction in coal use.

Table 9: Electricity consumption in 1990

Industry	62.1%
Domestic	15.5%
Others and losses	12.6%
Agriculture	5.2%
Transport	4.6%
Total	85.6 TWh

Source: Czech Power Company

The Czech Power Company exported 2210 GWh in 1990 and imported 5350 GWh, 80% of this from the Soviet Union. Czechoslovakia plays an important role in the transit of electricity from the Soviet Union and Poland through to Austria and Germany.

4.3 Hungary [19]

The first power generating plant in Hungary was established in 1884 and by 1949, when electricity production was nationalised, a 100 kV nationwide grid had been started. The state board MVMT acts as a holding company for 11 generation companies, the transmission company, OVIT, and six regional distribution companies. In 1992 this structure will be changed, with the distribution companies becoming limited companies responsible for their own budgets, guided by the successor to MVMT. This successor company will also be responsible for the transmission function of OVIT. The power supply companies are expected to generate on a contractual basis with greater independence, allowing scope for new ating plant at the end of 1990 is shown in Table 5. A further 485 MW was available from combined heat and power plant. The largest and newest of the coal-fired plant is the 800 MW lignite plant, 'Gagarin', completed in 1972. Owing to its age, some 80% of total capacity was refitted during the seventies to prolong operating life, but Hungarian plant, like that of Poland, still has a total lack of emissions control equipment.

A quarter of total capacity is sited in the Paks nuclear site, completed in 1987, and the remaining capacity is mostly dual oil/natural gas fired plant. More than half of this is situated at Dunamenti (1870 MW) to the south of Budapest along with 202 MW of open-cycle gas-turbine plant. A further 1850 MW of capacity is available to MVMT from Southern Power System of the USSR; 1100 MW is provided by long-term contracted power to 2004, while the remaining 750 MW can be called on to meet peaks in demand.

Fig. 3 *The Hungarian high-voltage network*

■ thermal ○ nuclear ▲ hydro —— 400 kV —— 750 kV

The sharing of capacity between coal, oil and gas (roughly one third each) is not reflected in production levels, shown in Table 10.

Table 10: Electricity production in 1990

Hard coal	3.4%
Brown coal	26.3%
Fuel oil	3.4%
Natural gas	16.3%
Hydro	0.6%
Nuclear	50%
Total	27 463 GWh

Source: MVMT

Hungarian generation only covers slightly more than two-thirds of demand. This necessitates a large import of electrical energy (11298 GWh) from the Soviet Union.

Agriculture	5.2%
Other	14.9%
Industry	44.2%
Total	37046 GWh

Source: MVMT

Hungarian electricity consumption by sector is given in Table 11.

The largest industrial consumers were the chemical and metallurgical industries, each taking nearly 10% of total consumption. The industrial sector, producing low-quality goods with low market price, consumes about 2.5 times as much energy per unit GDP as the Western average. Transmission losses are also high and have increased, by 41% since 1980, to 3846 GWh in 1990. Gross consumption increased by only 26% in the same period and there is large scope for improvement in this area. Industrial demand is likely to fall with the restructuring of the economy. Total electricity sales fell by 5% in the first five months of 1991. Household consumption totalled 9169 GWh in 1990, having grown by 83% through the eighties. Despite this, household consumption per inhabitant (776 kWh in 1988) remains low, at around half the figure for northern EC countries such as France and Germany. This sector is likely to grow as individuals gain more consumer spending power in the restructured economy.

5 Environmental problems

Large-scale use of low-grade coal has produced particular problems in Eastern Europe. These are well illustrated by the case of Czechoslovakia where environmental damage is said to reduce GNP by 7% and average life expectancy by 5.7 years [20]. The problem of atmospheric pollution is especially acute in North Bohemia, bility can drop to 2 m in the acrid, yellow smog which contains up to 20 times the level of sulphur dioxide considered harmful to health [21].

Number one in the list of environmental polluters in Czechoslovakia is the 1050 MW lignite-fired Prunerov 2 plant. In 1989 this plant alone discharged 202 kt of sulphur dioxide, 55.5 kt of nitrogen dioxide, and 10.7 kt of fly ash into the atmosphere. The Czechs hope to reduce production of electricity in North Bohemia by 40% by the year 2000. The Prunerov 1, Tisova and Tusimice brown-coal plants were closed in November 1991, reducing output by 10%, but further closures depend on the successful introduction of the 2000 MW Temelin nuclear plant in 1995. The Slovak utility is fitting electrostatic precipitators to remove fly-ash at the 660 MW Vojany 1 plant and fluidised-bed boilers to improve efficiency at the low grade coal burning Novaky A plant. Slovakia depends on power transfers from the Czech republic and, again, replacement of coal plant must wait until 1993 and the commissioning of the 1760 MW Mochovce nuclear plant.

A more immediate environmental benefit may be provided by flue-gas desulphurisation equipment, although this requires substantial capital investment and reduces plant efficiency, adding to operating costs. Austria has agreed to pay $M6.5 in aid towards the cost of FGD equipment at Novaky B in Slovakia. When completed, this will cut sulphur dioxide emissions by 68 kt/yr, equal to 60% of the emissions from the entire Austrian Industry. In a similar move, the Dutch utility SEP is paying $M30 toward FGD at the 4320 MW Belchatow plant in Poland; the resulting sulphur dioxide reduction equals the entire emissions from Dutch plant. Giving Western companies credit for reducing overall European emissions by investing in equipment for plant in Eastern Europe may prove more cost effective in terms of tonnes of pollutant removed for each dollar invested than imposing ever tighter limits within the EC.

6 Conclusions

From an examination of the electricity supply position of Poland, Hungary and Czechoslovakia as a group, three main problem areas are apparent:

(*a*) The strong dependence on the Soviet Union, currently a rather unstable region, for both primary energy and electrical energy imports.

(*b*) The question of nuclear safety in installed reactors and the problems of storage, transport and reprocessing of spent fuel and the disposal of radioactive waste.

(*c*) Environmental degradation through intensive use of polluting fuels in ageing, inefficient plant with a lack of emissions abatement equipment.

These problems appear at different levels in the region and blanket solutions would be inappropriate. In the short term, electricity demand will drop as price rises eliminate excess demand and large industrial users close under pressure from the economic reforms. This will allow the closure of some of the worst polluting, older plant and, possibly, a scaling down of any nuclear expansion plans to a more realistic level. A secure, competitively priced supply of electricity will be vital to the economies of Central Europe after economic restructuring has run its course and demand in the

Western aid and investment will play an important role in this process [22]. Improvements to the efficiency of transmission and distribution networks, possibly funded by EC aid for infrastructure development, would have an immediate effect on the reduction of fuel used thus aiding the trade balances of fuel importers. Greater interconnection and strengthening of transmission lines would allow these countries to enjoy the benefits of the growing electricity trading opportunities in Western Europe. Supply of electricity from outside sources can delay the need for large investment in the construction of new plant in the short term. This strategy would also open up Western Europe as a market for Soviet electricity exports.

Investment in efficient new plant, using the best available technology, has several advantages. Older plant may be closed when new plant comes onstream, reducing maintenance and fuel costs, and less efficient plant may be moved down the merit order. As less fuel is required to generate electricity, running costs and volumes of pollutants are reduced. Gas-fired plant, providing both heat and power, is favoured in the West as being efficient and clean with low capital construction costs. This mode of generation undoubtedly has a market in Eastern Europe, where many towns have direct heat supply networks currently fired by coal boilers, but gas is a relatively expensive fuel which must generally be imported.

Coal remains the only significant domestic resource of Poland, Czechoslovakia and Hungary. It seems almost certain that this fuel will continue to provide the largest share of fuel for electricity generation in the future. However, this must be utilized in the most environmentally benign plant as possible and this suggests a market for clean-coal technology and emissions control equipment. Both West and East can benefit from closer co-operation in the electricity sector and, it is hoped, this will provide a bridge to closer economic ties in general.

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THE EUROPEAN SUPERGRID - LINKING EAST AND WEST

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ABSTRACT.

The connection of power stations and load centres to form grids occurs for reasons of improved supply security and to achieve economies of scale. Use of grids allows reduction of operating reserves and exploitation of natural resources remote from demand. These motivations may be identified on a national and international scale and the electricity supply utilities in Europe have naturally coalesced into four large synchronous systems. This paper will examine the historical development of international power co-operation in Europe. The current situation of the systems and present methods of interconnection will be described and the potential for a European Super-grid assessed.

1. INTRODUCTION.

The connection of power stations and load centres to form area grids is generally for reasons both of improved security of supply and of economics. The use of interconnected grids allows economies of scale to be achieved in power station construction, reduction of total operational reserves and exploitation of natural resources, such as hydro-electric potential, remote from centres of demand.[1]

These underlying factors have relevance on an international as well as a national scale and as early as 1930 proposals were put forward for a pan-European electricity system.[2] Unfortunately political differences following the Second World War prevented this plan from being executed but the potential benefits of international interconnection remained. In time, utilities in the different European regions naturally coalesced to exploit these benefits, resulting in the position we see today with four large interconnected systems; the UCPTE (Union for the Co-ordination of Production and Transmission of Electricity) system which covers Western Europe, Nordel, covering Scandinavia, the IPS, covering Central Eastern Europe and the Ukraine and the UPS, covering the remainder of the former USSR.

2. CURRENT SYSTEMS.

Figure 1 illustrates the main interconnected systems in Western Europe, discussed below.

2.1 The UCPTE.

The UCPTE was founded in 1951 and currently comprises of representatives from the utilities of twelve member states.(Belgium, Germany, Spain, France, Greece, Italy, Yugoslavia, Luxembourg, the Netherlands, Austria, Portugal and Switzerland).In addition to the twelve member countries, mainland Denmark (Jutland) and Albania operate synchronously with the UCPTE and the UK National Grid is connected via a 2000 MW DC cable. The utilities responsible for the high voltage (220 and 380kV) grids in these countries are interconnected to their neighbouring utilities by synchronous three-phase links.

There is no central control of the grid or of the dispatch of generating plant in the UCPTE: each member must ensure that demand in its area is covered by its own or jointly-owned plant or by agreement to import power from other utilities. Each member must also ensure it maintains adequate frequency correction reserve and ensures single backup security in the operation of its interconnections such that if a transmission line fails, the remainder of the system must be able to take the additional load imposed on it.

Figure 1: European Interconnected Power Systems

Installed generating capacity in the twelve members of the UCPTE totalled 387 GW in 1992 (Figure 2) and production of electricity totalled 1533 TWh that year.[3]

2.2 Nordel.

Co-operation between electricity supply utilities in Scandinavia began in 1915 with the completion of an undersea cable between Sweden and Denmark. This allowed the Swedish utility to export surplus hydro power in the Summer, displacing production from Danish coal-fired plant. By 1959 Sweden had strong, high-voltage links with all three of her neighbours and power co-operation on a Scandinavian basis was proposed. This resulted in the formation in 1963 of Nordel, an advisory body comprising representatives of the Nordic power utilities.

Like the UCPTE system, Nordel has no central dispatch of generating plant and all trade is governed by bilateral agreements between the utilities concerned. The Nordel system is linked to Germany in the South and to Russia, via a 1000 MW HVDC link. As mentioned previously, mainland Denmark operates synchronously with the UCPTE and is connected to Norway and Sweden by HVDC undersea cables. Iceland participates in Nordel planning and technical work, but for reasons of geography, does not participate in electric power exchange.

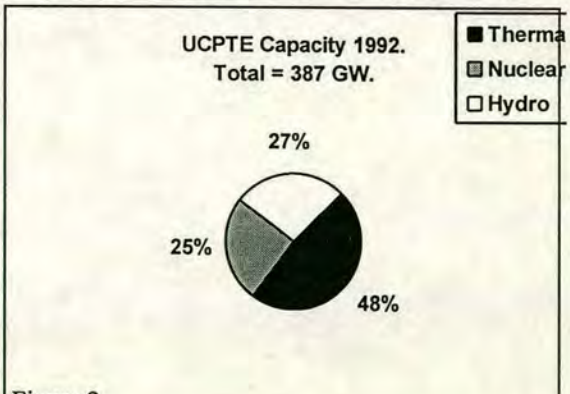


Figure 2.

The installed capacity of the Nordel system in 1992 stood at 86 GW (Figure 3) and production totalled over 346 TWh. Over 60% of production came from hydro-electric plant, 23% from nuclear plant and the remainder largely from coal and gas-fired plant.[4]

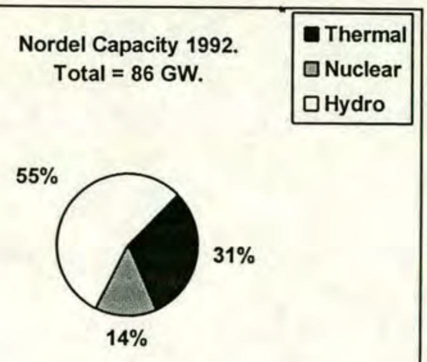


Figure 3.

Interconnection and co-operation in power exchange between the Nordel countries has been driven to a large extent by the desire to exploit economically the hydro-electric resources of Norway and Northern Sweden. In practice this has led to large imports of power by Denmark and Finland in the Summer months to take advantage of excess hydro electric potential, resulting from the winter snow melt, and reduce expensive thermal generation. In times of low hydro-power potential, thermal production may be increased to cover demand resulting in increased security of supply.

2.3 IPS.

During the sixties, the power systems of Poland, Czechoslovakia, East Germany, Hungary, Bulgaria, Rumania, Bulgaria and the Southern Power System of the USSR set up interconnections to form the Interconnected Power System. Unlike the UCPTE and Nordel, power exchange between these countries was managed by the Central Dispatch Organisation in Prague. In 1991, the IPS had a total installed capacity of 144 GW, (Figure 4) generating 623 TWh. 72% of this capacity was conventional thermal plant, much of it using brown coal or lignite for fuel. Of the remainder, 13% was hydroelectric and 15% nuclear plant of Russian design.[5]

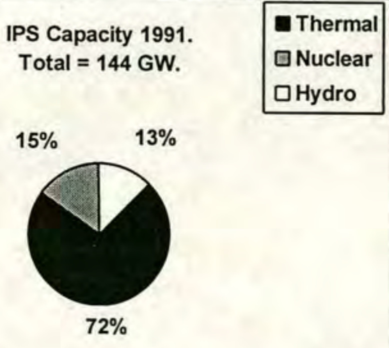


Figure 4.

The member countries of the IPS were all members of the Council for Mutual Economic Assistance, a trading bloc set up in 1949 to provide for greater 'integration' of the centrally-planned economies. The distorted trade patterns produced by this body resulted in the East European states becoming over-reliant on imports of fuel and electricity from the Soviet Union. Long-term one-way flows of electrical power from the Soviet Union to Hungary, Rumania and Bulgaria dominated the pattern of power exchange in the IPS. Poland, Czechoslovakia and the GDR were less reliant on imported power and trade between these countries was of a more short-term mutual support nature. A HVDC link between Austria and Czechoslovakia provided for power exports to the West in return for hard currency.

The political changes of late 1989 in Central and Eastern Europe have led to changes in the IPS system. Work is underway on the integration of the power system of the former-GDR with the UCPTE network, and new HVDC links are under construction between Czechoslovakia and Germany and between Hungary and Austria. Electricity imports from the area of the former Soviet Union must now be paid for in hard currency and the future of the IPS as a co-operative power exchange grouping is highly uncertain.

2.4 The UPS.

The United Power System of the Soviet Union is the largest power system in the world, in terms of area, stretching from the Baltic Sea to Lake Baikal in the East; a distance of approximately 7000km, crossing six time zones. Due to the large distances involved, extensive use is made of extra-high-voltage 750 kV lines and AC and DC lines operating above 1 MV are in use to transmit power from the large hydro-electric and coal field sites in Siberia to the industrial demand centres West of the Urals.

In 1991, the UPS had an installed capacity of 231 GW, generating 1170 TWh of electricity.(Figure 5)

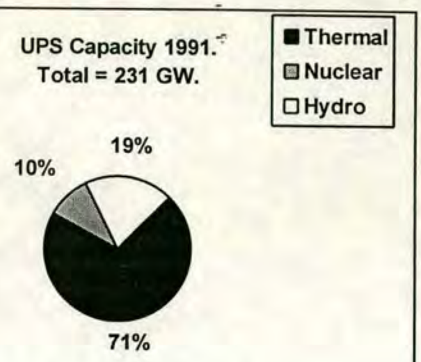


Figure 5.

The UPS is divided into nine regional grids with responsibility for regulating power generation in their own area and maintaining exchange with neighbouring grids within pre-arranged limits. The Central Load Distributor in Moscow monitors these exchanges and is responsible for overall frequency control. A variable amount of capacity in the Southern regional grid (in the Ukraine) is connected, in 'islanded' mode, to the IPS system to maintain frequency in that grid.

Despite Soviet achievements in UHV transmission and the construction of large hydro-electric stations, poor planning and maintenance, aggravated by problems of nuclear safety, have left the UPS with a shortage of available capacity. The current break-up of the Soviet Union also raises questions of Federal or Republic control of power projects funded by the central Soviet Government.

3 MOTIVATIONS FOR GREATER INTERCONNECTION.

An important motivation for the development of supply grids is the rationalisation of generation and exploitation of greater system flexibility by distributing demand among many consumers with different demand profiles and total system reserves among several generators. Large, efficient plant is used to supply a constant base-load for large industrial users and more flexible plant, such as hydro or gas-turbines, is used to follow the varying levels of domestic demand. Such load diversity, however, is generally easily found within the borders of one country and is not usually a motivation for international interconnection.

International interconnection of electricity supply grids develops to take advantage of different generation resources, especially the exploitation of large hydro-electric resources. There is little advantage in connecting two systems with very similar generation plant mixes and similar patterns of demand. This is illustrated by the Danish situation, where two supply grids, one in Jutland and one in Zealand, both mainly dependent on conventional thermal plant, remain isolated from each other. Both grids are connected to Norway and Sweden in the North to take advantage of these countries' hydro electric resources.

Consumption of electric power for industrial use in Central and Eastern Europe is currently in decline due to the economic conditions prevailing in the region, effectively allowing some base load plant to be used for export production. Central and Eastern Europe also have large reserves of brown coal which has a low calorific value and is uneconomic to transport as a primary fuel. Exploiting this resource, in an efficient and environmentally friendly manner, to produce electricity to supply demand in the West could prove economically attractive, provided sufficient transmission capacity existed to allow this trade.

A further advantage of large-scale interconnection from East to West results from the time difference between the various regions. This time difference produces a staggering of peak demands from West to East and gives a more balanced over-all system load. Estimates of up to 15000 MW increased exchanged power for every 1000 km covered by East-West interconnection have been made, although the extra transmission capacity required to cover this would severely reduce the benefits of this level of trade.[6]

4. INTERCONNECTION STRATEGIES.

4.1 Synchronous Links.

Where neighbouring utilities operate synchronous systems, bulk power exchange between the two systems may take place through ordinary high-voltage lines. The level of power exchanged by the systems may be decided on a bilateral basis, as in Nordel and the UCPTE, or centrally, as in the IPS and UPS. The high voltage systems in each country effectively form part of the same grid and care must be taken to ensure total system stability and security and to prevent faults in one country affecting the neighbouring systems.

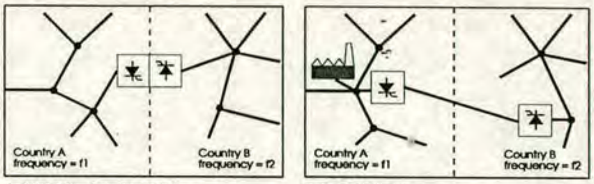
Figure 6.

Synchronous links are the simplest and lowest cost means of inter-connecting power systems.Provision for increased levels of exchange may be made by adding more cross-border lines or upgrading existing ones, provided planning and environmental objections have been overcome. Fig 6, details high-voltage synchronous connections between states in Europe.

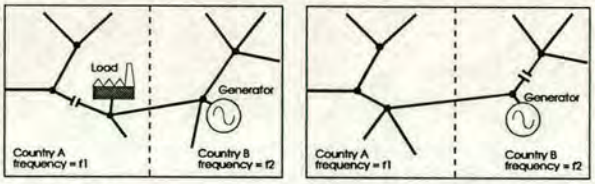
It can be seen from Fig 6 that while synchronous connection is common between states within each of the four power exchange organisations, there are relatively few synchronous links between them. This situation has arisen partly due to political differences between East and West Europe but mainly because of a lack of synchronism between the systems. This lack of synchronous operation makes direct inter-connection impossible and presents a technical and economic barrier to increased power exchange.

4.2 HVDC Links.

Presently, where exchange of electrical energy via direct, synchronous links is not possible for technical reasons, two strategies may be adopted; use of High-Voltage Direct Current (HVDC) links and the use of 'island' subsystems, as illustrated in figure 7.



A: HVDC Back to Back Link. B: HVDC Stitching.



C: Load Islanding. D: Generation Islanding.

Figure 7: Interconnection Strategies.

Where interconnection between systems must be made by long-distance undersea cable, such as between Norway and Denmark and England and France, use of HVDC is justified on both technological and economic grounds. Where adjacent asynchronous systems are to be connected 'back-to-back' HVDC links are used, i.e. rectifier and invertor equipment is housed within the same substation with no intervening cable. This method is used in the interconnections between Finland and Russia and Czechoslovakia and Austria. HVDC may also be justified where power is to be transmitted a large distance overland. This strategy is used in Russia to transmit power from the large coal and hydro-electric generation resources in Siberia to load centres West of the Ural Mountains. It has been suggested that this method of interconnection could justified in connecting areas with a generating over-capacity with demand centres in other countries. Care must be taken, however, to ensure that this does not result in an inefficient counter-transport of energy from the delivering invertor station back through the AC grid towards the supplier country's border.

4.3 Islanding.

In situations where the motivation for exchanging power between two asynchronous systems is of a more limited nature, the strategy of using 'island' subsystems may be used. Here, spare capacity in the form of one generating station or the excess demand of one large consumer or a small area close to the border is disconnected from the national grid and connected with that in the neighbouring country. This method of cross-border trading is also used where there is difficulty in supplying an area from its own national system for geographical or economic reasons, such as in mountainous or remote areas. (e.g. Northern Norway connected with Russia.) It has also been suggested that plant built in Eastern Europe using

Western finance could repay its capital investment by exporting part of its production through a dedicated radial link in a Build-Operate-Transfer (BOT) scheme. Such schemes are motivated by the difficulty in obtaining permission for new generation sites in Western Europe and the need for new capacity in Eastern Europe to meet higher environmental standards and/or generation under-capacities.

4.4 Synchronisation.

As mentioned above, the simplest method of connecting two systems is via synchronous AC links. Two systems may be synchronised and connected, as in the integration of the West and East German networks, but this may only occur when both systems have adequate reserve capacity and frequency-power control. Currently, the power systems of central Europe either are dependent on imports of power from the former Soviet Union and lack adequate domestic reserves, or do not have the necessary control systems and low levels of system losses necessary for direct connection to the UCPTE system.

5. INCREASING INTERNATIONAL CO-OPERATION.

The twelve states of the European Community form a powerful and unified economic bloc with a high degree of influence over the economies of its European trading partners in the European Free Trade Association and increasingly in Eastern Europe. Norway, Sweden, Finland and Austria have recently concluded membership agreements with the European Community, entry dependent on referenda in these states, and EC regulations on free movement of goods and services, including those in the energy sector, will apply. The Central European states, Poland, Hungary and the Czech and Slovak republics, have also demonstrated an intent to become full members of the EC. The current state of their economies, however, implies that a transitional stage of associate membership is likely to occur first but these countries currently qualify for assistance in the energy sector through the EC's PHARE programme.[7]

The states of Western and Eastern Europe, the republics of the former-USSR, the USA and Japan signed the EC-proposed 'European Energy Charter' on December 17, 1991 at the Hague. The Charter aims to improve security of energy supply, maximise efficiency in energy production and use and to implement market principles in the energy sector. Negotiations on specific areas requiring action and on implementation of charter recommendations are currently continuing. The European Energy Charter, while not legally binding, represents a statement by both East and Western Europe to move towards greater exchange of energy, including electricity, based on free-market principles. The potential advantages to both parties are large, with the East receiving Western investment and technology in exchange for energy and the West improving its security of supply and finding a growing market for energy production technology. Through the above developments, EC energy policy will have a significant impact on the development of the electricity supply industries in its neighbouring states.

5.1 European Grid Expansion.

The electric power transmission utilities of Poland, Hungary and the Czech and Slovak Republics founded the CENTREL organisation on October 11, 1992. CENTREL aims to up-grade the operating and technical standards of the power systems in the Central European States to UCPTE levels. In the Autumn of 1993, the CENTREL and East German grids operated for three days, isolated from external interconnections, to test their current standards of control. The East German grid will be integrated into the UCPTE system in 1994 and CENTREL is planning to operate its grid in isolation for one year before connection to the UCPTE system in 1997.

Following this extension of the Western power system, synchronous connection to Romania, Bulgaria and the Baltic states may become a feasible proposition. Detailed stability and cost-benefit analyses will be required before this, and connection to the power system in the former-USSR, can become a reality.

6. CONCLUSIONS.

The history of the European Electricity Supply Networks since the Second World War has been one of continued growth and expansion. The removal of central planning in the East and the growing influence of the EC has produced a political climate which allows for interconnection of the four large interconnected supply networks. There appears to be no technical barrier to this which cannot be overcome by some international co-operation between governments and utilities.

In the short term, power flows between East and West, using existing links, are likely to remain a fraction of the potential. Surplus power, resulting from the decline in industrial consumption, may be sold to the West for hard-currency. Power will increasingly be shipped from the West as the Central European States reduce dependence on the former Soviet Union for supplies, and to provide temporary support while they restructure. This restructuring will be necessary to bring network losses and grid control equipment up to Western standards, if synchronous connection is to occur, and also to bring levels of gaseous and particulate emissions down to an acceptable level.

In the longer term, electric power is likely to flow from East to West, generated in the East using fossil fuel and hydro-electric reserves in new or modernised plant, possibly built using Western technology and capital. Russia has vast potential for hydro-electric generation in Siberia.[8] Wheeling charges for transmitting this power to Western European consumers could provide an important source of revenue for Central European networks. Exchange of electricity is also likely to increase as the time differences, leading to different peak demand times, between East and West are exploited.

There are many obstacles which must still be overcome before greater interconnection and increased mutual dependence in electricity markets can occur. It is obvious that improvements to the supply networks and generating stock of East and Central Europe must occur. Investment for these improvements will, however, be likely to occur only at a slow rate until these countries can demonstrate the necessary political and economic stability required by investors. There seems no reason, at present, why a gradual process of increasing co-operation and integration cannot be begun. This would result in an enlarged grid offering greater security of supply and increased economy of operation to all parties - a true European Supergrid.

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