Prospects for coal and clean coal technologies in Ukraine

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Abstract

Ukraine's energy economy is largely served by natural gas imported from Russia, even though coal is the country's richest resource of fossil fuels. Within the power generating sector, nuclear power's role is expected to increase in the future. The country's 60 Mt/y coal industry, mostly bituminous and anthracite, has recently undergone a programme of changes, including mine privatisation, closing of unproductive mines and, in some cases, modernisation of equipment and improvement of safety measures. Non-fossil/nuclear energy sources play a minor role in the country's energy balance.

Coal is located mainly in Donbass, in the eastern Donetsk region of Ukraine. There are a few, smaller fields in other parts of the country. Ukraine's Energy Strategy to 2030 is based on the government's intention to decrease the country's dependence on imported fuels. It includes plans to increase the coal production. The power generation sector has over-capacity and is exporting to neighbouring countries. However, power shortages occur due to plant inefficiency and large transmission losses. While nuclear power is being pursued, coal is becoming a growing factor in the future prosperity of the Ukrainian economy.

Abbreviations

CBM	coalbed methane
CCS	carbon capture and storage
CCT	clean coal technology
CETI	Coal Energy Technology Institute within the National Academy of Science (NAS) of Ukraine
CHP	combined heat and power
CMM	coal mine methane
ECE	Economic Commission for Europe, UN
EEC	European Economic Community
EIA	Energy Information Administration, USA
ESP	electrostatic precipitator
EU	European Union
GHG	greenhouse gase
HPP	hydraulic power plant
IPS	integrated power system
IRR	internal rate of return
ITTP	Institute of Technical Thermal Physics of NAS of Ukraine
IUD	Industrial Union of Donbass
JI	Joint Implementation
NERC	National Electricity Regulatory Commission
NPP	nuclear power plant
OJSC	Open Joint Stock Company
PM	particulate matter
PPP	purchasing power parity (a basis for comparing GDP to reflect living cost)
SNRC	State Nuclear Regulatory Commission
TACIS	Technical Aid to the Commonwealth of Independent States
TFC	total final consumption
TPES	total primary energy supply
TPP	thermal power plant
TVEL	Russian Nuclear Fuel company
UAH	Ukrainian hryvnia – the national currency of Ukraine
UCTE	Union for the Co-ordination of Transmission of Electricity
UHE	UkrHydroEnergu
UNFC	United Nations Framework Classification
UNFCC	United Nations Framework Convention on Climate Change
UPS	Ukranian Power System
US EPA	US Environmental Protection Agency
USGS	US Geological Survey
USICE	Ukrainian State Institute of Coal Enrichment
VAT	value added tax
WEC	World Energy Council
WEM	wholesale electricity market
WPP	wind power plant

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1 Introduction

In Ukraine, imported energy accounts for a large proportion of the economy's energy supplies, most notably natural gas and oil. Security of supply of gas has become extremely high profile in recent years with pipeline disputes of imported and transit gas causing considerable concern. Consequently, coal received little attention even though coal is the country's richest resource of fossil fuels.

Based on data from the BP 2010 Report, Ukraine has about 16 Gt of proven reserves of anthracite and bituminous hard coal; reserves of lignite and subbituminous coal could more than double this. Based on information provided by the companies which report to the Coal Mining Ministry of Ukraine, in 2009 Ukraine was the 12th largest producer of hard coal in the world at about 72.5 Mt, yet the output is half of that produced in 1990 (Reference book of coal quality, mining values and coal enrichment in 2010 – Ukranian State Institute of Coal Enrichment). In 1990, Ukraine exported 17 Mt to Russia: a year later, Ukraine gained independence, and the output from Ukraine coal mines plummeted and export trade collapsed. The coal industry still employs roughly 400,000 people and has 160 mines in operation (Euracoal, 2008)

Past energy strategies envisaged coal production rising to 90 Mt by 2010, and to 120 Mt by 2015. With production in 2008 at roughly 77.3 Mt (Reference book of coal quality, mining values and coal enrichment in 2009), these aspirational targets remain unfulfilled by a large margin, nevertheless the spirit of the policy is to reopen mines and construct new mines. Coal prospects in Ukraine are, therefore, more positive than the country has seen in the past. This report will attempt to provide a better understanding of the country's policy and energy trends and examine the progress the country is making in its bid to fuel economic growth using domestic coal. It will also consider the operation and technologies used in the current fleet of coal-fired stations and also consider the prospects of cleaner coal technology.

Ukraine has more than 50 GWe (EBRD, 2010) of generating capacity, and 40–42% of total generation, or 95% of thermal power generation is coal-fired. This is the minimum required since nuclear power plants (NPP) provide only base-load power and it is up to the thermal power plant (TPP) to regulate the power supply on the grid. Most of the country's 20–22 GWe of coal-fired capacity employ supercritical steam conditions. However these plants are of an older design dating back before the 1980s, and so efficiencies will be far from the modern supercritical designs. Therefore, there must be scope to improve the existing plants (beyond current investment and upgrade plans). Ukraine's plans to use more coal will depend on the efficiency performance of the existing fleet, the growth in output from the fleet, and the development of new plants (along with funding). All these factors will, therefore, influence Ukraine's demand for coal and impact Ukraine's plans for domestic production and even open possibilities of exporting coal.

Ukraine's aim to become less dependent on imported natural gas can only be positive for the energy security of gas supplies into and through the country (destined for the EU). Coal policy in Ukraine could therefore have major implications on Russian gas supplies and prices to the EU.

The report will examine:
- indigenous energy resources (coal, oil, gas, nuclear, hydro, renewables) and the relative importance of each in the national economy;
- coal production (types produced, status of national mining industry, and future prospects);
- coal imports and/or exports (coal types, scale, sources and locations);
- scale of national coal consumption and future prospects in all main market sectors;
- environmental issues associated with the use of coal;
- current deployment of clean coal technologies and future prospects in relevant market sectors;
- types of technologies being deployed or planned;

- measures being adopted to encourage increased uptake of CCTs (funding programmes, energy policy, etc).

1.1 Key coal facts

It is difficult to provide exact numbers for the Ukranian coal industry. The estimates vary according to different information sources. Furthermore, the information available is offered in various units such as metric tonnes (t), short tons and tonnes of oil equivalent (toe), or tonnes of carbon equivalent (tce). While some conversion factors are straightforward, such as short tons (st) to tonnes (t), some, such as 'toe' to 't', are not and depend on the type of coal used, which complicates the matter when dealing with a mix of coal types. This report attempts to keep all units consistent (Mt).

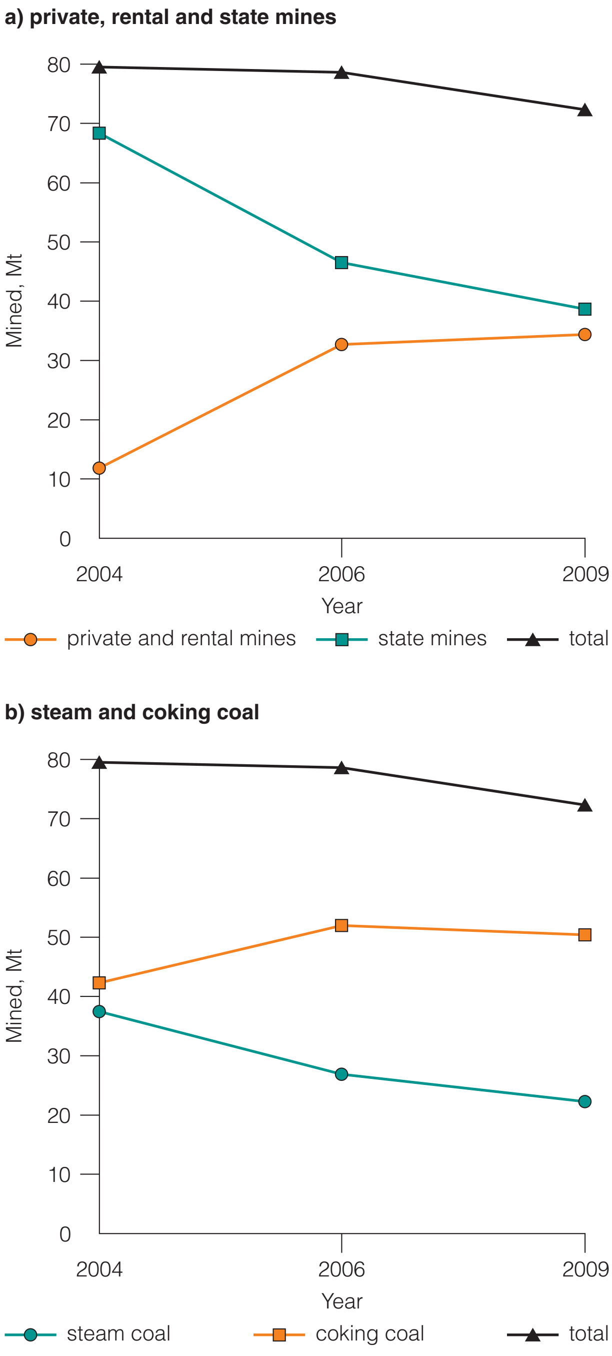


Figure 1 Ukraine's coal production

Total coal production (2009 estimates): 60 Mt (IEA, 2009). However, the official Ukranian value is 72.5 Mt (Chernyavski and others, 2010 – *see* Figure 1).

	Mt
Total coal demand (2009 estimates): (BP 2010)	52
Exports (2007 estimate):	10
Imports (2007 estimate):	13.3
Net imports (2007):	3.3
Proven reserves (2009 estimate): (WEC, 2010)	34,000

However, official Ukranian numbers are much higher, at over 45.5 Gt, out of which steam coals account for about 32 Gt including: bituminous steam coals – mainly high volatile ones and semi-anthracite (or lean coal) – 22.5 Gt, anthracite – 6.8 Gt and brown coal – 2.6 Gt.

Total resources (2009 estimate): (WEC,2010). 52,000

However, official Ukranian numbers are much higher, at 117,536 (*see* Table 2 on page 29).

People employed by the coal industry: 250,000–450,000

1.2 Geographical profile

Ukraine's geographical position, with Russia to the East and Europe (Moldova, Romania, Hungary, Slovakia and Poland) to the West, as well as Belarus to the North, makes it an

Figure 2 Map of Ukraine (CIA, 2010)

important trade link between the former Soviet Union and Europe for energy and other goods. Ukraine also has warm water ports on the Black Sea. It has a territory larger than France, at 603,700 km^2, and a population of about 47 million.

Most of the country has a temperate continental climate and is covered by steppes and mixed forests. The southern coast of the Crimea has a sub-tropical climate. Ukraine is divided into 24 counties (oblast), one autonomous region – Crimea, and two cities with special status – Kiev and Sevastopol.

Ethnic Ukrainians represent about 78% of the total population, while ethnic Russians represent over 17%. The official language is Ukranian, but approximately half of the population speaks Russian. Ukraine possesses a highly qualified labour force, but the population has been shrinking in recent years due to a low birth rate and emigration.

Because of its location (*see* Figure 2), Ukraine is one of the most important transit countries in the world: over 80% of the gas and about 15% of the oil that Russia exports to Europe travels through Ukraine. However, the transit infrastructure is in need of upgrade and modernisation in order for Ukraine to maintain its present strategic role.

2 A brief political history

Slavic tribes settled in central and Eastern Ukraine in the 6th century AD and played an important role in the establishment of Kiev (Kyiv). Situated on lucrative trade routes, Kiev quickly prospered as the centre of the powerful state of Kievan Rus. In the 11th century, Kievan Rus was, geographically, the largest state in Europe, but conflict among the feudal lords led to its decline in the 12th century. Kiev was razed by the Mongol in the 13th century.

Ukraine was conquered, occupied and partitioned several times. It was divided between Poland and Lithuania in the 14th century, then between Poland and Russia in 1667 and it was fully integrated into the Russian empire in 1793 following the partition of Poland. It was again partitioned in the 19th century between the Austro-Hungarian and Russian Empires.

Following World War I, Ukraine gained independence. However, after three years of conflict and civil war, the country was divided again between Poland and the Soviet Union where, in 1922, it became the Ukranian Soviet Socialist Republic. Following the invasion of Poland by Germany and the Soviet Union, the entire territory of Ukraine was incorporated into the Soviet Union. Armed resistance against Soviet authority lasted as late as 1950.

Ukraine became an independent state on 24 August 1991 and was co-founder of the Commonwealth of Independent States (CIS) following the dissolution of the Soviet Union.

3 Energy overview

After Russia, the Ukrainian republic was the most important economic component of the former Soviet Union. It generated more than a quarter of Soviet agricultural output and provided substantial quantities of meat, milk, grain and vegetables to other Soviet republics. Its diversified heavy industry supplied a variety of equipment to industrial and mining sites in other regions of the former USSR.

Due to its geographical position, Ukraine plays an important role in securing Europe's energy needs. Almost 84% of Russian gas supplies to Europe go through Ukraine via pipelines. Natural gas is by far the most important primary energy source for the country. Ukraine has one of the most energy-intensive economies in the industrialised world and, while energy consumption has dropped since the country's independence, reliance on imports, particularly from Russia, has not declined. Today, most of Ukraine oil and gas (three quarters of its requirements), and all of its nuclear fuel, come from or through Russia, and this will not change quickly. Ukrainian energy policy is driven by the country's strong desire to improve energy security and reduce imports. As Ukraine does not have, at present, many affordable and accessible supply alternatives, and as a result of substantial price increases that Russia is forcing on Ukraine for its supplies (in 2006 the price of gas almost doubled), tension between Ukraine and its main energy supplier has grown in recent years and led, at times, to gas cut-offs.

Soon after independence, the Ukranian Government liberalised most prices and created a legal framework for privatisation, but widespread resistance to reform within the government and the legislature stalled reform efforts and led to some backtracking. By 1999, output had fallen to about 40% of the 1991 level. Ukraine's economy was buoyant during 2006-07 due to high global prices for steel, Ukraine's top export, and increased domestic consumption resulting from higher pensions and wages. This was reversed in 2008 with the drop in steel prices and in the population's buying power caused by the economic crisis and aggressive foreign borrowing. In 2009 the economy contracted by over 14% (CIA, 2010). At the end of 2008 Ukraine reached a US$16.5 billion deal with IMF.

The 2009 estimated GDP (PPP) was US$294.3 billion, down from US$342.7 billion in 2008. The fall in GDP in 2009 was 14.1%, (one of the worst in the world) compared to growth of 2.1% in 2008 and 7.9% in 2007. The GDP per capita (PPP) in 2009 was estimated at US$6400 compared to US$7500 in 2008. The unemployment rate in 2009 was 4.8% (CIA, 2010).

For much of the 20th century coal fuelled Ukraine's industrial growth. However, the coal industry has been in decline for several decades since the fall of the Soviet Union. Recently production has stabilised, but the sector still faces major problems, mostly due to poor governance. Industrial groups control the sale of coal from many mines, while also supplying the same mines with equipment and materials, which keeps the coal mines operating at a loss.

The government provides significant production and investment subsidies and is planning to close unprofitable mines. While many of these mines have already been closed, the remaining mines are, by and large, not yet profitable. While the government has been privatising mines, most mines are still in state hands. The coal sector also needs to address significant environmental and employee safety issues as Ukranian coal mines are the second most dangerous in the world, after China's.

At the moment, most of state-owned mines are unprofitable, while most private mines are profitable, mainly due to the vertical coal-power generation-manufacturing trust organisation. The same applies to the five power generation companies, which are: one private (East-energo, three TPP), four state-owned (Donbass-energo, Dnipro-energo, Centre-energo, West-energo, combined into the National Energy Company of Ukraine, 11 TPPs). East-energo is part of a great coal-power generation-manufacturing trust, and it is profitable.

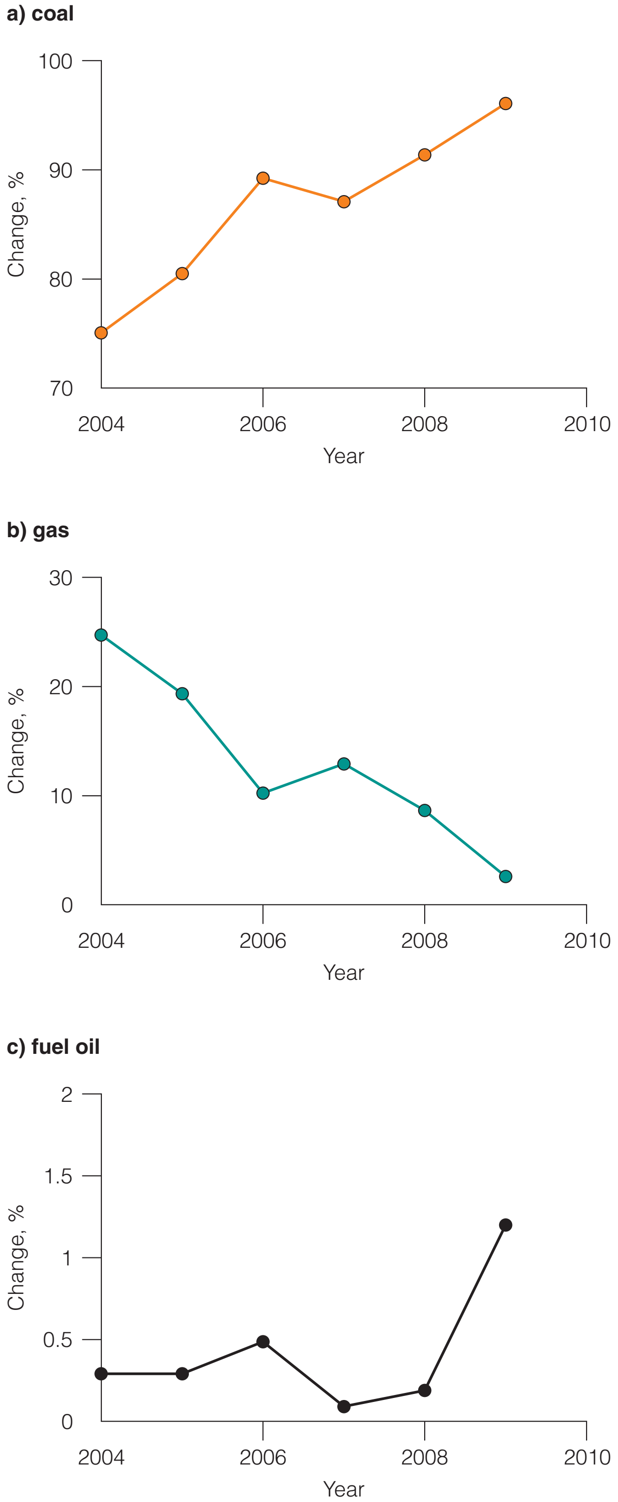


Figure 3 Change in the fuel base of the TPPs of the National Energy Company of Ukraine (Chernyavski and others, 2010)

The power sector has also undergone partial liberalisation and privatisation. Ukraine has a wholesale market with a single buyer, Energorynok (energy market). In theory, thermal power companies compete to sell their power, however, due to frequent fuel shortages and emergencies, the government plays a large role in allocating fuel. Nuclear, hydro and wind plants, also sell to the wholesale market, but at regulated prices. In 2007 nuclear energy accounted for just over half of the power generated, at 95,542 GWh, followed by coal at 67,101 GWh and gas at 25,545 GWh. However, gas was by far the main supplier of heat at 554,409 TJ with coal being a distant second at 14,842 TJ.

Presently, the proportion of natural gas used in Ukraine for power generation is in sharp decline. Gas is still used at city co-generation plants but hardly at all at the 14 large TPPs of the five power generation companies (mainly for start-up boiler heating) – *see* Figure 3.

In the mid-1990s, the government unbundled transmission and distribution from supply. However, in 2004, the government created the Energy Company of Ukraine, which took over the state power assets (generation and distribution). The grid company and the nuclear operator are also state owned, although in separate companies. A few regional distribution companies were privatised and are not part of the Energy Company of Ukraine. The power sector has achieved a certain level of stability in the past few years, with less outages, more stable frequency and higher levels of payment. While the government would like to see the share of nuclear energy in the energy balance grow further, this sector sees some of the largest distortions because wholesale tariffs fail to cover a large portion of the cost of nuclear energy.

4 Institutions and energy policy

Executive bodies that deal with various aspects of the energy sector include ministries and state committees, reflecting the legacy of the Soviet-style distinction between ‘large-scale energy’ (fuel production and generation) and ‘small-scale energy’ (residential services including district heating and distributed generation).

The Ministry of Fuel and Energy is the key administrative body for Ukraine’s energy sector. It develops the energy sector’s strategy and regulatory framework, and contributes to the development of the state budget and targeted economic and social programmes. It has authority over the state-owned Naftogaz of Ukraine (oil and gas of Ukraine) and the Energy Company of Ukraine, and thus controls major assets in the oil, gas, electricity and district heating sectors. The Ministry also allocates fuel to thermal power plants during fuel shortages and participates in preparing international contracts for fuel supply and energy agreements.

The Ministry of Coal Industry is responsible for the on-going management, restructuring and privatisation of the coal industry, including closing unprofitable mines. It manages budget allocations directed to coal companies and implements social programmes related to mine closures.

The Ministry of Environmental Protection develops and implements state policy in the area of nature protection, rational use of natural resources, ecological, nuclear and radioactive safety. It is the main co-ordinator of climate change policy and programmes, but the Ministry of Fuel and Energy determines priority action to reduce greenhouse gas emissions in the energy sector.

The Ministry of Economy is the main co-ordinator of co-operation with the European Union, including the harmonisation of EU and Ukranian energy policies.

The National Electricity Regulatory Commission (NERC) plays an important role in the energy sector through licensing and price regulation. The Commission was founded in 1994 to regulate the electricity sector, but since then its authority has been extended to other sectors, including for heat generated from cogeneration, nuclear energy, and renewable and non-conventional sources. It issues licences for:

- power generation, transmission, wholesales, distribution and supply to end users;
- combined heat and power generation;
- oil and oil product transportation;
- gas transportation, storage, distribution and supply.

NERC is independent from the Ministry of Fuel and Energy. However, the Ministry of Justice must approve and register NERC’s decisions, which limits its independence.

The State Nuclear Regulatory Committee (SNRC) was created to set criteria, requirements and conditions for nuclear safety, issue permits and licences for activities in this area, and supervise implementation of legislation, norms, rules and standards on nuclear and radiation safety.

Regional and local authorities can also influence energy companies by setting local taxes and levies, such as environmental taxes, and by issuing certain licences or permits, such as site permits for oil and gas drilling.

4.1 Ukraine’s Energy Strategy

Ukraine’s first official energy strategy was developed in the mid 1990s – National Energy Program of Ukraine 2010 – and it was adopted by Verkhovna Rada (Parliament) in 1996. However, by 2003-04 it became clear that the energy programmes were not being implemented as expected. The Ministry of Fuel and Energy was tasked by the government with preparing a new energy strategy. The Ministry used a draft document, prepared in 2001 by the National Academy of Sciences, updated with the most recent statistical data and state policy trends, and in March 2006 the Cabinet of Ministers approved the Energy Strategy of Ukraine to 2030 (Cabinet of Ministers 2006a; IEA, 2006). Its major objectives and tasks are to:

- create favourable conditions for meeting energy demand in a sustainable way;
- determine mechanisms for the safe, reliable and stable functioning of the energy system, and for its efficient development;
- increase domestic energy security;
- reduce the impact on the environment;
- reduce the cost per unit of energy production and use by ensuring efficient use of energy, introducing energy-saving technologies, rationalising the structure of the industry and reducing the share of energy-intensive technologies;
- integrate Ukraine's energy system into the European energy system, with gradual growth of electricity exports, and strengthen Ukraine's position as an oil and gas transit country.

However, the projections used in the strategy seem to be based not so much on statistical data and models but rather on political objectives, without the analysis of whether these objectives are feasible. Most objectives of the Energy Strategy 2030 echo the key tasks and priorities of the government programme *Towards the People*, endorsed by the parliament in 2005. Both set energy security as their top priority.

Given Ukraine's over-dependence on energy imports, energy security has long been an important concern for the government and at the top of its policy agenda. The goal is to reduce the country's dependence on Russia and Turkmenistan for energy supplies. The Ukranian government expects to enhance energy security, among other measures, mainly by:

- **Reducing energy intensity** (the energy used per unit of output). Ukraine's energy intensity was three times higher than the EU average in 2006 but has been slowly declining. The government plans to achieve this goal by introducing new technologies, modern systems of control, management and metering in all parts of the industry, including production, transportation and consumption of energy products. It is also planning to develop market mechanisms to stimulate energy efficiency improvements in all sectors of the economy. However, it also seems to want to keep outdated practice of establishing plant-specific norms of energy consumption per unit of industrial production. Worldwide, market-based energy prices that cover costs, as well as mechanisms for financing energy efficient measures are used.
- **Diversifying energy supplies and transportation routes**. Ukraine seeks to reduce its dependence on Russia by diversifying its supplies of gas, oil and nuclear fuel, by signing a long-term agreement with Turkmenistan and by looking into the possibility of importing gas from Kazakstan, Azerbaijan, Iran and Iraq and even Norway. Naftogaz of Ukraine is also assessing the feasibility of producing gas and oil in countries such as Lybia and UAE. How these resources will get to Ukraine is not clear but, should this approach fail to materialise, it will result in a gap between real energy supplies and those projected in the Energy strategy to 2030. The national nuclear company Energoatom, is strengthening its contacts with Westinghouse Electric Company (USA) and is planning a tender for alternative suppliers of nuclear fuel.
- **Shifting the fuel balance toward increased use of domestic resources like coal**. The plan to increase the share of domestic coal and nuclear in the energy balance, while also decreasing the share of imported oil and gas, is a key priority of Ukranian energy policy. The government expects to reduce dependency of imported fuels from about 55% to only 12.5% in 2030, which might prove unrealistic. It assumes that 'forecasted growth in international prices for crude oil and natural gas will happen under conditions of rather stable prices for coal and nuclear fuel, which improves the competitiveness of hydro, nuclear and condensing power plants operating on coal' (Cabinet of Ministers 2006a; IEA, 2006). Still, the cost of producing coal in Ukraine may be too high to make it a competitive option for the volumes planned. At present, the Ukranian coal industry receives large subsidies and most mines are unprofitable.

- **Planning elements of the nuclear cycle, domestically**. This raises the question would it be economically justified, given Ukraine's relatively scarce reserves of uranium and the high cost of processing facilities?
- **Seeking to enhance domestic production of oil and gas**, particularly in the Black and Azov Seas, which presumably contain some of Ukraine's most significant reserves. To meet this goal, Ukraine would need to improve the upstream investment climate to attract private investors.

4.1.1 Ukraine's heat supply strategy

The heat supply sector is the main user of natural gas. There are 65,000 heat generating boilers in Ukraine consuming more than 30 million m^3 of gas per year. The fuel base structure of communal and private heat supply sectors, as provided by Institute of Technical Thermal Physics of NAS of Ukraine, is: gas 77%, coal 13%, wood 5%, oil 2%, other 3%.

The Council of Ministers has requested the preparation of a National Strategy of public heat supply, the aim of which is to reduce the gas consumption to 22% by 2030 and replace it by coal and renewable resources. It will require more than 6 Mt/y of quality additional coal.

4.2 Overview of Ukraine's coal industry policy

The coal industry has gone through several administrative changes since independence. In the late 1990s, the Ministry of Coal Industry oversaw coal issues and production. The Ministry was abolished in 2000, and its functions were transferred to the new Ministry of Fuel and Energy. In 2005 the Ministry of Coal Industry was re-established, and a new company, Coal of Ukraine was created. Later that year, Coal of Ukraine was dismantled and its assets were transferred to the Ministry of Coal Industry. Such frequent reshuffling is expensive and disrupts work, making continuity in reforms, as well as monitoring and addressing corruption and price fixing, much more difficult.

Ukraine began the process of reforming its coal sector in 1996 with a presidential 'Decree On Coal Industry Restructuring'. This laid out a policy framework for reforming the sector's structure and ownership, cutting state subsidies and introducing market incentives. It began the long process of restructuring the centrally-planned Soviet system and closing down unprofitable mines. However, the reform stalled in the face of underfunding, understaffing, poor management and popular dissent. In September 2001, the government launched a 'Comprehensive Programme on Ukrainian Coal', under which the government would first denationalise mines, then corporatise them and finally auction them off to strategic investors. In addition, the Verkhovna Rada passed numerous pieces of legislation aimed at improving safety standards and dealing with the social consequences of mine closures. Under the Comprehensive Programme on Ukrainian Coal, the government successfully closed several mines and privatised others. Production remained roughly stable and labour productivity increased. However, the programme was severely underfunded and did not adequately incorporate job retraining and other social programmes. Wage arrears accrued, many miners died in mining-related accidents and major strikes occurred.

In 2005, the Cabinet of Ministers of Ukraine issued a new Concept for the Development of the Coal Industry, which outlines plans for the restructuring and developing the coal sector through 2030. The government will continue to corporatise state-owned mines, and then privatise them through competitive tender. Under the current coal policy, the government's main goals are to:

- develop the existing production capacity by attracting investment in better technology;
- use coal reserves efficiently by overhauling production facilities;
- adapt coal industry enterprises to market conditions, providing a viable legal framework to encourage private investment;
- transform the structure of the industry through clear segregation of functions among various governing bodies;

- enhance worker safety and social protection of all workers;
- ensure compliance with applicable environmental regulations.

The government hopes to meet these targets through privatisation and a more transparent coal market. In 2005, only 7% of mines were private but they produced 40% of Ukrainian coal. However, there does not appear to be a clear link between the mechanisms (privatisation and markets) and the production goals, as private companies would likely set their own production schedules based on market conditions. In 2005, the government allocated UAH 1.4 billion (US$278 million) to technological investment in existing mines and UAH 800 million (US$160 million) to restructuring, including closing mines and addressing the environmental consequences of doing so. In addition, subsidies for producing coal in past years have amounted to more than UAH 6 billion (US$1.2 billion) annually. The new Ministry has a Department of Social and Administrative Issues and a Unit of Labour Protection and Social Relations. Together, these units will manage social programmes for job training and placement, as well as implement workplace safety measures. These social programmes also receive assistance from the Ministry of Economy, which contributes money from its budget to regional administrations.

The government's policy establishes a clear goal of significantly increasing the production and use of coal over the next 25 years. The government has calculated that the coal sector will need UAH 221.7 billion (US$44.3 billion) in investment through 2030, UAH 48 billion (US$9.6 billion) of which will come from the state budget (*see* Table 1). No funding is specifically mentioned for addressing the environmental consequences of coal mining, although the government does plan to dedicate money from the State Fund for Environmental Protection to install emission controls and treatment at a few power plants, including several coal-fired plants. The creation of the new Ministry of Coal Industry does not appear to change the direction or strategy of the reforms. It remains to be seen whether the new policy will be funded as planned.

Table 1 Projected coal sector expenditures, 2006-30
(Cabinet of Ministers, 2006a; IEA, 2006)

Activities	UAH billion	US$ billion
New technologies in existing mines	76.3	15.3
Capital construction	82.8	16.6
Mine decommissioning	9.1	1.8
Mine rescue and coal research	4.0	0.8
Maintenance	49.5	9.9

Note: US$ figures are the converted equivalent of the UAH numbers (US$1.00 = UAH 5.00 – at the time of writing)

4.3 Overview of the Ukraine electricity market policy

According to preliminary data for 2004, Ukraine generated 177,000 GWh of electricity. The country is currently in the process of revamping its electricity sector, through privatisation, increased utilisation at existing facilities, and the completion of two new nuclear plants.

In Ukraine, thermal power plants (oil, natural gas, coal) account for nearly 50% of generation, with nuclear power generating another 40%, and hydroelectric generation accounting for approximately 10% (*see* Figure 4). Ukraine has sufficient generating capacity to supply more than its electricity needs. However, the country's transmission and distribution systems are in need of investment and maintenance, and significant quantities of generation are wasted via line losses. Also, several of the country's nuclear facilities are intermittently shut down throughout the year because of technical problems.

With the surplus electricity, Ukraine exported approximately 2800 GWh to Russia from January to July 2005. After the completion of two new nuclear reactors, Ukraine signed a deal with UES,

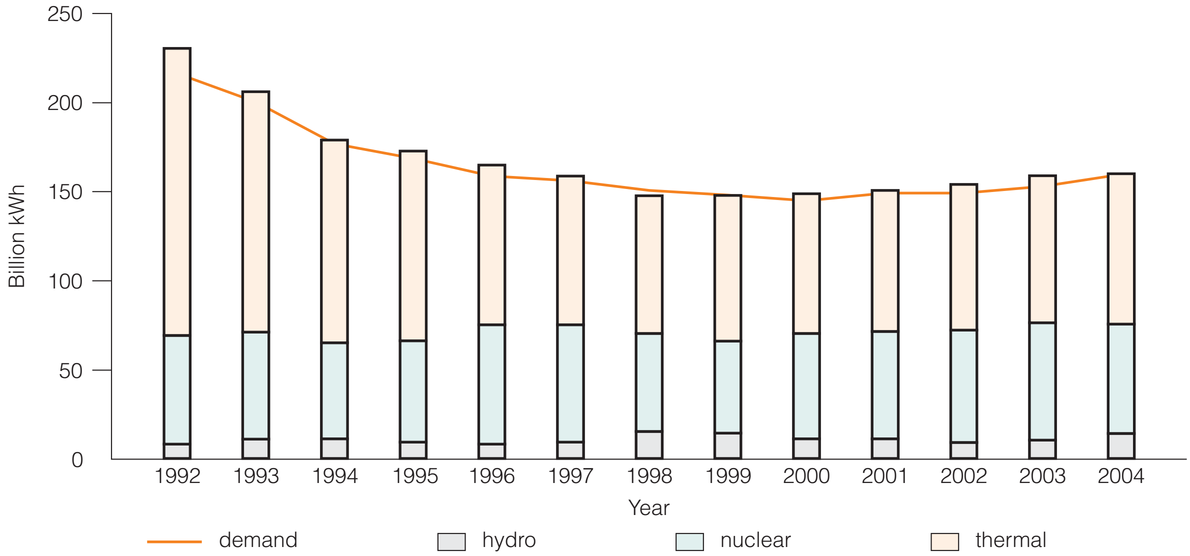


Figure 4 Ukranian electricity balance 1992-2004 (EIA, 2007)

Russia's main electricity supplier, to supply 500 GWh of power per month to Russia at a price of 0.014 $/kWh. After an increase in Ukrainian export tariffs, Ukraine's wholesale electricity operator, Energorynok, increased prices by 77%, to 0.024 $/kWh for electric power purchases on Ukraine's domestic market, prompting the State Committee for Nuclear Regulation to suspend power exports to Russia because it was no longer economically realistic.

State-owned UkrInterEnergo exports Ukrainian electricity to other markets. During 2004, the company exported 514,000 GWh to other countries. Ukraine signed a contract to supply 250,000 GWh to Belarus during 2006, resulting in a US$50 million benefit to the country. Ukraine also exports electricity from the Burshtyn thermoelectric power station to Moldova, Slovakia, Poland, and Hungary. It started exporting electricity to Romania in March 2005. The Burshtyn thermoelectric power station and part of Ukraine's western energy system have been connected to the Union for the Coordination of the Transmission of Electricity (UCTE) energy system of Europe since July 2002. EU officials met with Ukrainian energy officials in Kiev in early 2006 to discuss plans to fully integrate Ukraine's electricity grid into the UCTE by 2008.

During Prime Minister Yushchenko's administration in 2000-01, privatisation of the electricity sector was one of his key objectives and resulted in the sale of six distribution companies. AES, based in the USA, won two of the six tenders. Currently, only six Ukrainian distribution companies have been fully privatised, and 20–45% stakes in nine other utilities were sold in 1997-98. Further privatisation of the sector is not currently planned. Since 1997, the Ukrainian National Electricity Regulatory Commission (NERC) has facilitated a centralised market for wholesale electricity, called the Wholesale Electricity Market (WEM). Power producers sell into a common market, operated by Energorynok, and distribution companies distribute the power to the end user. Although the government fixes the price of nuclear and hydrogeneration supply, the market has made progress in basing wholesale electricity prices on a next hour and a next day basis by using its bidding cost of electricity production. The tariff methodology was determined in 2001 for privatised utilities concurrent with the sale of controlling stakes in six utilities.

Other problems hinder the full development of a deregulated market in Ukraine. First, there is a high level of transmission losses; transmission losses reached a peak of 20% in 2001 and decreased to 15% in 2004. For comparison, the average losses in the USA are around 3%. Again, only six of those companies have begun the process of privatisation, and the Ukrainian Government has been reluctant to give new buyers more than a minority stake in the companies. There are also worries that the government will not receive enough compensation for the sale. Also, the industry itself is in debt from

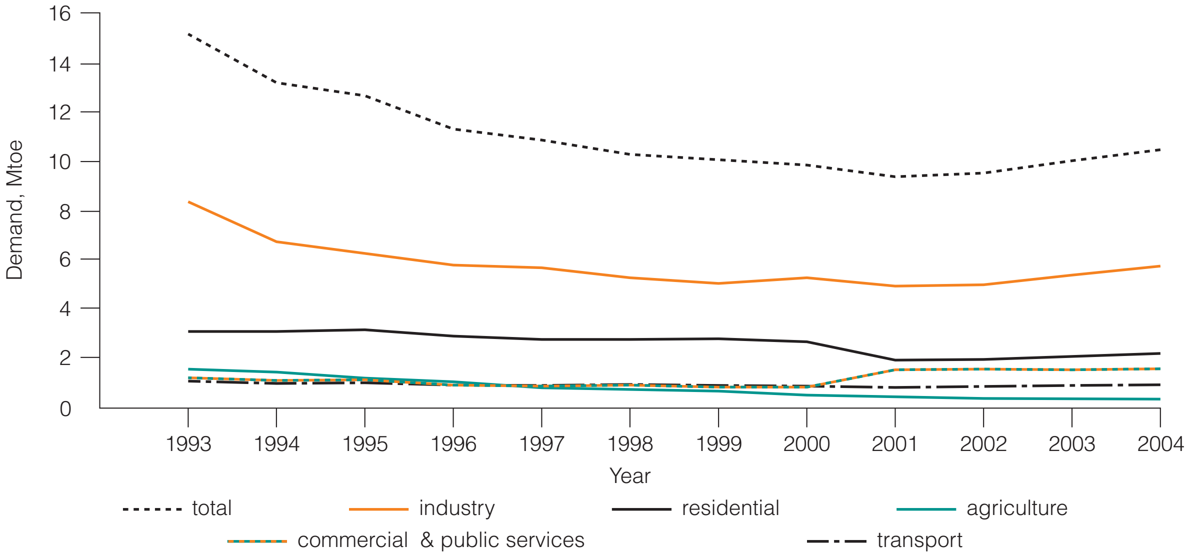


Figure 5 Trends in electricity demand, 1993-2004 (IEA, 2006)

a long history of problems which stem from insufficient collection mechanisms during the 1990s. Low regulated tariffs and lack of metering equipment do not provide incentives for reducing losses or inefficiencies. Distribution companies owe US$3 billion to the wholesale market. The combination of poor networks, high losses, corruption, and pressure to keep current tariffs low has created inefficiencies in the market and muted the necessary price signals. Despite all these obstacles, market operators have made some progress. In 1999, cash payments for electricity purchased in the wholesale market represented only 7–10% of the actual value of electricity. By 2005, most distribution companies were paying back 100% of their electricity purchases and were beginning to pay back debt.

Another important problem of the Ukranian energy sector is the obsolete infrastructure. Ageing, Soviet-designed power plants and corroding pipelines contribute to inefficiencies throughout the energy system, as well as increased production and transportation costs. All this considered, there is considerable overcapacity in the Ukranian energy sector, meaning no investment in new plants is necessary to ensure demand is met. While power shortages do occur during periods of peak demand, this is not due to lack of generating capacity, but rather fuel shortages, mismanagement, and poor maintenance of existing equipment.

Foreign investors have been actively courted, and supporting legislation has been upgraded several times. Foreign investors are, in principle, guaranteed equal treatment with local companies. However, the Ukranian courts' lack of true independence makes investors vulnerable to being ousted if they are investing in a strategic sector or company in which someone else, more powerful is interested. There have been numerous examples of successful investment projects in Ukraine, but the uncertain political environment is likely to deter many others unless there are clear signs of change, such as significant improvements to fight corruption, develop capital markets, and improve legislative framework.

Power consumption dropped dramatically after 1992 (*see* Figure 5). By 2004, total electricity consumption was only about 70% of the 1993 level. This drop can be attributed to the decrease in economic activity, as well as to supply limitations for big industrial companies and other users that resulted from fuel shortages at power stations. At the same time, a part of the decline was also due to improved efficiency, particularly after 1998. The industrial and residential sectors have remained the largest electricity consumers over the last decade: combined, they account for some 75% of Ukraine's electricity consumption.

Within industry, the largest declines in power demand from 1993 to 2004 took place in the textile and

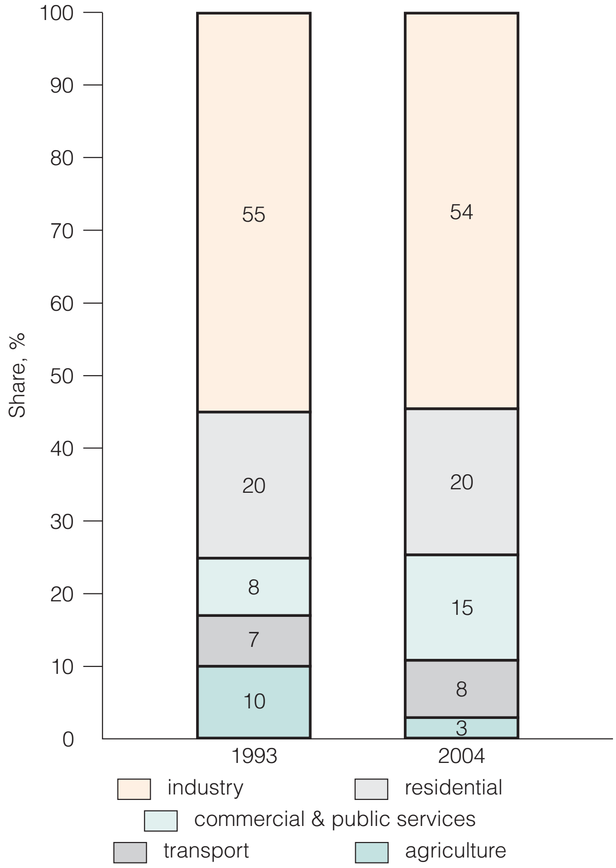
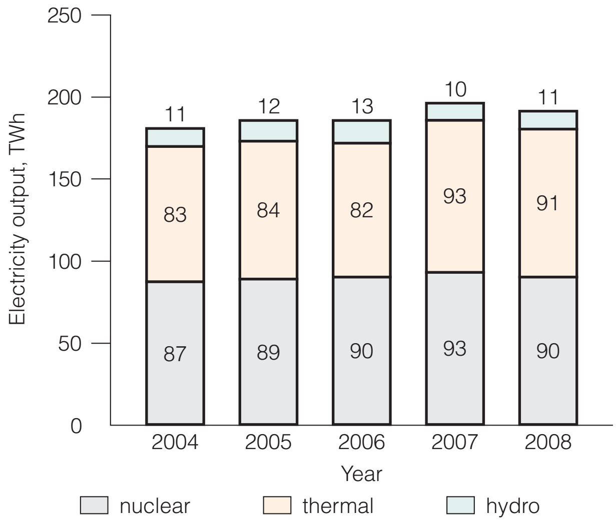


Figure 6 Share of electricity demand by sector, 1993 and 2004 (IEA, 2008a)



It is assumed that this includes CHP plants and plants powered only partially by coal

Figure 7 Ukraine's energy output (IMEPOWER Investment Group, 2009)

leather sector (74%), the machinery sector (71%), and the construction sector (62%), reflecting their economic collapse. The largest nominal decline in consumption occurred in the most electricity-intensive industries (mining, metallurgy, machinery, chemicals and petrochemical), accounting for more than one-third of the total drop in national power consumption. However, during the whole period industry remained the largest power consumer, accounting for over 50% of total electricity consumption.

The decline in electricity consumption in the residential sector (the second largest consumer of electricity) was less dramatic: in 2000 it was around 90% of its 1993 level. A low tariff has had a very limited impact on the demand; low substitution capacity of electricity in the residential sector also played a role. The stability in electricity demand can also be explained by the increased activities of small, private businesses working in residential flats and by the growing use of appliances. In addition, in the mid-to-late 1990s, residents supplemented district heating with small electric resistance heaters when district heating plants did not supply enough heat. Starting from 2001, residential electricity consumption declined more significantly: in 2004, it was about 70% of the 1993 levels (*see* Figure 6.

Electricity consumption in the commercial and public services increased sharply starting in 2001, due to the growing importance of services in the overall structure of the Ukrainian economy. This is the only sector in which 2004 consumption of electricity was higher than the 1993 level (26%). In the transport sector, the drop in power consumption from 1993 to 2004 came mainly from reduced demand for freight rail and pipeline transportation, linked to the economic downturn. Power demand for rail transport has actually grown since 2001, though it continues to decline for pipelines. Overall, the share of electricity in TFC decreased slightly from 13.6% in 1993 to 12.2% in 2003. However, in absolute terms, electricity consumption started to recover in 2002 with an annual growth rate of about 5%/y in 2003-04. This was specifically linked to growing electricity demand in almost all sectors (excluding agriculture). The most rapidly growing demand in 2002-04 was observed in industry (5%/y), transport and the residential sector (4%/y). Electricity use per capita in Ukraine is half the EU-25 average. Since 2000, stable growth of this indicator has been observed, due to the economic recovery and growing demand for appliances. The growth can also be linked to the resolution of supply problems associated with reconnecting to the Russian integrated electricity system in 2001.

The Ukrainian economy has become more efficient over time; this is also true for power consumption. Power consumption per unit of GDP (or electricity intensity) has dropped by about 16% since 1993. During the economic recession, electricity intensity actually rose from 1993 to 1996. From this peak level, it dropped by an impressive 32% by 2004. This trend is roughly in line with the percentage change in overall energy intensity (*see* Figure 7).

5 Primary energy supply

According to BP (2010), the global primary energy consumption declined by 1.1% in 2009 (the largest decline since 1980). OPEC oil production declined by 7.3% (the largest since 1983), natural gas production declined by 2.1% (the first decline on record), while coal's share of energy consumption showed the highest increase since 1970, at 29.4%.

By comparison, Ukraine's primary energy consumption declined by 17.5%, with oil consumption declining by 8.5%, natural gas consumption declining by 27%, coal consumption declining by 15%, nuclear energy consumption declining by 9%, while hydro energy consumption increased by 3.8%. Ukraine's total consumption of primary energy was about 112.5 Mtoe in 2009, down from 132.5 Mtoe in 2008 (*see* Figure 8).

The major reason behind the total primary energy supply (TPES) decline was the economic recession of the 1990s, although energy efficiency improvements also played a role (*see* Figure 9).

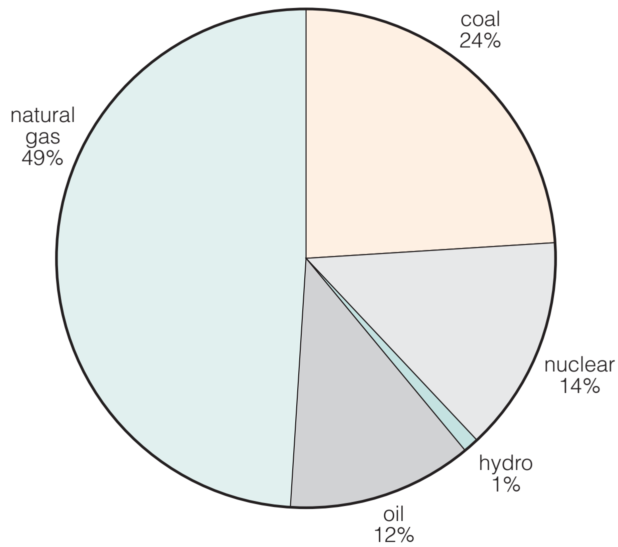


Figure 9 The energy consumption in Ukraine by type in 2004 (EIA, 2004)

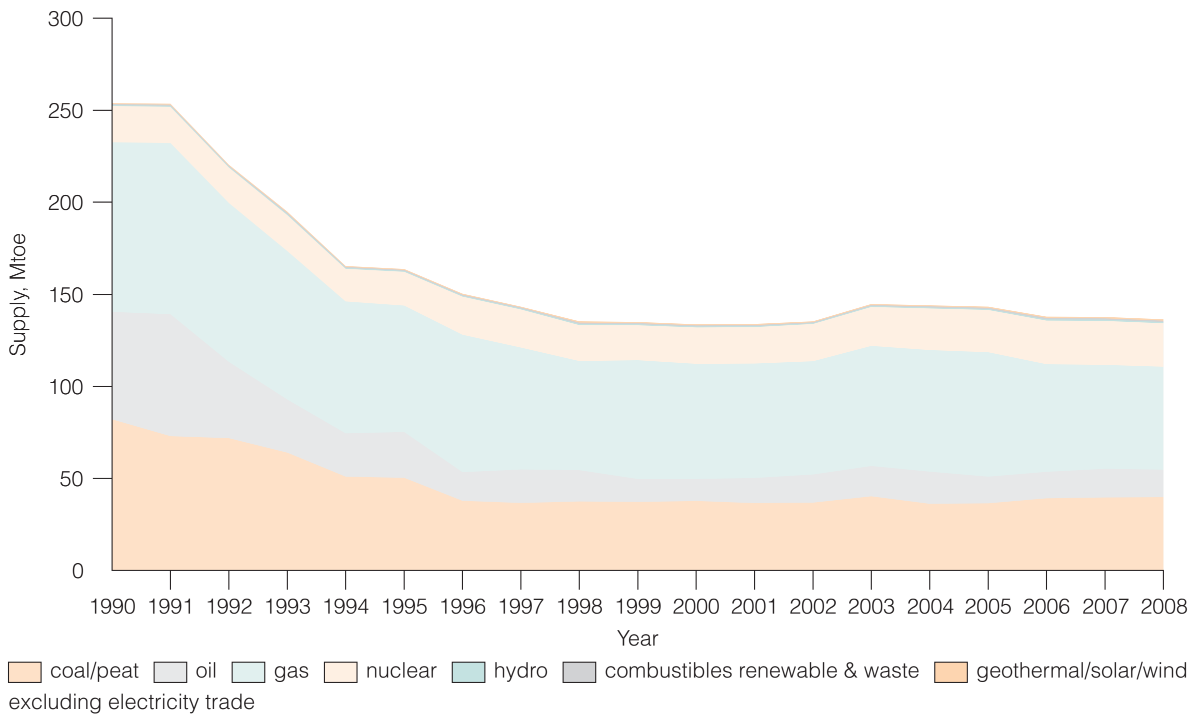


Figure 8 Total primary energy supply (IEA, 2008a)

6 Energy resources of Ukraine

Ukraine's energy resources play a key role in driving the country's energy policy and its main goal to reduce dependance on imported fuels and to ensure the country's energy security. In March 2010, the World Bank Office in Ukraine related the 'topic of the month' to the energy sector (World Bank, 2010b). The central event was the official launch of the report *Lights Out? The Energy Outlook in Eastern Europe and the Central Asia*.

According to this report, the region will face an energy crunch unless investments of more that US$3 trillion are made over the next 20 years, despite Russia and central Asia's current role as a major energy supplier to both Eastern and Western Europe. Ukraine would be particularly hard hit should the energy crunch materialise, as it is heavily dependent on gas supplies from Russia. In addition, Ukraine's energy infrastructure is old, inefficient and deteriorating. The gas transport system is in serious need of modernisation, its compressor stations use about 50% more gas than state-of-the-art equipment. Overall, the country's energy intensity (consumption of energy per unit of GDP), in spite of some progress made in recent years, is among the worst in the region, two times higher than the OECD average.

6.1 Natural gas

Natural gas is the most important energy source in Ukraine, and its role has grown since independence. Although gas demand in physical terms has been decreasing since 1990, the share of gas in TPES grew from 43% in 1993 to 49% in 2004 driven by relatively low prices for gas imports. About 75–80% of gas is supplied by imports from Turkmenistan and Russia, although there are questions about the future volumes and sources of gas imports. Domestic gas production, which accounts for more than 20% of supply, was relatively stable during the transition period largely because of previous investment in the sector. However, to further maintain and increase production levels, large investments in exploration are necessary to offset the accumulated deficit of geological prospecting (*see* Figure 10).

As Ukraine relies heavy on imported oil and gas, these imports are high on the political agenda, particularly as prices rise. The government is planning to reduce the imports and enhance domestic production. Achieving this goal requires reforms to attract investment to the sector. Today, the oil and gas industry in Ukraine is largely dominated by state-owned companies, though private and foreign investors have made some inroads. The presence of the state is most direct and pronounced in exploration and production, main pipelines (both oil and gas), gas imports and transit, and gas distribution.

The industry is heavily regulated. The government has many direct and indirect controls over the terms of investors' access to reserves and infrastructure, pricing and tariff setting, import and export transactions, and other key aspects of the market.

The largest company in the oil and gas industry of Ukraine is the national joint-stock company Naftogaz of Ukraine (oil and gas of Ukraine). Naftogaz of Ukraine dominates the exploration and production, as well as main oil and gas pipelines, gas processing, the imports and transit of gas, and gas distribution in Ukraine.

Naftogaz of Ukraine was created in 1998 as a holding company and is 100% owned by the state. Through its affiliates, it produces, transports and trades oil and natural gas, processes gas and condensate, distributes some oil products and holds shares in gas distribution companies. It also handles oil and gas transit, exports and imports. Natural gas operations far outweigh other company business: until 2005, some 51% of the company's revenues were from the sale of gas, and about 20%

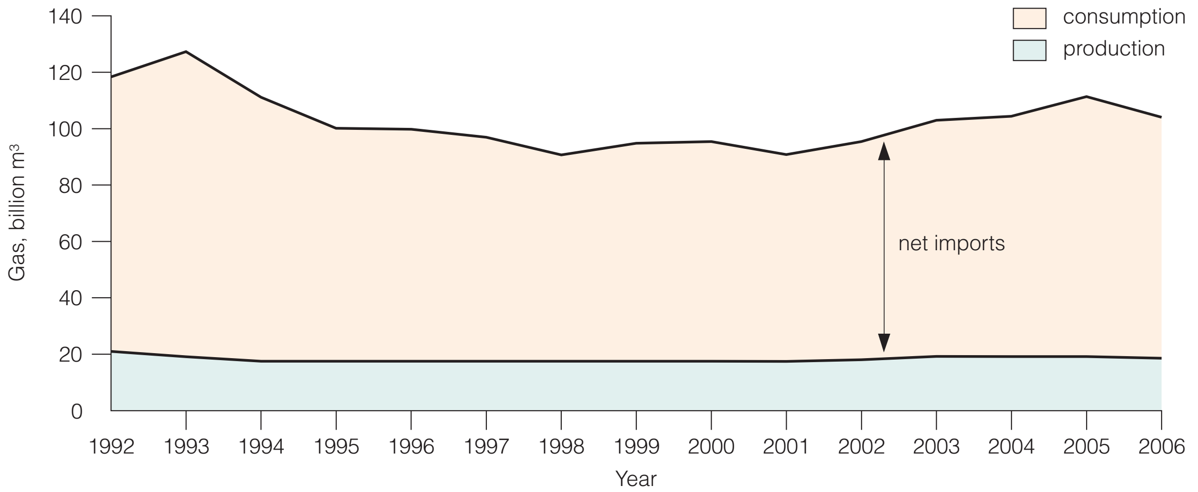


Figure 10 Ukraine's natural gas balance, 1992-2006 (EIA 2007; Encyclopedia of Earth, 2010)

from gas transportation (primarily transit). In 2004, Naftogaz of Ukraine accounted for some 13% Ukraine's GDP and approximately 10% of the state budget. As a consequence, any change in the terms of gas business has a large-scale and immediate impact on Naftogaz of Ukraine's finances and on the economy at large.

According to Brown (2003), Ukraine has roughly 1.13 trillion m^3 of natural gas reserves. Ukrainian gas production in the last two decades, was approximately 18–20 billion m^3 per year, compared with its record of 68.7 billion m^3 in 1975. Three Naftogaz of Ukraine affiliate companies produce the vast majority of Ukrainian domestic gas: Ukrgazvydobuvannia produces about 75%; Ukrnafta more than 17%; and Chornomornaftogaz another 4.2%. Domestic production started growing in 2001; almost half of the increase in production has been from independent producers. This is an important point as it indicates the role private investors can play in increasing gas production in Ukraine. In its basic scenario, the *Energy Strategy to 2030* suggests that domestic gas production will reach 23.2 billion m^3 in 2010, 26.1 billion m^3 in 2020 and 28.5 billion m^3 in 2030. By the end of 2009 the production was still under 20 billion m^3. The World Bank estimates that a production increase of 10 billion m^3 per year from proven reserves would require capital investment of US$1.5 billion (World Bank, 2010b).

6.2 Oil

According to Brown (2003), Ukraine has 54 Mt of proven oil reserves, the majority being located in the eastern Dnieper-Donetsk basin. The share of oil in TPES dropped from 15.7% in 1993 to less than 10% in 1999-2000, largely due to accumulated problems in the refining sector. It then grew to 12.7% by 2004. Imports from Russia and Kazakhstan account for some 83% of Ukrainian crude oil supply. Domestic production of crude oil and gas condensate decreased slightly from 1993 to 2000, then started recovering in 2001 and reached some 4.3 Mt/y in 2004. Even though they are an important element of the oil balance, IEA does not receive data on oil stock changes in Ukraine. Therefore energy balances account only for domestic production and imports/exports of oil.

Oil refining and distribution are the only elements of the Ukrainian energy sector that have well-developed competition and market-set prices. Refining and distribution of oil products are mostly in private hands. Refineries do not use state-of-the-art technology, and need significant investments in modernisation. To date, lack of competition, strong state involvement and inadequate price signals have undercut efforts to increase performance and efficiency. The presence of other factors is significant only in the oil refining and oil product retail markets, which are liberalised and open for competition. Foreign (mostly Russian) companies control four of the six Ukrainian refineries and most filling stations.

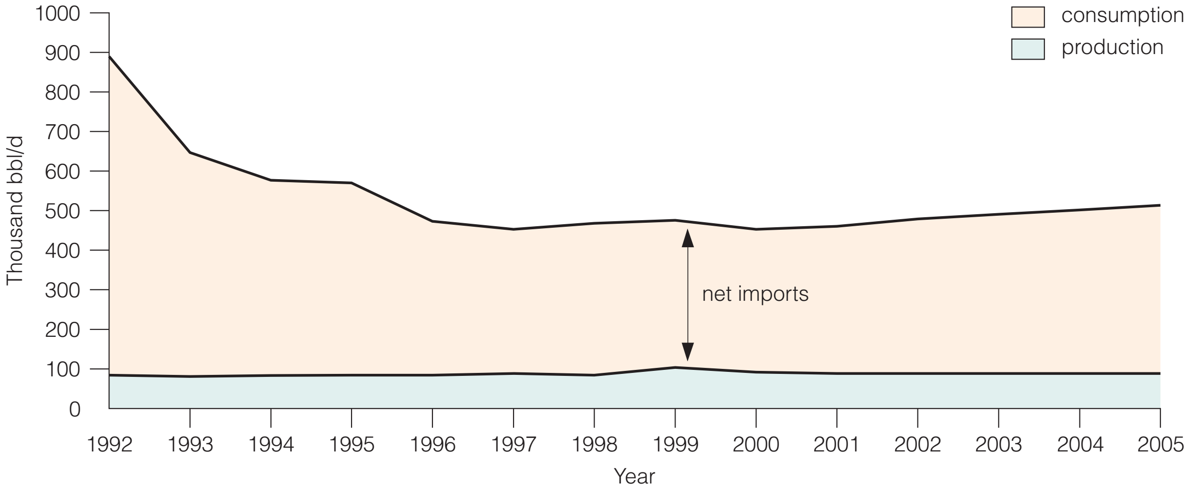


Figure 11 Ukraine's oil production and consumption, 1992-2005 (IEA, 2007; Encyclopedia of Earth, 2010)

Ukraine produces about 4.2–4.3 Mt/y of light, sweet crude oil and gas condensate, 97% of which is produced by Naftogaz of Ukraine (*see* Figure 11). As of 2005, Naftogaz of Ukraine operated 225 oil and gas fields with 2393 producing oil wells. A major oil production company is Ukrnafta, which produces about 2.9 Mt. The *Energy Strategy to 2030* expects that domestic oil production will reach 5.4 Mt in 2030. Companies that produce oil and gas condensate in Ukraine must sell them at oil auctions, operated by the Auction Committee.

Ukraine has six crude oil refineries with a combined throughput capacity of approximately 120,500 t/d. However, with domestic demand at just over 30% of the country's refining capacity in 2004, Ukraine's refineries operated below their capacity. In fact, until a few years ago, Ukraine's refineries did not get enough crude oil to supply even the country's domestic demand. This situation improved when Ukraine offered oil exporters in Russia and Kazakhstan a stake in the country's refineries. Ukraine's success in privatising its refineries has allowed the country to secure additional oil supplies to meet domestic demand, as well as attract funds for necessary renovation work and to boost utilisation rates of its refineries.

Ukraine's refineries were designed to process the Russian Urals grade of crude for a high yield of fuel oil. This low degree of sophistication of the refineries is now a major impediment to the diversification of oil supply. Oil from potential suppliers outside of Russia is of better quality (lighter and less sour) compared to the Urals. It makes no economic sense to process oil of this higher quality at refineries that turn out mostly low value products: the operation would result in a substantial loss on a netback basis (Encyclopedia of Earth, 2010).

6.3 Hydroelectricity

According to an IMEPOWER Investment Group report, published in 2009, hydroenergy in Ukraine accounted for some 11,600 GWh in 2008, down from 2006 (13,000 GWh) but up from 2007 (10,000 GWh).

Hydropower is the most developed renewable energy source in Ukraine today and is the least expensive power source on the wholesale market. Of the country's about 4800 MW of hydropower capacity, the majority is in large-scale hydro, which is a mature technology. The majority of the hydro resources are concentrated in Central and Western Ukraine on the Dnieper, Dniester, Yuzhny Bug and Tisa rivers. The Dnieper river basin is the most developed. Eight power stations on the Dniper River have a total capacity of 3907 MW and the Dnistrovska station on the Dnister River an additional

700 MW. Combined, these stations produce 11–13 TWh/y. As of 1 January 2005, Ukraine has 65 small and seven micro hydropower stations with a total operational capacity of 106 MW, and generation of 280–390 GWh/y. Additionally, there are some small hydropower stations that are not operational but could eventually be restored. Ukraine also has plans for five additional hydropower plants with a total capacity of 8143 MW. Environmental organisations in Ukraine project that hydropower production may reach 15.1 TWh/y by 2030 (including 3.7 TWh/y of small hydro) and up to 25 TWh/y in 2050.

The major equipment of many of the hydroelectric power plants has been operating for about 40 years and needs upgrading. Construction of the Dniester and Tashlytsky hydropower complexes has been delayed due to shortage of finance and negative attitude of local authorities.

In November 2009, the World Bank approved a loan for additional financing to the Hydropower Rehabilitation Project, for US$60 million (World Bank, 2009). The original loan for the Hydropower Rehabilitation Project for US$106 million was approved on 21 June 2005 and became effective on 3 February 2006. The main objectives of the Hydropower Rehabilitation Project are to improve the reliability, efficiency and safety of the operation of UkrHydroEnergo hydraulic structures and equipment, and to improve their environmental performance. The latter will be achieved through the reduction in emissions of greenhouse gases, the installation of non-polluting turbine runners, and the elimination of oil leaks into Dnieper and Dnister rivers. Recently, the first unit of the Dnister Hydroelectric Power Plant – one of the largest pumped-storage hydro plants in the world – was put into operation. (HydroWorld Weekly, 2010).

The rehabilitation project will help to increase the installed capacity of the Dnieper Hydropower Cascade by about 400 MW and its production by about 500 GWh/y, which is equivalent to building a major new hydropower plant. The project also pioneered the concept of Carbon Financing in Ukraine, as it was the first Joint Implementation Project under the Kyoto Protocol in the country (HydroWorld Weekly, 2010). Recently, Emerson Process Management, of Missouri, USA, installed its PlantWeb digital plant architecture with an expert control system at Unit 1 of the newly-commissioned Dnister pumped-storage hydropower plant in Ukraine. Emerson has also been awarded a US$28 million contract to control, protect and monitor 100 hydro units of the Dnieper hydroelectric complex for UkrHydroEnergo (UHE), the main hydropower generating company of Ukraine (HydroWorld Weekly, 2010).

The existing cascade of nine hydropower plants, with dams and reservoirs, has a total capacity of 4590 MW. The hydro plants are located along a 1000-km stretch of the Dnieper River from Kiev to Novaya Kahovska. The Emerson contract is part of the rehabilitation project of UHE’s hydro assets. The first hydropower plant of this system was built in 1934, and the last project was completed in 1980.

6.4 Nuclear energy

Ukraine’s targeted national energy policy stresses the importance of increasing the use of nuclear energy to reduce its dependence on hydrocarbon imports. By 2004, the share of nuclear in TPES reached 16.2% – up from 10.5% in 1993. In absolute terms, nuclear energy is the only source of supply that grew significantly higher (by 16%) than its 1993 level (hydroenergy grew by 6% and supply from other sources declined).

Nuclear energy has been the third largest primary energy source in Ukraine since 1996. In 2007, the country’s nuclear power plants generated 92,542 GWh of electricity, up from 90,225 GWh in 2005 and from 70,523 GWh in 1995 (IEA, 2008a). Ukraine has four operating nuclear power plants, with a total of 15 working reactors, with a combined installed capacity of 12.8 GW. In 2004, they produced 40% of the country’s electric power. The primary energy equivalent of nuclear energy is calculated with an efficiency factor of 33%. In December 2000, Ukraine permanently shut down the last remaining working reactor at the Chernobyl power plant. To replace Chernobyl, Ukraine resumed construction of two 1 GW reactors at the Khemelnitsky and Rivine power plants. The construction started under the Soviet Union and was 80% completed when Ukraine became independent and ran out of funds. The two units were eventually connected to the electricity grid at the end of 2004. In *Energy Strategy to 2030,* the Ukranian government plans to build or complete 22 new reactors with a total capacity of 29 GW. The share of nuclear would rise (in 2030) to 52% of power production.

Energoatom, a 100% state-owned company, created in 1996, owns and manages all of the nuclear power stations; it co-ordinates its work closely with the Ministry of Fuel and Energy.

The Ukrainian Government would like to use the nuclear power industry to reduce its energy dependence on Russia. Currently, Ukraine buys its nuclear fuel rods from Russia, but exports uranium and zirconium to Russia (zirconium is required to make the reactor fuel rods). It would like to build facilities for some elements of the fuel cycle to eliminate fuel rod imports from Russia and potentially lower fuel costs. Ukraine mines and mills uranium; in the future it also plans to make fuel rods using imported enriched uranium. Ukraine has 2% of world uranium reserves; most of its resources are associated with deep, low-grade deposits with relatively high extraction costs. The country has also bought an experimental batch of nuclear fuel from Westinghouse, but the cost is some 40% higher than that of the Russian fuel. In the near term, this is not a realistic source of fuel for Ukraine. However, TVEL, the Russian nuclear fuel company, may increase prices.

6.5 Renewable and geothermal energy

In 1996 the President of the Ukraine declared wind generation a national priority and established a target of 1990 MW to be reached by 2010, but this seems unlikely to be achieved given the current situation: Ukraine had 94 MW of installed wind capacity at the end of 2009. The country has a programme of state support for the development of non-traditional and renewable energy sources and small hydropower plants. The target set for renewables is 10% of generation by 2010.

On 1 April 2009 the Verkhovna Rada (Parliament) of Ukraine adopted the amendments to the Law of Ukraine *On the Electric Power Industry*, thereby establishing green tariffs to stimulate generation of the electricity from alternative sources. The tariff is valid until 2030 for all the facilities put into operation before 2014. For those put into service after that date, the tariff will be reduced.

Wind energy is currently only being generated by a few small state wind farms; while the lack of any private wind farm projects is due to a shortage of local know-how and government incentives. It is estimated that the Ukraine has 5000 MW of mid-term potential for wind generation in over 40% of its territory. Wind energy potential in the country is big enough to generate about 70 million MWh/y.

Wind power plants are required to sell all the electricity they generate to the state-owned company Energorynok, which operates Ukraine’s wholesale electricity market, and the latter has an obligation to buy all of it.

Ukraine aims to meet 19% of its total energy requirement from renewable sources by 2030. State and local authorities are keen to support initiatives to increase renewable energy generation, not least because some regions, particularly in the south and west, still suffer from electricity shortages.

Ukraine has a moderate technical potential for solar energy. The incidence of solar radiation increases from northwest to southeast with the highest potential on the Crimean peninsula. An emphasis has been put on the development of solar water heating.

Ukraine has considerable geothermal resources that are used primarily for heat supply. Total installed capacity of thermal systems is 13 MWth. Plans are in place to increase the thermal water utilisation up to 250 MWth by 2010. There are prospects for binary geothermal plants using existing wells at abandoned oil and gas fields, and a 1.5 MWe pilot binary geothermal was planned for Poltava.

The biomass potential is 4.0 Mtoe, which includes livestock manure, straw, and lumber mill waste. There is strong interest in the use of livestock manure for biogas power generation as well as straw and wood combustion for district heating plants and combined heat and power facilities.

The major impediments to the growth of renewables are the uncertain economy, lack of financing and extreme bureaucracy. However, given the good technical potential and experience with existing capacity, renewable energy prospects are reasonably good.

The Ukrainian National Agency for Efficient Use of Energy Resources, the National Space Agency of Ukraine, Mitsubishi Heavy Industries and Sumitomo Group have signed a letter of intent on the joint manufacture of 1 MW and 2.4 MW wind turbines at the site of Pivdenmash engineering plant in Dniepropetrovsk. Nova-Eco is planning to start construction of the largest wind farm in Ukraine of 300 MW installed capacity in the Western (Chernomorskoe site) and the Eastern (Lenino site) parts of Crimean peninsula, where the average annual wind speeds of about 7.5 m/s provide for favourable commercial use of wind energy. With the green tariff and about 35% capacity utilisation factor taken into account, the investment payback period will be about 7–8 years, with an internal rate of return (IRR) above 23%.

According to the law, 'green tariff' is a special tariff for electricity generated at the power plants with use of alternative energy sources (except blast-furnace and coking gases, and hydro power plants with capacities over 10 MW). This law obliges the wholesale electricity market of Ukraine to purchase electricity generated at the power plants with use of alternative sources of energy through special 'Green' tariffs which are to be adopted by the National Electricity Regulatory Commission of Ukraine. 'Green' tariffs are available for a ten-year period.

Currently, operational Ukrainian wind farms mainly consist of early model wind turbines with an average capacity of 107.5 kW. Since June 2003, the Belgian-built Turbowind's 600 kW turbines have also been assembled in Ukraine, with towers and blades manufactured locally. Twenty-three former military-industrial plants are now involved in component manufacturing while assembly is carried out at the Yuzhnyi Machinery plant in Dniepropetrovsk, the former rocket-building plant. The main problem that has restricted the development of renewable energy sites in Ukraine is the lack of financing.

7 Transit of energy supplies to Europe

Ukraine's geographical location makes it an ideal corridor for oil and natural gas to be taken from Russia and the Caspian Sea region to European markets, and this is very important for the country. The Ukrainian Government views transit as a partial guarantee of secure energy supplies, since energy suppliers in the East cannot easily shut off Ukraine without harming customers farther downstream. Ukraine is the largest gas transit country in the world by volume and also hosts major oil transit routes because of its location between Russia and Europe. However, the gas dispute in early January 2006 showed that simply providing transit routes does not make Ukraine immune from supply disruption. This has become even more evident in recent years as Russia has made concerted efforts to diversify its supply routes for gas and oil. Three pipelines – the North European Gas Pipeline, Yamal and Bluestream – are or will be serious alternatives to transit through Ukraine, which means that Ukraine's transit business and energy security will depend increasingly on its relations with Russia. Likewise, European buyers are relying more on sea routes for oil and gas supply, which could affect the geopolitical importance of Ukraine's transit business. The volumes of oil transported have dropped gradually in recent years, though gas transit volumes are more or less stable.

According to Ukrainian oil ministry data, Ukrainian oil pipelines transported an average of about 127,945 t/d in 2005, a decrease of 15% from 2004. Some of the decrease in transit volumes was due to Kazakhstan choosing cheaper transit routes (such as the Baltic Pipeline System in northern Russia) for its crude oil shipments. Of the total, 85,890 t/d were transported to Slovakia, Hungary and the Czech Republic, down 4% from 2004. Oil transportation via the Druzhba 'Friendship' pipeline system increased 17%, to 65,750 t/d, in 2005. Oil transportation via the Prydnieprovski Main Pipeline system fell 34% to 62,330 t/d.

As much as 220,000 t/d eventually could be exported through Ukraine after a 15-year intergovernmental oil transit improvement agreement in 2003 comes to fruition. Most of the oil transported via Ukraine is Russian oil, sent in part through the Druzhba pipeline. The southern fork of the pipeline runs through Ukraine. Also, the Prydnieprovski Main Pipeline operates nine interconnected pipelines throughout Ukraine with a total length of 2400 km and a capacity of 287,600 t/d. Prydniprovski transports crude to refineries in southern Ukraine as well as a substantial amount of Russian crude through Odessa on the Black Sea. Odessa loads approximately 26,300 t/d of Russian and Kazakh crude oil for export.

Ukraine's government has made clear its goal of becoming a transit centre for oil from the Caspian Sea region. Oil production from the region is expected to increase from 82,200 to 109,600 t/d over the next few years. One potential conduit for this oil in the Black Sea region is the Odessa-Brody pipeline. The pipeline was completed in 2001 and extends from Ukraine's Black Sea port of Odessa northward to the city of Brody (*see* Figure 12). The pipeline was initially intended to load Caspian Sea oil from the newly completed Black Sea marine terminal, Yuzhniy, and carry it northward through the Ukrainian system to Europe. However, for approximately three years the pipeline remained mostly dormant because Ukraine was unable to secure oil supplies from Caspian Sea area suppliers. Russia is now using the pipeline in the reverse direction, moving oil from the Urals basin southwards to tankers in the Black Sea and onwards to world markets. Since January 2003, TNK-BP has used the last 51 km leg of the pipeline (in reverse) for these purposes (EIA, 2007; Encyclopaedia of Earth, 2010).

Leading Caspian Sea region producer, Kazakhstan, has taken counter-measures. In July 2003, for instance, Kazakhstan agreed to help construct a 51 km pipeline parallel to the segment currently being used in reverse to transit Russian oil. In 2004, the Ukrainian Government pledged that its final intent for the pipeline would be for it to flow from Odessa north to Brody. But while the pipeline was idle, the Ukrainian state oil company UkrTransNafta, effectively reversed that decision, declaring that it had accepted an offer from the Russian-British company TNK-BP to ship 24,660 t/d from Brody

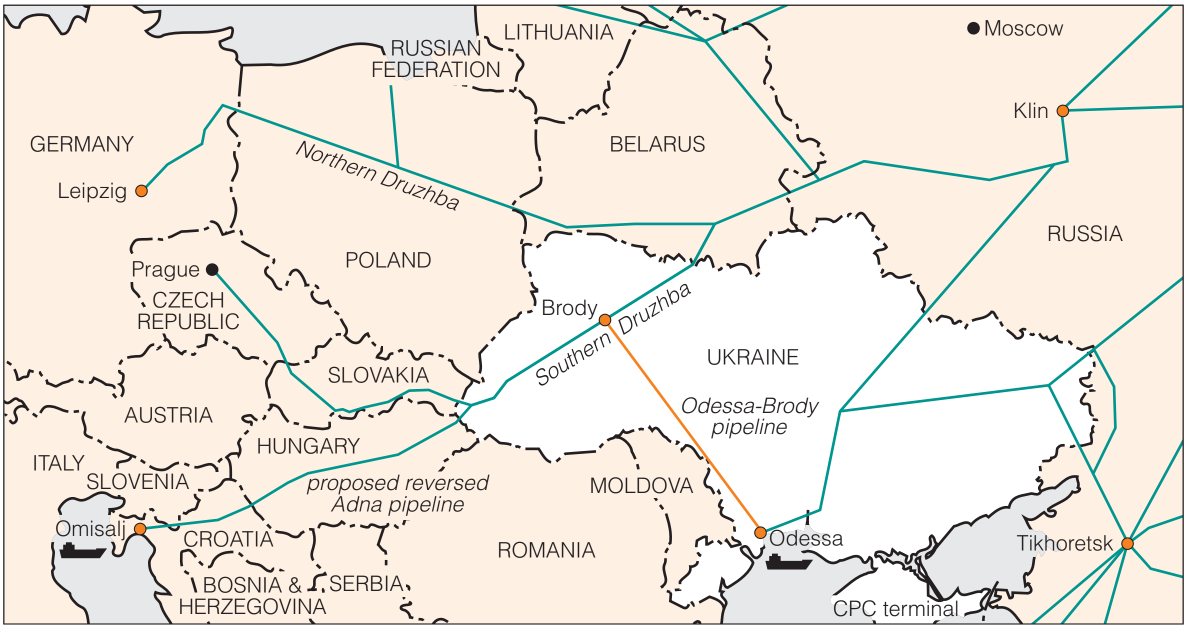


Figure 12 Proposed pipeline reversal (EIA, 2007; Encyclopaedia of Earth, 2010)

south to Odessa (in reverse). On a temporary basis, in September 2004, the first tankers departed from Odessa with Russian crude oil.

As gas exports from the Caspian region to Europe and Russia grow, Ukraine serves as the largest market for this natural gas. Roughly 93% of Ukraine's natural gas imports are re-exported to world markets. Statistics for 2005 show that roughly 29% of OECD Europe's natural gas imports and 78% of Russia's natural gas exports crossed Ukraine en route to Europe. The Ukrainian natural gas company, Naftogaz Ukrainy, also re-exports some of its contracted gas to the rest of Europe.

Europe's dependency on natural gas exports from Russia drew worldwide attention in January 2006 when a longstanding dispute over price and payment mechanisms caused Gazprom to shut off gas supplies to Ukraine. Supplies to Europe were also affected. Even though Russia has used the threat of a cut-off to demand higher natural gas prices in recent years, this was the first time that a supply disruption affected flows to Europe. Eventually, Russia's natural gas company agreed to sell its natural gas to RosUkrEnergo, a Zurich-based trading company 50%-owned by Gazprom at the market price of US$230 per thousand m^3. RosUkrEnergy will acquire some of the natural gas from Kazakhstan and Turkmenistan.

On 4 January 2006, Ukraine signed a five-year agreement to buy natural gas from RosUkrEnergo at US$95 per million m^3 (comprised of less expensive natural gas from Central Asia). In turn, Russia agreed to pay Ukraine natural gas transit fees of $2.84 for one thousand m^3 per 100 km, a 47% price increase from 2005. The contracts are also subject to review each year and may be adjusted to new market prices.

Ukraine's ageing natural gas infrastructure is of growing concern both to European consumers and Russian producers. Some of the pipes in the Ukrainian network have been in operation for 20–30 years, and repairs are rarely carried out because of a lack of available funds. In addition to pipeline disrepair, full capacity utilisation is a problem. Roughly 39.6 million m^3 per year of spare capacity is available on the system. An additional 28.3 million m^3 per year could be added through rehabilitation and upgrades of the existing infrastructure.

In June 2002, heads of state from Ukraine, Russia, and Germany, agreed to develop International Consortium for the Management and Development of the Gas Transport Network to manage and upgrade Ukraine's natural gas distribution infrastructure (Encyclopedia of Earth, 2010).

8 Coal resources and reserves in Ukraine

Coal continued to be the second largest contributor to energy supply, although coal's share in TPES declined from 30% in 1993 to 23.6% in 2004. Domestic production accounts for the majority of Ukraine's coal needs (93% in 2004); imports provided some 5–8% of coal supply in recent years (essentially coking coal). Ukrainian coal production has declined dramatically since the country gained political independence, although the decline began several decades earlier as production costs in Ukraine rose compared to other Soviet coal basins. The Energy Strategy to 2030 has three scenarios, pessimistic, reference and optimistic. In the pessimistic scenario, raw coal production grows to 87.6 Mt in 2010 (according to sources such as BP and IEA, the coal production levels reached, by the end of 2009, between 57.5 and 59 Mt – but 72.5 Mt according to Ukranian sources) and 121.5 Mt in 2030, while in the optimistic scenario, it grows to 100.4 Mt in 2010 and 146.3 Mt by 2030.

Ukrainian reporting of historical coal production trends may differ from that of IEA because of methodological differences. While IEA coal statistics normally refer to coal after washing and screening to remove inorganic matter, the Soviet era practice of measuring coal upon extraction (that is unwashed) continues to this day in some former Soviet-bloc countries. As a result, coal production may be over-reported, as compared to international standards. Ukraine has recently begun to provide official data on both washed and unwashed coal. Therefore, IEA has revised Ukrainian coal supply and demand statistics downward to reflect levels of washed coal. For this reason, IEA data may differ from data found in governmental and private sector reports.

With the deterioration in the quality of coal since 1991 (particularly in terms of sulphur content), Ukraine has gone from a net exporter to a net importer of coal. Quality has suffered as seams have been exhausted; in addition, the geology of remaining seams is such that the coal is of lower quality. Ukraine now buys coal from Russia and, to a lesser extent, Kazakhstan. In 2003, Ukraine imported 7.1 Mt of coal; most of these imports were of coking coal. No steam coal was imported in 2010. Coal exports from Ukraine have grown in recent years, but they are still quite small. According to the government, Ukraine's current production capacity is 91.5 Mt/y, which is less then half of what it was in 1991.

The estimates of Ukraine's resources and proven coal reserves vary widely. The World Energy Council (WEC) estimates coal resouces in Ukraine at 52,117 Mt (World Energy Council, 2000); the government puts its estimate at 117,000 Mt (IEA, 2006; Cabinet of Ministers, 2006a). Adjusting for an expected future increase in Ukraine's coal production, the proven reserves should last for 400–500 years (BP, 2010).

Similar discrepancies are found in relation to proven reserves. According to BP data, proven coal reserves in Ukraine, at the end of 2009, were estimated at 33,873 Mt, of which 15,351 Mt were anthracite and 18,522 Mt were subbituminous and lignite. WEC calculates them to be 34,200 Mt, including 16,300 Mt of bituminous coal and anthracite, 16,000 Mt of subbituminous coal, and 1900 Mt of lignite. The government estimates proven reserves to be at 56,700 Mt, only 6500 Mt of which are located in active mines. Moreover, for a variety of reasons, about 15% of the resources in a given mine are typically lost during exploitation.

At present, no international standards exist for determining what constitutes proven reserves. This contributes to the wide variation in the estimates for Ukraine and makes it difficult to ascertain true reserve levels. In addition, it is not clear what economic assumptions and analyses the government has used to arrive at its estimates. (WEC figures are widely accepted and are used by IEA's annual World Energy Outlook.) Given the poor physical condition of Ukraine's mines and mining equipment, the high costs of production and the low projections for future prices of coal (compared to other energy sources), it is likely that the less optimistic estimates of reserve levels are more realistic. In the absence of substantial improvements in coal quality and market conditions, it is possible that even these could be revised downward in the future.

The coal in the active mines will last for approximately 40–90 years, depending on depletion rates. The increased production planned in the Energy Strategy to 2030 will obviously accelerate depletion rates. Tapping new coal reserves requires attracting substantial investment and entails a certain degree of risk, due to uncertainty about the size of the reserves and future coal prices. Private investors will only be interested when prices for coal cover the full costs of production and also provide a reasonable return on mine investments. This may require the establishment of a competitive market for coal.

8.1 Where the coal is found

Coal is produced in two major basins in Ukraine, the Donetsk Basin, commonly referred to as Donbass (60,000 km^2) in southeastern Ukraine (and western Russia), and Lviv-Volyn basin (7500 km^2) in western Ukraine, which continues into Poland. Other basins are in the Luhansk region, Dniepropetrovsk and Kirovograd.

Table 2 Coal reserves of Ukraine (Chernyavski and others, 2010)

Basin	Total	By column	Balanced reserves		Off-balance
		(4+5+6)	$A+B+C_1$	C_2	
1	2	3	4	5	6
Ukraine	**117535.9**	**74161.2**	**45536.9**	**11245.0**	**17379.3**
Bituminous coal:	94615.7	59079.5	36127.8	9481.9	13469.8
coking coal	26726.4	22758.5	13598.2	4035.0	5125.3
steam coal	67889.3	36321.0	22529.6	5446.9	8344.5
Anthracite	14552.0	11603.4	6831.5	1442.7	3329.2
Brown coal	8368.2	3478.3	2577.6	320.4	580.3
Donetsk Basin	**101473.2**	**69426.8**	**42071.4**	**10665.2**	**16690.2**
Bituminous coal:	85014.6	57200.9	34953.2	9222.5	13025.2
coking coal	24956.8	21662.8	12859.4	3841.6	4961.8
steam coal	60057.8	35538.1	22093.8	5380.9	8063.4
Anthracite	14552.0	11603.4	6831.5	1442.7	3329.2
Brown coal	1906.6	622.5	286.7	–	335.8
Lviv-Volyn Basin	**2981.8**	**1878.4**	**1174.6**	**259.3**	**444.5**
Bituminous coal:	2981.8	1878.4	1174.6	259.3	444.5
coking coal	1769.6	1095.7	738.8	193.4	163.5
steam coal	1212.2	782.7	435.8	65.9	281.0
Dneprovsky Basin	**4162.0**	**2412.0**	**1861.7**	**320.4**	**229.9**
Brown coal	4162.0	2412.0	1861.7	320.4	229.9
Dnepr-Donets K Area	**8707.5**	**390.0**	**390.0**	**–**	**–**
Bituminous coal	6619.1	–	–	–	–
Brown coal	2088.4	390.0	390.0	–	–
Other fields (brown coal)	211.4	54.0	39.2	0.1	14.7

Table 3 Russian (USSR) classification being used (ECE, 2009)

Fundamental characterisation	Groups by economic efficiency	Categorised by project maturity	Categorised by level of geological assurance
Geological (in-place) reserves	Economic reserves	On production	A
		Identified	B
		Estimated	C_1
		Committed development project	$B+C_1$
		Uncommitted development project	C_2
	Sub-economic reserves		
	Unrecoverable reserves		

Coal reserves of Ukraine are shown in Table 2. The classifications under the columns 'Balanced reserves' (A, B, C_1 and C_2) are based on the system used in the former Soviet Union and are explained below, based on information provided by the Economic Commission for Europe, Mapping of the UN Framework classification for Fossil Energy and Mineral Resources, No.33, 2009 (*see* Table 3).

8.2 Hard coal reserves

As the coal demand develops and supply is hardly able to manage all requirements, a sound knowledge of the size of economic reserves is one of the key factors for a better understanding of future coal market trends. So far, the comparison of hard coal reserves and resources in the various countries of Europe is very difficult due to heterogeneous classifications with differing terms and definitions. Major variations among these classifications are due to different exploration requirements (such as drilling grid, borehole distances, geological structure) for the assessment of the reserve and resource categories and due to varying criteria regarding cut-off values for reserve and resource estimations.

The United Nations Framework Classification (UNFC) was introduced in 1997 to facilitate comparison of reserve and resource categories from different countries. However, since the UNFC does not include deposit defining criteria, such as minimum seam/coal thickness, maximum seam depth, and maximum ash and sulphur contents, the reserve and resource data published by most of the European countries are still not comparable.

Parameters generally used when estimating reserves, are the depth of the seams, the net coal thickness or seam thickness, the proportion of barren partings in the seam, the ash content in the seam or cleaned coal, the calorific value of the raw or cleaned coal, and the sulphur content. Besides the cut-off values for these parameters, which vary with the country, there is a legal aspect differentiating various countries' approach. As an example, German resource estimation uses a guideline called 'Bereichsrichtline 1/82'from the Deutsche Steinkohle AG (DSK). In Ukraine (as is the case in Russia and Poland), this is regulated by governmental orders, and has not changed since 1960. A differentiation of cut-off values for reserves and resources does not exist in the German guideline, in contrast to Donbass, in Ukraine.

The maximum depths considered for reserves and resources vary from 1000 m in Poland to 1500 m in the Ruhr basin, in Germany, to 1800 m in the Donbass, Ukraine and Kuzbass, Russia. The minimum net thickness for coking coal reserves ranges from 50 cm in the Donbass to 70 cm in the Kuzbass. The minimum steam coal net thickness varies from 60 cm in the Donbass to 100 cm in the Kuzbass. The parameter ash content is also treated in different ways. The ash content of the barren partings in the seam is used as cut-off criterium in Germany and for the Polish coking coal and anthracite. In addition, a maximum ash content of 10 wt% in the cleaned coal is required for the Polish coking coal. The German maximum barren partings content of 35 vol% (about 50 wt%) presents a very high cut-off value in comparison to the cut-off values used in the other basins. In the Donbass and Kuzbass usually the ash content of the raw coal is used as a cut-off criterion and ranges from 30 to 40 wt%. Limiting values for the total sulphur content which are known, for example, for Germany and Poland – being 2% for the German hard coals and Polish steam coals – is not known for Ukrainian coal.

The industrial reserves represent the amount of available in situ hard coal reserves in currently exploited deposits. In Donbass, these figures have declined in recent years, especially as a result of mine closures and no construction of new mines, and were estimated, in 2004, at 7-8 Gt (Schmidt and others, 2006). The 2009 estimates for Ukraine's proven anthracite reserve is 15–16 Gt. Table 4 shows Ukraine's coal production, in Mt, as published in the IEA, 2009.

Table 4 Ukraine's coal production, Mt (IEA, 2009)

	Hard coal	Out of which		Brown coal
		Coking coal	Steam coal	
2006	61.44	23.05	38.4	0.23
2007	58.74	21.53	37.2	0.19
2008 e	59.35	21.76	37.6	0.29

8.3 Coal geology and quality

One of the main challenges the Ukrainian energy sector faced up to 2004-05, was the low quality of coal mined and supplied to the thermal power plants. This was the result of the fact that coal was mined in complicated geological conditions such as 600–800 m depth, and from thin seams of 0.5–1.5 m, with additional ballast material (*see* Table 5).

Since 2005, the quality of coal supplied to power plants has improved, with LHV at about 5200–5400 kcal/kg, but it is still below the design level for most coal-fired boilers in operation, which is 5900–6000 kcal/kg. The improvement of coal quality has been achieved mostly through cleaning.

In respect to bituminous coal reserves, Ukraine, together with Germany, Poland and Russia, account for about 95% of the European reserves. Global hard (black) coal production has grown by almost 50% in the past 2–3 decades. It was 3837 Mt in 2002, out of which 83 Mt came from Ukraine (MBendi in World Coal Mining, 2008).

In 2005, almost all of Ukraine's production was hard coal, with only 0.3 Mt of lignite produced, comprising less than 0.7% of the total coal production. The World Energy Council estimated

Table 5 Geological properties of Donbass coal (Schmidt and others, 2006)

Basin characteristics	Time of formation	Area, km^2	Maximum thickness of coal bearing formation, m	Cumulative seam thickness, m	No of seams	Coal types
Foredeep + platform	Carboniferous	60,000	11,660	54	~330	Long flame to anthracite

Ukraine's proven reserves at about 34,000 Mt. Coal in 330 seams have been explored to a depth of 1800 m, with only 130 seams exceeding 0.45 m in thickness, and only ten suitable for development. The remaining seams are too deep or too thin. To better understand the actual coal production in Ukraine, it is useful to consider washed coal statistics. In 2004, Ukraine produced 80.5 Mt of raw coal but only 60 Mt of washed coal. Ukrainian coal undergoes substantial washing because of typically high levels of contaminants, which can result in as much as a 25% product loss (CMM Global Overview, 2009)

Lignite, also known as brown coal, is the lowest grade of coal and shares some characteristics with peat. It tends to have a carbon content of 25–35%, high levels of moisture and an ash content of 6–19%. Burning lignite for power generation produces higher CO_2 emissions on a per tonne basis than either bituminous or subbituminous coal. The fact that moisture can account for up to two-thirds of its weight, coupled with its much lower heat content than black coal, makes it uneconomic to transport over long-distances, and this has kept it out of the global coal trade. As a result, it is primarily used by power plants built close to the mining operations.

In Ukraine, lignite is plentiful, but high in sulphur and ash. Ash is 15–25% (dry basis), but moisture is 50–55%; LHV is 1800–1900 kcal/kg. The US Geological Survey (USGS) reported that the Ministry of Coal Industry is promoting the rapid expansion of the brown coal mining sector too. USGS also reported that the August 2005 calls for private sector bids, included proposal to develop two deposits – the Aleksandriiskoye deposit, which has brown coal reserves estimated at 485 Mt, of which 63 Mt were considered suitable for open pit development, and the Verkhnedniprovskoye deposit estimated at 236 Mt, with sections considered suitable for open pit mining. The Ministry calculated that these deposits have the potential to produce 5–6 Mt/y of brown coal by open pit mining (SourceWatch, 2010).

9 Coal mining

In 1997, a Ukraine mine closure plan was adopted that called for the closure of the most inefficient of the country's 284 active mines. By 1999 there were 244 active mines, in 2000 the number had dropped to only 232 (US EPA, 2008), and by 2005, 167 operating coal mines remained in Ukraine, of which 164 were underground and three were surface mines. Most of the mines in Ukraine are underground producing bituminous coal. The three surface mines all produce low-methane content subbituminous coal or lignite (CMM Global Overview, 2009).

The majority of Ukraine's 164 active mines are owned by 24 state enterprises that report to the Ministry of Coal Industry. Three private companies, Krasnodonvuhillya, Krasnoarmeiska-Zakhidna and Pavlohradvuhillya, own 25 mines, which are primarily coking coal mines. Only 7% of mines were private in 2005, but they produced 40% of the coal (IEA, 2006).

Most of Ukraine's mines are more than 40 years old. These mines are among the deepest, most dangerous and most inefficient in the world. Coal seams are typically less than 1.3 m thick, more than 700 m underground and have high levels of coalbed methane.

Ukrainian mines produce about 59-60 Mt washed coal (80 Mt unwashed). Mine closures and privatisation are increasing. Thus, the restructuring programme does seem to be bearing some fruit, though it is important to note the high social cost and the challenge of expanding future production.

Ukraine's three major coal basins are the Donetsk and Lviv-Volyn hard coal basins and the Dnieper lignite basin. These basins contain more than 95% of the country's coal reserves. The Donetsk basin contains more than 98% of Ukraine's hard coal reserves (*see* Figure 13).

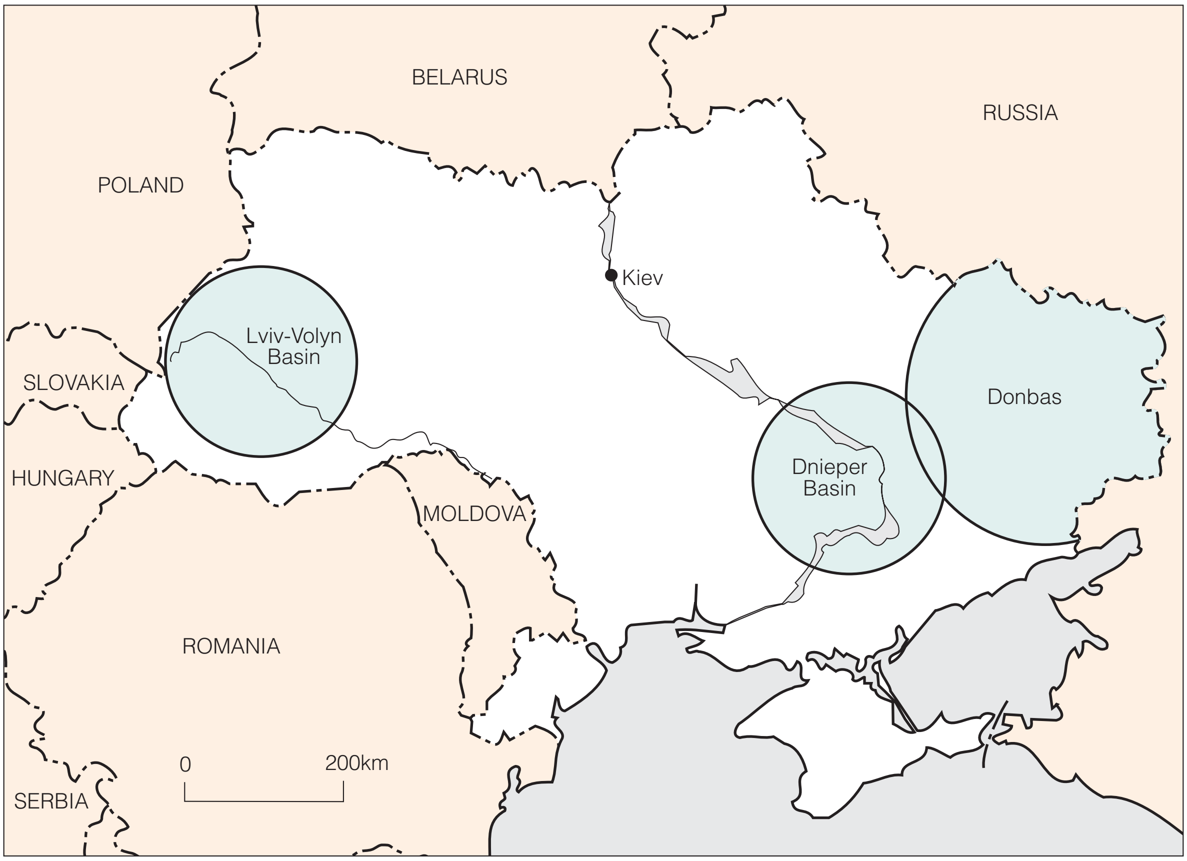


Figure 13 Ukraine's major coal basins (EIA, 2007)

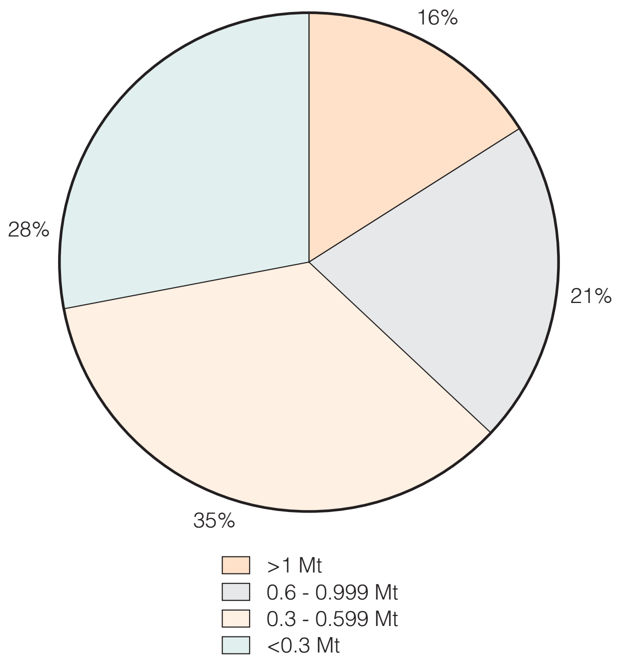


Figure 14 Coal mines by annual output (tonnes per mine) (IEA, 2006; Cabinet of Ministers, 2006a)

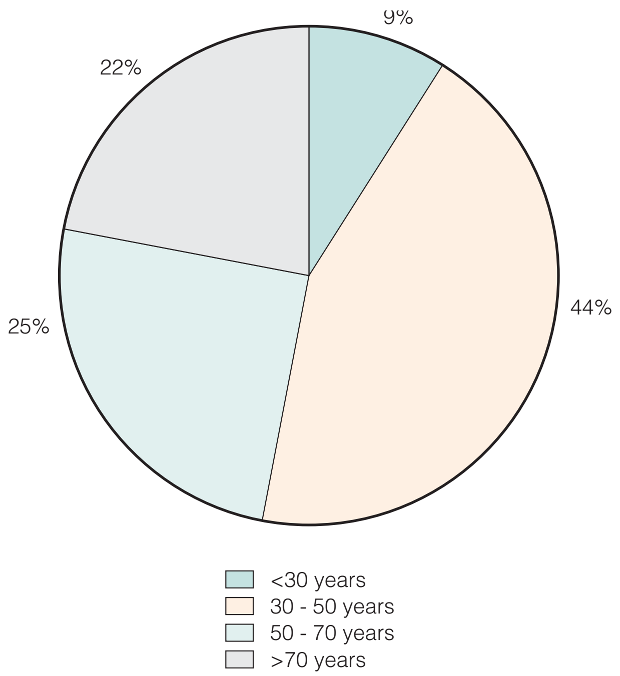


Figure 15 Coal mines by age (IEA, 2006; Cabinet of Ministers, 2006a)

Mining and geological conditions in Ukraine's mines make profitable coal extraction difficult. Average mine depth is more than 700 m; in approximately 20% of mines it is 1000–1400 m. In addition, coal beds are very thin – 85% of those containing extractable coal are less than 1.2 m thick – and often very steep, which makes mechanised extraction costly and difficult or impossible. In the Donbass region, 35% of coal beds are steep enough to make the extraction of coal possible only by hand (IEA, 2006). This environment creates hazardous working conditions, reduces labour productivity and raises the marginal cost of extracting coal.

Ukraine has the oldest mine stock in the former Soviet Union; the average mine is 40 years old. Only 4% of the mines have been renovated in the last 20 years. Two-thirds of the mining equipment has operated longer than the lifespan for which it was designed. The average annual coal production per mine is less than 800,000 t (*see* Figure 14 and Figure 15), which is low compared to neighbouring coal-producing countries. The coal quality is also poor. Ash content in extracted coal is extremely high (partially due to the thin coal seams), at 37.9% for coal used domestically, and 25.5% for coal intended for export. These levels have risen steadily since 1991 when they were, respectively, 29.8% and 18.3%. Sulphur content, at 2.5% on average, is also high. The poor quality of the extracted coal makes significant treatment of the coal prior to its sale necessary and renders Ukrainian coal less competitive in global markets. In fact, the decrease in quality since 1991 is a major factor behind the decline in coal exports.

According to the *Energy Strategy to 2030*, the coal industry's most critical problem is that many mines are so obsolete and depleted that they have not been able to attract the investment in the new technologies necessary to compete.

9.1 Mine closure

Mine closures present several social policy challenges and are difficult in the best of circumstances. The challenges begin with the decision to close a mine and the process by which that decision is made. On average, the government has closed 15 mines per year by 2005 (Prudka and Kadochnikova, 2005). By 2005, more than half of the 122 mines slated for closure in 2001 had already been shut down, though this was behind the original schedule. The government was hoping to close down approximately 50 more mines over the course of the following years. The government has also announced that mines will be classified into three categories:

1 those that are currently profitable and are thus ready for privatisation;
2 those that have economic potential though are currently not profitable;
3 those that are not economically viable and must be shut down. This categorisation suggests that additional mines will likely be added to the closure list.

Closing a mine has social consequences, both for individual workers and for the mining communities as a whole. Finding new jobs for workers can be difficult and expensive. However, World Bank analysis shows that more workers are able to acquire new jobs on their own than policy makers may project (World Bank, 2003). The Donetsk Region, where most mines are concentrated, is economically better off than Ukraine as a whole, so neighbouring communities often have the ability to provide jobs to former miners. Older workers or women may have a harder time finding new jobs, which indicates that funding for job retraining and creation might be better targeted. Handling the housing, heating systems and social assets of mining towns are also challenging, particularly during and after mine closures. Municipalities may need assistance to develop viable plans in these areas.

Mine closure also creates environmental concerns: who will be responsible for cleaning up the mine site and for purifying mine wastewater to ensure that it does not contaminate drinking water or local rivers? For now, the government has special funding set aside for environmental restoration as part of its mine closure programme. However, this funding is rarely enough for more than initial efforts to decommission a mine. Ensuring that these costs are fully covered is important not just for the environmental health of mining areas, but also in providing the proper market signals regarding the environmental costs of energy.

9.2 Labour productivity

Labour productivity is an important indicator of a coal industry's viability; improving labour productivity is also the main mechanism for boosting coal workers' standard of living. Labour productivity in Ukraine is significantly lower than in most other comparable coal-producing countries: the labour force in Ukraine is one-half as productive as in Poland, one-fifth as productive as in Western Europe, and one-twentieth as productive as in the USA. Labour productivity also varies

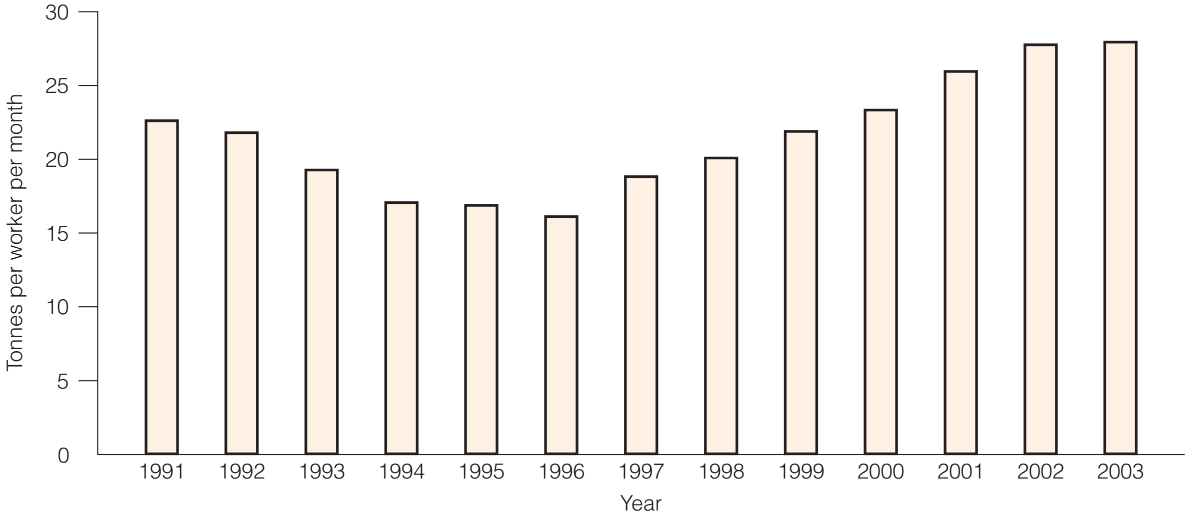


Figure 16 Labour productivity (Razumkov Centre, 2003; IEA, 2006)

widely from region to region and between private and state-owned mines. It ranged from slightly more than one tonne per month per worker in one mine in the Donetsk Region to close to 95 tonnes per month per worker at the Krasnoarmeiska-Zakhidna mine in the first five months of 2005. The national average over this period was 27.6 tonnes per month per worker, while the average among state-owned mines was 23.3 tonnes per month per worker. The average among privately held mines was 57 tonnes per month per worker. It is clear that labour productivity has been increasing steadily since the beginning of the reforms in 1996 and appears set to continue to rise (*see* Figure 16).

Labour productivity is also important because of its relationship to safety in coal mines. Typically the fewer miners required per tonne of coal, the lower the number of fatalities, because fewer miners are exposed to risk.

However, the difficult social conditions, the late payment of wages, and insufficient re-training and job-placement programmes make reform and privatisation particularly controversial and delicate issues. This is especially true among the largest group of miners (in Eastern Ukraine).

9.3 Mine safety

Ukraine's coal mines are among the most dangerous in the world. Ukrainian coal mining accidents have caused more than 3000 deaths in the past decade. However, fatalities and fatality rates in coal mines have declined consistently since 2000 (*see* Figure 17). To a large extent, this is due to improvements in mine safety within the context of coal-sector reforms. There were approximately several hundred thousands workers at Ukraine's mine enterprises in 2004.

Still, with a fatality rate of more than 2.5 workers per 1 Mt of coal, Ukraine remains a dangerous place for those who earn a living in this sector. This is significantly worse than the fatality rates in the USA, India and even Russia (in Russia, fatality rates are less than one worker per 1 Mt, which itself is high by international standards). The only country with a higher fatality rate is China, where there were 5.8 fatalities per 1 Mt in 2000. Safety problems are often exacerbated when mines have intense pressure to increase production and profitability. In some cases, particularly at coking coal mines, output is up to double the design capacity, which leads to unsafe working conditions and additional fatalities (World Bank, 2003).

The Ministry of Fuel and Energy has prepared an analysis of fatalities in 2005 indicating that the main causes of fatal coal mining accidents include human error (both poor worker discipline and

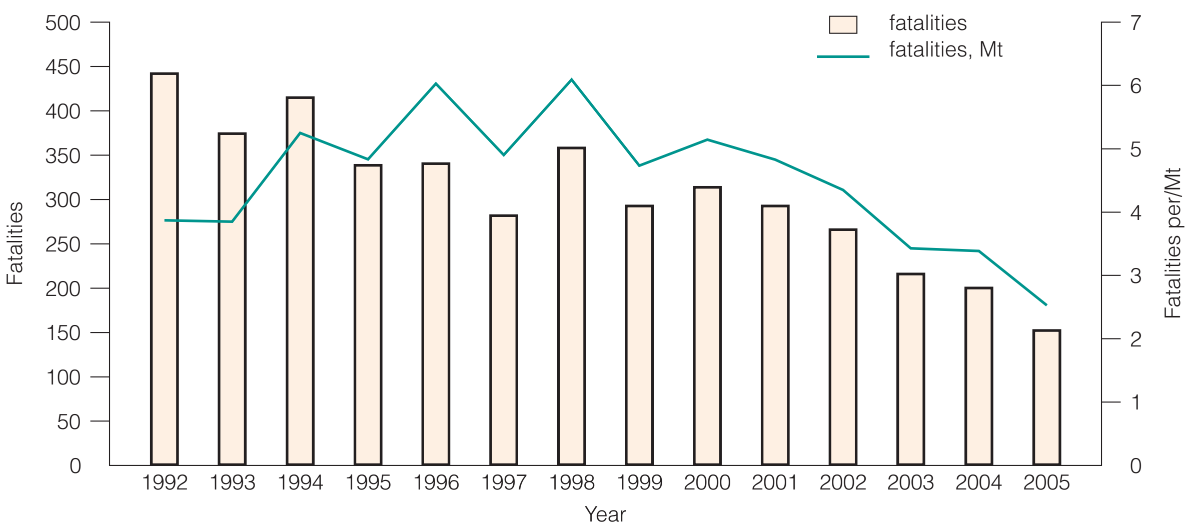


Figure 17 Coal mining fatalities in Ukraine (IEA, 2006)

engineering mistakes), slow or inadequate medical attention, poor training of experts and managers, equipment failures, lack of reinforcing materials, and a low level of mechanisation for auxiliary jobs. The majority of these cases are the physical result of explosions of methane gas that leak from coal seams and the surrounding rock.

Ukraine's mines tend to have large quantities of methane trapped in the coal seams and inadequate safety provisions. In February 2004, the Cabinet of Ministers approved a revised *Programme to Raise the Worker Safety in Coal Mines*. The government allocated US$19 million for the programme in 2004 and US$23 million in 2005. Much of this money was spent on technical measures to improve safety in the mines, for example, degasification equipment and telecommunications. The mines themselves are expected to provide additional funding. The programme lists 130 actions that various ministries and government institutions must undertake in various categories including research activities, steps to develop better degasification and ventilation systems, and administrative actions such as developing new regulations.

A wide range of stakeholders are involved in implementing the programme including the Ministry of Fuel and Energy, the Ministry of Labour, and the Ministry of Environmental Protection, along with mines, regional administrations, research institutes and other entities. The programme does not list specific goals, such as reducing fatality rates by a certain amount, but rather focuses on the actions that would likely lead to improved safety.

The Partnership for Energy and Environmental Reform, a US-Ukrainian non-governmental organisation, is working with Ukrainian mines and with the US Department of Labor on mine safety in Ukraine. They believe that the fatality rate can be reduced with the installation of enhanced methane degasification systems, utilisation of rock dust, underground water filtration, improved ventilation systems, and the enforcement of safety laws and regulations.

On 8 June 2008, the Karl Marx mine, in the Donbass area, collapsed because of a gas pipe explosion, at a depth of 533 m. Thirty-seven miners were trapped underground at 1000.6 m below the earth surface. The blast was described as one of the most powerful in the industry. Interestingly, Karl Marx coal mine had been closed for safety violations, yet audio tapes recovered at site, by the safety agency, showed that the miners were extracting coal that day, in violation of the ban.

10 Coal supply trends – domestic production and world trade

Understanding energy demand and supply trends is important for energy policy making. However, data collection and reporting in Ukraine are not sufficient to gain a clear picture of the energy demand. In addition, energy projections do not sufficiently take account of demand issues, which undermines the quality of forecasts. Inadequate energy demand and supply data complicate the task of designing appropriate and realistic policies in Ukraine. A Soviet legacy, energy balances in Ukraine consist of 'input' and 'output' sections. The input section includes production and imports of primary fuels, as well as electricity and heat generated from hydro, nuclear and renewables. The output section includes exports and domestic consumption of the same energy sources. Thus, the balance does not show transformation of primary energy or total domestic consumption of final energy such as electricity, heat and oil products. The result is that policy makers and other stakeholders do not have reliable information on energy consumption, which makes decision making difficult.

The focus on supply is characteristic of Ukraine and other former Soviet countries, where energy supplies were centrally planned and demand simply followed supply. In market economies, energy demand has more prominence because it drives the need for supply. Ukrainian policy makers should pay much more attention to the evolution of energy demand.

The share of coal in total final consumption (TFC) declined slightly from 14.6% in 1993 to 13.2% in 2004. Coal remained the fourth largest fuel in TFC. The decline of coal consumption in absolute terms was about 30%. This was due to supply difficulties associated with major inefficiencies and financial problems in coal companies, as well as to the price distortions among fuels. Indeed, a significant share of coal consumption for electricity and heat generation was replaced by the relatively cheap gas.

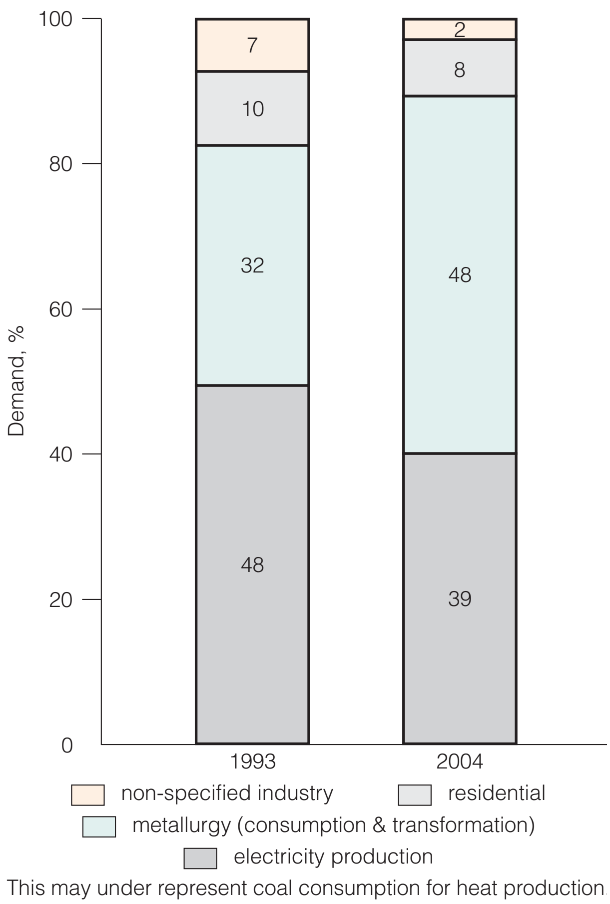


Figure 18 Coal demand by sector, in 1993 and 2004 (IEA Energy Statistics, 2008)

Two largest consumers of coal in Ukraine are electricity (and heat) plants, and the metallurgical industry. Data on coal use by electricity and heat plants should be considered with caution. Relying primarily on the information submitted by Derzhkomstat, IEA data show that approximately 39% of coal supply went to electricity generation and only 0.2% to district heating in 2004 (*see* Figure 18). However, coal consumption by heat plants may be under-represented because of insufficient reporting of heat data and because of the way the Ukrainian data allocate fuel between power and heat in combined heat and power generation.

According to the IEA methodology, electricity production accounted for nearly half of Ukraine's coal use in 1993; this figure dropped to 39% in 2004. Coal consumption for electricity generation declined in absolute terms by 50% during the transition period, two times greater than the decline in electricity generation.

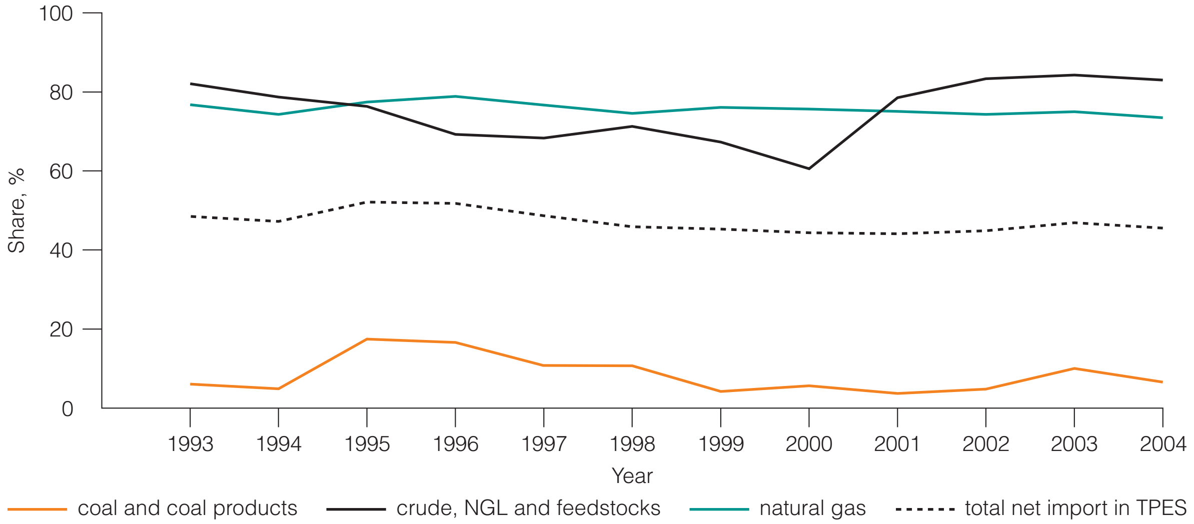


Figure 19 Share of net imports in TPES, 1993-2004 (IEA Energy Statistics, 2008)

Coal consumption by the metallurgical industry remained stable from 1993 to 1999, then increased after 2000, due to the growing export demand for steel. Metallurgy (final consumption and transformation) represented almost half of the use of coal and coal products in 2004 as compared with 32% in 1993. In absolute terms, coal consumption by the iron and steel industry in 2004 was 8% higher than in 1993.

Ukraine is highly dependent on imports for its oil and natural gas supplies, while most of its coal supply is produced domestically. Figure 19 presents the evolution of the share of imports in the supply of primary fuels in Ukraine. In relative terms, the share of total net imports in TPES decreased slightly from 49% of TPES in 1993 to some 46% in 2004. It peaked at 52% from 1995-96, essentially due to the deepening problems in domestic coal production.

The government outlined its long-term projections of energy supply and demand in the *Energy Strategy to 2030*. These projections are based on forecasts of economic growth for three distinct periods: the first period of 'structural readjustment' (until 2010); the second period of 'advanced development of the service industries' (2011-20); and the third period of 'transition to a post-industrial society' with corresponding structural changes (2020-30). The government developed three scenarios of energy sector development: optimistic, reference and pesimistic. The main concern with the approach of the *Energy Strategy to 2030* is that its projections are based not on economic analysis, but on policy goals. In other words, energy supply and demand patterns in the current strategy look more like government aspirations than real projections.

In the *Energy Strategy to 2030*, projections do not sufficiently take into account the potential evolution of demand. The designers of the strategy seem to assume (again) that energy demand will follow the supply trends. The danger of this approach is that future demand will surely be different from the projected supply mix.

Structural changes and technological evolution on the demand side, in both the medium and long term, will certainly have an impact on the volumes of energy consumption and on substitutions amongst various energy sources. Improving energy statistics is another essential action. To make solid demand projections, it is necessary to improve actual and historical energy consumption data. Missing information on demand characteristics could mislead projections of the energy mix, both in primary energy supply and final energy consumption. Energy pricing is another important issue to take into consideration. At present, most energy prices and tariffs in Ukraine do not cover long-term costs, thus part of consumption is driven by non-economic stimuli. In other words, demand is higher than is economically efficient.

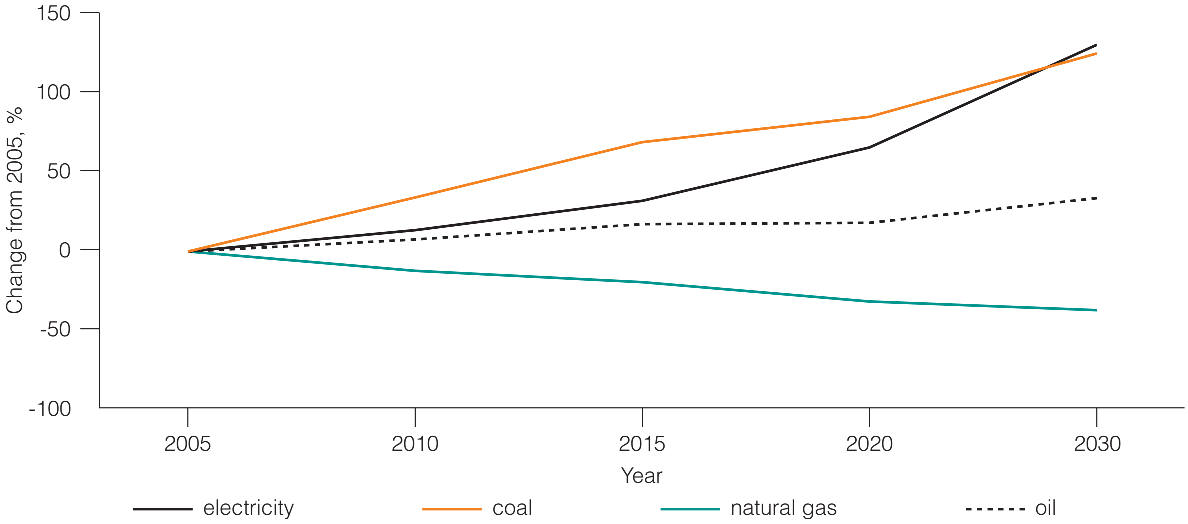


Figure 20 Forecasted energy consumption by fuel, 2005-30 (IEA Energy Statistics, 2008)

The government projects coal consumption to increase to 99 Mt by 2015 and to 130 Mt by 2030 (*see* Figure 20). The government expects that a larger share of electricity will be generated by coal-fired thermal plants (in order to decrease Ukraine's current dependence on natural gas imports). It is also likely that the government is anticipating increased coal use in the metallurgical industry, due to a projected boom in consumer goods and continued strong performance in the defence sector. However, the growing use of coal will lead to increasing GHG emissions.

The IEA World Energy Outlook (WEO) (IEA, 2008b) publishes energy demand and supply projections in various groups of countries, including 'transition economies'. WEO projects that energy demand in transition economies (including Ukraine but without Russia) will grow by 1.4%/y, on average, until 2030. The WEO projections for energy supply structure in the region are fundamentally different from the Ukrainian Government's projections. WEO forecasts that gas will remain the dominant fuel in transition economies: its share in total primary energy supply will rise from 43% in 2002 to 48% in 2030, as most new power generators will be gas fired. The share of oil is also expected to increase from 23% in 2002 to 27% in 2030, driven by strong demand for transportation fuels. The share of coal in TPES is expected to fall from 21% to 16%; nuclear's share will also decline as plant retirements will outweigh the addition of new capacity.

10.1 Coal imports/exports

While importing coal from Russia, Ukraine exports it to many countries (*see* Figure 21) and, while exporting steam coal, Ukraine lacks coking coal. Ukrainian metallurgy needs around 30 Mt/y of coking coal, while Ukrainian mines are able to supply less than 20 Mt/y. Thus in the first seven months of 2008, metallurgical enterprises bought 18.53 Mt of coal concentrate and run-of-mine coal, only 11.93 Mt of which were of Ukrainian origin. The major role in coking coal supply is played by Russia, imports from which reached 4.93 Mt by August 2008, while the USA and Canada sold 0.97 Mt and Kazakhstan sold 0.67 Mt.

The presence of North American countries in the list of major coal suppliers is of some significance, as these remote countries became important suppliers due to the efforts of just one coke and chemical plant, JSC Alchevskkoks (member Industrial Union of Donbass, IUD). The plant failed to secure a stable coal supply from within the Ukrainian companies or from Russia. While iron and steel magnates, who also own coke and steel companies, have the possibility to reduce the cost of coke by purchasing it in Russia, long distance logistics seem to be incompatible with economic operation. However, in summer 2007 Russian Railroads OJSC reduced the number of carriages used for coal

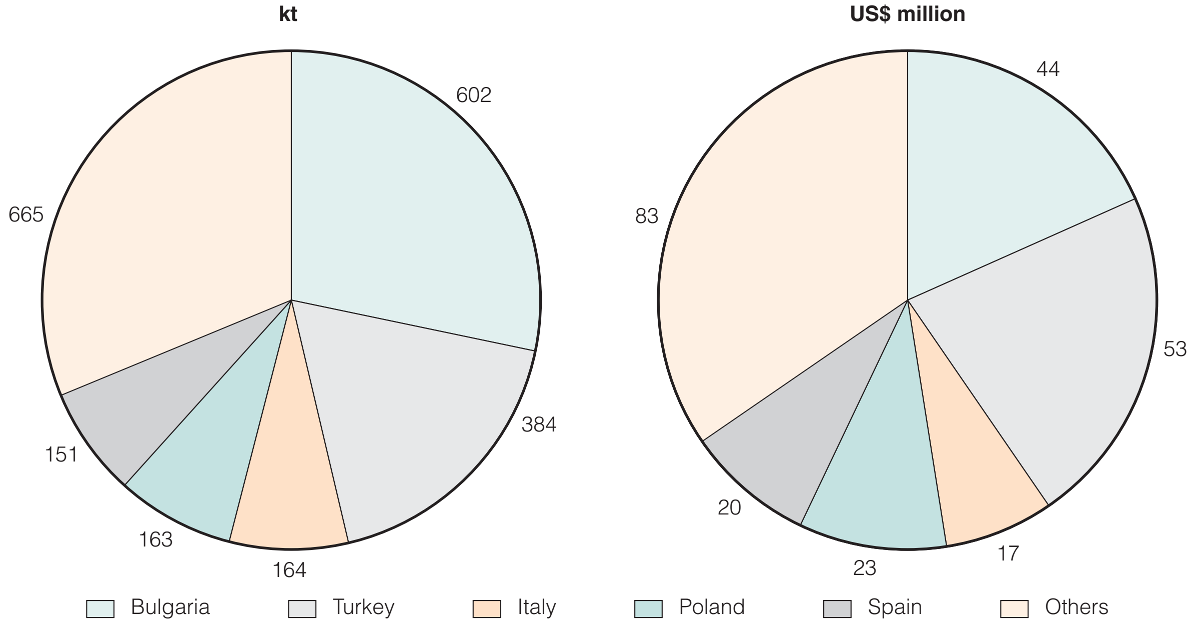


Figure 21 Ukranian steam coal export, first half of 2008 (Herasimovich, 2008)

delivery from Kusbass (Russia) to Ukraine, which cut its import by 10%. Russian financial and industrial groups benefited from this situation, as the Ukrainian companies obtained proposals to buy more coke rather than coal from Russia. IUD corporation was the one who suffered the most from the conflict with Russian Railroads as it had to import coking coals from different markets.

Table 6 Ukraine's coal trade, Mt (IEA, 2009)

	2006		2007		2008	
	Import	Export	Import	Export	Import	Export
Hard coal	9.75	–	11.86	–	10.27	—
Coking coal	7.75	0.53	8.18	0.408	7.38	0.04
Steam coal	2	2.92	3.7	2.94	2.9	4.23

Alchevskkoks started importing coking coal from the USA in 2007. In 2008 Alchevskkoks intended to import about 1.5 Mt of coking coal. Increasing coal imports by sea resulted in some problems due to Ukraine's lack of deep-water ports able to accept vessels of up to 100 kt deadweight. Thus, coal for Alchevskkoks is supplied by large capacity vessels to the Romanian port of Constantza and then reloaded to smaller ships with a carrying capacity of 20–30 t to be delivered to the Mariupol port. This route of coal supply increases its cost dramatically and is economically feasible only if coal prices remain high in the Ukrainian market (380–400 US$/t). Table 6 provides some information on Ukraine's coal trade.

11 Estimating the cost of coal and coal production in Ukraine

World coal prices have kept pace with the surge in the international oil and gas prices, although on an energy basis, coal remains the cheapest fossil fuel. According to IEA, 2008b, the average price of steam coal imported into the European Union in 2007 was 83.40 US$/tce, (3 US$/million Btu) compared with 244 US$/tce (8.80 $/million Btu) for imported high-sulphur oil, US$203/tce (7.30 US$/million Btu) for natural gas imported by pipeline and 180.7 US$/tce (6.60 US$/million Bbtu) for liquefied natural gas. In 2008 the average price of coal imported by OECD countries was well over 100 US$/t and it is expected that prices will stabilise at around 120 US$/t until about 2015, following which, they could fall slightly as new mining and transportation capacity becomes available (IEA, 2008b).

While oil and natural gas prices influence coal prices through contractual linkages and opportunities for fuel switching, notably in power generation, there are many other factors which have contributed to higher coal prices. Supply has been tight during a period of demand growth. Unforseen events in mining industries in major supplier countries have added to the tightness. Strong demand for steel production and power generation resulted in the world's bulk carrier shipping fleet having to struggle to meet demand. Despite these significant cost increases, a large margin still remains between coal prices and costs, which is attracting new investment into the industry and is stimulating merger and acquisition activity.

In Ukraine, only oil and oil product prices are at international levels. Despite recent increases in import prices, retail natural gas prices remain lower than prices in Western Europe and they are also lower than prices in neighbouring countries, such as Russia. Coal prices do not cover production costs; thus, coal mines are in dire financial straits. Clear market rules that are enforced uniformly would stimulate investment and enhance fair competition in Ukraine.

The increases in gas and electricity tariffs, implemented in 2006, are an important step toward sustainable pricing levels; however, electricity and natural gas (especially for households) are still priced below the long-run marginal cost. Despite some progress with price liberalisation in the early 1990s, real prices for energy actually declined from 2000-05. While inflation (the producer price index) grew by 47% from 2001-04, prices for electricity, natural gas and heating grew only by 22% over the same period. The sharp growth in price for gas imports in 2006 made an increase in domestic prices unavoidable. NERC raised gas prices for various consumer groups by 25% from May 2006, and by a further 80–85% from July 2006. NERC is also gradually raising electricity tariffs with the intention of reaching cost-recovery levels.

Coal prices are formally set by the market. However, in practice, large industrial groups that own metallurgical plants have tremendous influence over the price of coal. As a result, Ukrainian coal is reportedly priced 20–40% below costs at the mines. Mines receive direct production subsidies and many mines also receive capital investments from the state budget, but even with subsidies most mines are loss-making.

While using natural gas to fire TPPs has well-known environmental benefits over coal, the use of coal for power generation is based on much larger available resources and lower prices per tonne of conventional fuel energy (7000 kcal/kg). In the 1990s, there were no incentives to develop coal power generation in Ukraine, as the price ratio between conventional fuel gas and conventional fuel coal was very low at 1.1–1.2. A number of studies performed at the time, showed that coal becomes the fuel of choice when conventional fuel gas/conventional fuel coal is, at least, 1.8–2.0. Presently, the world conventional fuel gas/conventional fuel coal average is 2.5 to 3.0. On 1 November 2010 gas price at the TPP's inlet was 2960 UAH per thousand m^3, or approximately 2600 UAH/t conventional fuel.

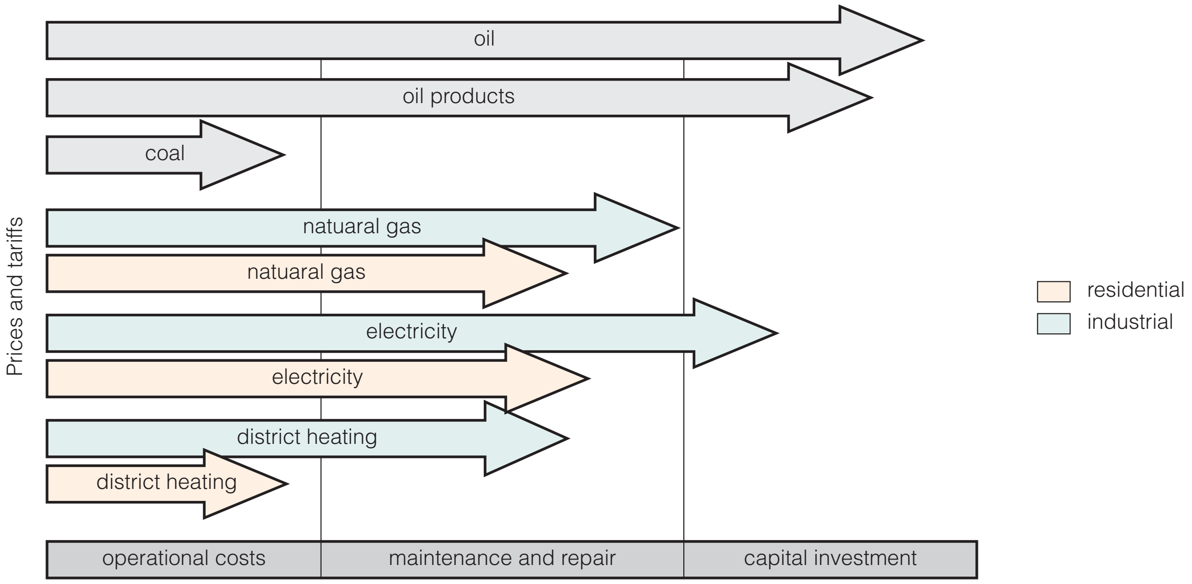


Figure 22 Energy prices and tariffs compared to costs, June 2006 (IEA, 2006)

Steam coal price is regulated by a progressive scale of discounts (adopted by a committee of the Council of Ministers in 2007) which stimulates quality increase. The basic quality level corresponds to design parameters of TPP's boilers.

Assuming a 20% tax and 65 UAH/t transport cost, the basic coal cost 810 UAH/t or, depending on coal type, from 965 to 1070 UAH/t conventional fuel. Conventional price for higher bituminous coal is calculated based on its combustibility, without gas or oil addition at partial load. Thus, at basic steam coal quality, conventional fuel gas/conventional fuel coal in Ukraine is 2.4–2.7, which is close to the world level, and favourable to coal power generation. However, the situation is different in the heat supplying sector, where gas for communal needs is cheaper, and does not justify use of coal for heat generation.

11.1 Subsidies

Ukraine does not have many explicit subsidies but the existing cross-subsidies and other distortions deflate prices for many energy products. Residential consumers, public institutions and agricultural users obtain energy at a relatively low, regulated rate. Electricity tariffs for households and natural gas prices for the residential and public sectors are lower than those for industrial users. Thus, industries bear the financial burden by cross-subsidising the residential and public sectors. On the other side, some industries are also subsidised, for example, through coal subsidies, and government-funded investments in coal mining and nuclear safety. Until the end of 2005, all Ukrainian consumers also paid relatively low natural gas prices, which were subsidised by Naftogaz of Ukraine through substantial revenues from transporting Russian gas to Europe.

The Ukrainian Government recognises that it should raise energy prices to stimulate energy-efficiency improvements and attract the necessary investment to the sector. The *Energy Strategy to 2030* states that one of Ukraine's main tasks is underwriting production costs to create conditions for the sustainable development of energy companies. NERC began raising electricity and gas tariffs in May 2005, but tariffs for households and some other consumer groups have not yet reached cost recovery levels. Raising tariffs for households further is politically difficult. This highlights the necessity for strong co-ordination between energy policy and social and economic policy.

11.2 Taxation

Ukraine has made progress in reforming its tax system over the last several years. The European Business Association reports that Ukraine has resolved a number of problematic issues in taxation and made the whole system more transparent and simple. Nevertheless, the Ukrainian tax system still appears rather unpredictable due to repeated changes in legislation, often retrospective, failure to proceed with declared intentions and schedules for tax reform, and many cases of one-sided fiscal interpretation of the law by the tax authorities.

Ukraine has several nationwide taxes specific to the energy sector, which include:

- Surcharge on the effective tariff for electricity and heat, except for electricity produced by cogeneration plants.
- Surcharge on the approved tariff for natural gas for all consumer types.
- Royalties for producing oil, natural gas and gas condensate, for natural gas transit and for transportation of oil through main oil pipelines.
- Fee for exploration activities. This fee is intended to create an economic mechanism to compensate for exploration and prospecting costs financed by the state, and to collect funds for financing further exploration.

Ukraine also has several, more general, nationwide taxes, duties and levies that have an impact on the energy sector, including a value-added tax (VAT) of 20%. Small companies, non-profit organisations and state institutions do not have to pay the VAT. Companies exporting goods, including energy products, must pay VAT on exports but the tax authorities ultimately reimburse it. Ukrainian refineries exporting their products have reported significant delays in VAT reimbursement, which has a negative effect on their finances. In addition, there are local taxes set by regional and city administrations. Ukraine also has environmental pollution fines.

11.3 Market mechanisms

Coal prices in Ukraine are theoretically freely-set by the market. In reality, there are many price distortions. The largest are coal subsidies, state fuel allocation in the power sector and the influence of private, monopoly buyers. Because of their dominant role and exclusive contracts to buy coal from some mining companies, private industrial groups have tremendous market power. Thus in practice, the government and large industrial groups set the price in a non-competitive manner. There is a wholesale market for coal in Ukraine but the production costs exceed the prices at most mines. The government compensates a portion of the difference through direct production subsidies. In 2004, the government distributed subsidies of about 3.00 US$/t of coal, equal to approximately 9% of the average wholesale price. The government also funds other, long-term coal mining costs at state-owned mines, including many capital expenditures, and mine closure and decommissioning costs.

As part of the coal sector restructuring programmes, the government has made significant investments in coal mines to try to make them profitable. However, these investments come directly from the government budget and are not reflected in the coal price. In 2005, the government made US$277 million of capital investments in coal mine technology and paid another US$158 million for restructuring and closing mines (including addressing the environmental consequences of the mining operations). Additional funds have been allocated for job retraining and addressing the social consequences of mine closure.

Most mines are still state-owned and many consumers (particularly power plants) are in state hands. The Ministry of Fuel and Energy allocates fuel to power plants. Thus while there is a wholesale exchange, the market does not set the prices; it only has a muted influence on them. As indicated above, large industrial groups have tremendous influence over the price of coal. According to the 2003 Razumkov Centre study, as well as the World Bank (2003) study, Ukrainian coal is under-priced by

20–40% at the mines because private intermediary structures monopolise distribution. Moreover, the price of coking coal is lower than the price of steam coal, a situation that does not occur anywhere else in the world and thus points to a major market distortion. Industrial groups that own metallurgical plants control both the distribution and purchase of coking coal. The Industrial Union of Donbass is one of the most powerful industrial groups in Ukraine. It owns, either directly or indirectly, a large number of metallurgical and machine-building companies, coal mines, and intermediaries. In turn, the metallurgical groups supply equipment and materials to the mines at prices that appear to reflect their monopoly over the production of these items. As a result, the prices of materials and equipment sold to mines increased by approximately 220%. Over the same period, steam coal prices increased by 49% from 2000 to 2005.

In its *Energy Strategy to 2030*, the government also highlights that private businesses with a monopoly on the production of certain types of coal mining equipment gain excessive profits, while coal mines have large losses. These private companies are able to amass these profits at the state's expense because of the subsidies and the state ownership of the mines. The trend is particularly evident for coking coal, where the coal is eventually used to produce steel for export markets. This form of corruption keeps coal prices artificially low and the cost of coal extraction high. It also creates a mechanism for funnelling state funds intended to subsidise a troubled sector into the hands of private companies controlled by rich industrialists.

As of 1 December 2005, the coal sector had unpaid debts of US$1.86 billion and net indebtedness of US$1.4 billion. A large portion of these debts are for taxes or workers' pay. Though unpaid debts are increasing from year to year, the rate at which they are increasing has been declining since 1996. An adjustment of the artificially-low coal prices to market conditions, coupled with investment in capital and new technologies, should make it possible for coal to be extracted in an economic and sustainable way, at least from a significant percentage of mines, without relying indefinitely on large state subsidies.

12 Inland transport and port infrastructure

Increase in coal imports from abroad by sea resulted in some problems due to Ukraine's lack of deep-water ports able to accept the vessels with up to 100 kt deadweight. Thus coal is supplied by large capacity vessels to the Romanian port of Constantza and then reloaded to smaller ships with a carrying capacity of 20–30 t to be delivered to the Mariupol port. This route of coal supply increases its cost dramatically and is economically feasible only if coal prices remain high in the Ukrainian market (380–400 US$/t).

The most important Ukrainian port for the export of hard coal from the Donbass, is the Black Sea port of Mariupol, which is situated about 100 km south of the Donbass. In order to secure the domestic supply the government increased the railway and port tariffs. Thus the railway transport cost from the Donbass to the Western Ukraine border (about 1000 km as the crow flies) increased to 40 US$/t and made exports via railway uneconomic (Schmidt and others, 2006).

13 Environmental issues

World CO_2 emissions from fossil fuels increased by 98.7% between 1971 and 2006, going from 14.1 Gt in 1971 to 21 Gt in 1990 and 28 Gt in 2006. Over the same period, coal-related emissions increased by 125% from 5.2 Gt in 1971 to 8.3 Gt in 1990 and 11.7 Gt in 2006, accounting the for 41.7% of CO_2 emissions from fossil fuels. Since 2004, coal has been the leading source of CO_2 emissions ahead of oil and natural gas (*see* Figure 23) (IEA, 2009).

The increase in coal related emissions was bigger in the non-OECD countries, which became responsible for the majority of these emissions from 1992 onward.

A comparison of average efficiencies with those of the best available power plants, shows that fuel consumption and CO_2 emissions could be reduced considerably if the best available technologies were used for retrofitting existing power plants. Efficiency improvements can significantly reduce CO_2 and other emissions. Efficiency improvements also have the potential to reduce emissions of sulphur dioxide and, in certain cases, nitrogen oxides (NOx). Natural gas, combined-cycle plants have the lowest emissions of fossil fuel-based technologies because of its low carbon intensity and plant high efficiency (*see* Figure 24).

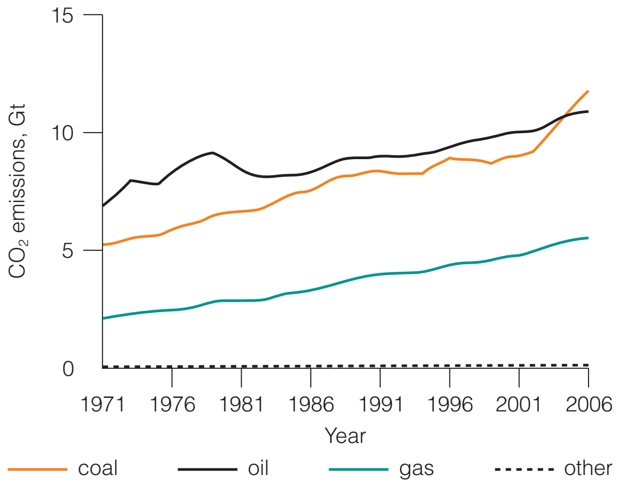


Figure 23 World CO_2 emissions by fuel (IEA, 2009)

Ukraine's energy sector has high pollution levels. Two main reasons for this are Ukraine's high energy intensity and the obsolete technology used in energy transformation. Power and heat plants are old and have few pollution controls. In addition, government energy policy has not traditionally placed high priority on environmental concerns, although the situation is changing gradually. The government now has programmes to promote energy efficiency and modernisation at power plants. The *Energy Strategy of Ukraine to 2030*, did address environmental protection in each sectoral chapter.

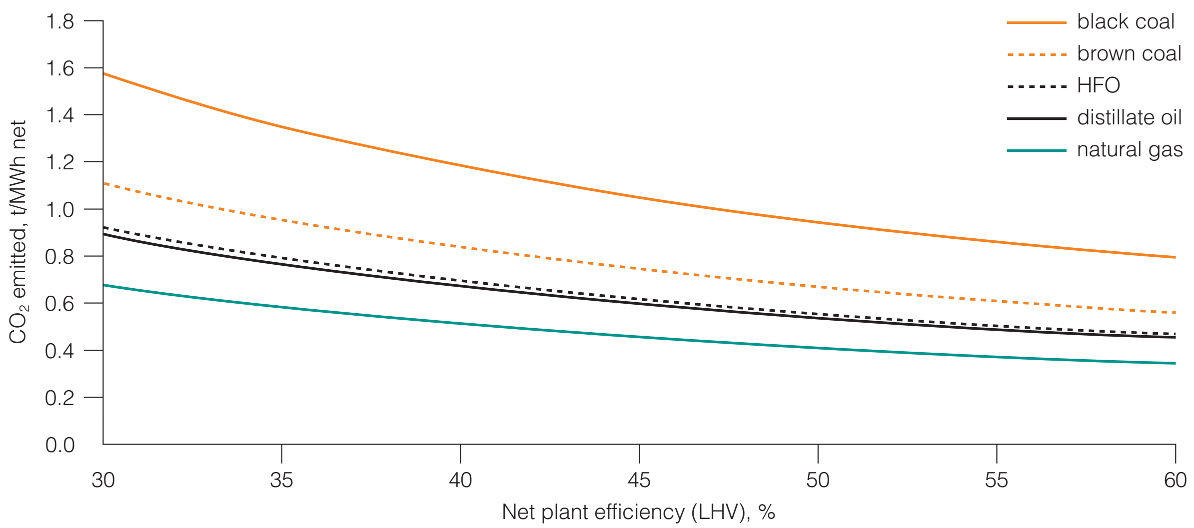


Figure 24 Impact of fuel type and efficiency on the CO_2 emissions of power plants (IEA, 2009)

Table 7 Annual total emission of five large energy-generating companies of Ukraine (Cenrenergo, Dniproenergo, Donbassenergo, Vostokenergo and Zakhidenergo)

	PM, kt	SO_2, kt	NOx, kt	CO, kt	CO_2, Mt
2005	290	900	105	7.9	62,943.9
2006	305	1130	125	8.4	72,040.2
2007	265	1075	130	9	71,953.9
2008	260	1080	140	9.0	74,253.6
2009	240	1055	130	7.8	67,652.3

The energy sector in Ukraine is responsible for 75% of emissions of sulphur dioxide (SO_2), 50% of emissions of particulates and 45% of nitrogen oxides (NOx) emissions. Ukraine's energy sector also contributes 69% of total domestic emissions of greenhouse gases. The average specific CO_2 emission for coal combustion is more than 1000 g/kWh of electricity.

The *Energy Strategy of Ukraine to 2030* draws attention to the environmental problems associated with energy production, as well as extraction and transportation of coal, oil and gas. The *Energy Strategy to 2030* provides encouraging figures on the emission reductions envisioned. However, it does not set a clear roadmap on how it will achieve these reductions. It provides positive signs as it devotes a separate chapter summarising major environmental concerns, and it discusses further details on environmental issues within the chapters on specific sub-sectors (including thermal power production, coal mining, and oil and gas extraction) – *see* Figure 25.

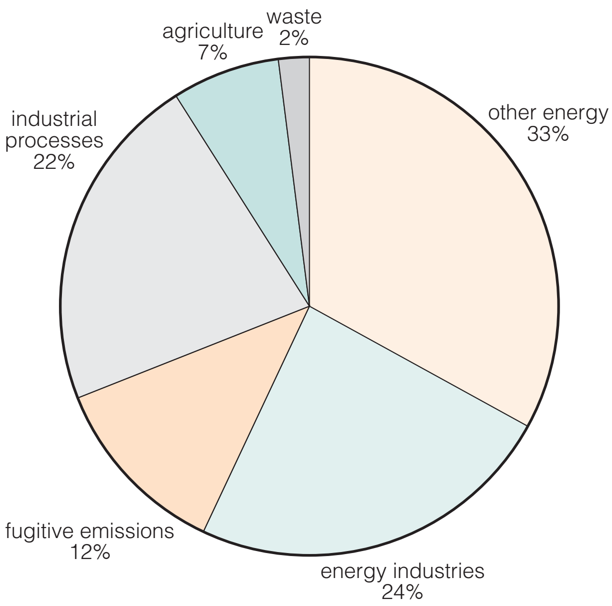


Figure 25 Ukraine's GHG emissions by sector, 2004 (IEA, 2006)

Ukraine became a signatory to the Kyoto Protocol in 1999 and ratified the Protocol in February 2004. Under the Protocol, Ukraine's greenhouse gas emission target in the period 2008-12 is 100% of its 1990 level (925 $MtCO_2$-e/y or 260 Mtce/y (IEA, 2006).

The energy sector is the main source of carbon dioxide (CO_2) and methane (CH_4) emissions in Ukraine, representing 69% of total greenhouse gas emissions (electricity and heat plants alone are responsible for 24% of total CO_2 emissions) (*see* Figure 26). Greenhouse gas emissions in Ukraine decreased through the 1990s, mostly due to the sharp economic decline. Emissions in 2000 (the lowest point in the last 20 years) were about 60% of the 1990 level. Since 2001, greenhouse gas emissions have grown again. (*see* Table 7 *and* Figure 26).

Ukraine's CO_2 intensity of energy use per economic output (GDP) has changed only slightly since the early 1990s. While Ukraine's energy-related CO_2 emissions have declined by nearly half since 1990, the share of CO_2 emissions per unit of GDP declined by only 14%. Ukraine has one of the highest levels of CO_2 emissions per GDP among Annex I countries. However, CO_2 emissions per capita are among the lowest in Annex I countries. Energy-related CO_2 emissions are expected to grow, but most projections assume that they will not exceed the 1990 level by 2012, the end of the commitment period under the Kyoto Protocol. In fact, all scenarios show that greenhouse gas emissions from the

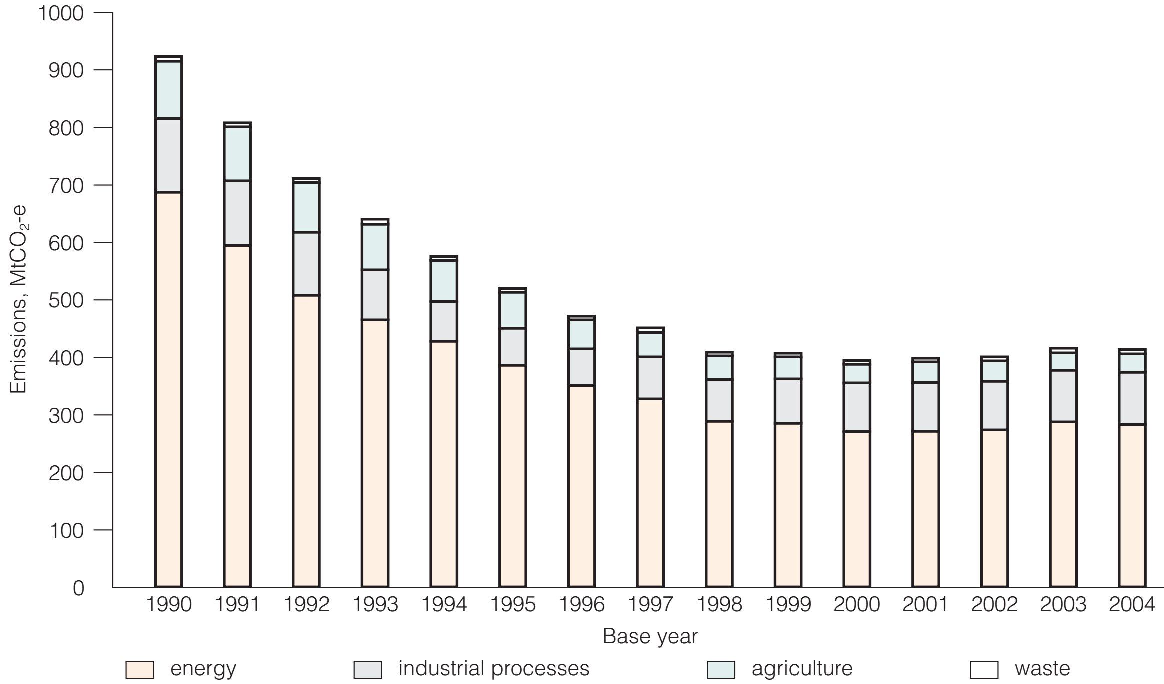


Figure 26 Ukraine's GHG emissions, 1990-2004 (IEA, 2006)

energy sector will not return to 1990 levels by 2020, even under a scenario with high economic growth and relatively few energy-efficiency investments. Under any scenario, Ukraine is likely to have a surplus emission quota to sell on the international market through emissions trading, as well as opportunities to generate credits for sale through the joint implementation (JI) mechanisms that are envisioned under the Kyoto Protocol. JI, emissions trading and investments through a green investment scheme could provide at least partial financing for projects to reduce greenhouse gas emissions.

In spite of this favourable situation, many individual power plants have emission levels up to ten times the 200 mg/m^3 SOx/NOx limits prescribed by the EU directive 2001/80, to be implemented by the end of 2017. Ukraine has signed a memorandum of participation in the Energy Treaty of the European Network of Transmission System Operators (ENTSO)/Annex 2, committing itself to abide by the above directive, which is also known as the Large Combustion Plant Directive (LCPD). However, Ukrainian officials argue that such targets are not realistic for Ukraine where presently no plant has either de-NOx or de-SOx equipment. It is noted that a 95% reduction in sulphur emissions is considered the highest realistic technological effort. Any attempt to go higher than that will be subject to the principle of diminishing returns, in which the amount of money spent will increase much faster that the benefits obtained. As an example, it is shown that the coal used in Western Europe has an average of 0.5% sulphur content resulting in 1500 mg/m^3 emissions. When reduced by 95%, the emissions become 75 mg/m^3. The coal used in Ukraine has up to 2.5% sulphur content resulting in 7500 mg/m^3 which, when reduced by 95%, becomes 375 mg/m^3, well above the 200 mg/m^3 prescribed by the EU Directive. Any attempt to improve on that would be either uneconomical, or would have grave social consequences if poor coal quality mines are to be closed.

At this time, a new EU directive, 2010/75, having more stringent emission requirements, is being prepared for 2017. Ukraine expects (and hopes) that, following the recent problems with the nuclear power plants in Japan (as a result of the earthquake and tsunami), the requests for new thermal power generation will increase, and this will lead to some relaxation of the emission limits presently imposed or under consideration.

On 30 March 2011, the Ukrainian Parliament will hold public hearings in advance of the preparation

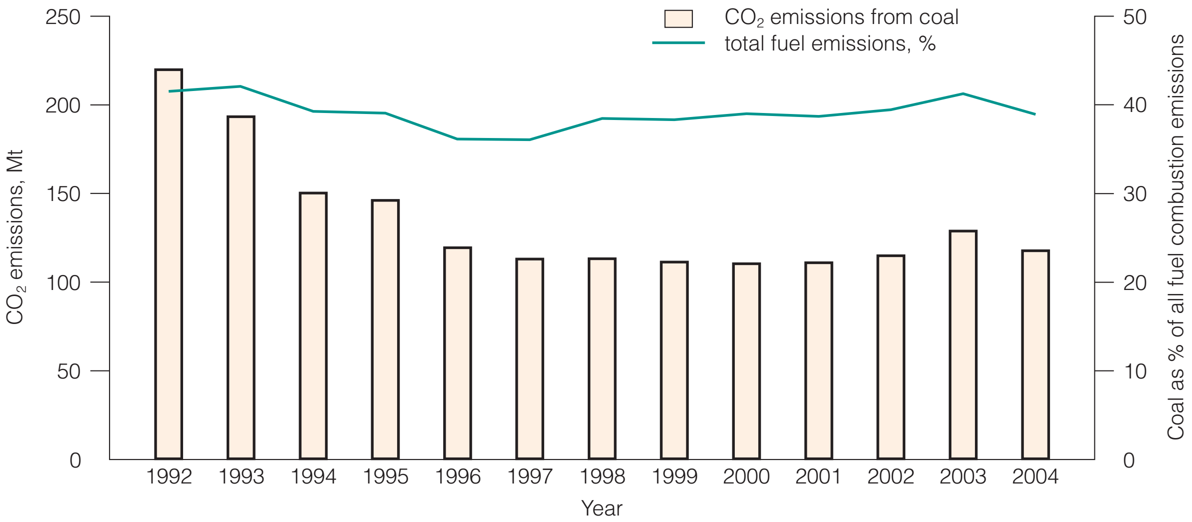


Figure 27 CO_2 emissions from coal combustion, 1992-2004 (IEA Energy Statistics, 2008)

of a Road Map for plant emission control in accordance with LCPD. However, it is expected that a realistic road map will be likely to acknowledge the fact that the 2017 deadline is not realistic for Ukraine, and that 2025 would be a more realistic target. Therefore, it is unlikely that non-compliant units will suffer any negative repercussions. It is also considered uneconomical to refurbish some of the very old plants, with low efficiencies, as adding additional emission control equipment will further reduce their efficiency. Some Ukrainian officials believe that as part of the country's drive to join the EU they should be given similar derogations as other Eastern European countries have received, followed by very large grants from the EU.

The EU, through its technical assistance programme, supports several climate change related activities in Ukraine. These include developing national greenhouse gas inventories, assessing the feasibility of greenhouse gas registries and setting up the national JI infrastructure. Thanks to this assistance programme and the efforts by the Ukrainian Government, the national inventory reports were developed and submitted to the UNFCCC in 2005 and 2006. The USA has also assisted Ukraine with inventories, JI infrastructure and national communications.

Coal is a major source of greenhouse gases and other emissions. Based on IEA data, coal accounted for nearly 40% of all Ukrainian CO_2 emissions from fuel combustion in 2004, even though coal's share in the energy balance was 24%. Total coal-related CO_2 emissions have declined as coal demand has dropped in recent years (*see* Figure 27), but reached more than 130 $MtCO_2$ in 2004 from coal use.

Ukrainian coal has particularly high levels of sulphur and ash. These impurities have been increasing as the quality of Ukrainian coal declined over the past 20 years. The Ukrainian Government does not prepare data on other emissions from coal use specifically. Ukrainian power plants and steel mills typically have limited or non-existent pollution control equipment. For example, coking facilities in Ukraine often vent large volumes of toxic coke-oven gas, while most IEA countries have strict limits and penalties for such emissions. Emissions of criteria pollutants during coal mining have declined in recent years. For example, particulate emissions from coal mining declined by 18% from 2000 to 2004, according to the Ministry of Environmental Protection. These declines may be related to the closure of small, unprofitable mines. A list of electrostatic precipitators (ESP) installed at Ukraine's TPP is shown in Table 8.

For particulare removal, the 150 and 200 MW power units are equipped with wet scrubbers with Venturi tubes (4–5 scrubbers per unit). The dust efficiency of wet scrubbers is 85–94% and depends on the water consumption. The existing Ukrainian TPPs do not have de-NOx and de-SOx equipment.

Table 8 Characteristics of ESP installed on Ukraine's TPPs (Chernyavski and others, 2010)

Model	Manufacturer	Electrode length, m	Actual efficiency, %	Power unit, MWe
EHA-2-58-12-6-3	Semibratovo, Russia	12	98.4	300
EHV-2-36-12-6-3	Semibratovo, Russia	12	98.2	300
UH 3-44-177	Semibratovo, Russia	12	98.6	300
EHA-2-58-12-6-4-330	Semibratovo, Russia	12	98.3	300
EH3-3-265-03	Semibratovo, Russia	12	92–95	300
EGE-3-177-03	Semibratovo, Russia	12	98.6	300
EGBM-2-50-12-6-3U	Semibratovo, Russia	12	98.3	300
EH3M-180-50-12-11-3	Semibratovo, Russia	12	98.4	300
EHBM-2-54-12-4-6	Semibratovo, Russia	12	98.5	300
EHBM-2-40-12-6-4	Semibratovo, Russia	14	98.1	300
EHT-175-38-12-10	Energomashengineering, Ukraine	14	98.5	200
H 358.4*4.016/400G	Balcke Duerr, Germany	14	99.6	325
'CFB Starobeshevo'	Alstom Power, Sweden	14	99.8	210
FAA-404040-2	Flaekt, Sweden	11	92	800
UH-2-4	Semibratovo, Russia	7.5	90–96	200
PHDS-4-50	Semibratovo, Russia	7.5	92–95	300
PHD-3-50	Semibratovo, Russia	7.5	92	200

Given the deteriorating quality of Ukrainian coal, the environmental and health implications of greatly expanding coal use could be very significant. The government aims to increase coal use by 70% from 2005 to 2030. However, the government has not estimated the potential emissions from such a significant expansion. IEA estimates that such an increase in coal use will cause CO_2 emissions to grow by between 213 and 230 Mt, based on the current coal use profile. Without more detailed information on the government's assumptions, it is difficult to understand what the full impacts might be. However, it is almost certain to lead to growth in emissions of greenhouse gases, particulates, SO_2, NO_2 and other pollutants.

14 Electricity generation, transmission, distribution and market structure

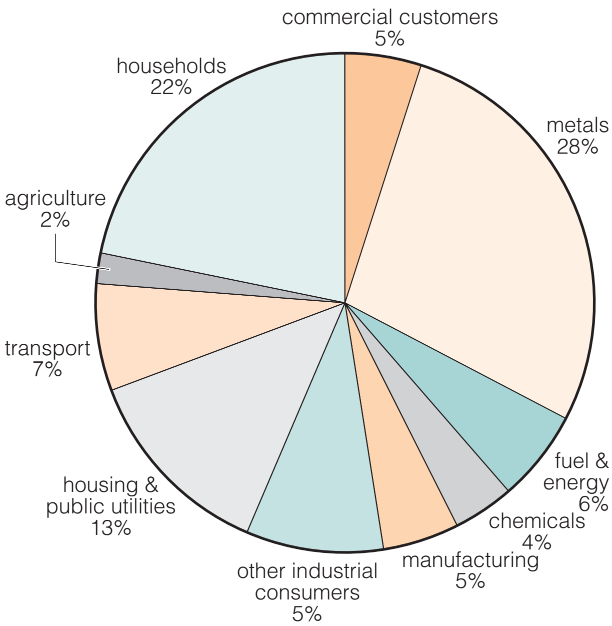


Figure 28 Domestic electricity consumption in 2008 (IMEPOWER Investment Group, 2009)

Ukraine's power sector's regulation is performed by the National Electricity Regulatory Commission (NERC) and the Ministry of Fuel and Energy. The power sector is organised along the classic activities of generation, transmission and distribution.

Some 97% of the electricity produced in Ukraine is consumed domestically. Industry, the largest consumer, uses some 52%, while households account for about 22%. Consumption per capita in Ukraine is comparable to that of neighbouring countries (3300 kWh), the same as Poland, but less than the EU average of 6500 kWh (IMEPOWER Investment Group, 2009). Figure 28 provides a breakdown of Ukraine's domestic electricity consumption in 2008 by sector.

According to the State Statistics Committee of Ukraine, energy transformation accounted for 58% of total fossil fuel consumption in 2004. This is 14% more than the OECD average to produce each kWh of electricity.

14.1 Structure of the electricity market

Ukraine's electricity market is organised under a single-buyer model. A competitive wholesale electricity market (WEM) was established in 1996, with SE Energorynok functioning as market administrator (*see* Figure 29).

Energorynok buys all electricity from the generation companies, averages the price and sells it to electricity distribution companies and independent suppliers at a blended rate. Apart from this function, Energorynok administers WEM's settlements and funds.

Each member of WEM must sell all electricity produced or imported for sale in Ukraine, exclusively on WEM, except for:

- electricity used for their own needs by each electricity producer;
- electricity produced at CHPs and supplied to consumers of the region where they are located;
- electricity produced at power stations with installed capacity of less than 20 MW and annual energy output of less than 100 GWh.

The WEM deals with TPPs and a few larger CHPs on the competitive segment of their business, while nuclear, hydro, wind and smaller CHPs are on the fixed tariff segment (with tariffs approved by NERC).

On 29 September 2008, the Ukrainian Government held the First Ukrainian Electricity Market Reform Conference, outlining directions for WEM reforms, which are to divide the market into

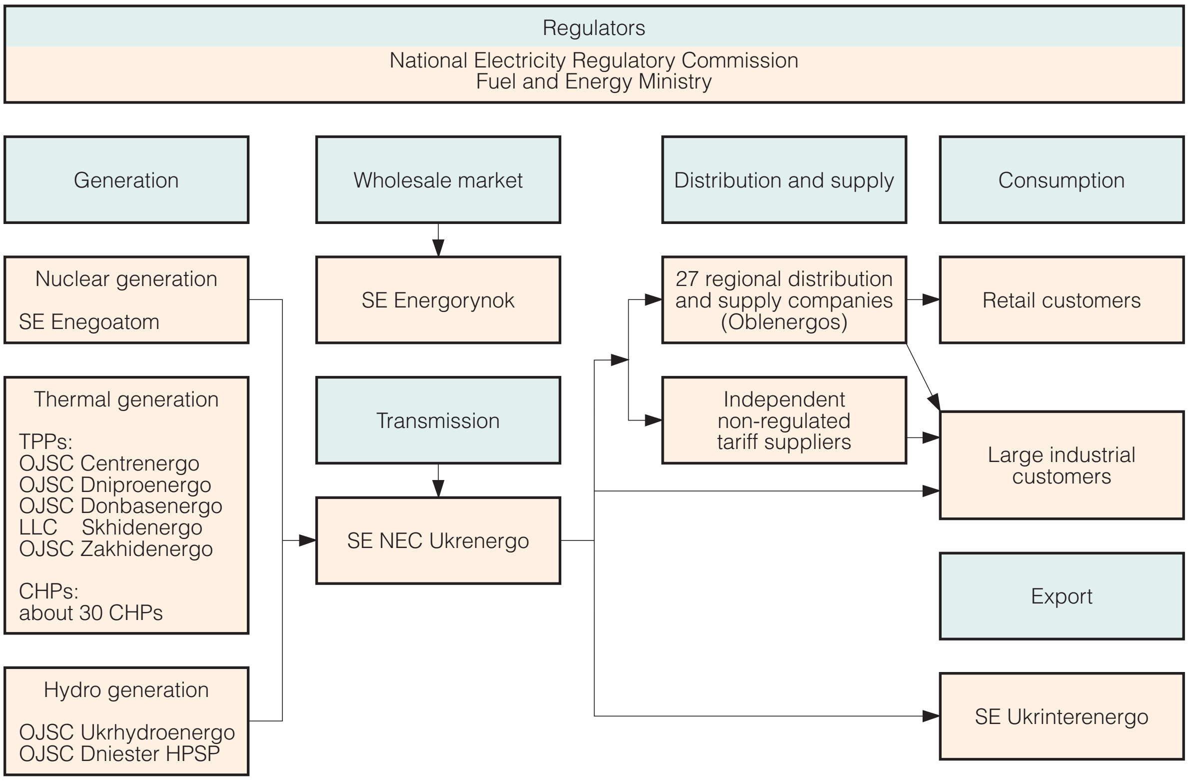


Figure 29 Structure of the electricity market in Ukraine (IMEPOWER Investment Group, 2009)

several parts according to how generation companies will sell their output-bilateral contracts, day-ahead market, balancing market, system/ancillary services market and export/import electricity auctions. This concept was approved by the government in 2002 and re-confirmed in 2007 (IMEPOWER Investment Group, 2009).

Retail electricity price incorporates the wholesale electricity price, transmission, distribution and supply tariffs. Retail tariffs for households and export are regulated and set by the NERC, while retail tariffs for other customers reflect wholesale price fluctuations. Retail tariff levels for households are less than cost recovery levels and, as such, households are subsidised by the industry for which: i) either the tariffs are higher than the cost recovery, or ii) tariffs are the same for all regions, regardless of distribution and supply cost. Figure 30 shows where main Ukranian power production and transmission assets are located.

Energorynok operates the wholesale power market and is a 100% state-owned enterprise. Energorynok has accumulated significant debt because Oblenergos have not paid in full for their power purchases. In turn, generating companies did not get paid in full, which compromised the effectiveness of the market. The Ministry of Fuel and Energy frequently intervened to allocate fuel under emergency rules. These allocations reduced the ability of generators to freely compete in producing and selling power.

The WEM members agreed that only NERC (not the Ministry of Fuel and Energy) could change the algorithm for cash allocations to power suppliers, and only in times of clearly defined technical emergencies. Nonetheless, the Ministry continues to allocate fuel to power plants, which means that for all practical purposes, there is no competitive market. This lack of a competitive market has led to uneconomic dispatch decisions, which one consultant calculated has caused an almost 13% increase in fuel consumption for fossil-fired power production nationwide (as the most efficient plants were not dispatched first (IEA, 2006)

By 2002, the WEM participants decided that the WEM concept needed reform: the single buyer

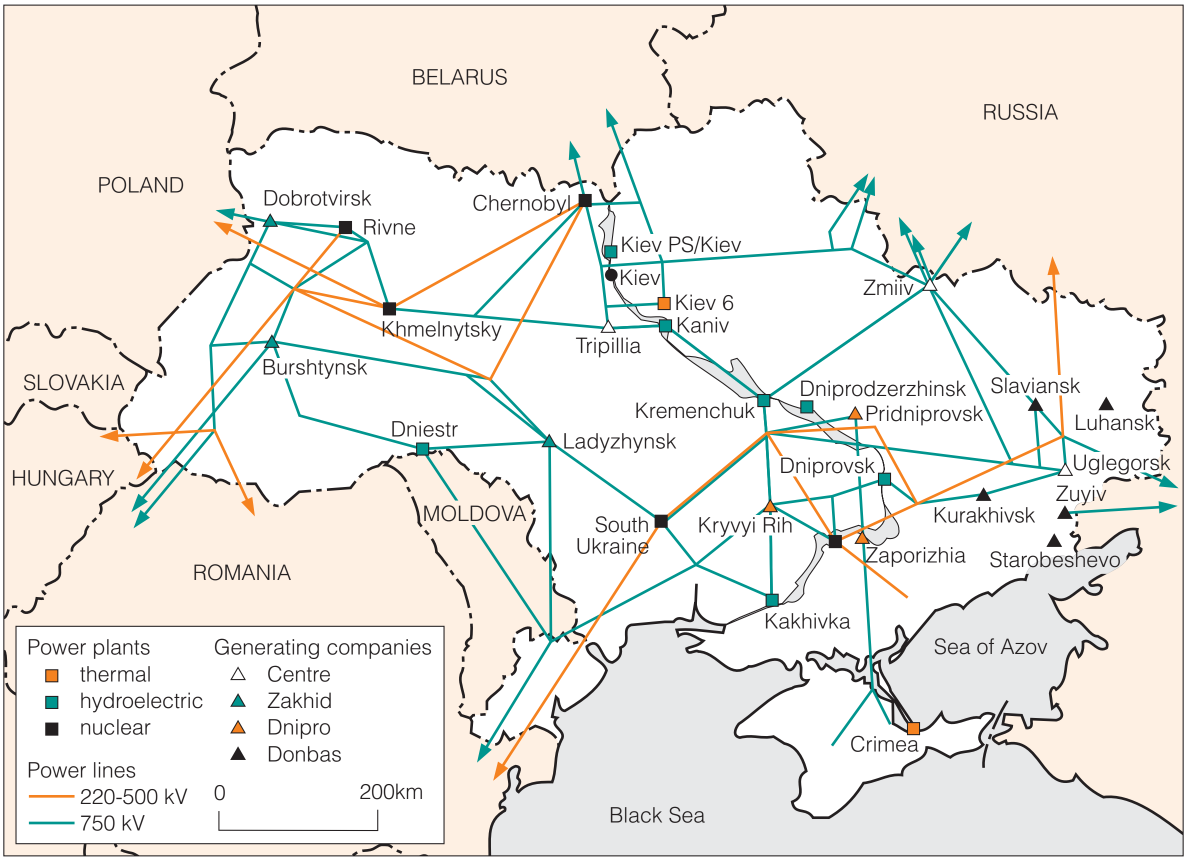


Figure 30 Ukranian power network (IEA, 2006)

system was not working in Ukraine. Non-payments burdened the power market with heavy levels of debt. Government intervention in fuel allocation and prices also reduced the market's efficiency. The risks of new non-payments or supply problems in a re-invigorated market prompted the participants to consider whether this was the best model for Ukraine. WEM participants proposed a new market concept that would involve three separate types of transactions: bilateral purchase agreements (generally long term), standard agreements through an exchange, and a residual balancing market under a revised set of market rules.

The benefits of the new WEM Concept would include simplified payments, reduced likelihood of government intervention, and revenue clarity for investment decisions. A WEM Concept Commission and working group have developed detailed proposals on a five-year transition period moving from the current single-buyer model to the bilateral model. These proposals include: addressing the accumulated debts; upgrading equipment; changing to an automated transaction system; optimising tariff methodologies and mechanisms to eliminate unfair competition; reforming tariffs to remove cross-subsidies; and preparing the legislative basis for the new power market model. All these proposals are aimed at improving the financial condition of the power sector.

The direction and objectives of the reform are encouraging but questions remain over how competitive the market will be. The structure of the market at the point of final supply implies that there is unlikely to be significant competitive pressure passed up the supply chain. Also, a significant proportion of energy sold into the market is at regulated prices.

Collections saw significant improvement after 2000 when the government began requiring payment in cash through special bank accounts instead of barter. This secured the integrity of transfers and made payments easier to track. However, the past non-payments were still a weight on the industry because many companies were effectively bankrupt. In June 2005, the Verkhovna Rada passed legislation that addressed this by developing a verified registry of the debts and levying a surcharge for debt payment on the sale of electricity. This law is now being implemented and debts between WEM participants have dropped steadily over the past years.

The ownership status of the power sector assets also has important implications for the power market. It is hard to imagine a truly competitive power market when the government has consolidated the majority of production and distribution assets into a single holding company. For now, however, the advent of the Energy Company of Ukraine has not resulted in a change in the power market structure or rules.

14.2 Power transmission network

Ukraine's electricity transmission system is organised within Ukrenergo, which owns and operate the high voltage network and cross-border lines. The length, of more than 22,000 km, of the transmission lines is divided as follows (IMEPOWER Investment Group, 2009):

- 8.4115 km of 750 kV lines
- 9.375 km of 500 kV lines
- 10.340 km of 400 kV lines
- 11.13,000 km of 330 kV lines
- 12.4170 km of 220 kV lines

Transmission losses reached a peak of 20% in 2000-01 and decreased to 15% by 2004, compared to 6% in OECD countries. The major reasons for these high losses is under-investment in replacement, maintenance and repair of ageing infrastructure, low regulated electricity tariffs and lack of metering equipment.

The *Energy Strategy to 2030* envisages significant energy efficiency improvements in the energy sector, including modernising and replacing worn-out equipment, installing automated metering systems for better accounting of energy consumption, and reducing transmission losses to 9–12%.

Ukrenergo is independent of the generation and distribution companies, but collaborates closely with the market operator, Energorynok, of which it is a member, but the two are separate entities with distinct budgets. Ukrenergo operates the central dispatch centre in Kiev and is also responsible for maintaining and upgrading the high voltage lines as necessary. NERC regulates the transmission tariff.

14.3 Local power distribution

The power distribution in Ukraine is performed by 27 regional distribution companies (Oblenergos). Two of them are in Kiev and Sevastopol, and one in the autonomous republic of Crimea. Among these 27 regional distribution companies, there is a mix of state and private ownership. Some distribution companies also own small cogeneration assets, mainly to produce heat for district heating. Kyivenergo is unique in that it is a vertically-integrated joint stock utility, which both generates and distributes power and heat to the capital, Kiev. In general, the distribution companies buy power from Energorynok and sell it to all but the largest consumers in their service territory. Thus, they each have a monopoly on electricity supply to end users. Oblenergos distribute and supply electricity to retail customers at regulated tariffs. There are also independent suppliers that hold licences for electricity supply at non-regulated tariffs. Most of them are industrial customers that purchase electricity for their own needs and are allowed to use Oblenergos' networks for distribution.

The National Electricity Regulatory Commission (NERC) sets distribution tariffs on a cost-plus basis. It also reviews the investment proposals of each Oblenergo. Since September 2005, while NERC still reviews and approves costs regionally, it also sets a unified distribution tariff for the whole country.

Local authorities also play an important role in that they determine whether customers in arrears are disconnected. In the past, they have often tried to delay disconnections for social reasons, which contributed to growing debts in the electricity sector. Collection levels have significantly improved in recent years.

Overall, the private distribution companies have a better track record than the state-owned ones with reducing losses from electric power lines. Private companies have also invested more on average. However, the government plans to modernise and replace worn-out equipment, and install automated metering systems for better accounting of energy consumption.

In addition to the distribution companies, there are also several hundred supply and service companies that operate the last kilometre or so of electric wires going to households and other small consumers.

14.4 Power generating capacity in Ukraine

Most of the electricity generation is provided by the thermal and nuclear power plants. There are five thermal power generation companies – Centrenergo, Donbassenergo, Dnieproenergo, Skhidenergo and Zahidenergo – comprising 14 thermal power plants with total installed capacity of 27.3 GW. Four nuclear power plants, with the total installed capacity of 13.8 GW operate as part of SE Energoatom, and two hydropower generation companies – Ukrhydroenergo and Dniester HPSP – comprise cascades of hydropower plants on Dnieper and Dniester rivers with total installed capacity of 4.6 GW (IMEPOWER Investment Group, 2009).

There are also small heat and power plants, with a combined capacity of 1.7 GW, some operated by local power distribution companies and other institutions, and some separate enterprises. There are small electricity producers, including small hydro and wind, but their share of total energy production is insignificant, at about 0.2 GW.

In 2009, total installed capacity amounted to about 52 GW with around 66% being installed in thermal power plants, 26% in nuclear power plants and 9% in hydropower plants. Nuclear power accounts for 46–50% of the total electricity production, and thermal power plants for 40–44%, with the remaining provided by hydro and renewables.

The Ukranian thermal power stations have a very low load factor (28% in 2004 compared to 70% in 1990) (IEA, 2006). Most thermal power plants in Ukraine have already exceeded their useful life. In 2004, the average age of large thermal power plants was 36 years; the average age of a cogeneration plant was 42 years.

The *Energy Strategy to 2030* envisages modernisation and replacement of worn-out power plant equipment, expanding use of new technologies for electricity generation and the introduction of combined heat and power generation, which offers efficiencies of 80–90%.

Ukraine has significant excess power capacity. Private investment analysts estimate that the current capacity will be sufficient to meet demand for the next decade. Because of this, and low power prices, relatively little investment has been directed towards new capacity at Ukranian utilities in the past two decades. Several projects that have proceeded were mainly with public subsidies and sponsorship (such as the two 1000 MW nuclear reactors, Khmelnytsky-2 and Rivne-4).

Some of the installed thermal power capacity has lost functionality because equipment has been worn or damaged through lack of use. Some plants have been cannibalised to repair others. The World Bank estimates that about one quarter of installed thermal capacity at utilities is, in fact, not available even though the Ukranian Government and generating companies continue to list the capacity.

Most of Ukraine's thermal power plants are power-only (also known as condensing power plants). Only three of the 17 major power plants are combined heat and power plants, with 1670 MW of installed capacity. Regional power distribution companies have additional combined heat and power capacity of 4100 MW. Thus, only 17% of Ukraine's thermal power capacity is from combined heat and power plants, despite Ukraine's substantial demand for district heating. While most of Ukraine's power capacity is owned by generation and distribution utilities, industrial enterprises own at least 2600 MW of capacity, primarily in condensing power plants.

14.5 Electricity exports and interconnections

Ukraine is a net exporter of electricity, selling approximately 3500 GWh of power abroad in 2005. Ukraine would like to increase these exports and become a more important transit route for electricity from Russia to Central Europe. Significantly increasing exports requires improving the reliability of the grid and stabilising system frequency. Currently, only the so-called 'Burshtyn Island' of power plants in Western Ukraine is connected to the Union for the Co-ordination of Transmission of Electricity (UCTE) European grid. Ukraine re-synchronised its grid with Russia's in 2001, though exports to Russia dropped significantly after NERC decided to raise the export tariffs in mid-2005. The Ukrainian system also began working in parallel with the Belarusian system in 2006.

Until 2006, Ukrinterenergo was the sole authorised power exporter from Ukraine, buying power from Energorynok and also arranging electricity transfer through Ukraine. NERC regulated export prices and Ukrinterenergo's average revenue per kWh was significantly lower than the average price of power across the border in Hungary and Slovakia, which indicates that Ukraine was losing money. Concerns about the loss of export revenue prompted the Ministry of Fuel and Energy to change the export regime in early 2006. The government allowed multiple companies to compete in exporting power and the Ministry audited existing export contracts. Following these changes, total reported income from power exports more than doubled, despite a drop in export volumes.

Ukraine's high-voltage power grid is connected to the power systems of neighbouring countries, including Russia, Moldova, Belarus, Poland, Slovakia, Hungary and Romania. This makes it part of the large regional integrated power system (IPS/UPS) of the Commonwealth of Independent States (CIS) and the Baltic countries, as well as part of the trans-European electricity grid. However, integration exists only at a technical level; there is no common electricity market. In 2002, the Electricity Power Council of the CIS and Baltic States requested the Union for Co-ordination of Transmission of Electricity (UCTE) to consider a synchronous interconnection of the IPS/UPS power systems with UCTE. In April 2005, the UCTE-Consortium and the IPS/UPS companies signed a Co-operation Agreement in Brussels, which defines the overall legal framework for co-operation. Synchronising IPS/UPS with UCTE will be challenging because the two systems have different historical, technical, organisational and legal backgrounds. Western European power companies support interconnection but emphasise that CIS producers must meet EU nuclear safety and environmental standards prior to full-grid interconnection. The European Commission is providing Ukraine with technical assistance to facilitate integration with UCTE.

14.6 Existing coal-fired capacity

Most thermal power plants in Ukraine are capable of operating on multiple fuels – coal, oil and natural gas. While the majority of them are normally powered by a specific fuel at a time, some of them operate on several fuels at the same time, as all of them are multi-unit plant (*see* Table 9).

It should be remembered that stable combustion of low reactive coals (such as anthracite and semi-anthracite) needs the use of a supplementary fuel such as expensive imported natural gas, or

Table 9 Coal-fired power plants in Ukraine (IEA CCC, 2010)

	Capacity, MWe	No of units	Installed capacity, MW	Boiler type	Boiler steam production, t/h	Start-up	Fuel type
Starobeshevo	175 210	9 1	1785	TP-100 CFB-210	640 670	1961-67 2004	A A
Kurakhovskaya	210 200	6 1	1460	TP-109 TP-109	640 640	1972-75	high ash bituminous coal rejects
Luganskaya	175	8	1400	TP-100	640	1961-69	A
Zuevskaya	300	4	1200	TPP-312A	950	1982-88	high ash bituminous coal rejects
Slavyanskaya	720	1	720	TPP-200-1	2550	1971	A
Zaporozhskaya	300 800	4 3	3600	TPP-312A TGMP-204	950 2550	1972-73 1975-77	B gas/oil
Krivorozh-skaya	282 282	6 4	2820	TPP-210A P-50	475 x 2 475 x 2	1965-73	L
Pridneprov-skaya	285 285 150	2 2 4	1740	TPP-210 TPP-110 TP-90	475 x 2 950 500	1963-66 1959-61	A, L A, L A, L
Burshtynskaya	195 185	8 4	2300	TP-100A TP-100	640 640	1965-69	B
Ladyzhynskaya	300	6	1800	TPP-312	950	1970-71	B
Dobrotvor-skaya	150	2	300	TP-92	500	1963-64	B
Uglegorskaya	300 800	4 3	3600	TPP-312A TGMP-204	950 2550	1972-73 1975-77	B gas/oil
Zmievskaya	275 175	4 6	2150	TPP-210A TP-100	475 x 2 640	1967-69 1960-64	A, L A, L
Tripolskaya	300 300	4 2	1800	TPP-210A TGMP-314	475 x 2 950	1969-70 1971-72	A gas/oil
Kyivskaya CHP-6	250	3	750	TGMP-344A	950	1982-84, 2004	gas/oil
Kyivskaya CHP-5	250	2	500	TGMP-314A	950	1974-76	gas/oil
Kharkovskaya CHP-5	250	1	250	TGMP-344A	950	1990	gas/oil
Total	–	104	28175	–	–	–	–

A – anthracite; L – lean coal (low volatile coal); B – bituminous coal (high volatile coal); CHP – combined heat & power plant

fuel oil, to provide stable operation of wet-bottom boilers. Usually, the natural gas added for this purpose, accounts for about 3% of the total heat input.

15 Coal-fired power and cleaner coal technologies

According to Ukrainian officials (Chernyavski and others, 2010), Ukraine has suffered more from the recent economic and financial world crisis than generally believed abroad. While the interest in new, state-of-the-art supercritical pulverised coal plants exists, the economic/financial means to build such plants are not available, and this situation is expected to last for a number of years.

In the late 2000s a project for a 600 MW supercritical plant, in co-operation with Mitsubishi of Japan, was considered at the Burshtynskaya site. A feasibility study was prepared and credit from Japan was approved. However, following the presidential elections of 2009, the project was frozen. The project also ran into technical difficulties due to Mitsubishi's lack of experience in burning anthracite. While Japan burns bituminous coal imported from Australia, with 10% ash content, the anthracite available in Ukraine has over 20% ash content.

One other issue under consideration is that the supercritical boilers are normally used for base load and are in excess of 600 MW. In Ukraine, where much of the base load is provided by nuclear power, most TPPs are used for load levelling, for which 200–300 MW is considered optimal, as they operate at a low utilisation factor. Several large TPPs are out of action because operating at low utilisation factors is uneconomical and greatly reduces overall efficiency. New large power plants are not currently considered a necessity in Ukraine (Chernyavski and others, 2010).

While all new plants in Ukraine will be of the supercritical type, using fluidised bed, none is currently being considered. The only projects under way at this time are refurbishment of existing plants and the implementation of the industry privatisation plans, which is expected to last into 2012. Once the new owners are established, consideration will be given to building new plants. However, at this time no one wants to take this risk, while the industry goes through a period of transition. While policies and documents to improve the state of the coal and power industry are being prepared, it is not likely that any action will be taken until the country balances its budget and no predictions can be made on this.

The only technology considered in Ukraine on a limited basis, leading to cleaner coal burning, is the fluidised bed combustion technology.

15.1 Circulating fluidised bed technology

Ukraine was the first country in CIS to implement industrial-scale use of circulating fluidised bed (CFB) technology for coal combustion at a 210 MW boiler unit, within the framework of the project on rehabilitation of aged boilers, with the intention of introducing clean coal technologies. The boiler unit No 4 of the Starobeshevo TPP (located near the city of Donetsk) was used. This TPP is one of the plants owned by the Donbassenergo energy company. The aim of the project was to implement and demonstrate the potential of CFB technology to burn high ash (ar $\leqslant$50%) coal rejects (resulting from anthracite cleaning) efficiently while meeting strong environmental requirements (not required in Ukraine, but required in the EU).

The work at the site was based on the recommendations in the 'Technical conclusions on modernisation of Starobeshevo boiler unit No 4' of April 1997. An open international tender was initiated in 1997-98 consisting of two phases (technical and commercial). Within the framework of the tender the scope of the work was divided into three lots:

- Lot No 1 'Boiler'. The aged existing pulverised coal-fired boiler (of TP-100 type, having steam capacity of 640 t/h) was replaced by a new, atmospheric CFB boiler (having upgraded steam capacity of 670 t/h) capable of firing high ash coal rejects (schlamm);

- Lot 2 'Dryer'. A schlamm dryer with capacity of 220 t/h (on dried product) was built, including the system of preparation and transportation of wet schlamm and dried product, manufacturing new side discharge tipplers to unload wet schlamm and local transport system;
- Lot 3 'Dust collector'. A new electrostatic precipitator was installed, for the deep cleaning of flue gas from the CFB boiler.

The contract for Lot 1, 'Boiler' and Lot 2 'Dryer', was awarded to Lurgi Lentjes AG (Germany). The contract for Lot 3, 'Dust collector' was awarded to Alstom Power Environmental Systems AB (Sweden). All three 'turn-key' contracts were signed in 2000. The funding for the project was provided by the European Bank for Reconstruction and Development (about 90% of total finance allocation). The remainder was provided by Donbassenergo.

The civil work (including old boiler removal and the installation of the new one) was completed in July 2005. The commissioning works were carried out by experts of sub-contractor SES, Tlmache, Slovakia. However, at the end of July 2005 an accident resulted in severe damage to the convective pass of the boiler, and the work was stopped. The repair work lasted until the end of 2007 and, at the beginning of 2008, the first 'hot' runs of the boiler took place, followed by the hydraulic test runs in April-May. Despite stable operation at lower load, of about 130–160 MWe (design load was 215 MWe), some problems in the boiler operation were found during commissioning at higher load.

Table 10 Design performance of the CFB boiler, Unit No 4 of Starobeshevo TPP (Chernyavski and others, 2010)

Parameter	Value
Boiler steam capacity, t/h	670
Live steam at the inlet of HPC (high pressure cylinder of turbine):	
Pressure, MPa	12,75
Temperature, °C	540
Reheat steam (inlet):	
Temperature, °C	540
Feed water:	
Pressure, MPa	18,0
Temperature, °C	244
Range of load change (L) of boiler, % (of nominal)	50–100 (40)
Boiler efficiency, %:	
At L = 100%	90,5
At L = 50%	900
Fuel consumption, t/h:	
Anthracite cumulative	95,390
(or) Dried schlamm	159,233

During 2009-10, modifications were made to the installation which improved the stability of solid particle circulation and external fluidised bed heat exchangers operation. The commissioning work is presently approaching completion. Recent test runs were promising in terms of meeting the emission requirements: NOx – less than 200 mg/m^3, SO_2 – less than 200 mg/m^3, particulates – less than 30 mg/m^3 at a load of about 200 MW. The final assessment of boiler performance will be completed shortly. Table 10 lists the fuel parameters of the CFB boiler.

The CFB boiler furnace is of pant-leg design having four cyclones, four seal pots, four external fluidised bed heat exchangers (FBHE) each divided into two sections. There are eight heating surface sections located in FBHEs: four evaporating surfaces (one in each FBHE), two reheat ones and two superheat ones. The operating temperature in the furnace is about 880ºC and the linear gas velocity is about 6 m/s. To cool down the bottom ash, two fluidised bed ash coolers are used. To provide in-furnace capture of SOx, the feed of limestone is used. The old, but modernised steam turbine (K-200-130) is used at this unit. The new CFB boiler was installed on the site of the removed 200 MWe TP-100 coal-fired boiler unit.

15.2 Carbon capture and storage (CCS)

CCS plants are not part of any present or near future plans in Ukraine. The economics of this process considered beyond any present or near future justification. Should funds become available for investment in the power generation industry, the general view is that they would be better used in refurbishing present units rather than in CCS-related projects.

The Ukrainian power plants have, on average, an efficiency which is about 7% less than the average EU efficiency. Therefore, the most important target for coal-fired power plants is to improve that efficiency, and this would be the primary target for any future investment.

15.3 Underground coal gasification

At the moment, underground coal gasification (UCG) is not considered a high priority in Ukraine. As well as the economic aspect, there is also a very serious safety concern, that the geology of the sites would allow the upward infiltration of poisonous carbon oxide (CO), which will eventually break to the surface causing problems.

An example is cited in which, an attempt to use UCG in Donbass, under the village of Golovka, in 1955, resulted in CO surfacing and poisoning 12 villages and killing thousands of people. A similar negative experience has also been in Uzbekistan. UCG is often compared with underground nuclear bomb testing in terms of environmental and health damage. There is awareness that the process has been successful elsewhere, such as in Illinois and Australia, where the geological structure of the site did not permit the upward infiltration of gas. However, Ukraine is not prepared to take any action that could potentially harm the environment and people. This is particularly true in Western Ukraine which has a pristine natural environment. Shale gas mining is being considered as it does not result in the harmful CO emissions.

15.4 Emissions control at Ukranian coal-fired stations

Most of the boilers are outdated, both physically and technologically, as they have been in operation for more than 25–30 years. Also, the electricity-producing Ukrainian TPPs have not been provided with equipment for sulphur and nitrogen oxide removal from the flue gas.

15.5 Coalbed/coal mine methane

Removing methane from coalbeds is necessary in order to:
- prevent fatal explosions within mines;
- use recovered methane as a cleaner energy source either as a substitute for natural gas or burnt on-site for heat or power generation;
- help reduce GHG emissions, and possibly help Ukraine, to obtain carbon credits in the future.

Ukraine ranks fourth in the world for coalbed methane resources, with an estimated 11–12 trillion m^3. According to Rousaki (1999), this resource is only 1.4 trillion m^3, which in itself is a very large amount, out of which 10% is believed to be recoverable. The Ukrainian Government estimates that up to 3 billion m^3 of methane escapes from coalbeds every year and only a fraction of this gas is collected.

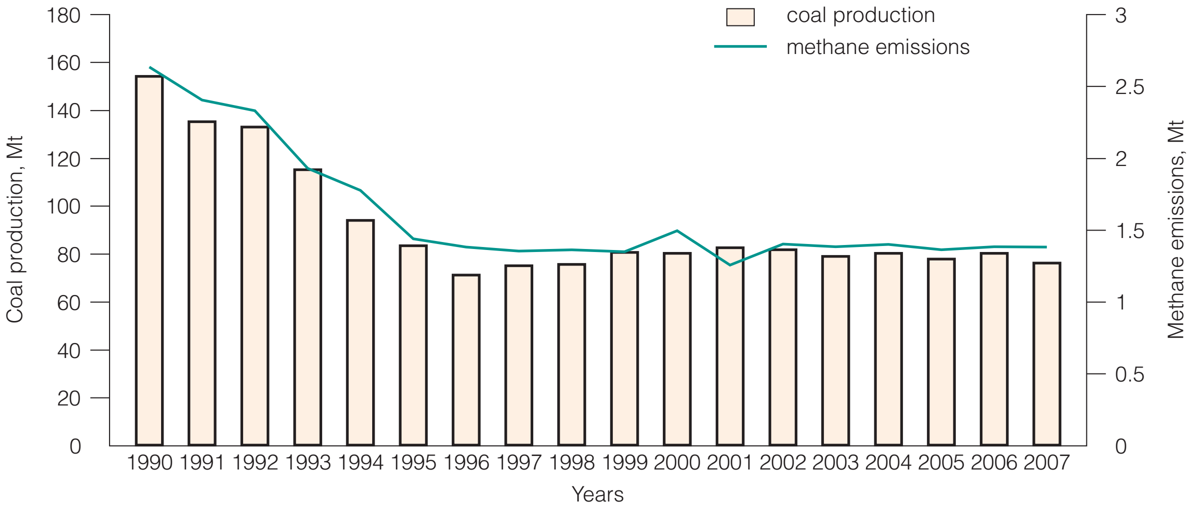


Figure 31 Ukranian coal production and methane emissions (Meredydd, 2009)

The Methane to Markets International CMM Projects Database identifies nine CMM recovery projects in Ukraine, eight of which are in place in active, underground mines in the Donbass and one in the Lugansk basin. The methane is used for boiler fuel in four of these projects, for combined heat and power in two, for industrial use in one, and for power generation in the remaining two (CMM Global Overview, 2009). Four projects are currently proposed to expand activities, and improve CMM capture and utilisation (CMM Global Overview, 2009).

Ukraine is considered to be one of the world's largest emitters of methane from coal mining activities (US EPA, 2006), even though emissions have been significantly reduced by mine closures and reduced coal production. It is estimated that in 2004, 1221 million m^3 of CMM was emitted by underground coal mines, 357 million m^3 of which was drained by degasification systems and 179 million m^3 of which was utilised (CMM Global Overview, 2009). At that time, 42 mines employed degasification. The low percentage of capture can be attributed to numerous factors, including poor degasification system maintenance and lack of investment in new degasification infrastructure.

Most of the attention to potential CMM development has focused on the Donbass due to its vast coal and methane reserves, large number of coal mines, high rank coal deposits, and the depth of the mines, which are often in excess of 600 m (2000 feet). Numerous projects have been conceptualised for development in Ukraine, including several for which detailed business plans were drafted. None of those have come to fruition and only a small number are being actively considered. However, the continuing evolution of new mining laws, tax benefits, privatisation efforts and private domestic and multinational collaborative efforts offer promise for increased implementation of CMM and coalbed methane (CBM) projects (CMM Global Overview, 2009).

In 2004, the Ukrainian Government held talks with two companies (one American and one Japanese), both of which were interested in investing in coalbed methane programmes in Ukraine. Pilot projects are already under way. The Krasnodonvuhillya, the largest coal company in Ukraine, completed a project to collect coalbed methane at one of its mines, primarily for use in on-site heating and for power generation. The project cost is US$350,000 and will pay for itself in less than one year. The European Union's TACIS programme has funded a feasibility study for a US$3 million project to improve mine safety, which includes €750,000 for methane evacuation and recovery. The USA, through its Environmental Protection Agency and Department of Labor, has funded extensive work on coalbed methane in Ukraine.

In August 2005, the US Trade and Development Agency (US TDA) awarded a US$585,570 grant to the Donetsk Regional Administration for conducting a feasibility study on commercial development of CBM and CMM in the Donbass region. The project aimed to increase the domestic supply of natural gas, increase mine safety, and improve local environmental quality. The analysis focused on developing the best technical and economic approach for methane drainage at mines, evaluating the technical and economic merits of producing CMM, and assessing the most likely markets and infrastructure required to utilise CMM and CBM (US TDA, 2007).

Mine operations affect the environment in several ways. One of the most problematic issues is that they release methane into the atmosphere, a powerful greenhouse gas almost 25 times more powerful than CO_2. Ukraine uses mining techniques that tend to result in greater release of methane from coal seams, which is typically not captured as is done in many other coal-mining countries. The US Environmental Protection Agency has published an inventory of coal mine methane (CMM) in Ukraine. Ukrainian coal mine methane emissions were 2.6 Mt in 1990 and dropped to 1.2 Mt by 2003, primarily due to the drop in coal production.

A second issue is that, as coal is mined, significant waste (or tailings) accumulate. These waste piles can scar the landscape and even ignite if not properly treated. In OECD countries, mining companies usually must fund extensive restoration works to cover the tailing piles with earth. Such practice is rare in Ukraine, even though mines occupy 22,500 hectares of land.

Hundreds of mines have been closed and abandoned in Ukraine since the inception of its coal industry. Between 1990 and 2004, 119 underground mines were abandoned or were in the process of closure in a major effort by the state to increase mine efficiency, improve mine safety, and achieve mine profitability. According to some estimates, the amount of methane released by abandoned mines could be as high as 23,000 t/y per km of excavated mine. In Ukraine, 77% of abandoned mines are considered gassy (assuming the same percentage as active operating mines). The number of projects at abandoned coal mines is unknown but thought to be zero at present, although several mines are being evaluated for abandoned mine methane potential.

Ukraine's CBM resource is approximately 1.7 trillion m^3 (CMM Global Overview, 2009). The US TDA grant awarded to the Donetsk Regional Administration in 2005 aimed to assess the most likely markets and infrastructure required to utilise virgin CBM (US TDA, 2007). In 1999, Ukraine's Cabinet of Ministers adopted an Energy Programme which sets a CBM use goal of 8 billion m^3 by 2010 (CMM Global Overview, 2009). Ukraine has very limited R&D resources available for pursuing CMM or CBM research, namely the lack of technology for and experience in applying hydro-fracturing to stimulate CBM production.

Ukraine has signed and ratified both the UNFCCC and the Kyoto Protocol (*see* Table 11). As an Annex I country, Ukraine is eligible to host Joint Implementation (JI) projects.

Nine JI projects were approved by Ukraine, mostly for the installation of CHP or new heat boilers. They were all submitted for approval in 2006 or later. As examples, projects at Zasyadko and Komsomolets Donbassa mines received UNFCCC approval in August 2008 (1.2 and 0.3 $MtCO_2$/y, Track 2), Sukhodilska Skhidna received approval in 2009 (0.06 $MtCO_2$/y, Track 1) and Zasyadko Mine: 24 CHP units with total capacity of 73 MW for on-site consumption and sale to network.

Table 11 Ukraine's Climate Change Mitigation Commitment

Agreement	Signature	Ratification
UNFCCC	11 June, 1992	13 May, 1997
Kyoto Protocol	15 March, 1999	12 April, 2004

According to the Kyoto Protocol, Ukraine must stabilise greenhouse gas emissions at the 1990 level of 854.1 $MtCO_2$-e. Emission reductions since 1990 (due largely to coal mine closures) have resulted in current estimated emissions of 565 $MtCO_2$-e (CMM Global Overview, 2009).

While methane in coal is owned by the state, it is assigned to companies, mines, and individuals. CBM/CMM development is subject to the approval of the Coal Industry Ministry (CMM Global Overview, 2009). Most CMM that is not currently flared is used for basic applications such as boiler firing and mine air heating. There is significant potential, however, for CMM to fuel power generation in gas or dual-fuel power plants; to supplement supplies for other residential, commercial and industrial uses; or to be converted into transport fuel. Ukraine currently imports 78% of its natural gas requirement. The potential markets for natural gas and CMM in Ukraine and the surrounding region are significant, especially as prices for natural gas increase. The principal barrier to expanding the use of CMM is poor market access, including the lack of modern infrastructure to gather and transport methane produced by CMM processes to internal end use markets and to existing international pipelines that serve foreign markets (CCM Global Overview, 2009).

State programmes to advance CMM production do not appear to include direct government funding but rely instead on private investment. In 1998, a law was passed establishing Free Economic Zone status to the Donetsk Region, which provides for various tax incentives to attract investment. Legislation passed by the Rada (Ukrainian Parliament) exempted foreign-manufactured materials and equipment used in CMM development from Ukraine's value added tax in 2008. Additional tax exemptions, credits, and deferrals may still be needed to stimulate private investment in CMM development.

The Green Tariff Law, adopted in April 2009, to provide a guaranteed feed-in tariff for renewable energies, includes CMM for 20 years. The rate of about 11.5 cents, is indexed to the Euro and is about four times higher than the average wholesale rate. In fact, it may be so favourable that projects using it cannot claim additionality for carbon credits.

The law is the first step to clarify legally what CMM is and how to promote it. The government should issue CMM leases with the coal mining leases to mine operators, and allow coal mines to sell their rights to the CMM, but not require them to do so. It would also require mines to limit CMM emissions according to norms, or be fined for non-compliance, which is a very controversial provision.

On 22 February 2006, the Ukrainian Cabinet officially approved a set of JI procedures formally outlining the government's procedures for consideration, approval, and implementation for domestic companies such as coal mines to carry out JI projects under Article 6 of the Kyoto Protocol; several projects have already been submitted under these guidelines.

Twenty-nine mines have been identified as primary opportunities for CBM/CMM development in Ukraine. These mines have been profiled in great detail by the Partnership for Energy and Environmental Reform in its Handbook on Opportunities for Production and Investment in the Donetsk Basin. Table 12 summarises mine data of the major Donetsk Basin Mines considered to have the best CMM potential (CMM Global Overview, 2009).

Table 12 Major Donetsk Basin mines with significant CMM devekopment potential (CMM Global Overview, 2009)

	Methane liberated by mining, million m³/y			Methane utilised, million m³/y	Methane content in captured gas, %	Specific methane emissions, m³/t	Coal product-ion, kt/y
	Ventilat-ion	Degasifi-cation	Total emissions				
Almaznaya	10.93	0.21	11.14	0.00	11–12	20.50	543.20
Bazhanova	22.92	13.25	36.17	9.88	50.0	31.08	1136.80
Belitskaya	3.08	2.05	5.13	0.00	7.8	22.53	227.70
Belozerskaya	7.99	1.79	9.78	0.00	22.0	24.76	395.50
Dobropolskaya	9.20	0.79	9.99	0.00	3.2	8.23	1213.00
Faschevskaya	11.97	1.55	13.52	0.00	12.0	47.55	284.90
Glubokaya	33.40	7.90	41.30	5.41	42.0	59.66	692.60
Gorskaya	8.24	0.00	8.24	0.00	n/a	32.58	252.90
Holodnaya Balka	29.40	15.70	45.10	12.62	66.0	74.08	608.80
Kalinin	44.57	2.94	47.51	0.00	22.0	143.66	330.70
Kirov	8.41	7.31	15.72	0.00	33.0	16.40	958.10
Komsomolets Donbassa	116.81	11.56	128.37	4.20	30.0	93.43	1373.90
Krasnorarmeyskaya-Zapadnaya	78.73	12.40	91.13	0.00	30–38	25.0	3137.50
Kransnolymanskaya	40.21	21.56	61.77	0.00	19.5	18.93	3263.75
Molodogvardeyskaya	10.38	4.23	14.61	0.00	19.6	27.28	535.60
Oktyabrsky Rudnik	12.30	1.26	13.56	0.00	6.0	40.20	337.22
Rassvet	36.11	5.26	41.37	0.00	20.0	116.44	355.30
Samsonovskaya-Zapadnaya	n/a	n/a	n/a	n/a		n/a	
Skochinsky	34.60	3.99	38.59	0.00	38.0	49.15	784.70
Stachanova	35.45	16.78	52.23	0.00	42.0	33.51	1558.50
Suhodolskaya-Vostochnaya	52.50	7.10	59.60	0.00	15.0	286.50	208.00
Vinnitskaya	8.80	3.20	12.00	0.00	22.0	37.24	322.20
Yasinovskaya-Glubokaya	19.88	1.84	21.72	0.00	18.0	65.46	331.80
Yuzhno-Donbasskaya No 1	15.38	1.89	17.27	0.00	13.5	15.24	1133.40
Yuzhno-Donbasskaya No 3	15.27	2.89	18.16	0.00	25.0	14.83	1244.90
Zasyadko	79.10	30.60	109.70	12.36	30.0	36.20	3027.00
Zhdanovskaya	12.98	2.26	15.24	0.00	17.2	30.35	502.10
Zuyevskaya	33.00	3.10	36.10	0.00	30.5	99.60	362.50

16 Co-operation agreements with foreign countries

In September 2010, the European Commission approved and signed the Protocol on the Accession of Ukraine to the European Energy Community (EEC). The Community was established in 2006 and the member states commit themselves to liberalising their energy markets and to implementing key European legal acts in the fields of electricity, gas, environment and renewable energy.

By joining the EEC, 'Ukraine will have access to a pan-European energy market, based on the principles of solidarity and transparency' (Günther Oettinger, EU Commissioner for Energy).

17 Conclusions

Ukraine now stands at a threshold as it confronts both higher energy prices and changes in government. According to IEA Ukraine Energy Policy Review 2006, the three key priority areas where the government could reduce its energy dependency and improve policy are: energy efficiency, cost-reflective pricing and transparency.

Ukraine has one of the most energy-intensive economies in the industrialised world, thus energy efficiency represents Ukraine's single best opportunity to improve energy security. Improved efficiency is essential for Ukraine's growth and development, and for protecting its environment. Ukraine can considerably improve its energy efficiency both through targeted policies and through market-oriented energy pricing.

Today, most energy prices only cover operational costs, which has created a pressing need to invest in upgrading the infrastructure. Cost-reflective prices are necessary to attract adequate investment and to provide incentives for much-needed reform across many areas of the energy sector. Ukraine could strengthen its energy policy by improving the transparency of energy data and clarifying market rules.

Ukrainian energy policy is driven by the country's strong desire to improve energy security and reduce natural gas imports. The majority of its energy supply comes from or through Russia. Since it gained political independence in 1991, Ukraine has made some progress in reducing its dependence on energy imports, primarily by improving energy efficiency. At present, Ukrainian energy policy remains mainly focused on energy production, thus there is much opportunity to achieve greater gains through energy efficiency. However, domestic energy prices have typically been well below international levels; this limits investment in infrastructure, as well as incentives for efficiency.

In addition, the government maintains a strong role in owning and regulating energy assets; this is often done in a way which minimises competition and, hence, reduces efficiency. Ukraine must contend with tremendous change in the international energy scene as energy prices are growing globally. The rate of price increases is particularly fast in Ukraine because the country must also adjust to new terms from Russia. Today, most of Ukraine's oil and gas – and all of its nuclear fuel – comes from or through Russia.

Because of its geographic position, Ukraine does not have many affordable and accessible supply alternatives. Because of low energy prices, the energy sector has had little or no money for investment, which has ultimately had a negative effect on reliability, efficiency and long-term, economic sustainability.

To attract investment, Ukraine must allow investors to cover their costs and make a reasonable return. Today, Ukraine uses energy about three times less efficiently than EU countries on average; even neighbouring Russia and Belarus are less energy intensive. The government's own projections for energy efficiency and expanded domestic energy supply show that energy efficiency is less expensive and has a bigger impact on reducing imports than projected new domestic supply. Ukraine put an energy-efficiency policy in place in 1994. However, insufficient funding was allocated to this goal so the policy could not be fully implemented. In 2005, a government decree closed the State Committee for Energy Conservation. This Committee was responsible for developing and implementing energy-efficiency programmes nationwide; it also worked to encourage energy efficiency through standards, public information campaigns and mechanisms to promote financing. Recognising the void left by the closure of the State Committee for Energy Conservation, the government has now opened a new National Agency on Efficient Energy Use. Investment in energy efficiency is growing, reflecting the economic benefits of such investments. Ukraine also has many energy-efficiency experts in the private sector and academia, providing needed intellectual capacity to develop effective strategies.

European Commission's approval of Ukraine's Accession to the European Energy Community in 2010, underlies the importance of Ukraine to the European energy markets. According to Günther Oettinger, EU Commissioner for Energy, 'for the Community, Ukraine is an important new member and security of supply further improved'.

18 References

BP (2010) *Statistical review of world energy.* London, UK, BP p.l.c., 44 pp (June 2010)
Bown J (2003) *Ukraine's oil and gas sector – an emerging opportunity.* The Deane Group (Ukraine), Kiev, Ukraine, 12 pp (2003). Available from: http://www.paneurasian.com/Ukraine_update.pdf
Chernyavski N, Volchyn I, Topal A (2010) Kiev, Ukraine, Coal Energy Technology Institute (CETI). *Personal Communication (Nov 2010)*. Reference book of coal quality, mining values and coal enrichment in 2009 *Ukranian State Institute of Coal Enrichment*
CIA (2004) *World fact book/Ukraine.* Washington, DC, USA, Central Intelligence Agency (August 2004). Available from: CIA - The World Factbook.mht
CIA (2010) *World fact book/Ukraine.* Washington, DC, USA, Central Intelligence Agency (August 2010). Available from: CIA - The World Factbook.mht
CMM Global Overview (2009) *Methane to markets, chapter 34 Ukraine*. pp 270-280 (2009). Available from: http://www.globalmethane.org/documents/toolsres_coal_overview_ch34.pdf
EIA (2004) *Independent Statistics and Analysis-Ukraine*. Department of Energy, Washington, DC, USA, 1 pp (2004)
EIA (2007) *Independent Statistics and Analysis-Ukraine*. Department of Energy, Washington, DC, USA, 1 pp (2007). Available from: http://www.eia.doe.gov/emeu/cabs/Ukraine/Background.html
EBRD (2010) *Renewable Development Initiative-Ukraine*. London, UK, pp 3 (2010). Available from: http://www.ebrdrenewables.com/sites/renew/countries/Ukraine/default.aspx
European Bank for Reconstruction and Development (EBRD) (2010) *Country profile-Ukraine* (2010). London, UK. Availabe from: http://ws2-23.myloadspring.com/sites/renew/countries/ukraine/profile.aspx
Encyclopedia of Earth (2010) *Energy profile of Ukraine*. Washington, DC, USA, Environmental Information Coalition, National Council for Science and the Environment (2010). Available from: www.eoearth.org/article/Energy_profile_of_Ukraine
ECE (2009) Economic Commission for Europe *Mapping of the UN Framework classification for Fossil Energy and Mineral Resources No.33*. Geneva, Switzerland, UN, ECE, 76 pp (2009)
Euracoal (2008) (European Association for Coal and Lignite) *Country profiles-Ukraine (2008*). Bruxelles, Belgium. Available from: http://www.euracoal.org/pages/layout1sp.php?idpage=269
Fenwick S (2010) *Lignite: still in play?* Industrial fuels and power, Dorking, Surrey, UK, Tradeship Publications Ltd. (2010). Available from: http://www.ifandp.com/article/002801.html
Herasimovich V (2008) *Ukraine coal mining sector review.* Center for social and economic research (CASE) Ukraine, 5 pp (September 2008). Available from: http://www.case-ukraine.com.ua/u/publications/ab54a81758cfe81414cb286493ce3750.pdf
HydroWorld Weekly (2010) Available from: www.hydroworld.com
IEA (2006) *Ukraine Energy Policy Review (2006).* Paris. France, International Energy Agency, 379 pp (2006)
IEA Energy Statistics (2008) *Electricity for Ukraine (2008)*. Paris. France, International Energy Agency (2008)
IEA (2008a) *Energy statistics of non-OECD countries (2008).* Paris. France, International Energy Agency**,** 675 pp (2008)
IEA (2008b) *World Energy Outlook (2008)*. Paris. France, International Energy Agency, 569 pp (2008)
IEA (2009) *Coal Information (2009)*. Paris. France, International Energy Agency**,** 361 pp (2009)
IEA (nd) *Country blurb Ukraine*. Paris, France, 1 pp (nd). Available from: www.iea.org/country/country_blurb/ukraine.asp
IEA CCC (2010) *Coal-fired power plants in Ukraine*. IEA Clean Coal Centre, London, UK (2010)
IMEPOWER Investment Group (2009) *Ukraine power sector overview*. Kiev, Ukraine, 2nd entrance, 4th floor, Business Centre Olimpiyskiy, 7 pp (2009)
Kupchinsky R (2005) Radio Free Europe/Radio Liberty. *Analysis: Problems in Ukraine's coal industry run deep.* Munich, Germany, 3 pp (2005)

MBendi in World Coal Mining (2008) *Industry overview*. Information Services Ltd, Capetown, South Africa. Available from: http://www.mbendi.com/indy/ming/coal/p0005.htm#15
McKinsey (2011) *Updated Ukraine's Energy Strategy for the Electric Power Industry through 2030*, preliminary discussion draft. Foundation for Effective Governance, Kiev, Ukraine, 49 pp (2011)
Meredydd E (2009) *Coal mine methane activities in Ukraine*. Presentation at the US coal mine methane conference, Boulder, CO, USA, 18 pp (2009)
Rousaki K (1999) *Coal in Ukraine.* CS/06. IEA Coal Research, London, UK, 40 pp (1999)
Schmidt and others (2006) *Compatibility of hard coal reserves and resources in Europe*. Institute of Geology and Geochemistry of Petroleum and Coal. Aachen, Germany, 9 pp (2006)
SourceWatch (2010) *Ukraine and coal*. Available from: http://www.sourcewatch.org/index.php?title=Ukraine_and_coal
US State Department (2001) *Ukraine history*. Washington, DC, USA. Available from: http://workmall.com/wfb2001/ukraine/ukraine_history.html
US Trade and Development Agency (2007) *USTDA grant enhances ukraine's energy efficiency*. Available from: www.ustda.gov
WEC (2010) World Energy Council. *2010 Survey of Energy Resources*. World Energy Council. Available from: http://www.worldenergy.org.documents/ser_2010_report.pdf, p 608 (2010)
World Bank (2003) *The coal sector and mining communities of Ukraine: advancing restructuring to the benefit of all* (2003). World Bank, Washington, DC, USA, 15 pp (2003). Available from: http://siteresources.worldbank.org/UKRAINEEXTN/Resources/Coal%20Paper_e.pdf
World Bank (2009) *Ukraine: Hydropower Rehabilitation Project*. World Bank, Washington, DC, USA, 1 pp (2009). Available from: http://web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,contentMDK:22396528~pagePK:34370~pi PK:34424~theSitePK:4607,00.html
World Bank (2010a) *News & Broadcast.* World Bank, Washington, DC, USA, 1 pp (2010). Available from: http://web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,,contentMDK:22396519~pagePK:34370~pi PK:34424~theSitePK:4607,00.html
World Bank (2010b) *Energy efficiency and investments in focus as World Bank launches its regional flagship report on energy in Kyiv in March 2010*. World Bank, Washington, DC, USA, 2 pp (2010). Available from: http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/ECAEXT/UKRAINEEXTN/0,,contentMDK:22568290~menuPK:328539~pagePK:2865066~piPK:2865079~theSitePK:328533,00.html
World Bank (2010c) U*kraine-new financing opportunities for clean technologies*. World Bank, Washington, DC, USA, 1 pp (2010). Available from http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/ECAEXT/EXTECAREGTOPENERGY/0,,contentMDK:20685908~menuPK:959253~pagePK:34004173~piPK:34003707~theSitePK: 511377 ,00.html