Advanced Clean Coal Technology for Power Generation-An Opportunity for Southeast Asia

Author: Miro R. Susta, IMTE AG, Switzerland
Co-Author: Dr. Sohif Bin Mat, Transtherm Engineering & Construction Sdn Bhd, Malaysia
imte@bluewin.ch

Introduction

On a worldwide basis, the prospect for Advanced Clean Coal Technology (ACCT) for power generation is extremely good, especially in rapidly developing markets such as Asia, Africa and South America. ACCT will pay considerable contribution not only to efficiency improvement but also to emissions decrease to the environment.

ACCT is defined as technology designed to enhance both the efficiency and the environmental acceptability of coal extraction, preparation and use. This technology reduces emissions and waste, and increase the amount of energy gained from each tonne of coal.

It is expected that Supercritical Steam (SC), Ultra-SC (USC) technology, Pressurized Fluidized Bed Combustion (PFBC), Integrated Gasification Combined Cycle (IGCC), Hybrid Combined Cycle (HCC), Direct Coal fired Combined Cycle (DCCC), Molten Carbonate Fuel Cell (MCFC) and Magneto Hydrodynamics (MHD) power generation will realize high thermal efficiencies in this order and be put into practical use in the reverse order.

Both, PFBC and IGCC represent a unique partnership between coal gasification and the most efficient Combined Cycle Gas Turbine (CCGT) cycle for power generation.

The primary goal of leading power generation industry and many governmental bodies worldwide is successful introduction of ACCT into the energy marketplace.

The gasification, which utilizes coal, residual heavy oils and other low value feedstocks in the cleanest possible way, is not new.

The first coal gasification process was developed in Germany more than 65 years ago. Coal remains one of the most abundant primary energy sources for electric power generation worldwide. Currently, coal is used to generate around 40% of the electricity worldwide and is projected to supply over 50% of power generation plants worldwide beyond 2015.

For example, during the first 10 months of the year 2002, only in USA the total net generation of electricity was 3,222 billion kWh, 1% above what was reported for the corresponding period in 2001.
In USA, more than 55% of the generation was produced by coal-fired power plants (burning around 580 millions tons of coal annually).

Wide application of gasification for power generation purposes was mainly delayed by its economics. The installed IGCC kW-price is much higher comparing to conventional CCGT using natural gas (NG) fuel.

When linked with modern CCGT, IGCC is one of the few technologies that significantly increase efficiency of coal fired power plant and have a beneficial environmental effect in reducing emissions of CO_2.

Additionally, an IGCC power plant produces marketable by-products, rather than large volumes of solid wastes typical of scrubber-equipped or fluidized bed combustion power plants using coal or petroleum-based heavy fuels.

The Present experience in USA and Europe shows that coal based IGCC power plant technology is ever closer approaching commercial status.

As such, IGCC is a technology that may be used not only in industrial but also in developing countries in the long term.

Current IGCC coal gasification projects would not have been economically viable, unless amply subsidized under various national & international entities and supporting programmes like the Clean Coal Technology (CCT) programme sponsored by the US Department of Energy or some programmes like THERMIE sponsored by European Countries (EC).

But to be truly competitive with conventional, NG fired CCGT cycles, NG prices need to raise and larger gas turbines (GT) to be used.

Since IGCC technology has remarkable implications for energy conservation and environmental protection, indirect economic and social benefits are substantial.

If the predicted growth in coal-fuelled power generation continues without widely applied pollution-suppressing technologies, emissions levels would increase by 350% within the next double-decade, and by 1000% by the year 2035. Such estimates have been issued by the World Bank.

As worldwide air emissions standards become stricter, the superior environmental performance of IGCC will take on added economic benefits because the technology can achieve greater emissions reductions at lower cost than less advanced technologies.

According to World Bank statistics, the greenhouse emissions increased in Malaysia from 3.8 tonnes per capita in 1994 to 5.7 tonnes in 1998.
Among ASEAN countries this is the third highest after Brunei and Singapore.

Modern IGCC power generation technology will make an important contribution to the improvement of the global environment.

For example, a coal plant without environmental controls generates 1000 to 1500 ppm of NOx, compared to about 20 ppm for NG fired CCGT power plant.

State-of-the-art, IGCC power plants generate as little as 20 ppm of NOx, or about the same as NG fired power plants.

Similarly, an uncontrolled coal power plant generates 2500 ppm of SO_2, while a state-of-the-art IGCC power plant generates as little as 10 ppm SO_2.

This paper presents review and technical / commercial analysis of several most important IGCC projects with their basic economical indicators and benefits for global environment. SC, USC, PFBC, HCC, DCCC, MCFC and MHD technologies are also briefly introduced.

Fuel Consumption Trends in Power Generation Industry – Present Situation in Southeast Asia

World energy consumption is projected to rise 75% between year 2000 and 2025, from 12’800 GWY to 22,600 GWY **(1GWY=31.5MioGJ=0.03QUAD=3x10^{13}BTU)**, according to the reference case in the *Energy Information Administration's International Energy Outlook 2002 (IEO 2002).* If that level is reached, total consumption will have nearly tripled in 50 years period (Figure 1).

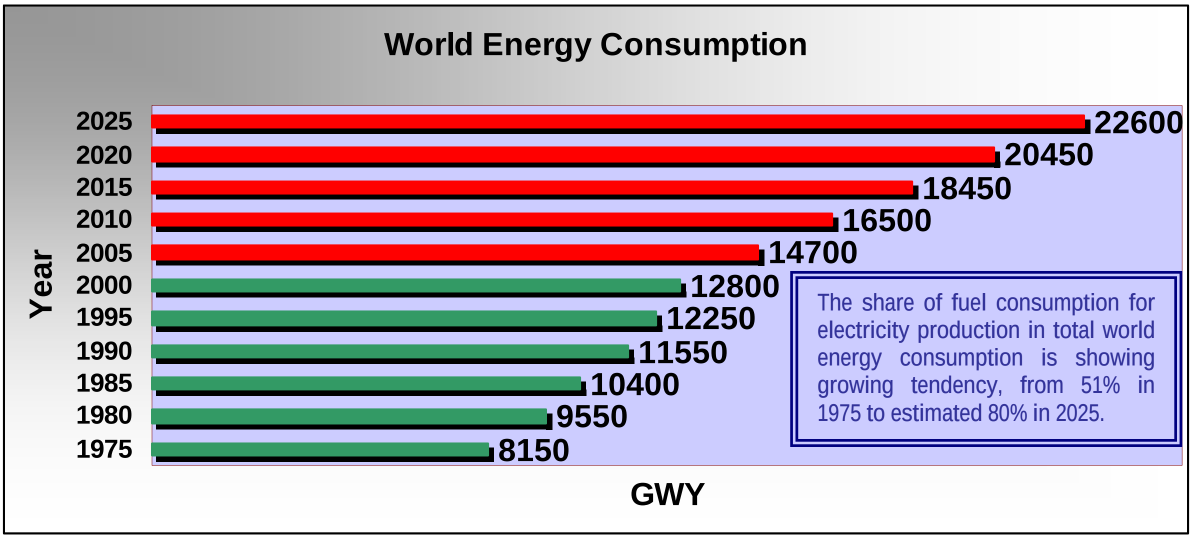

Figure 1

Much of this growth will be driven by rising demand in the developing world (Africa, the Middle East, Central and South America, and parts of Asia), where energy consumption in 2025 is projected to be 6 – 10% higher than in the industrialized world.

For better illustration the current world energy consumption compared to the population in miscellaneous regions is shown in the diagram, Figure 2.

From this diagram it is obvious that the world highest energy consumer is USA & Canada following by Japan and Europe. Only USA & Canada alone have twenty times higher specific (per capita) energy consumption than whole Africa.

All figures shown in the diagram are as a % of the world total energy consumption and population respectively.

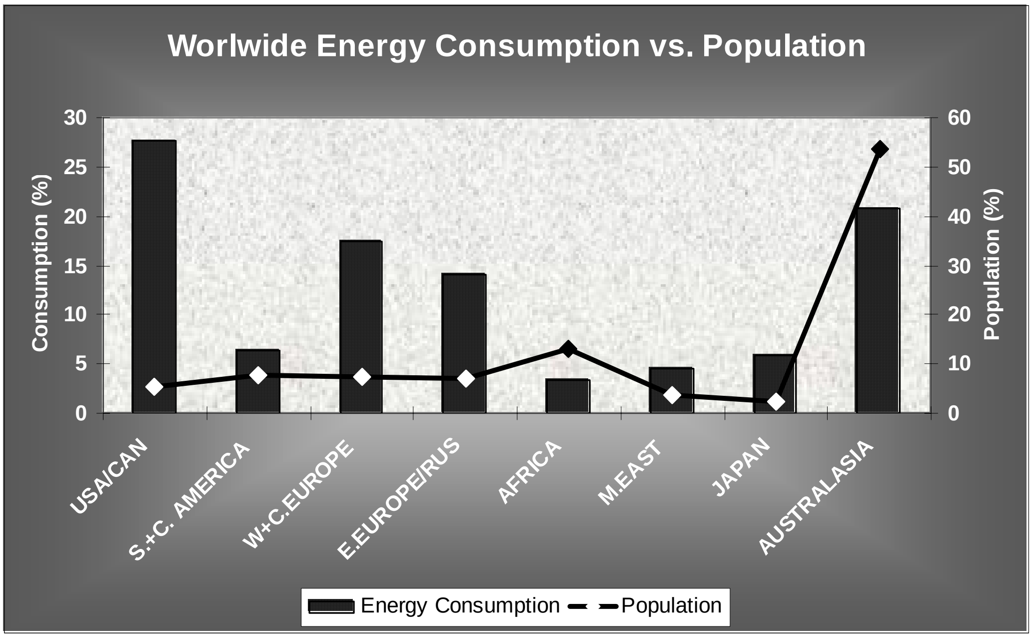

Figure 2

Over the next decade, China and India will contribute by 50% to the world's increase in anthropogenic greenhouse emissions.

These two countries will continue to be dependent on coal-based power production. Successful commercialization of IGCC may become top urgent for them.

In China alone, 70% of smoke and dust in the air and 90% of the country's SO2 are generated from burning coal used for industry and residential heating.

USA, which has 55% of its huge 900 GW power generation capacity based on coal fuel, will be the second biggest market for coal-fired technologies.

At the same time, 60% of this obsolete capacity is older than 30 years, some of them suffering anxiety to cope with 1992 Clean Air Act Amendments (CAAA).

Use of NG, coal, and renewable energy is projected to expand, with coal posting the most rapid growth from 2000 through 2025.

Until now, reliability and comparatively low capital costs have helped fuel the boom in NG fired power generating capacity.

An increase in demand for coal is foreseen in the industrialized nations through the forecast period, but strong demand in the developing world drives growth in coal use at a rate of more than 2% per year.

Renewable energy consumption grows about 2% per year, but low fossil-fuel prices prevent any increase in its share of the total.

Of the major energy sources, only nuclear power actually declines, due to public opposition, nagging difficulties in handling wastes, and competition from NG.

Despite net additions to nuclear generating capacity in Japan and certain developing nations, world total capacity is projected to fall below 0.5% per year as nations with long-established nuclear programs retire aging reactors.

Ratification of the Kyoto Climate Change Protocol could affect many of these projections. In particular, industrialized nations might reduce their consumption of fossil fuels. Possible alternatives include fuel switching, emissions trading, and other types of offsets.

In order to enable us to predict future tendency in power generation technology and selected or preferred fuel usage, the following major counter-effecting influences have been seriously considered.

- Increasing share of the Independent Power Producers (IPPs) worldwide. Their business philosophy prefers short-time investment return periods. Presently, these are guaranteed by the NG based technologies.
- Increasing pressure of environmental legislation in most countries. This also favors NG as the dominant choice in green-field projects.
- Worldwide deposits of NG are restricted. NG resources are enough for half century, while proven deposits of coal are sufficient for another 250 years. If we suppose a half century limit for NG it means that the tension in the market will become much earlier. Deposits of NG exploitation will be ever deeper and more remote.
- Costs of the NG distribution infrastructure investment and maintenance will be growing. Competitive power of NG may further be reduced by its possible conversion as the feedstock in the hydrocarbon processing industry.
- Almost three quarters of NG resources are situated in countries with not very high political stability, like Middle East, Russia and other former Soviet Union States.
- Deposits of coal are distributed in many politically stable countries worldwide.
- New exploitation technologies, like underground gasification will amplify competitive power of coal.

Fuel scenario in double-decade 1996-2015 is outlined in the following Figure 3 in which the percentages of fuel commodities are listed.

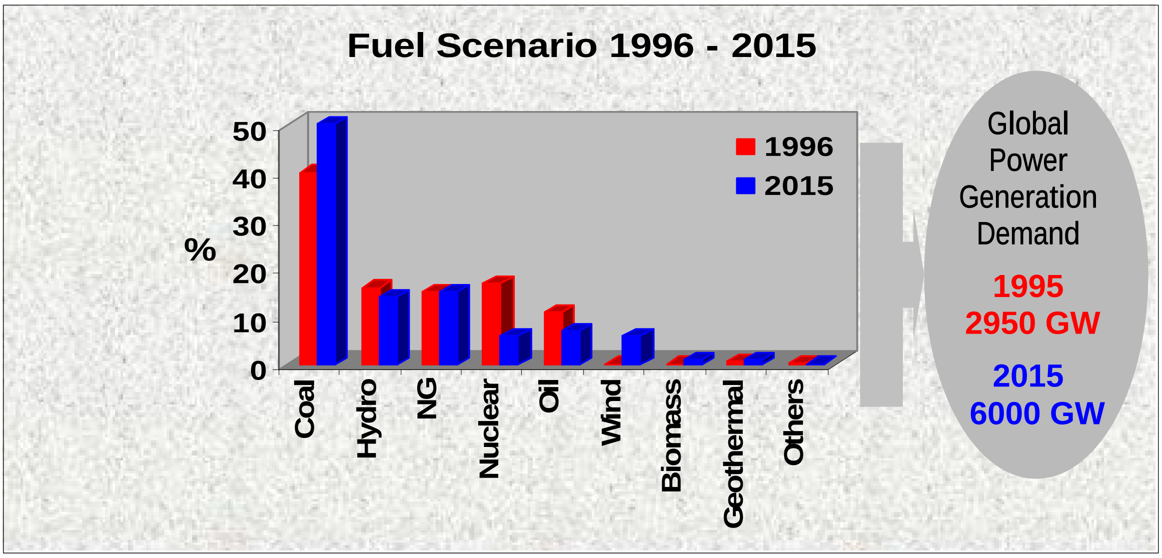

Figure 3

As it is obvious from the above listed figures, the increase in NG, coal, hydro, biomass and wind primary energy is counter-balanced by the nuclear drop from 15% to 8%. Coal will retain its dominant position with over 50% share.

For better illustration, the leading producers and consumers of NG & Coal are shown in the following Figure 4 and 5 respectively.

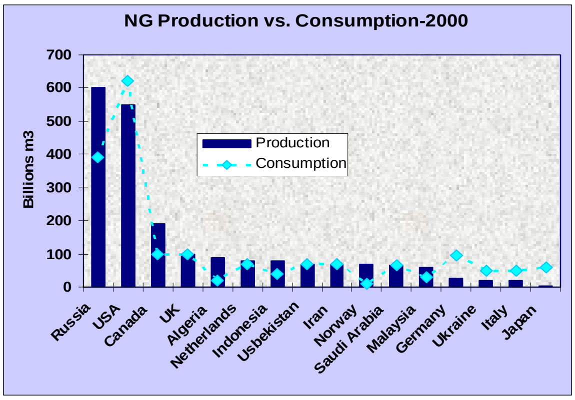

Figure 4

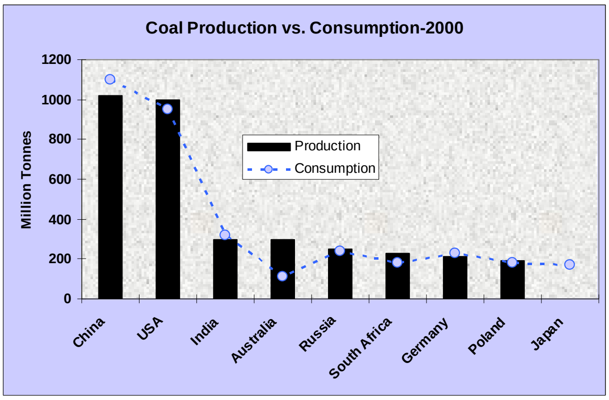

Figure 5

Countries in Southeast Asia (SEA) region have reached different levels of economic welfare, and this is reflected in their energy use patterns.

Some of the countries are well endowed with energy resources - to the extent of being major exporters of energy.

Others still face poverty problems, accompanied by low levels of energy use. To achieve improved standards of living throughout SEA, significant increases will be needed in supplies of available energy.

Currently all SEA countries are experiencing fast growing electricity demand with estimated demand for electricity grow between 6% and 8% per year for the next decade.

In several countries of SEA region, the increase in per capita energy consumption has been quite dramatic.

For instance, over the period 1965 to 1995, the per capita energy consumption of Indonesia, in kilograms of oil equivalent, increased from 91 to 240; in Thailand, from 80 to 360; in Malaysia, from 312 to 950; and in Singapore, from 670 to 2300.

While energy scarcity may occur in specific countries or in particular circumstances, it seems unlikely that there will be serious limitations on the overall supply of energy in SEA.

Historically, predictions of impending scarcities for natural resources, including primary energy, have largely proved to be unfounded.

Scarcities have been countered by changing the composition of energy inputs to the economic system, improved technologies for discovering and extracting energy, increased efficiencies in energy production and use, and improved energy demand management including energy conservation programs.

In the future, constraints on energy system management are more likely to derive from environmental considerations than from energy scarcity.

The enhanced greenhouse effect has emerged as a serious international policy concern, raising critical questions about the extent to which countries will be able to rely on fossil fuels as a basis for future economic growth.

Energy generation is considered a strategic industry in SEA. Currently, foreign investors are limited by equity stake in power generation projects in SEA countries.

This will probably change. Under the rules of the World Trade Organization (WTO) and Asean Free Trade Area (AFTA), of which they are signatories to both, SEA will need to further liberalize the energy sector and open it up to greater foreign investment.

It is well recognized that the ACCT will play key role in meeting expanding energy needs in SEA countries.

The 21st century holds the promise of high living standards for all SEA countries. Development will put greater pressure on the environment, but governments and communities will also place pressure on industry to protect the environment.

As SEA countries endeavor to achieve improvements in their living standards over time, energy development within the region will be of relevance to individual countries, the SEA region itself and increasingly, the global community.

On the energy front this requires cleaner, more reliable and more abundant energy.
The energy sector, particularly ACCT, certainly has some challenges ahead.

Equilibrium between Natural Gas & Coal - Switch-over from Natural Gas to Coal

The end of the double-decade, 1996-2015, is indicated as the starting point in which an interesting inversion between the two main fuel commodities may happen.

By our opinion, year 2015 may represent the point at which the decline of NG, accompanied with an ever increasing share of coal and other solid fuels in fossil-fuelled generation, starts.

Traditionally, coal has never been internationally traded on a large scale. Indigenous character of this primary source has always been prevailing. The new trend of becoming a world trade commodity is dated by 1973.

Since then, the international coal trade has doubled and it will probably be additionally tripled by 2015.

Today, the world price differential between coal price 1.6 USD/GJ and NG price 3.5 USD/GJ is too small to make coal competitive enough in territories where both these fuels are available.

The dramatic increase in CCGT systems implementation in private sector has been the result of cheap and easily available NG supplies.

NG with all of it excellent attributes in CCGT construction- and ecology preferences would have to cost more than 5 USD/GJ to be replaced by coal.

This may, however, come true with growing expenses for NG exploitation from ever less accessible resources, deeper wells and increasing costs for NG distribution network and related infrastructure bottleneck restriction.

In new technology scenario such switch-over between NG and coal will be accompanied with massive expansion of GT into the domain of solid fuel commodity.

As we have already outlined, this solid fuel and technology convergence is the main topic of our paper.

Clean Coal Technologies

Coal Gasification History, Present Situation and Future Prospects

Gasification has been known for more than 200 years. First record of its commercial application origins from the year 1830. Later, gas industry manufacturing producer gas from coal and biomass was established.

Primitive coal gasification (CG) systems provided town gas in many countries worldwide more 100 years ago and gasification industry produced coal and wood based transportation gaseous fuel for many European countries during Second World War. Later it has widely been used in chemical and fuel conversion industry.

For example SASOL process operating in South Africa, where more than 90 Lurgi gasifiers consume 30 millions tons per year of sub bituminous coal is commercially the most important application worldwide.

Worth mentioning are also trials carried out by Underground Gasification Europe (EGU) in partnership of Spain, Belgium and UK, supported by EC via THERMIE Programme.

This technology is also not new, but it is developed for large-scale commercial basis. Trials were carried out in the former USSR in thirties and recently in the USA.

The utilization of advanced gasification technology, adopted for power generation purposes, consists of two innovative attributes which both correspond with adaptability to GT admission circumstances.

The first is the combination of CG technology with combined cycle power generation employing IGCC and PFBC systems.

IGCC, like PFBC technology, combines both GT and steam turbines (ST) in combined cycle operation. Depending on the level of integration of the various processes, IGCC may in short term achieve 40 to 42% and in long term upto 50% efficiency. Using IGCC, approximately 60-70% of the power comes from the GT, compared with about 20% using PFBC.

The other important attribute is the gas cleanup system (GCS). The syngas leaving the gasifier must be properly cleaned.

The minimum requirements in terms of cleaning of the fuel gas produced by gasification are that:

- ✓ Solids such as ash must not pass through a GT because they lead to erosion, so must be removed.

- ✓ Alkali metals in combination with sulphur will lead to severe corrosion and therefore have to be removed.

In order to avoid condensation of volatile compounds in the GT, the temperatures at which the particulates and the alkali metals are removed from the GT shall preferably lay below the minimum GT temperatures.

The typical steps for GCS aim at particulates, sulphur (SOx) and NOx removal. This is achieved as follows:

- ➢ Particulate Removal → Combination of Cyclone Filters & Ceramic Candle Filters
- ➢ SOx & NOx removal → Combination of steam/water washing and removing the sulphur compounds for recovery of sulphur as a saleable product.

Usually the cleanup occurs after the syngas has been cooled. This, so called cold gas cleanup system (CGCS), decreases overall plant efficiency and indirectly increases power plant specific thus operational costs.

On the other side, the highly efficient hot gas cleanup system (HGCS) technology, which operates under high pressure and temperature, is currently under advanced demonstration phase.

> Due to higher reliability and availability, CGCS wet scrubbing technology, though with a lower efficiency, still remains the preferred option for gas clean-up systems.

Typical IGCC plant using CGCS is shown in the following picture, Figure 6.

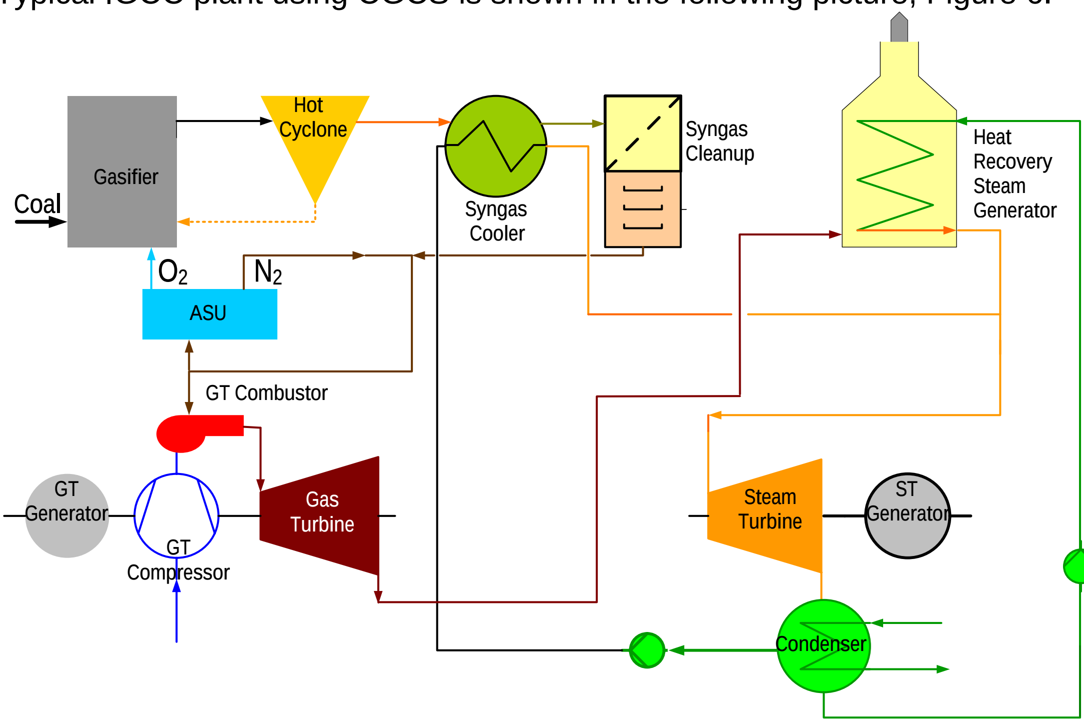

Figure 6

Each IGCC plant consists of three parts. Two of them, namely GT Power Plant and ST Power Plant are analogical to the standard CCGT system.

Third part is the chemical technology part - Gasification Island which is the key segment. Simplified IGCC scheme is shown in the following picture, Figure 7.

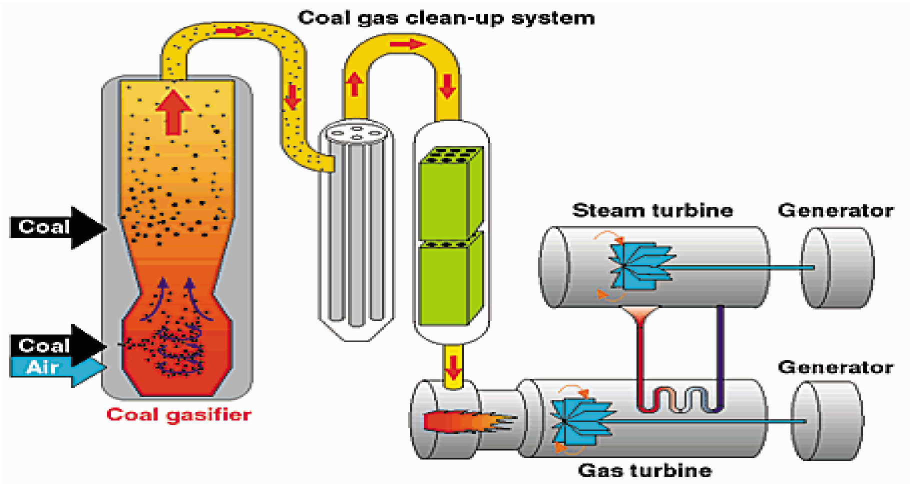

Figure 7

The gasifier can be blown either by oxygen or air. Steam injection may be also applied for moderation purposes.

The modern gasifier works under elevated operating pressure, what is the main difference compare to the classical gasification processes widely applied for more then a century.

Temperatures are much higher in the oxygen blown atmosphere due to the absence of nitrogen heat dissipating effect.

Energy saving effect is based on chemical energy transfer. In this manner, syngas medium is utilized with highly effective exergy balance, rather than sensitive heat of flue gas.

Gasification is carried out under oxygen-deficit reaction environment. 20% to 40% of stochiometric amount of O_2 related to a complete combustion enters the reaction, what is enough to cover the saturation energy necessary for a complete gasification.

Reaction temperatures are much higher compare to a general combustion process. Under such temperatures increased extend of devolatilization is made possible.

High concentrations of CO_2 and increased concentrations of H_2O are produced through.

IGCC systems can be built down to 100-150 MW modules, allowing flexibility in capacity expansion and lower unit costs than onsite fabrication.

Efficiencies approaching 50%, >99% SO_2 removal, and NOx <50ppm, normally impracticable with any other solid fuel fired technology, are potentially possible.

It should be noted that IGCC has yet to achieve significant market entry and commercial deployment.

For this to occur, IGCC components must continue to evolve and attain a concurrent decrease in production costs.

Coal Gasification Technologies

Coal gasification is a process that converts carbonaceous feedstock (in this case coal) into gaseous products (synthesis gas → syngas) at high temperature and elevated pressure in the presence of oxygen and steam.

Partial oxidation of the feedstock provides the heat. At operating conditions, chemical reactions produce syngas, a mixture of predominantly CO and H_2.

There are also several options for controlling the flow of coal in the gasifier section (e.g., fixed-bed, fluidized-bed, and entrained-flow systems).

Many gasification processes being demonstrated use O_2 as the oxidizing medium. Coal gasification systems can incorporate any one of a number of gasifiers.

Eight gasification technologies that are predominantly used in commercial applications are briefly described in this section.

1. Lurgi Dry Ash Gasifier

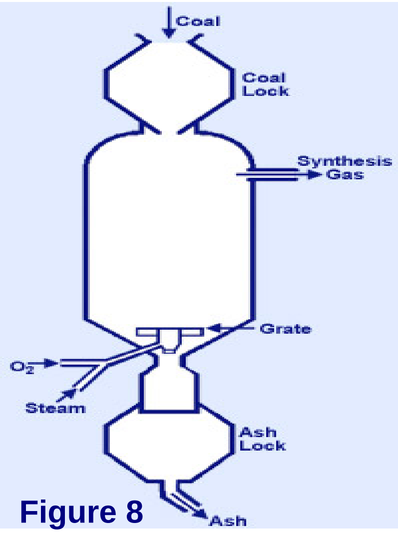

Figure 8

Lurgi dry ash coal gasification takes place in a double shelled pressure gasifier (25 - 28 bar) with steam oxygen mixture (Figure 8).

In gas purification process ammonia and phenol are removed, H_2SO_4 95% is produced Coal (lignite) graded 10mm to 30mm enters the top of the gasifier through a lock hopper and moves down through the bed.

Steam and oxygen enter at the bottom and react with the coal as the gases move up the bed.

Ash is removed at the bottom of the gasifier by a rotating grate and lock hopper.

The countercurrent operation results in a temperature drop in the reactor.

Temperatures in the combustion zone near the bottom of the gasifier are in the range of 1100°C, whereas gas temperatures in the drying and depolarization zone near the top are approximately 260 - 540°C.
The raw gas is quenched with recycle water to condense tar. A water jacket cools the gasifier vessel and generates part of the steam to the gasifier.

Sufficient steam is injected to the bottom of the gasifier to keep the temperature below the melting temperature of ash.

2. Texaco Entrained Flow Gasifier

Texaco coal gasification technology uses a single stage, downward firing, entrained flow coal gasifier in which a coal/water slurry (60 - 70% coal) and 95% pure oxygen are fed to a hot gasifier (Figure 9).

At a temperature of about 1500°C, the coal reacts with oxygen to produce raw synthesis gas (syngas) and molten ash.

The hot gas flows downward into a radiant syngas cooler where high pressure steam is produced.

The syngas passes over the surface of a pool of water at the bottom of the radiant syngas cooler and exits the vessel.

Figure 9

The slag drops into the water pool and is fed from the radiant syngas cooler sump to a lock hopper.

The black water flowing out with the slag is separated and recycled after processing in a dewatering system.

3. E-GAS Entrained Flow Gasifier

The E-GAS coal gasifier is a slurry-feed pressurized up flow entrained slogging gasifier whose two-stage operation makes it unique (Figure 10).

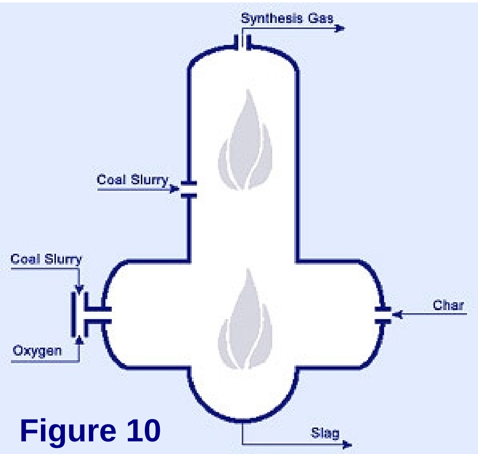

Figure 10

Wet crushers produce coal slurries. About 80% of the total slurry feed, combined with 95% pure O_2, is injected into the first (bottom) stage of the gasifier.

The highly exothermic gasification/ oxidation reactions take place rapidly at temperatures of 1300 - 1430 ºC and 28 bar.

The coal ash is converted to molten slag which flows down through a tap hole.

The hot raw gas from the first stage enters the second (top) stage which is a vertical cylinder perpendicular to the first stage.

In the second stage, the examining 25% coal slurry is injected in to the hot raw gas.

The endothermic gasification/devolatilization reactions in this stage reduce the gas temperature to about 1040°C and add some hydrocarbons to the product gas. Particulates are removed in a hot/dry filter and recycled to the gasifier.

The syngas is water scrubbed to remove chlorides and passed through a catalyst that hydrolyzes COS into H2S. H2S is removed in the acid gas columns.

A Claus unit is used to produce elemental sulphur as a salable by-product.

The 1040°C hot gas leaving the gasifier is cooled in a fire-tube product gas cooler to 600°C generating saturated steam which is sent to the steam turbine.

The "sweet" gas is then moisturized, preheated, and piped to the GT power block.

4. Shell Entrained Flow Gasifier

The Shell gasifier is a dry-feed, pressurized, entrained slagging gasifier (Figure 11).

Feed coal is pulverized and dried with the similar type of equipment used for conventional pulverized coal boilers.

The coal is pressurized in lock hoppers and fed into the gasifier with a transport gas by dense-phase conveying.

The transport gas is usually nitrogen; however, product gas can be used for synthesis gas chemical applications, where nitrogen in the product gas is undesirable.

The oxidant is preheated to minimize oxygen consumption and mixed with steam as moderator prior to feeding to the burner.

The coal reacts with oxygen at temperatures in excess of 1370°C to produce principally hydrogen and carbon monoxide with little carbon dioxide.

Operation at elevated temperatures eliminates the production of hydrocarbon gases and liquids in the product gas.

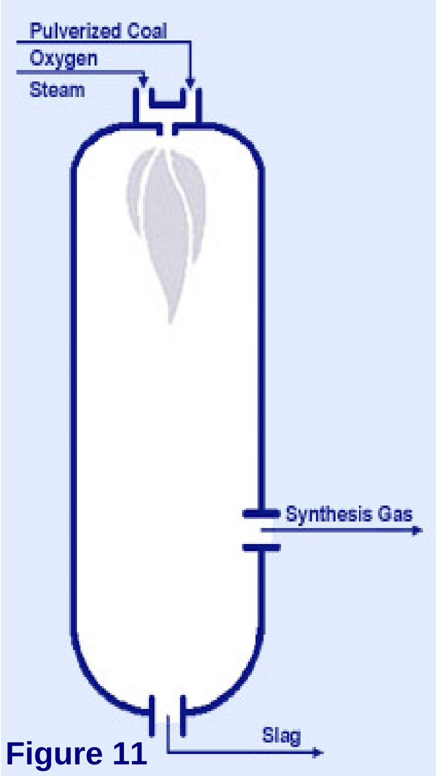

Figure 11

The high-temperature gasification process converts the ash into molten slag, which runs down the refractory-lined water wall of the gasifier into a water bath, where it solidifies and is removed through a lock hopper as slurry in water.

Some of the molten slag collects on the cooled walls of the gasifier to form a solidified protective coating.

The crude raw gas leaving the gasifier at 1370-1650°C contains a small quantity of unburned carbon and about half of the molten ash.

To make the ash non-sticky, the hot gas leaving the reactor is partially cooled by quenching with cooled recycle product gas.

Further cooling takes place in the waste heat recovery (syngas cooler) unit, which consists of radiant, superheating, convection, and economizing sections, where high-pressure superheated steam is generated before particle removal.

5. KRW Fluidized-Bed Gasifier

Kellog-Rust-Westinghouse (KRW) is an air-blown fluidized-bed gasifier with HGCS (Figure 12).

Coal and limestone, crushed to below 7 mm, are transferred from feed storage to the gasifier.

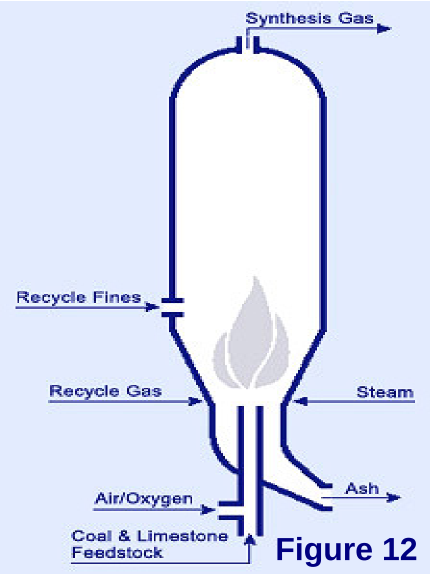

Figure 12

Gasification takes place by mixing steam and air (or O_2) with the coal at a high temperature.

The fuel and oxidant enter the bottom of the gasifier through concentric high velocity jets, which assure thorough mixing of the fuel and oxidant and of the bed of char and limestone that collects in the gasifier.

Upon entering the gasifier, the coal immediately releases its volatile matter, which burns rapidly, supplying the endothermic heat of reaction for gasification.

The combusted volatiles form a series of large bubbles that rise up the center of the gasifier, causing the char and sorbent in the bed to move down the sides of the reactor and back into the central jet.

The recycling of solids cools the jet and efficiently transfers heat to the bed material. Steam, which enters with the oxidant and through a multiplicity of jets in the conical section of the reactor, reacts with the char in the bed, converting it to fuel gas.

At the same time, the limestone sorbent, which has been calcined to CaO, reacts with H_2S released from the coal during gasification, forming CaS.

As the char reacts, the particles become enriched in ash. Repeated recycling of the ash-rich particles through the hot flame of the jet melts the low-melting components of the ash causing the ash particles to stick together.

These particles cool when they return to the bed, and this agglomeration permits the efficient conversion of even small particles of coal in the feed. The velocity of gases in the reactor is selected to maintain most of the particles in the bed.

The smaller particles that are carried out of the gasifier are recaptured in a high efficiency cyclone and returned to the conical section of the gasifier, where they again pass again through the jet flame.

Eventually, most of the smaller particles agglomerate as they become richer in ash and gravitate to the bottom of the gasifier.

Since the ash and spent sorbent particles are substantially denser than the coal feed, they settle to the bottom of the gasifier, where they are cooled by a counter-flowing stream of recycled gas.

This both cools and classifies the material; sending lighter particles containing char back up into the gasifier jet.

The char, ash, and spent sorbent from the bottom of the gasifier flow to the fluid-bed sulphator, where both char and calcium sulphide are oxidized.

The CaS forms $CaSO_4$, which is chemically inert and can be disposed of in a landfill. Most of the spent sorbent from the gasifier contains unreacted CaO. Sulphur released from burning residual char in the sulphator is also converted to $CaSO_4$.

6. PRENFLO Entrained O_2 Blown Gasifier

PRENFLO gasification process, developed by Krupp-Koppers and Siemens/KWU. PRENFLO technology uses entrained, oxygen-blown gasifyer based on the Kopper´s Totzek process adapted to pressurized system.

In PRENFLO gasifyer, coal is converted with oxygen of 95% purity. Residence time is few seconds. Syngas leaves the gasifier at 1300 °C. Raw gas is quenched to 900°C and subsequently cooled in convection boiler to 450°C.

7. Kellogg Transport Gasifier

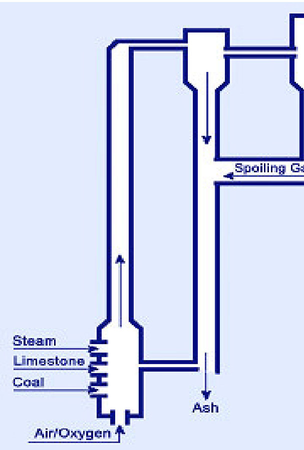

Figure 13

The Kellogg Transport Gasifier is a circulating-bed reactor concept that uses finely pulverized coal and limestone (Figure 13).

The gasifier is currently in development, which may lead to a commercial design. It is expected that the small particle size of the coal and limestone will result in a high level of sulfur capture.

Additionally, the small particle size will increase the throughput compared to a KRW gasifier, thereby potentially reducing the gasifier size and the cost.

The gasifier consists of a mixing zone, a riser, cyclones, a standpipe, and a non-mechanical valve.

Oxidant and steam are injected at the bottom of the gasifier in the mixing zone. Coal and limestone are fed in the upper section of the mixing zone.

The top section of the gasifier discharges into the disengager or primary cyclone.

The cyclone is connected to the standpipe, which discharges the solids at the bottom through a non-mechanical valve into the transport gasifier mixing zone at the bottom of the riser.

The gasifier system operates by circulating the entrained solids up through the gasifier riser, through the cyclone, and down through the standpipe.

The solids reenter the gasifier mixing zone through the non-mechanical valve.

The steam and oxidant jets provide the motive force to maintain the bed in circulation and oxidize the char as it enters the gasifier mixing zone. The hot gases react with coal/char in the mixing zone and riser to produce raw gas.

The raw gas and entrained solids leave the primary cyclone pass through the secondary cyclone to provide final de-entrainment of the solids from the gas.

The syngas leaving the secondary cyclone passes through a gas cooler, which reduces the gas temperature from about 1050°C to <600°C.

8. British Gas/Lugi Fixed-Bed Gasifier

The British Gas/Lurgi (BGL) coal gasifier is a dry-feed, pressurized, fixed-bed, slagging fix bed gasifier. The reactor vessel is water cooled and refractory lined (Figure 14).

Each gasifier is provided with a coal distributor/mixer to stir and evenly distribute the incoming coal mixture.

O_2 and steam are introduced into the gasifier vessel through sidewall-mounted lances at the elevation where combustion and slag formation occur.

The mixture of coarse coal, fines, briquettes and flux, which is introduced at the top of the gasifier gradually descends through several process zones.

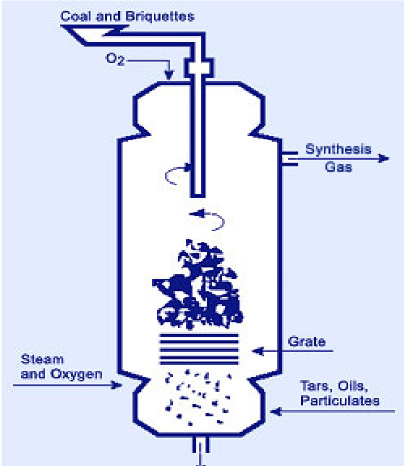

Figure 14

The mixture of coarse coal, fines, briquettes, and flux, which is introduced at the top of the gasifier gradually descends through several process zones.

Coal at the top of the bed is dried and devolatilized. The descending coal is transformed into char, and then passes into the reaction (gasification) zone.

Below this zone, any remaining carbon is oxidized, and the ash content of the coal is liquefied, forming slag. The slag flows downward into a quench chamber and lock hopper in series.

The pressure differential between the quench chamber and gasifier regulates the flow of slag between the two vessels.

Syngas exits the gasifier at approximately 560°C through an opening near the top of the gasifier vessel and passes into a water quench vessel and a boiler feed water (BFW) preheater designed to lower the temperature to approximately 150°C.

Entrained solids and soluble compounds mixed with the exiting liquid are sent to a gas-liquor separation unit. Soluble hydrocarbons, such as tars, oils, and naphtha are recovered from the aqueous liquor and recycled to the top of the gasifier.

Other ACC Technologies

SC - Supercritical Steam Conditions & USC – Ultra Supercritical Steam Conditions

SC and USC coal fired power plants use specially developed high strength alloy steels, which enable the use of supercritical and ultra-supercritical steam with pressures higher than 245 bar and temperatures above 570°C. Such power plants can achieve, depending on location, 45% and higher efficiency.

Application of new advanced materials to USC power plants should enable efficiencies of 55% to be achieved in the future.

This results in corresponding reductions in CO_2 emissions as less fuel is used per unit of electricity generated.

Currently, an efficiency of 47% has been proved in SC power plants Nordjylland & Skaerbaeck and 48% at Avedore (both in Denmark).

This is superior to Puertollano, the most advanced IGCC project in Europe with design efficiency 43%. It should be pointed out, however, that this technology, as a conventional coal-fired technology has almost 100 years development over, but limited space for further technical progress.

Efficiencies above 50% are expected only under extreme steam conditions of 350 bar, 720°C in the 2015 time horizon (refer also to our paper "**Supercritical Steam Power Plants - an Attractive Option for Malaysia**" presented at Malaysia Power 2003 conference).

PFBC - Pressurized Fluidised Bed Combustion

PFBC combustion is a method of burning coal in a pressurized bed of heated particles suspended in a gas flow.

At sufficient flow rates, the bed acts as a fluid resulting in rapid mixing of the particles. Coal is added to the bed and the continuous mixing encourages complete combustion and a lower temperature than that of pulverized fuel (PF) combustion.

The advantages of fluidized beds are that they produce less NOx in the outlet gas, because of lower combustion temperatures, and they produce less SOx when limestone is continuously added with the coal.

They can also use a wider range of fuels than PF combustion. PFBC power plants, which can achieve efficiencies of 45%, are now in commercial operation.

HCC - Hybrid Combined Cycle

HCC cycles, which are currently under development, can combine both gasification and combustion technologies, using coal in a two-stage process.

The first stage gasifies the majority of the coal and runs a GT, the second stage combusts the residual 'char' to produce steam for ST drive.

Additionally the waste heat from GT can be utilized in heat recovery boiler to generate additional steam for ST. Efficiencies greater than 50% are possible.

DCCC- Direct Coal fired Combined Cycle

The research on direct coal firing in gas turbines has been carried out for almost fifty years. The initial difficulties were related to the severe effects of coal ash on turbine blade path components (corrosion, erosion and deposition).

This technology is concentrating on two following major areas:

- The coal quality and
- Combustion technology.

Only high purity, chemically cleaned ultra clean coal (UCC) can be fueled directly into gas turbines, to provide high efficiency power generation.

The residual ash must be reduced to less than 0.2% of the coal and the particles of ash need to be less than 5µm in size and the coal must contain extremely low levels of alkali metals such as sodium and potassium.

High pressure (18-30 bar) slagging coal combustors must allow removal of residual ash as a liquid prior to entering the turbine. The hot gas clean up must take place above the ash melting temperature (1400-1600ºC) and high pressure (at least 18 bar).

There is an efficiency penalty with respect to NG fuelled CCGT power plants. The expected efficiency ranks around 45%. Its estimated costs would be twice those of NG-fuelled CCGT power plant. DCCC is not yet a proven technology, its state of development being still in the laboratory phase.

FC - Fuel Cell

FC technology is still in the early development stage. FCs allow hydrogen from coal gas to react electrochemically with oxygen from the air to generate electricity.

FCs have the potential for high power generation efficiency (above 52%) and low CO_2 emissions.

The use of fuel cells has been demonstrated at the 2 MWe size in Australia and plans are underway to use hydrogen from coal gasification in this and other technologies.

Currently, the molten carbonate fuel cell (MCFC) is being developed as a part of the New Sunshine Program of the Agency of Industrial Science and Technology, in the Ministry of International Trade and Industry (AIST/MITI) in Japan.

Together with sequestration of CO_2 in isolation, this clean coal technology provides a nil CO_2 option.

However, lower cost equipment and more particularly markets for hydrogen need to be developed.

MHD - Magneto Hydrodynamics

MHD is an advanced coal fired power generation technology that is in the development stage for more than 30 years. In a coal-fired MHD system, coal is burned to form an extremely hot gas or plasma. This is given an electric charge by adding a seed compound like potassium salt.

When the charged gas is passed through a strong magnetic field, electricity is produced. Heat from the combustion gases is also used to produce electricity using a conventional steam turbine.

Technological & Commercial Constraints

If the energy generated from an IGCC plant is to compete with energy price generated from NG CCGT power plant, it will have to tolerate a maximum capital cost of 650 US$/kW for a stand alone power generation unit a highly improbable task.

650 US$/kW is the current estimated cost of a state-of-the-art NG fired CCGT power plant in 2005, whereas a fully mature IGCC plant would probably cost in the range of 1'100 to 1'400 US$/kW and the first generation IGCC power plant will cost over 1'500 to 2'000 US/kW (Refer also to Table 1).

If IGCC is to be benchmarked against conventional fired stations with NG installations to ensure competitiveness, IGCC specific costs should aim to be below US$1,000/kW.

A number of methods may be suggested to reduce specific capital costs for IGCC power plants built in SEA:

- Use the most advanced, large heavy duty GTs available;
- Standardize and modularize the equipment;
- Decrease overhead expenditures such as engineering and project management;
- Maximize the local content;
- Rationalize measures for construction and installation;
- Increasing economy of scale (specific costs for larger installations are lower).

A major factor in the comparative costs of coal- and NG-based power generation systems is fuel price. Compared with the price of oil and NG, the price of coal is expected to be stable.

In fact, coal prices are expected to decline in the next two decades while the price of NG is projected to more than double for the same period.

If this happen in the future and NG price increases, NG could be replaced by syngas generated by gasifiers.

The Figure 15 shows the estimated current specific investment and fuel cost for selected power generation systems, each at the nominal 10 to 1000 MW size.

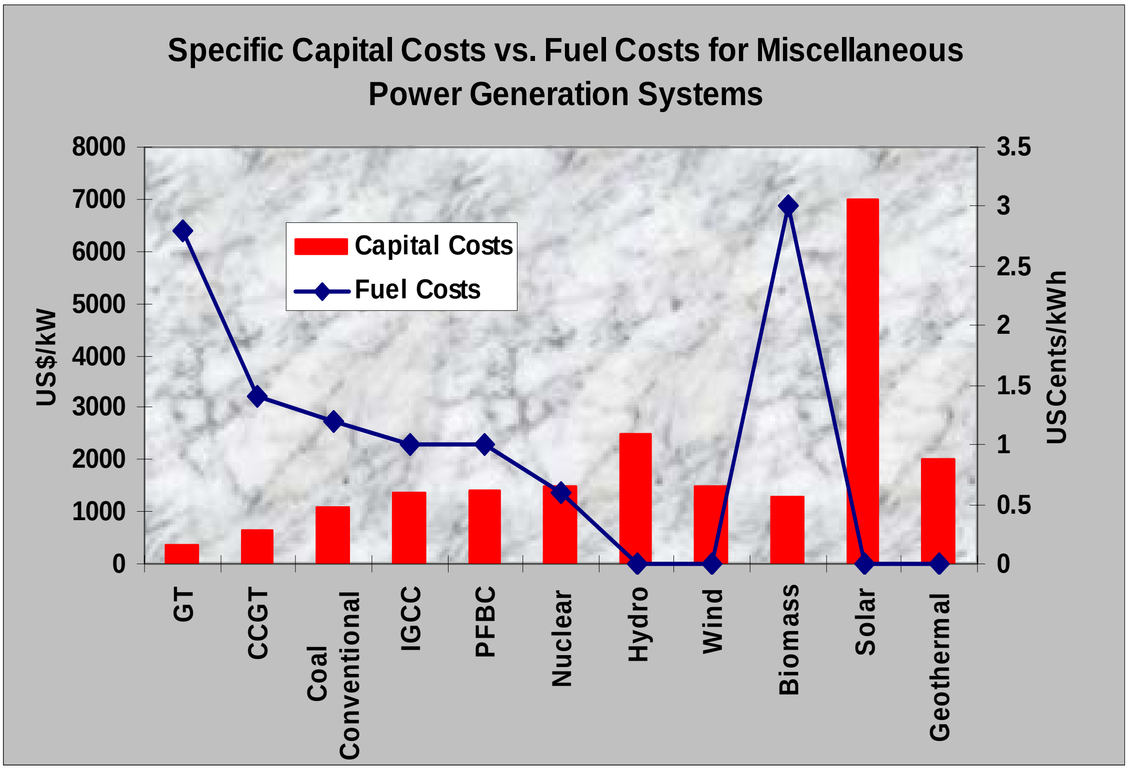

Figure 15

The size is depending on selected system, smaller size is applicable for solar, biomass and wind power generation systems, the larger size for conventional coal, hydro and nuclear power generation systems.

An important cost aspect considered for IGCC and PFBC is rather an expensive air separation unit (ASU) necessary for oxygen supply. In both cases, estimated ASU price is approximately 15% of the total investment cost.

For numerous reasons the cost of a given power generation technology will vary for different countries. For the purposes of this paper, the convention assumed was that the subject power plant would be SEA region.

It was also assumed for the purposes of the assessments, that the each power plant technology would represent the present state-of-the-art.

Assessment conventions such as site and climatic conditions, and fuel quality, were set so that the assessments would give an indication of the best that could (reasonably) be expected to be achieved for a given technology.

This enables each technology to be compared against the others on the consistent basis of it being applied in favorable circumstances (Figure 15).

The Figure 16 shows specific NOx emissions from selected power generation systems.

The results should be compared with caution as differing extents of NOx mitigation were applied in the studies, as being representative of state-of-the-art technology.

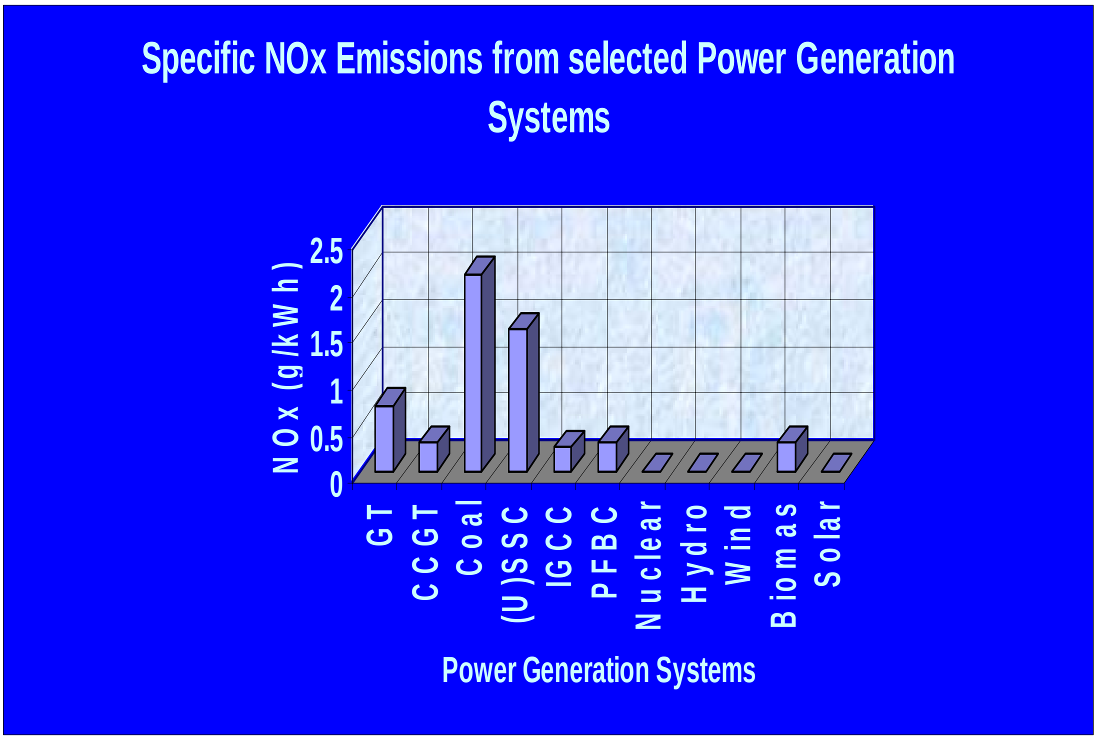

Figure 16

For the two coal combustion cases, NO_x reduction was limited to the use of low- NO_x burners; the IGCC case assumed injection of nitrogen from the ASU into the GT to limit NO_x formation; and the GT and CCGT case assumed the use of modern, low dry NOx burner technology.

Review of IGCC Projects Processing Coal as the Main Feedstock

Why Governments and power generation industry in many countries are supporting design and construction of “more expensive and slightly less reliable” clean coal, IGCC and PFBC power plants?

The answer is simple. In year 2025 the worldwide consumption of primary energy will be around 50 to 55% higher than today.

This need cannot be met without using coal because of the limitations of other fuels.

The known worldwide supply of NG is estimated to be about 50 years' worth based on current rates of consumption and renewable are still not close to being viable for large-scale power generation.

The general public may be unaware of how much cleaner coal has become, but much of coal's poor reputation is deserved.

In today's terms, many existing coal power plants are relatively inefficient with high levels of emissions. Efficiency and emissions level improvements through alternative methods of combusting coal are required.

Old coal fired power plants, built before strict environmental regulations were enacted, are exempt from the regulations and continue to pollute at an uncontrolled rate in many countries worldwide.

Coal emits more CO_2 and SO_2 than other fossil fuels, and the public is increasingly concerned about global warming.

CO_2, which is not yet regulated, is believed by many to be a leading cause of global warming.

Miscellaneous ACCT programs in Europe, USA and Japan have successfully demonstrated the simplest use of gasification for electricity, the IGCC.

Even though that the coal processing category of IGCC projects has not definitely overcome the demonstration stage of development there are many IGCC power plants either in operation or under construction.

Nevertheless that these projects still need subsidies in various forms to attain economical viability in the competitive free market environment, the gasification technology will probably be one of the most important energy technologies because it offers strategic flexibility with respect to fuel in the uncertain world of competitive markets and the need for least cost options for carbon mitigation.

Furthermore, IGCC power plants have environmental superiority over any other coal-based technologies

The process of transferring the theory into practical commercial applications has proved to be difficult and still proves to be the main stumbling block behind their lack of widespread implementation.

However, there are already many coal fired IGCC power plants in operation or under construction.

A brief technical and economical review of some selected IGCC power plants fired with coal based syngas is given in Table 1 below.

ID. No.	Project	Location	Gasification Technology	Fuel	Efficiency (%)	Total Power Output (MW)	Start of Commercial Operation	Capital Costs (US$/kW)
P1	SUV / EGT	Litvinov, Czech Republic	Lurgi	Lignite		350	1997	
P2	Elcogas SA	Puertollano Spain	Prenflo-O_2	Coal & Petcoke	42.7	335	1997	2900
P3	Tampa Electric	Polk City USA	Texaco	Coal	40	316	1996	2000
P4	PSI/ Destec	Wabash River USA*)	E-GAS	Coal & Petcoke	39.7	260	1995	1600
P5	Willem Alexander	Buggenum Netherlands	Shell	Coal	41.3	253	1994	2110
P6	Lakeland Water/DOE	Lakeland USA	ACFBCC	Coal		240	2007	
P7	Steag Kellerman	Lunen	BGL	Coal	31.7	170	1969	
P8	LGTI	Plaquemine	E-GAS	Western Coal	36	160	1987	2140
P9	SCE Cool Water	Cool Water USA	Texaco- O_2	Coal	31.2	100	1984	4890
P10	Sierra Pacific	Pinon Pine USA	KRW-air	Lignite	38	99	1996	2300
P11	Schwarze Pumpe	Cottbus Germany	Lurgi-O_2/BGL	Coal / Wastes		75	1995	
P12	Vresova	Vresova Czech Republic	HTW	Lignite		376	1996	

*) Wabash River is a repowering IGCC

Table 1

P1-SUV / EGT Power Plant

Owner SUV/EGT

Location Town of Litvinov, Czech Republic.

Gasification Technology Lurgi pressurized coal gasification.

Fuel Lignite

SUV/EGT, had been producing town gas (CO_2-25%, CO-15%, H_2-48%, CH_4-12% with LHV 14.5 kJ/kg) from lignite using 26 pressure gasification Lurgi reactors before this IGCC was commissioned.

P2-Puertollano Power Plant

Owner	Elcogas S.A, Spain, started commercial operation on syngas by the end of 1997.
Location	Pueratollano, Spain
Gasification Technology	Puertollano is the first project to use the PRENFLO gasification process, developed by Krupp-Koppers and Siemens/KWU.
Process parameters	Gross Power Output 317.0 MWe GT Power Output 182.0 MWe ST Power Output 135.0 MWe Auxiliary Consumption 39.0 MWe Net Efficiency (LHV) 42.7 %
Fuel	A mixture of ash-rich petroleum coke from nearby refinery is used.
Financing	Project was funded by CEC and by German Ministry of Research & Development. Investment cost was about 1500 US$/kWe.

Owing to the fact that Puertollano station is a single-train plant it can be considered as IGCC with the biggest output per train among all currently operating plants in the world.

At the same time it has the highest design efficiency among all IGCC plants in operation or under construction.

P3-Tampa Electric Power Plant

Owner	Tampa Electric Company, started commercial operation of this IGCC in locality of Polk Power Station in June 1996.
Location	Mulbery, Polk County, Florida, USA.
Gasification Technology	Texaco, entrained flow.
Process Parameters	Total Gross Power Output 316.0 MW Total Net Power Output 250.0 MW Gross Efficiency 40.0 %
Fuel	Coal→Illinois #6, Pittsburgh #8, Kentucky #11, and Kentucky #9; 2.5%-3.5% S
Investment cost	303 Millions US$ (50% of this cost was subsidized by the US Department of Energy-DOE).
Financing	DOE

The Tampa Electric IGCC project conducted at Polk Power Station in Florida, USA, has successfully demonstrated the commercial application of Texaco coal gasification in conjunction with electric power generation.

The gasifier operated more than 29,000 hours and processed coal at a rate of 2,300 tons/day, while the combustion turbine operated over 28,000 hours to produce over 8.6 million MWh of electricity on syngas.

Carbon burnout exceeds 95%, and emissions of SO_2, NO_x, and particulates are well below the regulatory limits set for the Polk plant site.

Along with other IGCC demonstrations in the CCT Program, the Polk Plant is one of the cleanest coal-based power generation facilities in the world.

P4-Wabash River Power Plant

Owner	JV Destec Energy, Inc & PSI Energy, Inc., Indiana	
Location	West Terre Haute, Indiana, USA	
Gasification Technology	E-GAS entrained flow.	
Fuel	Illinois basin bituminous high-sulphur coal.	
Process Parameters	Syngas Capacity	495.0 MWt
	GT Power Output	192.0 MWe
	ST Power Output	104.0 MWe
	Auxiliary Consumption	36.0 MWe
	Total Net Power Output	260.0 MWe
	CCGT Net Efficiency	52.8 %
	Gasification efficiency	75.2 %
	IGCC Net Efficiency	39.7 %
	Sulphur Removal Efficiency	>99.0 %
Investment cost	438 Millions US$ (50% of this cost was subsidized by the US DOE).	
Financing	DOE	

As one of 40 USA government/industry funded projects in the ACCT program, the Wabash River project repowered the oldest of six pulverized coal units using a "next-generation" coal gasifier, an advanced GT and a heat-recovery steam generator.

The demonstration unit is designed to use 2’550 tons/day of high-sulfur (2.3-5.9% S), Illinois Basin bituminous coal.

The design heat rate for the repowered unit is 9’530 kJ/kWh (approximately 37.7% efficiency).

P5-Willem Alexander Power Plant

Owner	NUON, Netherlands
Location	Bruggenum, The Netherlands
Gasification Technology	Shell Entrained Flow gasifier.

Fuel	Internationally Traded Coal	
Process Parameters	Total Net Power Output Net Efficiency	253.0 MWe 41.3 %
Investment Costs	535 Millions US$	

The Willem Alexander plant was one of the first successful IGCC power plants in the world. The project was ordered in 1990.

Construction was completed at the end of 1993, and the plant was commissioned in 1994. It was a pioneering example of combined-cycle technology applied to coal-fired power generation.

The operator, Demkolec BV, currently faces the challenging prices of the French nuclear electricity power in the new deregulated market.

P6-Lakeland (Mc Intosh) ACFBCC Power Plant

Owner	Tampa Electric Company & City of Lakeland, DOE and Water Utilities, USA.	
Location	City of Lakeland, Florida, USA.	
Gasification Technology	Foster&Wheeler's (F&W) advanced circulating fluidised bed combined cycle (ACFBCC) technology.	
Fuel	Coal	
Process Parameters	GT Power Output ST Power Output Steam Pressure Steam Temperature	60.0 MWe 200.0 MWe 165.0 bar 538.0 °C

The power plant integrates two steps. First step is partial gasification of coal resulting in syngas production for GT fuel supply and the second is PCFB process for steam generation for ST drive.

Because this unit operates at temperatures much lower than gasifiers currently under development, it also produces a char residue.

Lime-based sorbents are injected into the carboniser, to catalytically enhance tar cracking and capture of sulphur as calcium sulphide.

Sulphur is captured in-situ, and the raw syngas is fired hot. Thus, expensive, complex, fuel gas heat exchangers and chemical or S-capturing bed cleanup systems otherwise typical for IGCC are eliminated.

Time schedule of this project is planned as follows:

- Demo operation initiated 07/2005
- Demo operation completed, final report issued 07/2007

P7-Lunnen Power Plant

Owner	Steag & Kellerman
Location	Lunen, Germany

Gasification Technology	BGL (British gas Lurgi)
Process Parameters	Net Power Output 170.0 MW Net Efficiency 31.7 %
Fuel	Coal

This project is believed to be historically the first true IGCC plant. STEAG Kellermann, Lunnen, Germany, commissioned it in 1969.

After 10,000 hours of operation it was decommissioned in 1972. BGL (British Gas Lurgi) was the technology applied.

P8-Plaquemine Power Plant

Owner	Destec & Dow Chemical
Location	Plaquemine, Louisiana, USA
Gasification Technology	DOW 2-stage, entrained, coal-fired, oxygen-gasification, ash slagging, with CGCU
Process Parameters	Net Power Output 160.0 MW Net Efficiency 36.0 %
Fuel	Western coal
Investment Costs	560 Millions US$

This IGCC was commissioned by LGTO in Plaquemine, Louisiana in 1987. Destec and Dow Chemical gasify the 2500 tons of western coal per day 160 MW of power.

P9-Cool Water Power Plant

Owner	EPRI, USA
Location	Barstow, Mojave Desert, California, USA.
Gasification Technology	Texaco Entrained Flow, O_2 gasifier.
Process Parameters	Total Net Power Output 100.0 MW Net Efficiency 31.2 %
Fuel	Coal
Investment Costs	489 millions US$

The pioneering 100 MWe Cool Water demonstration in California commissioned in 1984, the first of its kind in the world, operated for 4 years. It was decommissioned in 1989.

P10-Pinon Pine Power Plant

Owner	Sierra Pacific Power Company
Location	Reno, Nevada, USA
Gasification Technology	KRW (Kellog-Rust-Westinghouse) air-blown fluidized-bed gasification with HGCS.

Process Parameters	GT Power Output	61.0 MWe
	ST Power Output	46.0 MWe
	Gross Power Output	107.0 MWe
	Net Power Output	99.0 MWe
	Net Efficiency	39.0 %

Fuel Coal Southern Utah bituminous, with 0.5%-0.9% sulphur.

Investment Costs 250 Millions US$

Financing 50% funded by US DOE

P11-Schwarze Pumpe Power Plant

Owner Sekundarrohstoff-Verwertungszentrum Schwarze Pumpe GmbH, Germany

Location Cottbus, Germany

Gasification Technology 1st Phase: Lurgi dry ash fixed-bed, O_2-blown.
2nd Phase: BGL slagging fixed-bed.

Process Parameters Net Power Output 75 MWe

Fuel Pelletised refuse & lignite (85 % town waste and 15 % lignite)

After the German reunification, the "Schwarze Pumpe" town gas plant near Cottbus was converted within a short period of time from producing town gas from local lignite to making syngas for methanol and fuel gas for IGCC.

75 MWe power is produced from a mixture of lignite with wide variety of solid and liquid wastes, residues and contaminated materials.

P12-Vresova Power Plant

Owner Sokolovska Uhelna (SU) is a joint-stock company at Sokolov, Czech Republic, around half publicly owned and another half privately owned.

Location Sokolov, Czech Republic

Gasification Technology KRW

Process Parameters	Gross Power Output	376.0 MWe
	Net Power Output	358.0 MWe

Fuel Lignite

SU main activities are coal (lignite) mining, and electricity generation. SU built fixed bed pressurized lignite gasifier and gas purification plant in 1960's to convert lignite to gas and supply town gas.

It was one of the largest town gas generation plant in Central Europe until 1996. However, the town gas has been replaced by NG from Russia since 1996.

SU installed two units of 200 MW CCGT cycle to generate electricity to be fed by the gas produced by the gasification plant.

After studying several alternatives, SU concluded that installing new units of fluidized bed gasifier with HTW gasification technology is most economical solution.

Conclusions

- IGCC is still in early stage of commercialization. Several commercial demonstration projects which are on going worldwide are associated with technical risks and higher cost.
- Demonstration power plants with an installed capacity up to 400 MW are in operation or under construction. The commercial availability of larger units is not expected before 2005.
- The primary constraints to the application of IGCC power plants in developing countries are that the technology needs further demonstration; the costs are higher than those of competing technologies, and the fact that environmental regulations in many developing countries still do not require the high SO_2 removal and low-NO_x emissions achieved by IGCC.
- Current IGCC coal gasification projects would not have been economically viable, unless amply subsidized under various national & international entities and supporting programmes.

Despite of existing, above mentioned problems, IGCC has very big margin how to boost efficiency considerably above 50% and to reduce emissions to NG fired power plants level.

The strongest arguments for IGCC technology are:

- IGCC technology it is one of the advanced coal utilization technology with high efficiency and low environmental emissions including CO_2.
- It has a large potential to reduce GHG (Greenhouse Gas) emissions in the long term when the technology is wide spread in the world.
- Modern coal gasification technology can use low quality coal or lignite which can be found in many Asian countries such as India, Indonesia and China.
- Combination coal gasification technology with the most advanced, large heavy duty, GTs with highest turbine inlet temperatures and with steam-bottoming cycle with once-through heat recovery steam generator operating under supercritical steam parameters resulting in unbeaten efficiency.
- Reusable process media remove sulphur from syngas prior to combustion in the GT. By contrast, plants that employ flue gas desulphurization techniques as well as PFBC power plants use limestone, dolomite, or other sulphur sorbents. These substances require disposal.

- With the advent of IGCC systems, coal-fired plants can realistically expect to attain maximum efficiency levels above 50% as early as the year 2010. This means that in less than two decades, IGCC technology promises to raise efficiency levels by more than twice the amount achieved over the last half century!
- In an IGCC system 99% of the coal's sulphur is removed before combustion, NO_x is reduced by over 90%, and CO_2 is cut by 35%.
- The water required to operate an IGCC plant is only 50 to 70% of the quantity required to run a pulverized coal plant with a flue gas desulphurization system.
- The IGCC process generates a minimum of waste. Moreover, the by-products produced by the process have marketability. Sulphuric acid and elemental sulphur are two primary by-products for which there is market demand. Ash and any trace elements that have melted become an environmentally safe, glass-like slag once they are cooled. That slag is useful to the construction and cement industries.
- In addition to producing electricity, the coal gasification process is easily diverted to co-produce such products as methanol, gasoline, urea for fertilizer, hot metal for steel making, and assorted chemicals.
- It is expected that by 2010 IGCC plants will produce power at a rate of 75% of the cost incurred by conventional plants.
- The components of the IGCC system are modular. This permits a user to integrate the technology into an existing system.
- IGCC technology provides flexibility to power producers because the combined-cycle portion of the process can be fuelled by NG, oil or coal. A power plant can switch to coal from NG as NG becomes unavailable or unacceptably expensive. In addition, most gasifier systems are easily adapted to different coals.

To conclude, ACCT has the potential to become a major technology for power generation in medium- and long-term future.

However, there are some risks and possible obstacles in coal importing countries in terms of security of coal supply, which is less the case in countries that still have reasonably accessible coal reserves.

Other risks include environmental regulations, technological improvements, cost reduction and market confidence that have to be met or overcome, if ACCT is to achieve its potential and expectations.

By our opinion, all the ambitious targets of ACCT are not only a vision, but they will be met in the medium- and long-term future.

It is crucial that we optimize the development and use of modern clean power generation technologies, which we can apply today, tomorrow and in the future, to assure sustainable progress of our planet's healthy development.