CLEAN COAL: PROSPECTS AND NEW SCENARIOS

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Abstract

In terms of reserves, coal is the most important energy source available in the world. Estimated world coal reserves are sufficient to guarantee, at present level of consumption, about 250 years of electricity production, compared with 40 years for oil and 60 years for natural gas.

This paper considers historical, economic, politic and technological reasons behind the comeback of this energy source. In particular, we analyse the new clean technologies made in rendering the coal source more compatible with environmental and health regulations. In Italy, the strategy adopted by ENEL is, therefore, that of modifying its energy source mix. According to the plans made by ENEL the energy contribution of coal will increase also with the valorization of Sulcis coalfield.

Riassunto

In termini di riserve, il carbone è la principale fonte energetica disponibile a livello mondiale. Le riserve stimate nel mondo sono tali da assicurare, agli attuali consumi, circa 250 anni di produzione di energia elettrica contro i 40 anni del petrolio e i 60 del gas naturale.

Nel lavoro vengono considerate le ragioni storiche, economiche, politiche e tecnologiche del rilancio di questa fonte energetica.

In particolare, vengono analizzate le nuove tecnologie "pulite" che rendono l'uso di tale fonte del tutto compatibile con le crescenti esigenze ambientali e sanitarie.

Anche in Italia, nella pianificazione strategica di ENEL è prevista la modifica del proprio mix energetico, con un incremento notevole del contributo energetico del carbone anche attraverso la valorizzazione del bacino carbonifero del Sulcis.

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Introduction

The term "**fossil coal**" means any "*substance made from remains of vegetation, more or less completely fossilised by the process of carbonisation, with the property of causing a strongly exothermic reaction in combination with atmospheric oxygen*".

The analysis of the various types of coal measures factors such as the humidity, volatile matter, ash content, carbon and sulphur (1).

In statistical terms, coal accounts for 25% of the total energy consumption of the international economy, second only to oil (35.3%), but firmly ahead of natural gas (20.7%), biomass (10.4%) and the various sources of primary energy (8.9% divided among hydroelectric, nuclear, wind and others).

With the exception of France (where 77% of energy is nuclear), all the countries in competition with us resort to coal: 51% United States, 35% Great Britain, 36% Spain, 34% Japan. In Germany and Denmark, countries well known for their use of renewable energy, coal accounts for 52% and 46% of electricity production respectively.

Outside of Europe the role of coal is of even greater importance, especially in China, where coal now accounts for 70% of the energy resources used to produce electricity, in line with the policy of sustaining an explosive rate of economic growth.

Italy, on the other hand, is the country with the greatest dependency on imports, with coal accounting for just 15% of national energy requirements (*Table 1*); this situation also depends on the fact that the only coal resources are those found in Sardinia (Sulcis field) (2).

TABLE 1

ITALY'S DEPENDENCY ON IMPORTED ENERGY SOURCES (PERCENTAGES)

Year	**Solid fuels %**	**Natural Gas %**	**Oil %**	**Total %**
2000	97.8	77.6	95.1	**83.7**
2001	96.5	78.2	95.4	**83.6**
2002	96.0	80.2	94.0	**84.1**
2003	95.9	81.7	93.9	**84.6**
2004	97.7	83.8	93.9	**84.7**

Source: Enea- Rapporto Energia e Ambiente 2005

In terms of reserves, coal is the most important energy source available in the world (proved reserves total 984 billion tonnes of mineral, divided into 519 of anthracite and bituminous coal and 465 of sub-bituminous coal and lignite, the equivalent to about 600 billion tep), accounting for over 50% of total electricity production requirements. Estimated world coal reserves (*Table 2*) are sufficient to guarantee, at present levels of consumption, about 250 years of electricity production, compared with 40 years for oil and 60 years for natural gas. In energy terms world coal reserves are equivalent to 263,000 EJ (1 exajoule=1,018 Joule), almost three times higher than oil reserves (96,000 EJ), and 5 times higher than natural gas (51,000 EJ) (3).

TABLE 2

COAL RESERVES, PRODUCTION AND CONSUMPTION. GEOGRAPHICAL BREAK-DOWN

	Stock (Bn. Ton.)	**Production (Mn. TEP)**	**Consume (Mn. TEP)**
North America	253.2	602.0	594.8
South & Central America	21.1	48.4	27.7
Europe	59.8	219.6	362.2
Ex URSS	227.3	214.9	175.0
Middle East	0.4	0.6	9.1
Africa	50.4	140.3	102.8
Asia & Australia	296.9	1506.3	1506.6
TOTAL	**909.1**	**2732.1**	**2778.2**

Source: BP Statistical Review

The price of coal, in terms of calorific value, is about half of that of fuel oil and gas. As regards the quality of the coal making up world reserves, it can be divided into two wide categories: high quality coals, which make up about 50 per cent of reserves, and low quality ones, making up the remaining 50 per cent. Coal produced for export is high quality coal and accounts for just 1 per cent of production, the rest, and in particular low quality coal, is used locally, thus it is common to find thermoelectric power stations near coal mines.

World industrial coal reserves (*Table 3*) are divided thus into the various types of resource (4):

TABLE 3

WORLD INDUSTRIAL COAL RESERVES (2005)

Proved reserves at the end 2005 - Million tonnes	Anthracite and bituminous	Sub-bituminous and lignite	Total	Share of total	R/P ratio
USA	111,338	135,305	246,643	27.1%	240
Canada	3,471	3,107	6,578	0.7%	101
Mexico	860	351	1,211	0.1%	121
Total North America	**115,669**	**138,763**	**254,432**	**28.0%**	**231**
Brazil	-	10113	10113	1.1%	-
Colombia	6,230	381	6,611	0.7%	112
Venezuela	479	-	479	0.1%	56
Other S. &Cent. America	992	1,698	2,690	0.3%	-
Total S. & Cent. America	**7,701**	**12,192**	**19,893**	**2.2%**	**269**
Bulgaria	4	2,183	2,187	0.2%	83
Czech Republic	2,094	3,458	5,552	0.6%	90
France	15	-	15	-	25
Germany	183	6,556	6,739	0.7%	33
Greece	-	3,900	3,900	0.4%	54
Hungary	198	3,159	3,357	0.4%	351
Kazakhstan	28,151	3,128	31,279	3.4%	362
Poland	14,000	-	14,000	1.5%	88
Romania	22	472	494	0.1%	16
Russian federation	49,088	107,922	157,010	17.3%	-
Spain	200	330	530	0.1%	27
Turkey	278	3,908	4,186	0.5%	68
Ukraine	16,274	17,879	34,153	3.8%	436
United kingdom	220	-	220	-	11
Other Europe & Eurasia	1,529	21,944	23,473	2.6%	370
Total Europe & Eurasia	**112,256**	**174,839**	**287,095**	**31.6%**	**241**
South Africa	48,750	-	48,750	5.4%	198
Zimbawe	502	-	502	0.1%	126
Other Africa	910	174	1,084	0.1%	493
Middle east	419	-	419	-	399
Total Africa & Middle East	**50,581**	**174**	**50,755**	**5.6%**	**200**
Australia	38,600	39,900	78,500	8.6%	213
China	62,200	52,300	114,500	12.6%	52
India	90,085	2,360	92,445	10.2%	217
Indonesia	740	4,228	4,968	0.5%	37
Japan	359	-	359	-	323

New Zeland	33	538	571	0.1%	111
North Korea	300	300	600	0.1%	20
Pakistan	-	3,050	3,050	0.3%	-
South Korea	-	80	80	-	28
Thailand	-	1354	1,354	0.1%	64
Vietnam	150	-	150	-	5
Other Asia Pacific	97	215	312	-	25
Total Asia Pacific	**192,564**	**104,325**	**296,889**	**32.7%**	**92**
TOTAL WORLD	**478,771**	**430,293**	**909,064**	**100.0%**	**155**
Of which:					
OECD	172,363	200,857	373,220	41.1%	178
Former Soviet Union	94,513	132,741	227,254	25.0%	487
Other EMEs	211,895	96,695	308,590	33.9%	94

Source of reserves data: Survey of Energy Resources, World Energy Council

We will now take a brief look at coal production in the main producer countries and the relative geographical areas (5):

China:

Most of the coal reserves are situated in Manchuria and in the northern areas. Coal production totals around 1.5 billion ton/coal per year and in 2003 more than 700 million tonnes of coal were consumed for the production of electricity.

Two years ago the country unveiled a plan to build 562 coal-fired power stations. Coal is being extracted at a frenzied rate, as can be seen from the thousands of miners that die each year (more than 6,000 in 2004). China is responsible for 90 per cent of the growth in world demand for coal over the last three years.

China is the most important producer and consumer of coal, covering 70% of domestic energy requirements. It is predicted that production will reach 2.45 billion tonnes in 2010, also because of the co-operation between China and South Africa for the transformation of coal into oil. This agreement was signed in late June 2006 and the process, developed by Sasol (a leading company in the production of synthetic fuel), regards the advanced phase of a study for the construction of coal liquefaction plant in the province of Shaanxi, with a production capacity of 80 thousand barrels of fuel per day.

An agreement for a similar project in the Ningxia Hui region was signed on 21 June. The two projects - according to Pat Davies, CEO of Sasol - could reduce Chinese oil imports by as much as 15%.

Australia:

Australia is the largest exporter of coal: almost a third of all the coal sold on the international market comes from here and, in 2001-02, coal exports totalled about 3.4 billion dollars (6).

The lignite coalfields in the state of Victoria supply coal for the industrial production of electricity and amount to 82 billion tonnes.

Colombia:

Colombia possesses the most important coal reserves in Latin America; this coal is mostly extracted from open mines. In the largest open mine in the world Cerrejon Coal of Colombia, owned by BHP Billiton, is expanding production capacity by 45%, reaching 32 million tonnes per year. The Cali coalfields are also important.

South Africa:

There are significant coal reserves (174 million tonnes); the largest coalfield extends from the ex-province of Natal into the whole of the ex-province of central Transvaal. Other mines are situated in the ex-province of the Orange Free State.

U.S.A:

Coal reserves amount to 250 billion tonnes. West Virginia is well known as a major coal producing area.

Indonesia:

There is a particularly interesting huge open coal mine covering 1,200 hectares at Bukit Asam, opened by the Dutch in 1810, where, once the coal is extracted, the area is re-compacted with fertile soil and oil-palm trees so as not to leave any trace of the mining activity. Extraction totals 800 thousand tonnes of coal per year.

Russia:

The Republic of Tatarstan has rich coal and lignite fields but greater importance must be given to the Republic of Komi, since in national terms it is the most important area of coal production and the main supplier of fuel for the European part of Russia. We must not forget the province of Timan-Pechora for its rich reserves of carbon coke in the Pechora coalfield and also for its reserves of peat and firewood.

In terms of their energy value, world coal reserves are two and a half times greater than those of oil; American coal reserves are three times higher than the oil reserves of Saudi Arabia. America and China, together, possess 40% of known coal reserves.

What are the reasons behind such an important reappraisal of coal as an energy source?

There are various reasons behind the comeback of this energy source on a world level. Firstly, there are historical motives, relating to the certainty of supplies, both from a geopolitical point of view and with reference to the levels of world reserves.

The economic reasons are mostly of a contingent nature and are due to the ever increasing price of oil. We need only remember that a kWh produced by coal is much less expensive than one produced by gas or oil; indeed, taking into consideration all the costs involved, a MWh produced from coal cost around 40 Euros, compared with 65 Euros for a MWh produced by the most efficient gas plants and more than 80 Euros for a modern oil plant (a hypothesis based on a crude oil price of 50 dollars a barrel, much lower than the current price of around $70 (September 2005).

Another important reason behind the reappraisal of coal as an energy source is the considerable technological progress made in rendering it more compatible with environmental and health regulations; indeed, the impact of modern coal-fired power stations is very similar to that of other thermoelectric power stations. Other factors favourable to coal are those relating to "externalities" associated with the entire life cycle and referring to the service unit produced (one kWh net of electricity generated), also including in the calculation the social costs relating to the exhaustibility of resources and the savings made by the use of by-products such as ash in the cement and concrete industry, as well as in road surfacing works.

It is hardly surprising, then, that in many countries, especially the United States, steps are being taken to accelerate the development of Ctl (coal-to-liquid) technology, a process which allows the transformation of coal into petrol and diesel. Peabody, a large American coal producer, has calculated that through Ctl technology it is possible to produce fuel at a cost equivalent to an oil purchase price of 35-40 dollars a barrel (45 dollars according to the South African company Sasol), a level which was considered too high until recently, but cheap in a context of ever rising crude oil prices.

The two basic processes for the production of diesel and gasoline from coal are:

• "**Gasification**", which transforms coal and oxygen into a gas (syngas) with the help of a catalyser. The three main technology providers for gasification are General Electric, Conoco and Shell.

• **The Fischer Tropsch reaction**, which allows the conversion of syngas with catalysers, in order to produce a series of hydrocarbons, light gases, heavy waxes and water. The waxes are sold for the production of candles and for the packaging industry, while the gases are cooled and hydrogen is added for the production of diesel fuel and other light petrochemical elements. The main Fischer Tropsch technology providers include Sasol, Rentech, Syntroleum and Shell.

Ctl technology is now an integral part of the many companies' business strategies. South Africa currently has the highest production capacity in the world, China is in second place, having overtaken the United States thanks to the opening of new plants, and in fourth place is India, with a series of projects currently under study by experts.

In the United States, in particular, Ctl projects attract preferential financing, thanks to the initiatives undertaken by the government; over the last few months both houses of the American Congress have discussed bipartisan bills to support the development of this technology. The American Defence Department has requested quotes for the supply of aircraft fuel derived from coal, while the Southern States Energy Board, an organisation grouping together sixteen states of the union, each represented by their governor and a member of the Senate and of the House, has requested the production by means of Ctl of 5.6 million barrels of fuel per day. Finally, it would seem that China has put aside 15 billion dollars for the creation of new Ctl conversion plants.

What is the situation in Italy regarding energy production from coal?

In Italy, the high energy prices paid by families and by industry are due to the production costs for 60%, while the remaining 40% is divided among infrastructure costs (20%), system costs (10%) and fiscal costs (10%). Thus, production costs account for almost 61% of the final price and the fuel alone accounts for 40%.

The cost of electricity in Italy, for example, is about double that of the UK and, on average, 30% higher than the rest of Europe.

During a recent convention, the director of electricity for the

Energy Authority pointed out that the use of coal at the same average levels as in the rest of Europe (35%) would lead to a 10% reduction in the cost of electricity in Italy. Translated into economic terms this means that, considering a rough weekly consumption of 6,000,000 MWh in Italy, the saving would be about 36,000,000 Euros a week (considering the total number of customers), that is to say almost 2 billion Euros per year.

The cost of one kwh produced from coal, also taking into consideration the cost of running the plants, is around 25-30% less than that produced from oil and gas (7).

In other words, at present in Italy the mix of energy sources used by Enel (the main energy distributor in Italy) is not balanced, being divided thus: 48% gas, 27,8% oil, 4% orimulsion and only just over 20% *coal*. From this analysis we can deduce that a greater use of coal is the only strategy that can be followed in the short-medium term in order to reduce the cost of electricity.

The strategy adopted by Enel is, therefore, that of modifying its energy source mix: the need to rebalance in order to reduce the cost of energy necessarily involves a greater use of coal, since it is a cheaper fossil fuel and, above all, because it is less subject to price fluctuations.

According to the plans made by Enel, the energy contribution of coal and orimulsion will increase considerably, rising from the present level of 27% to 47% in 2009. This will happen at the expense of oil-fired power stations, which will almost completely be eliminated, and together with a further increase in electricity production from renewable sources (these will account for 32% of electricity production in 2009), while the level of production in combined cycle power stations will remain steady.

We must remember, however, that in Italy there is only one coalfield, the Sulcis field in Sardinia. The Palaeogenic coalfield covers an area of about 500 Km2. Reserves are estimated at about 600 million tonnes of commercial coal and, in relationship to the area in which the available information is sufficiently detailed to allow evaluation of the reserves, they amount to a potential of 375 million tonnes; of this amount, research, exploration and tracing have brought to light 50 million tonnes to be exploited. The calories contained in these reserves alone would be sufficient to generate all of Italy's electricity requirements for more than two years, if this coal could be extracted at a cost comparable with that of imported coal (providing that the mine can produce a quantity as high as or higher than the economic point of return, which is estimated to be between 900,000 and 1.000,000 tonnes of commercial coal annually) (8).

According to the results obtained by the CNR using standard international reflectometric ranking methodologies, Sulcis coal is a sub-bituminous coal (sub-bituminous B/A, ASTM) or Glanzbraunkohl (*Table 4*).

TABLE 4

AVERAGE VALUES FOR THE CHARACTERISTICS OF SULCIS COAL

FEATURES	VALUE
Dampness	10.5%
Volatile residuals	39.0%
Cinders	16.0%
Fixed Carbon	35.0%
Sulphur	6.06%
Heat power inf. (kcal/kg)	5,000

In particular, Sulcis coal is distinguished either as lean long-burning bituminous coal, which is the coal that was obtained from the Serbariu mine, or lignite (even more recent coal) found at a Seruci and Nuraxi Figus. These types are characteristic of tout-venant coal (burnt as it is mined, mixing together pieces of coal with the bare rock) extracted from the various mines and of the relative coal which has undergone an enrichment process.

Industrial scale mining began in 1853, with the first mining concession at Terras Collu. The first two mines at Seruci and Nuraxi Figus were opened in the 1940s and were state-of-the-art for that period. Until 1962-1963 the mines were managed by Carbonsarda (Sardinian coal company), then a government decree in November 1965, based on the law nationalising the electricity industry, ownership passed to Enel (this took place in July 1966), since the coal was now destined to be used in power stations.

Management of the mines was given over to Carbosulcis S.p.A., who were granted the "Monte Sinni" mining concession in 1982, regarding the exploitation of the solid fuels over an area of 59.4 Km^2 in the Sulcis coalfield for a period of 30 years.

The first project undertaken by Carbosulcis dates back to 1985. In 1996 the shares of Carbosulcis passed into the hands of the Sardinian

Regional Government and the mines were brought up to date in terms of infrastructure and technological innovation, in line with international standards.

Carbosulcis S.p.A. has the mining capacity to produce more than 1,500,000 tonnes per year of commercial coal (showing that long term investments have been made).

Today Carbosulcis has a contract with Enel (*Table 5*) for the supply of 1.1 million tonnes of commercial coal over three years.

The contract is especially concerned with the supply of coal intended for use in the "Grazia Deledda" power station. Carbosulcis will deliver one million one hundred thousand tonnes of local coal to Enel, divided thus: 300 thousand tonnes in 2005, 370 thousand in 2006 and 430 thousand tonnes in 2007.

Moreover, Enel's Sulcis power station, which has EMAS environmental quality registration, will adopt the highest international level of technology for the treatment of emissions (Clean Coal Technologies), such as plants for desulphurisation, denitrification and particle reduction in the 240 MW section already in operation and, above all, the combustion and treatment systems of the new 340 MW Circulating Fluidised Bed section. This project will meet the all the electricity requirements of Sardinia.

TABLE 5

RANGE OF VALUES OF CHARACTERISTICS OF SULCIS COAL (ANALYSIS CARRIED OUT BY ENEL)

FEATURES (Source: ENEL contract)	**value**	
	Min	**max**
Dampness (% weight)	10.00%	30.00%
Cinders (% weight)	15.00%	19.00%
Volatile residuals (% weight)	38.00%	40.00%
Fixed carbon (% weight)	32.00%	37.00%
Sulphur (% weight)	5.60%	8.50%
Heat power inf. (kca l/kg)	4,700	5,100
Mincing (Hardgrove)	45	48
Dimensions (mm) • **< 5% > 50 mm** • **< 20% < 1 mm**	0	50
Cinders fusion temp. (°C)	1,140	1,230

Sulcis coal is thus available in large quantities and can be mined at costs comparable with those of the market.

This coal is often erroneously defined as a poor quality coal: it should be remembered that Sulcis coal is classified according to international standards as a long-burning sub-bituminous coal and belongs to lower level group of coals mentioned above, which make up 50% of world coal reserves, thus it is unthinkable for any country in the world to ignore this resource. Indeed, this can be seen from the enormous financial resources made available to research centres and the energy industry in order to develop new more advanced technologies, with particular attention to the lower level coals (this is the case in the USA, Canada, the United Kingdom, etc.). Besides, if we take a look at the Environmental Impact Evaluation Report drawn up by the Ministry of the Environment for the IGCC plant at the ATI Sulcis, we discover that, by using a mix of coals with 60% Sulcis coal, produced an environmental impact well below the legal limits and, indeed, lower than the limits set by the Ministry of the Environment for the construction of the IGCC plant which was supposed to be built in the Portovesme area, an area considered to be environmentally highly vulnerable and thus in need of regeneration.

It can therefore be said that Sulcis coal can be considered as an important national resource and that existing conditions allow it to be used with low environmental impact and in accordance with EU regulations.
It is, however, necessary to carry out a worldwide awareness campaign concentrating both on politicians, who more readily take into account the views of the environmental and renewable energy lobbies, and on the public, who know little or nothing about clean coal technologies aimed at "zero" CO_2 emissions (9).

In this context feasibility studies have been carried out on Sulcis coal by the University of Cagliari in co-operation with Sotacarbo (the public corporation set up by the Sardinian Regional Government and ENEA), in order to identify future industrial scale research and development activities, as well as new technologies for the use of this resource and of the by-products produced when burning it, as below (10):

- **Recovery of fine coal dust from the waste of the Nuraxi Figus mining operation for energy use**; study carried out by the Department of Geo-engineering and Environmental Technology (DIGITA) and Sotacarbo which, on the basis of the characteristics of the dust waste from the Sulcis coal scrubbing plant, has identified and initiated the "Industrial research project on the exploitation of the fine waste granulometries from the Nuraxi Figus treatment plant, by means of the selective flotation process in a continual pilot plant".

• **Re-use of ash and chalks from the Enel power station**; a study carried out by the Department of Chemical Engineering and Materials (DICM) and Sotacarbo which, from a study of the technologies available for the reuse of combustion ash and chalk, of the chemical technologies applied to coal, of the techniques for the reuse of residues for simultaneous disposal or for the treatment of other residues and on the basis of the main chemical and physical characteristics of the residues from the combustion of Sulcis coal, has identified as most appropriate the "Pilot industrial scale project for the reduction of ash and sulphur in Sulcis coal by means of lixiviation with mineral acids".

• **Use of energy and chemical technologies for the employment of Sulcis coal**; a study carried out by the Department of Mechanical Engineering (DIMECA) and Sotacarbo which has led to the identification of two industrial scale applied research projects:

1. ECBM (Enhanced Coal Bed Methane) pilot project for the production of methane from the Sulcis coalfield with the injection and sequestration of CO_2.

2. Development and experimentation of technologies and innovative processes for the treatment of syngas from coal in order to produce hydrogen.

By the end of 2006 Sotacarbo will start up the production of hydrogen from the gasification of Sulcis coal, as per the two clean technology projects illustrated above. This decision was announced during the International Congress on the use of clean coal which was held in Sardinia, in Castiadas, with the participation of more than 200 technicians and scientists from 28 countries, including the USA, Canada, Japan, the European Union, Australia, Brazil, India and, for the first time, also China (which consumes 60% of the coal produce in the world but uses highly pollutant and obsolete plants).

The research made by Sotacarbo is now concentrating on the extraction of methane from the Sulcis undersea coalfields by a process using carbon dioxide (CO_2) captured in the atmosphere and pumped underground.

The Sulcis coalfield is not only able to be mined to a depth of 700 metres but is also the most suited to the process known as ECBM, Enhanced Coal Bed Methane, that is to say the extraction of the methane contained in the coal beds at depths of over 800 metres and, at the same time, the storage of CO_2 (11).

The project is based on a revolutionary technique, the so-called deviated shafts, which allows for drilling diagonally towards the seabed. The extraction of methane from deep coal is not of any particular economic importance because the methane obtained is barely sufficient to cover the expense of drilling the shafts, but it has scientific and environmental importance for the storage of CO_2. In the Sulcis coalfield it will be possible to store from 100 to 500 million tonnes of carbon dioxide, a greater quantity than that of all the emissions from the power stations in the area of Sulcis, Portoscuso and even Sarroch until 2050; in practice, for the next 50 years there is no risk from degassing (that is when CO_2 is pumped) because the rocks above the coal are impermeable, nor are there risks from seismic activity (which can be excluded in Sardinia in any case) because the deep injection of fluids would reduce the seismicity.

It is, thus, a simple process: the coal absorbs the CO_2 molecules and this permits the release of methane.

With this technology, Sardinia is at the forefront in Europe regarding projects for the extraction of methane from coal, with the great advantage that large quantities of energy can be produced from the coal without CO2 and, from an economic point of view, production costs, with the "capture" and geological "storage" of CO_2, will be recovered after just five years of activity. In addition to this, the methane produced, though limited in quantity, can be used locally for various needs, such as heating in greenhouses. Moreover, a not insignificant effect will be the creation of new job opportunities, not only in the traditional coal mining field, but in all the areas associated with the extraction of methane: in Canada, where a storage plant similar to the one planned by Sotacarbo has been inaugurated, 400 new jobs have been created.

Finally, there will be advantages for the University of Cagliari, which will attract investment both from the IEA (International Energy Agency) and from the European Union.

We can thus assert that the projects for the exploitation of Sulcis coal resources will be successful only if precise choices are made: these depend upon the national and regional governments, who need to resolve the problems of energy costs and the Sardinian energy industry and to verify that the use of Sulcis coal is an important step towards a rational and economical exploitation of resources; this argument is supported by the positive characteristics of Sulcis coal mentioned above (*ample quantity, extraction possible at a cost comparable with market costs, limited environmental impact*).

The only obstacle is represented by the state bureaucracy, which needs to act rapidly and on the basis of strict rules in order to avoid wasting considerable quantities of public and private funds and thus to guarantee the success of the initiatives.

The recent decree law approved by the national government, aimed at improving the competitiveness of the Italian economy (DL n°35 March 2006), contains various specific measures regarding the problems of the Sardinian energy industry and proposes important initiatives for the restructuring of the industry, in order to make low cost energy available, thanks to the greater use of Sulcis coal. This is, therefore, an important step in the right direction, especially if Parliament, when debating the approval of the law, takes into account the requests and observations made in a joint study by the regional government, the energy suppliers and the Sardinian trade unions.

New technologies used to obtain "clean"coal

"Clean" coal technologies are attracting considerable interest, as is shown by the conversion of oil-fired power stations to coal-fired, so as to obtain a significant reduction in emissions of all kinds (12). For example, we can look at the case of the Torrevaldaliga Nord power station (Civitavecchia), where the new coal-fired plant will bring about a reduction in emissions of 82% for sulphur oxides, 61% for nitrogen oxides and 82% for particles, compared with the existing oil-fired plant. It has also reduced carbon dioxide emissions by 18%, a gas which, although it is not a local pollutant, is of great importance because of global warming and the undertakings of the Kyoto Protocol. The project also ensures that the flue gases coming out of the boilers will be completely "scrubbed" by the new treatment systems, in particular the denitrification system reduces nitrogen oxides, the sleeve filters block 99,9% of particles and the desulphurisation plant reduces sulphur oxides with 97% efficiency and, with the scrubbing of flue gases, also the particulate and metals.

Currently, Enel operates 7 coal-fired power stations in Italy (Fusina - 975 MW, Marghera - 140 MW, La Spezia - 600 MW, Genoa - 295 MW, Sulcis 3 in Sardinia - 240 MW and Bastardo in Umbria with 150

MW) with a total installed power of 5,046 MW, of which 2,640 are accounted for solely by the Brindisi power station.

The strongpoint, however, as we mentioned above, is use of advanced environmental technologies for the operation of the three new coal-fired power stations resulting from the conversion of existing plants: Torrevaldinga Nord (Civitavecchia) for 1,980 MW and Porto Tolle for 2,640 MW.

The third power station, Sulcis 2 (340 MW), is of particular importance because, alongside coal, it will also burn biomass using a circulating fluidised bed boiler.

In summary and on the basis of the above premises, we can state that the decisive choice of energy source to be made in order to guarantee survival of the energy crisis is that of coal, since it has the following *advantages*:

1) cheapness
2) abundance
3) possibility of being less pollutant than in the past with the use of new technologies.

As stated above, with the improvements made by new "clean" technologies (Clean Coal Technologies) now available, guaranteeing a lower environmental impact of coal-fired power stations, Italy has made investments sufficient to increase the contribution made by coal to total national electricity production from 9% to 12%.

The Northside power station in Jacksonville Florida is of particular interest because it was used by Enel officials as a model for the conversion of Italian power stations. It is a power station fired by oil and gas since 1970 and converted to coal in 2002, situated on the edge of the Timucuan nature reserve (famous natural habitat) and consisting of two 300 MW circulating fluidised bed boilers (the largest in the world before the building of Enel's Sulcis power station). For these reasons the American authorities imposed strict limits on the emissions of the main gaseous pollutants, which must be 10% lower than in 1995, even though production has increased by 2.7 times compared with 10 years ago.

There are basically two new elements included in the Northside power station in Jacksonville and also used by Enel for the Torrevaldaliga Nord power station:

1. **The conveyor belt**: 1 km long and airtight, which carries the coal directly from the hold of the ship into two enormous aluminium cupo-

las, before it is burnt. This means that the coal is continually sheltered from the air and wind, thus avoiding any possibility of dispersal of dust.

2. **The geodetic cupolas**: built with a Buckminster Fuller *triangular structure* and made of aluminium, where the coal is piled up and dropped by a mechanism onto another conveyor belt leading to the burner, making the whole unloading process faster and reducing the time during which coal dust may disperse into the environment.

Thus, in short, according to the project for the conversion to coal of the Torrevaldaliga Nord power station, near Civitavecchia, the coal will arrive at the station by ship and will be transported directly from the holds to the storage areas (sealed and without any dispersal of dust), consisting of bunkers covered by cupolas (also called "domes"), by means of a covered conveyor belt.

The ash removed from the sleeve filters will be collected in silos, which are equipped with an automatic system for transfer directly into the holds of the ships that will take them to their place of reuse. Even the chalk produced in the desulphurisation system will be extracted, filtered and temporarily stored in a covered warehouse equipped with automatic remote controlled machines for discharge and recovery for transportation to the place of use.

These modifications for the conversion to coal have been possible thanks to the use of new technologies, that is: desulphurisation, scrubbing and CO_2 storage techniques, which have considerably reduced pollutant emissions and set in motion a new policy of "clean" energy production. Moreover, with special burners and boilers, also to be used in Civitavecchia, it is possible to produce steam at extremely high temperature and pressure, while the new generation of turbines, called hyper-supercritical, guarantee a higher level of efficiency; greater efficiency can also be obtained in the fume reduction systems which "scrub" dust, nitrogen compounds and sulphur oxides.

There are some particularly important technologies still under development, such as IGCC-integrated plants for gasification and combined cycle (the process transforms coal into a synthesis gas composed of hydrogen, carbon monoxide and other substances, the gas is then burnt in a turbine so as to produce electricity, while the hot flue gases are used in a heat recovery boiler to produce steam and drive the second turbine) and integrated gasification/fuel cell plants (where the gas obtained from coal contains hydrogen and is used to feed the fuel cells); both processes offer particularly high levels of performance.

In short, the net level of efficiency currently reached by new clean coal technologies is around 45%, but in the future it is expected to reach higher levels, up to 55%.

In the "Energy Report", ENEA divides the commercially available technologies into:

- **Pulverised fuel (PF)**: an innovative combustion technique suitable for all coal-fired plants that use a single steam turbine. This innovation comes from recent developments in low NOx burners with more and more pulverised coals;
- **Ultrasupercritical technology (USC)**: an evolution of the previous technology in which the thermodynamic parameters are pushed up to 600-630 °C and pressure value up to 300-320 bar and with fluid-dynamic innovations regarding the machinery and combustion techniques;
- **Integrated gasification combined cycle (IGCC)**: an alternative to the current combustion system consists of exposing the dust to high temperatures in contact with steam and oxygen. Gas is produced in the turbines while the hot flue gases generate the steam that drives the turbine, with an efficiency of around 50%. The sulphur is recovered and the ash is converted into inert vitrified waste.
- **Fluidised bed combustion**: the combustion of the coal takes place in a bed (bubbling or circulating) of heated particles suspended in a gaseous fluid that permits rapid mixing.

Efficiency is around 42-45% but there is a reduction of up to 90% of SO_x as stable gaseous residues and of NO_x, caused by the lower combustion temperatures.

- **Externally fired combined cycle (EFCC)**: in this case the plant is based on a conventional cycle fed by the flue gases coming from the external combustion of fuels such as biomass, refuse or coal. Expected efficiency is around 45-50% but these plants will not come into operation before 2010, as there are problems in the development of the heat exchanger.

In particular **Enel**, on the basis of their environmental impact reduction policy, aims to divide the use of new technologies in coal-fired power stations on the basis of:

- ***<u>increased boiler efficiency</u>***: The **ultrasupercritical boilers** that burn coal dust allow an improvement in thermodynamic performance of at least 7% (from 38% to 45%). The most widespread combustion technique is that of **coal pulverisation**; further developments are being made in burners so as to reduce the formation of pollutants at origin (nitrogen oxides) in the combustion chamber. **Ultrasupercritical technology (USC)**; apart from the above mentioned fluid-dynamic innovations regarding machinery and more advanced combustion techniques, this process also brings about considerable savings in fuel (and thus reductions in emissions) for each kWh produced.

- *Heavy reduction in pollutant emissions*: New catalytic systems for denitrification of flue gases ($DeNO_x$), based on the chemical reaction between NO_x, ammonia (NH_3) and oxygen, are highly efficient in reducing nitrogen oxides (NO_x) by levels of over 85%. The technique used is that of injecting gaseous ammonia into the flue gases coming out of the boiler, along with particular elements called "selective catalysers" (thus the technology is called: Selective Catalytic Reduction-**SCR**) that favour this combination, with the result that the NO_x are transformed into nitrogen and water. **Use of state-of-the-art sleeve filters for the scrubbing of flue gases**, where the flue gases coming out of the boiler are passed through filters made of tightly woven permeable "fabric" positioned inside cylinders -sleeves - made of synthetic micro-fibres (nylon, Teflon or Ryoton). This system allows air to pass through but not the suspended particles. Advanced systems for the desulphurisation of flue gases ($DeSO_x$) of the moist limestone/chalk type, highly efficient in reducing sulphur oxides (SO_2). The system is based on combusted gases which are washed by a spray of water enriched with a solution of limestone; in the presence of air, the calcium carbonate contained in the mixture reacts with the sulphur oxides producing pure chalk, which is ideally suited to reuse in the building industry. This is a very reliable system (by far the most widely used in the world) which reaches an efficiency level of 95% in reducing SO_2. Adoption of a crystallisation plant for crystallising the salts contained in the drainage water from the desulphurisation system. This water is completely recovered and thus no longer constitutes a liquid effluent leaving the plant.

- *Correct and safe management of fuel*: The **movement and storage of coal** will take place in completely sealed depressurised and automated environments, thus ensuring no dispersion of dust into the outside air.

Conclusions

A project is under way for the development of a new advanced technology based on a new highly efficient combustion system, in order to reduce all thermoelectric power station emissions practically to zero.
This project was drawn up in an agreement signed in Rome on 17 October 2006 by Enel, Itea (a company in the Sofinter group) and Enea.
The project is divided into two phases:

▪ **Initial experimental and modelling activity** of over 4,000 hours in order to carry out the basic process with higher capacities than that of the prototype 5 MW pilot plant situated at Gioia del Colle (Bari), patented by Itea; the new plant will be able to use solid fuels, keeping the production of pollutants to a minimum, guaranteeing a high degree of energy efficiency and the recovery of residual products. Above all, however, it will obtain a combustion gas essentially made up of CO_2, thus favouring the removal and sequestration of this greenhouse gas. The duration of this planning phase is one year.

▪ **Construction of a commercial plant** of a capacity between 50 and 70 MW to be situated at one of Enel's coal-fired power stations. The estimated time scale for the building of the plant is about 3 years.

The roles in this partnership are thus defined:

▪ Itea will make available the pilot plant and the acquired know-how;

▪ Enel will provide its long experience in the field of combustion and the site for the building of the final plant;

▪ Enea will have the function of technological advisor, guaranteeing the implementation of the policy of the Ministry for Economic Development on research into electricity production from clean coal.

In terms of costs:

▪ Enel will cover two thirds of the development costs in the first phase of the project;

▪ Itea will cover the remaining third.

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