Capacity Building for Air Quality Management and Application of Clean Coal Technologies in Central Asia

Post-combustion stage of Analytical CCT Review

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Post-combustion stage

Chapters:

- ✓**An overview of the country characteristics of the by-products of combustion in Central Asian coal-fired power plants**
- ✓**An economic assessment of the capture and use of these by- products**
- ✓**Suggested local markets for use of the combustion by-products**

REGION AND COUNTRY CHARACTERISTICS:

Central Asia:

-Kazakhstan, Uzbekistan, Kyrgyzstan, Tajikistan, Turkmenistan

SHARE OF TOTAL PRIMARY ENERGY SUPPLY/ COUNTRIES OF CENTRAL ASIA/ 2001:

Table 1

	Kazakhstan:	Uzbekistan	Kyrgyzstan	Tajikistan	Turkmenistan
Total (ktoe)	40 324	50 650	2 235	3 036	15 309
Out of that (in %):					
- Coal:	52,3	1,8	13,3	1,8	00,0
- Gas:	21,7	83,3	24,5	16,9	74,2
- Hydro:	1,7	1,0	44,7	41,4	00,0
- Oil:	24,1	13,9	17,4	41,4	25,8

Coal as the fuel-source for energy generation

Coal as the fuel-source for energy generation –

Important role in:

- **Kazakhstan**
- **Kyrgyzstan**
- **Uzbekistan**

Small importance:

- **Tajikistan**

No importance:

-Turkmenistan

Therefore:

Concentration on the power sector in Kazakhstan, Kyrgyzstan, Uzbekistan and Tajikistan, only

1. KAZAKHSTAN

- Third largest in the FSU (after Russia and Ukraine)
- Installed capacity of around 18,000 MW:
  15,700 MW in steam-electric plants, and the balance in hydroelectric plants;
- In 2000 - power plants produced 51.4 billion kilowatt-hours of energy, (9% more than in 1999 and 5% more than in 1998);
- In 2001- domestic production was up 7.3% to 55.2 TWh and consumption was up 4.2% to 56.7 TWh.

1. KAZAKHSTAN (continuing)

- Electricity imports - sharply at 3.6 TWh (an increase of 20.3% from 2000);
- In 2002 Power Grid became a surplus power supply system for the first time;
- Electricity production increased from 2001 to 2002 by 5.3%;
- Demand for electricity in Kazakhstan in 2002 increased by 2.5% from the year 2001
- Electricity imports fell by half - from 2,95 billion kW/h in 2000 to 1.43 billion kW/h in 2001

1.1. CHARACTERISTIC OF POWER GENERATION SECTOR - COAL DEPOSITS

Major coal producer;

- **with reserves of about 37.5-bil tons**
- **annual coal production now amounts to about 82 mil tons**
- **The most important coal resources:**
  - **Ekibastuz (the third largest coal basin in the FSU), and the largest mining company in this area is Bogatyr Access Komir**
    - **The Bogatyr mine is one of the world's largest (and has produced over a billion tons of coal)**
  - **Maikuben-Vest mine**
  - **Vostochny open cast mine in the Pavlodar region**

1.1. CHARACTERISTIC OF POWER GENERATION SECTOR COAL DEPOSITS - continuation

- Annual coal production:
  - about 40 mil. tons
  - coal sold to local power plants and exported to Russia
- Coal exports to Russia have been significant but there are long-running disputes on cost, quality, and delivery issues.
- In partial settlement of these disputes, the Russian utility - Sverdlovskenergo acquired:
  - two mines near Ekibastuz in 1996

THERMAL POWER PLANTS; GENERALLY

- Thermal power plants produce the dominant share of electricity (and hydroelectric plants produce the remainder);
- The established national power industry capacity totals 18.2 thousand MW;
- The structure of the electric power output falls into the following elements, depending on the energy source:
  - coal-powered plants (70.3 % of the total)
  - gas-fuel oil-powered plants (17%)
  - hydroelectric plants (12%)
  - nuclear power plants (0.7%)

THERMAL POWER PLANTS; GENERALLY - continuation

- The generation of electric power in Kazakhstan decreased faster than the demand reduction
- In 1993 the domestic production totaled 77.44 billion kWh, while Kazakhstan needed 89.15 billion kWh of electric power - the deficit being 11.71 billion kWh.
- Forty-six of Kazakhstan's 54 coal/petroleum-fired plants supply electricity, heating, and hot water to nearby residences and industries during the winter.
- The remaining **eight coal / petroleum-fired plants, the country's largest generating facilities, are devoted solely to electricity production**

THERMAL POWER PLANTS; GENERALLY - continuation

- Heated power plants generate 84.7% of power in Kazakhstan.
- They account for three fourth of the heat produced nation-wide
- Individual boiling houses contribute more than one fourth
- The largest portion of power and heat is produced by the heated power plants of Pavlodar and Karaganda regions (add 56.2% and 37.8% in the nation-wide volume of power generation)

COAL POWER GENERATING CAPACITIES; AND OWNERS

- The country's installed capacity base is heavily centralized with 7,400 MW of thermal capacity at just two sites:
- Ekibastuz-1 (8 X 500 MW)
- Ekibastuz-2 (2 X 500 MW)
- Ermakov (8 X 300 MW).
- There are 38 combined heat and power (CHP) plants -- 32 of which are in urban or suburban locations (and 8 hydroelectric plants).
- The thermal power plants use coal, oil, and gas, but **brown coal from the Ekibastuz basin is the dominant fuel source with a 75% share**, followed by natural gas at 14% and oil at 11%

POWER PLANTS, CAPACITIES, LOCATION, AND MAIN OWNERSHIP STRUCTURE

- The U.S. power company AES Corp. acquired Ekibastuz-1 in August 1996 (8 X 500 MW). Ekibastuz-1 has appr. 25% of Kazakhstan's total installed power-generating capacity.
- In fall of 1997, AES purchased four combined heat and power stations and won concessions on two hydroelectric stations in East Kazakhstan region, with a combined total capacity of more than 1,300 megawatts.
- Ekibastuz-2 has been under intermittent construction for years and has two 500 MW sets in operation. It is run by a state-owned company.

POWER PLANTS, CAPACITIES, LOCATION, AND MAIN OWNERSHIP STRUCTURE - continuation

- Ermakov (8x300 MW) - owner Eurasian Energy Corp.
- (EEC jointly owned by Japan Chrome Corp (65.67%), the Kazakh government (24.33%), and company employees (10%)).
- APC has 1,239 MW of electric capacity and 3,975 Gcal of heating capacity. Annual production is about 4,500 GWh of electricity. It has three CHP plants in Almaty – ATETS-1(173 MWe), ATETS-2 (145 MWe), and ATETS-3 (290 MWe)
- Ispat-Karmet JSC took over the running of the thermal power plant Karagandinskaya TEZ-2.
- The Kazakhmys corporation currently includes the Zhezkazganskaya and Balkhashskaya thermal power stations, the Karagandinskaya GRES-2.

POWER PLANTS, CAPACITIES, LOCATION, AND MAIN OWNERSHIP STRUCTURE - continuation

- **Kaztzink JSC includes the Tekely power complex.**
- **Kazakhstan and Russia: an agreement - Russia's UES to receive a 50% in the Ekibastuz State Regional Power Station 2 in Pavlodar--the last power station not to be privatized.**

2. UZBEKISTAN

- Currently the largest electricity producer among the Central Asian republics, and a net exporter of electricity;
- Total installed generation capacity of 11,283 MW;
- Achieved self-sufficiency in energy after gaining independence in 1991;
- Maintenance of its power systems has deteriorated – and as a result - generating units have ceased operation;
- Much of the equipment in generation, transmission and distribution systems is outdated and extremely inefficient;
- According to some estimates (at the current rate of energy production and consumption) the demand for power would exceed the projected production by 10 percent in 2010.

2.1. CHARACTERISTIC OF POWER GENERATION SECTOR - COAL DEPOSITS

- The installed capacity 11,200 MW;
- comes from 37 power plants, (including 18 thermal power plants with a total capacity of 9,800 MW and 28 hydroelectric power stations with a total capacity of 1,400 MW);
- There are no nuclear power plants in Uzbekistan;
- Electricity derived primarily from thermal plants with 85 percent of thermal plants powered by natural gas, 8 percent by heavy oil and 7 per cent by coal;
- The most significant coal-powered facilities are two power plants in the vicinity of the Angren mine near Tashkent, one that is Novo-Angren (2,100 MW);
- Uzbekistan produces approximately 48,000 GWH of electricity annually with almost all electricity consumed domestically. Only about 1,000 GWH of electricity are exported to the neighboring countries (Tajikistan and Kyrgyzstan)

2.1. CHARACTERISTIC OF POWER GENERATION SECTOR - COAL DEPOSITS - continuation

- 24.21 billion kWh of electric power generated by enterprises of Uzbekenergo state joint-stock company;
- Heat generating plants of industrial enterprises and small hydroelectric power stations, (under the Ministry of Agriculture and Water Management) produced the remainder;
- Production of electric power at general-use thermal power plants was reduced by 1.6 percent or 21.1 billion kWh, at general-use hydro power stations and block stations - increased by 14.2 percent to 3.9 billion kWh;
- Uzbekistan is part of the United Central Asia Power System (CAPS);
- A decree on partial privatization, de-monopolization and deregulation of power engineering and coal mining industries issued.

2.1. CHARACTERISTIC OF POWER GENERATION SECTOR - COAL DEPOSITS - continuation

- The Ministry of Power Energy has been transformed into the Uzbekenergo State Joint-stock Company.;
- Major power stations and electric grids also transformed into joint-stock companies, and partially offered to the foreign investors.;
- However, Uzbekenergo still holds the control shares of those companies.

3. KYRGYZSTAN

- Suffered from a financial and technical deterioration of the power system;
- Power transmission capacities are used almost to the full, especially during peak time in the heating season;
- From 1991 to 1998, technical and commercial losses increased by more than 4 times and stood at 33.9 per cent of total electricity supply in 1998;
- Rich in hydroelectric potential estimated at 26,000 MW with an energy content of 10,000 GWh in a seasonally normal year. Only about 10% of this has been developed;
- Its coal reserves estimated at 1.2 billion tones; costly to mine and only reserves of 650 million tons have been developed;
- Thus imports of coal, oil and natural gas; and exports electricity.

3. KYRGYZSTAN - continuation

- Electricity exports are mostly to Kazakhstan and partly to Tajikistan and Uzbekistan;
- A small export of about 5 GWh to China through a 10 kV line commenced in 1993;
- Power system is a part of the Central Asian Integrated System to which it provides reserve capacity;
- The country is fully electrified;
- Total generation and domestic sales in 2000 and 2001 were about the same as in 1990, though the volumes of exports have declined;
- During this period the consumption mix has undergone a major change. The share of industrial consumption declined from 45.2% to 14.3%, while that of residential consumers went up from 14.5% to 54.6%

3.1. ELECTRICITY GENERATION AND SALES IN KYRGYZSTAN

(IN GWH)

Year	1990	1994	2000	2001
Gross generation	13,155	12,860	14,844	13,728
Of which: Hydro:	8,953	11,720	13,635	12,444
Thermal:	4,202	1,140	1,210	1,284
Total Net sales	11,622	10,336	10,615	9,152
Of which: Exports-net	3,978	2,505	2,833	1,982
Domestic sales	7,644	7,830	7,782	7,169
Total System Losses	1,538	2,524	4,229	4,576
Total System Losses (%)	11.7	19.6	28.5	33.3

- Peak demand went up from 1,590 MW in 1990 to 2,173 MW in 1994. Presently it is estimated at 2,700 MW.
- Defined as the difference between the gross generation and the billed sales, in GWh.

3.2. STRUCTURAL DEVELOPMENT

- After separation from the Soviet Union:
- Kyrgyzenergo (State Electric Company) was formed in April 1992 to own and operate the electricity and district heat systems;
- Early in 1994 it was renamed as Kyrgyz National Energy Holding Company (KNEH) and operated till 2001 as a state owned vertically integrated national utility;
- In 2001, Kyrgyzstan embarked on a restructuring of Kyrgyzenergo, splitting off the company's distribution networks and leaving the former monopoly as just an electricity generating company;
- Four joint-stock companies — Sever Elektro, Vostok Elektro, Osh Elektro, and Dzhalalabad Elektro--were created from Kyrgyzenergo

SYSTEM DIMENSIONS AND CHARACTERISTIC/ ENERGY GENERATED FROM COAL

- Power system is relatively small;
- Installed generation capacity of 3,532 MW consisted of 18 hydroelectric stations (2873 MW) and two combined heat and power thermal plants (659 MW) at Bishkek and Osh.
- These are burning bituminous coal/ anthracite.

4. TAJIKISTAN

- Coal reserves surpass those of oil and gas;
- Proven deposits of coal are estimated to hold 5-6 billion tons of coal;
- Most of coal mining sites are located in hard-to-reach mountainous areas (what makes industrial development not feasible);
- Its declining coal production (20,700 tons in 2000) meets fully the country's declining coal demand and leaves 50% of the production for export.

4.1. SYSTEM DIMENSIONING AND CHARACTERISTIC

- 4,400 MW of installed electricity generation capacity consisting of:
- seven large hydroelectric stations with a total of 4,052 MW;
- and two fossil fuel fired thermal plants at Dushanbe and Yavan with total capacity of about 350 MW
- Tajikistan also exports electricity to the southern areas of Kazakhstan, mainly in summer;
- The volume of exports and imports vary as a function of water availability (see next Table).

TAJIKISTAN'S EXPORTS AND IMPORTS OF ELECTRICITY (GWH)

Item	1990	1995	1999	2000
Generation	18,200	14,800	15,797	14,247
Exports	5,700	4,200	3,831	3,901
Imports	6,900	4,900	3,641	5,242
Available for domestic market	19,400	15,500	15,607	15,580

CHAPTER 2
POST-COMBUSTION CLEAN COAL TECHNOLOGIES

- SOLUTIONS PROPOSAL
- ALL COUNTRIES OF CENTRAL ASIA

GENERAL

- **Post-combustion clean coal solutions shall – in a complex - include:**
  - **Measures for increase efficiency of dust elimination after burning process;**
    - **what means implementation of high efficient electro-precipitators after the boilers, to reach the dust removal efficiencies around 99,5 % (and higher);**
  - **Measures for reduction of SO2 concentrations in flue gas;**
    - **what means implementation of flue gas desulphurization process-technology after the burning process;**
  - **Measures for NOx reduction (secondary measures),**
    - **using catalytic de-Nox process technology;**
  - **Possibilities for the further safe utilization of post-combustion by-products (fly ash/ bottom ash; gypsum/ stabilizate, etc.)**

GENERAL - continuation

- Due to the specific conditions, further solution proposals do not consider:
  - measures for NOx reduction (primary or secondary measures - be a part of "combustion phase"), and no speculations on any systems for secondary de-NOx program done in this stage (these always applied after the application of primary de-NOx measures);
  - Dust elimination measures not discussed - technical solution is well know and widely available. The dust elimination program has always to be applied prior any de-NOx and de-SOx technologies.
- The target of this Study can not be a definition the country's clean coal solution policy, or program;
- Nevertheless the implementation of post-combustion clean air measures will have to be under respective countries government responsibility – perhaps in a form of "Country Clean Coal Air Act".

FLUE GAS DESULPHURIZATION PROCESS – THE WAY HOW TO REDUCE SULPHUR IN FLUE GASES

- **DESULPHURIZATION METHOD:**
- **Due to boiler capacities and coal parameters – predominantly the wet limestone desulphurization process technology shall be applied;**
- **The main advantages of wet limestone process:**
  - **Simple and reliable process;**
  - **commercial accessibility; available references;**
  - **very good performance and consumption figures;**
  - **end product – gypsum, or stabilizate – is a stable substance safely and easily to be stored, deposited, and/ or further commercially utilized**
- **Investment costs for FGD implementations constantly decrease due to many proven applications worldwide**

WET FLUE GAS DESULPHURIZATION PROCESS FEATURES; simplified

- To provide needed operation flue gas pressure (flue gas fans for each boiler block shall usually replace the old fans);
- Flue gas enters the absorber via collecting duct. (Old stack enables to by-pass the extra flue gases in case of bigger flue gas load than given by the contract, or at emergency conditions);
- Limestone powder unloaded on the railway siding (or truck unloading pit), and stored in a silo; or lump limestone to be crushed and milled in the own mills;
- Reaction of limestone slurry with counter-flow of raw flue gas (reaction results in obtaining of gypsum slurry composition in re-circulated slurry);
- The bleed gypsum slurry is being dewatered on batteries of hydro-cyclones and belt filters, or on centrifuges
- De-watered gypsum transport into gypsum storage house and from there into a mixing center

WET FLUE GAS DESULPHURIZATION PROCESS FEATURES; simplified – cont.

- Complete auxiliary units, as process water preparation, oxidation air system, etc., are also included in the supply for FGD Project;
- End product - gypsum - stabilized by adding of ash and lime is ecologically safe and stable product. (usually outside the supplier's battery limit);
- Cleaned flue gas leaves the absorber through gas-gas heater (where clean flue gas is heated-up to pass the stack), or via wet stack, or via cooling towers;
- Desulphurization efficiency has to be designed to cope with by valid country Clean Air Law (efficiency normally as 95 %, and concentration of sulfur oxides in cleaned flue gas under 400-500 mg/ Nm3).

PRESUMPTIONS FOR SPECIFIC PROCESS/ PRODUCTS DIMENSIONING

- the future retrofits of existing power plants' boilers may include approximately 20% of these capacities converted to fludized bed technology; within the term from 2007 to 2 027 (see specifically for respective countries);
- therefore the rest capacities may ask for flue gas desulphurization (FGD) solutions;
- brown coal having heat value from 14 000 to 16 000 kJ/kg; H2O content (Wtr) around 15 % mass; Sd content in orig. sample approximately 1,2 % mass;
- flue gas flow rate (used for an estimates of required capacities of FGD applications) set as some type of the "nominal value" will be:
  - for brown coal: 2 000 000 Nm3/h per one of 400 MWe module of electricity production (dry status, 6% O2, normal conditions),
  - for hard coal: 1 600 000 Nm3/h per one of 400 MWe module of electricity production (dry status, 6% O2, normal conditions),

PRESUMPTIONS FOR SPECIFIC PROCESS/ PRODUCTS DIMENSIONING - continuation

- considered is SO2 concentration at the FGD outlet on 500 mg/Nm3 (at limestone reactivity of 97%);
- FGD plants delivered as “turn-key” supplies;
- FGD “nominal” concept:
  - 1 absorber per each 400 MWe production block;
  - 1 limestone acceptance and 1 limestone slurry preparation unit common for 2 absorbers (where possible);
  - 2 dewatering lines per one 400 MWe de-sulphurized capacity; no milling and crushing plants considered (powder limestone to be procured from central milling source; no gypsum deposit areas preparation considered in this Study);

PRESUMPTIONS FOR SPECIFIC PROCESS/ PRODUCTS DIMENSIONING - continuation

- The owners ordering (prior the projects' starts) the owner's engineering;
- FGDs are to be of "state-of--art" technical level;
- investment costs are forecasted on a presumption that full engineering, all mechanical/ electric/ I + C supplies, and 70% of civil and erection work, and full commissioning and documentation is to be delivered by abroad companies;
- Price/ costs level for equipment based on Central Europe price level of 2004, and inflation rate forecast be 5% annually;
- FGDs implementation schedule proposed for as maximum 12 years (for total number of desulphurized sources), depends on a country – see further;
- No financing possibilities/ sources/ instruments discussed in this place

TECHNICAL SCOPE AND SPECIFICATION OF SERVICES RELATED TO FGD IMPLEMENTATIONS

- **Engineering; like Civil permit release design, Basic design, Detail design (all for civil, process, mechanical, electro and instrumentation part), Manufacturing and As-built design;**
- **Procurement of components, works and services:**
  - **Complete civil part;**
  - **Absorber units with spray header system; steel flue gas duct system; supporting steel structures; induced draft fans (and/ or booster fans); process tanks; process piping; process and re-circulation pumps; valves; insulation of ducts and tanks; limestone unloading unit; silo for limestone storage (including the de-dusting and fluidization); hydro-cyclone batteries (or centrifugal units); de-watering filters; discharge, distribution and storing of gypsum in a gypsum store; isolation and by-pass dampers; expansion joints; agitators, etc.; stabilizate mixing units;**
  - **Gas/ gas heaters, or wet stack, or inlets into existing cooling towers;**

TECHNICAL SCOPE AND SPECIFICATION OF SERVICES RELATED TO FGD IMPLEMENTATIONS - continuation

  - Electro-part supply, as HV/ LV motors, trafos, switchboards, MCCs, cables, etc.;
  - Instrumentation and Control part supply, including Fanuc control system, field instrumentation, cabling, analyzers, etc.;
- Mechanical erection for the mechanical equipment (scope and spec. – see above);
- Erection of electro and I&C, parts, including the cable work, energizing, inspection (scope and spec. – see above);
- Project management; for the full Project scope;
- Commissioning and test run of the civil, mechanical, electro and I&C part; as well as warranty testing;
- Training for all equipment and disciplines;
- Warranty service

IMPLEMENTATION KEY TERMS AND DURATIONS

- As a typical FGD project implementation schedule – in months (key points only; valid for implementation of 1 FGD project of size 400 MWe of electrical output):
  - The Contract signature day…….day 0
  - Site opening…….....0 + 4 (month)
  - Start of civil work……0 + 5
  - Finish of civil work……0 + 22
  - Start of mechanical erection……0 + 7
  - Finish of mechanical erection……....0 + 24
  - First flue gas-in into FGD plant……...0 + 26
  - FGD Trial run start……..0 + 28
  - Take-over/ hand-over of FGD plant……0 + 30

FGD BASIC IMPLEMENTATION PLAN; BASED ON COUNTRIES INPUT DATA AND CONDITIONS; BY COUNTRIES - KAZAKHSTAN

- Brown coal (lignite) fired power capacities; totally installed 5 500 MWe;
- Based on the only available data, next are the basic proposals for implementation of post-combustion clean coal technologies. These are proposed – in this stage – for only those brown coal (lignite) fired power capacities of totally 5 500 MWe.
- Total capacity to be desulphurized:
  - 4 400 MWe
- Average generated volume of flue gases subject to gas clean-up (FGD wet limestone process); presumptions – see above:
    - 22 000 000 Nm3/h (as a final status in 2022)

FGD BASIC IMPLEMENTATION PLAN; BASED ON COUNTRIES INPUT DATA AND CONDITIONS; BY COUNTRIES - KAZAKHSTAN - continuation

- Estimated total sulfur removal rate (at a final stage - in 2022):
  - 70 to 72 ton/ hour (what means 590 000 up to 600 000 ton of sulfur removal per year, considering 350 operation days a year);
- Estimated production of gypsum (at a final stage - in 2022):
  - 185 to 190 ton/ hour (what means 1 554 000 up to 1 596 000 ton of gypsum per year, considering 350 operation days a year);
- Estimated number of “nominal” FGD production blocks:
  - (Note: “nominal” FGD see in Presumptions);
  - 11 (no any specific conditions of individual power plants taken into account, as f.e. power blocks design/ magnitude, owners’ structures/ intentions, etc.);

FGD BASIC IMPLEMENTATION PLAN; BASED ON COUNTRIES INPUT DATA AND CONDITIONS; BY COUNTRIES - KAZAKHSTAN -continuation

- Estimated overall direct investment costs for FGDs (only):
  - 350 mil. EUR (spent during the period of 2007 to 2022).
- Other related costs:
  - planning stage/ basic land preparation: 7 mil. EUR
  - owners' engineering costs: 18 mil. EUR
- Estimate of total investment costs from 2007 till 2022:
  - 375 mil. EUR/ for KAZAKHSTAN

FGD BASIC IMPLEMENTATION PLAN; BASED ON COUNTRIES INPUT DATA AND CONDITIONS; BY COUNTRIES - UZBEKISTAN

- Brown coal (lignite) fired power capacities; totally installed 2 100 MWe.
- Based on the available data; only for brown coal (lignite) fired power capacities of totally 2 100 MWe.
- Total capacity to be desulphurized:
  - 1 600 MWe
- Average generated volume of flue gases subject to gas clean-up (FGD wet limestone process); presumptions – see above:
  - 8 000 000 Nm3/h (final status at 2017)
- Estimated total sulfur removal rate (at a final stage - in 2017):
  - 25 to 28 ton/ hour (what means 210 000 up to 235 000 ton of sulfur removed every year, considering 350 operation days a year);

FGD BASIC IMPLEMENTATION PLAN; BASED ON COUNTRIES INPUT DATA AND CONDITIONS; BY COUNTRIES – UZBEKISTAN - continuation

- Estimated production of gypsum (at a final stage - in 2017):
  - 66,5 to 75 ton/ hour (what means 559 000 up to 630 000 ton of gypsum per year, considering 350 operation days a year);
- Estimated number of “nominal” FGD production (or reaction) blocks:
  - (Note: “nominal” FGD production unit means the unit treating 1 500 000 Nm3/h inlet flue gases, having the parameters as in the Presumptions)
  - 4 (no specific conditions of individual power plants taken into account, as f.e. power blocks design/ magnitude, and owners’ structures/ intentions, etc.);

FGD BASIC IMPLEMENTATION PLAN; BASED ON COUNTRIES INPUT DATA AND CONDITIONS; BY COUNTRIES – UZBEKISTAN - continuation

- Estimated overall direct investment costs for FGDs (only):
  - 128 mil. EUR for the period of 2007 to 2017.
- Other related costs:
  - planning stage/ basic land preparation: 4 mil. EUR
  - owners' engineering costs: 8 mil. EUR
- Estimate of total investment costs from 2007 till 2017:
  - 140 mil. EUR/ for UZBEKISTAN

FGD BASIC IMPLEMENTATION PLAN; BASED ON COUNTRIES INPUT DATA AND CONDITIONS; BY COUNTRIES - KYRGYZSTAN

- Hard coal (lignite) fired power capacities; totally installed 659 MWe;
- Based on the available data; proposed – in this stage – for those hard coal fired power capacities of totally 659 MWe;
- Total capacity to be desulphurized:
  - 400 MWe
- Average generated volume of flue gases subject to gas clean-up (FGD wet limestone process); presumptions – see above:
  - 1 600 000 Nm3/h (final status at 2012);
- Estimated total sulfur removal rate (at a final stage - in 2012):
  - 4,4 ton/ hour (what means 37 000 ton of sulfur removed every year, considering 350 operation days a year);

FGD BASIC IMPLEMENTATION PLAN; BASED ON COUNTRIES INPUT DATA AND CONDITIONS; BY COUNTRIES – KYRGYZSTAN - continuation

- Estimated production of gypsum (at a final stage - in 2012):
  - 12 ton/ hour (what means 100 800 ton of gypsum per year, considering 350 operation days a year);
- Estimated number of “nominal” FGD production (or reaction) blocks:
- 1 (no specific conditions of individual power plants conditions taken into account);
- Estimated overall direct investment costs for FGDs (only):
  - 32 mil. EUR for the period of 2007 to 2012
- Other related costs:
  - planning stage/ basic land preparation: 2 mil. EUR
  - owners’ engineering costs: 2 mil. EUR
- Estimate of total investment costs from 2007 till 2012:
  - 36 mil. EUR/ for KYRGYZSTAN

FGD BASIC IMPLEMENTATION PLAN; BASED ON COUNTRIES INPUT DATA AND CONDITIONS; BY COUNTRIES - TAJIKISTAN

- Hard coal (lignite) fired power capacities; totally installed 350 MWe.
- Based on the available data; the basic proposals for implementation of post-combustion clean – in this stage – for those hard coal fired power capacities of totally 350 MWe;
- Total capacity to be desulphurized:
  - 350 MWe
- Average generated volume of flue gases subject to gas clean-up (FGD wet limestone process); presumptions – see above:
  - 1 400 000 Nm3/h (final status at 2012)
- Estimated total sulfur removal rate (at a final stage - in 2012):
  - 3,8 ton/ hour (what means 32 000 ton of sulfur removed every year, considering 350 operation days a year);

FGD BASIC IMPLEMENTATION PLAN; BASED ON COUNTRIES INPUT DATA AND CONDITIONS; BY COUNTRIES – TAJIKISTAN - continuation

- Estimated production of gypsum (at a final stage - in 2012):
  - 10 ton/ hour
- Estimated number of “nominal” FGD production (or reaction) blocks:
  - (Note: “nominal” FGD production unit; see in the Presumptions)
  - 1 (no specific conditions of individual power plants conditions taken into account);
- Estimated overall direct investment costs for FGDs (only):
  - 28 mil. EUR for the period of 2007 to 2012
- Other related costs:
  - planning stage/ basic land preparation: 2 mil. EUR
  - owners’ engineering costs: 2 mil. EUR
- Estimate of total investment costs from 2007 till 2012:
  - 32 mil. EUR/ for TAJIKISTAN

ESTIMATED MAIN INPUT, PROCESS, AND PRODUCTION PARAMETERS OF FGD APPLICATIONS IN COUNTRIES OF CENTRAL ASIA (Coal Burning Power Stations)

	Kazakhstan	Uzbekistan	Kyrgyzstan	Tajikistan
Total coal burning power/ heat plant capacities (2003) – brown coal/ lignite - MWe	5500	2100	0	0
Total coal burning power/ heat plant capacities (2003) – hard coal	0	0	659	350

BY-PRODUCTS; UTILIZATION; TYPES; SPECIFICATION; PARAMETERS

- **Bottom ash:**
- **The solid phase consisting mainly from Si02 and Al2O3;**
- **Containing 15 to 45% of water;**
- **Normally expedited in wet status or directly from hoppers;**
- **Producers normally guarantee extraction limits and mass activity 226Ra (not to exceede the locally set standard for radiation protection)**

USE OF BOTTOM ASH AS A WINTER ROAD MAINTENANCE MATERIAL; POSSIBLE STANDARD DEMANDS

LIMIT VALUES OF EXTRACTIVITY			
	max. acceptable concentration (mg/l)		max. acceptable concentration (mg/l)
Ar	0,10	Hg	0,005
Ba	2,00	V	0,20
Be	0,005	Zn	3,00
Cr	0,1	Fluorides	1,50
Cd	0,02	Sulfites	300,00
Co	0,1	PAU +	0,003
Cu	1,00	Conductivity *	300,00
Ni	0,50	pH	5,5 – 11,0
Pb	0,50	* (mS/m)	

BY-PRODUCTS; UTILIZATION; TYPES; SPECIFICATION; PARAMETERS – cont.

- Fly ash/ Characteristic:
- The solid phase has a granulometry 0 to 1000 mm.
- Mass of repose 750 to 950 kg/m3.
- Chemically inert material, composition mainly SiO_2 a Al_2O_3; rest carbon max. 1% mass
- (Fly ash must not contain any disvaluating impurities as bottom ash, clay, stones, brick parts, wooden parts, metal particles, etc).

BASIC (typical) PHYSICAL AND CHEMICAL PROPERTIES OF FLY ASH (from lignite); FOR A USE INTO CONCRETES

Loss by heating-up	% mass.	max. 5,0
Content of free CaO	% mass.	max. 1,0
SO3 content	% mass.	max. 3,0
Cl- content	% mass.	max. 0,1
Fly ash granulometry – rest on sieve 0,045 mm	% mass.	max. 40
Index of effectivess after 28 days	%	min. 80
Volume stability	Mm	max. 10
Specific mass	kg.m-3	1950 -2100
Value of mass activity 226Ra	Bq.kg-1	120

BY-PRODUCTS; UTILIZATION; TYPES; SPECIFICATION; PARAMETERS – cont.

Gypsum/ typical physical-mechanical properties:

- **Gypsum is di-hydrate of calcium sulfite (CaSO4.2H2O), gained as by-product at wet limestone desulphurization process;**
- **Contains particles of fly ash from flue gas and minerals from limestone used in FGD process.**

1) :at average gypsum humidity 11 % mass:

Properties [1]	Unit	Found value	
Specific mass of wet freely spilled gypsum	$kg.m^{-3}$	830 – 900	1)
Granulometry – rest on sieve 63 μm	% mass.	10 – 25	

PHYSICAL AND CHEMICAL PROPERTIES - usually guaranteed - GYPSUM

1) humidity at loading in power stations; 2)in dry sample

Properties	Unit	Guarantee value	
Humidity	% mass.	6 – 15	1)
pH value		5 – 8	
$CaSO_4.2H_2O$ content	% mass.	min. 90	2)
SO_3 content	% mass.	min. 41,8	2)
MgO content	% mass.	max. 0,2	2)
Chlorides content	% mass.	max. 0,1	2)
Fluorides content	% mass.	max. 0,4	2)
Alcalic substances content (Σ Na_2O+K_2O)	% mass.	max. 0,5	2)
Evaluation of content of natural radionuklcledes - Mass radioactivity Ra^{226}	$Bq.kg^{-1}$	max. 25	

BY-PRODUCTS; UTILIZATION; TYPES; SPECIFICATION; PARAMETERS – cont.

- Stabilizates:
- Stabilizate is a civil industry substance;
- produced in mixing centers; from coal burning process and by-products from FGD, adding lime and mixing water;
- Possibility to produce civil stabilizate mixtures acc. to various prescriptions;
- Gypsum from FGD process and bottom ash can be added into stabilizate;
- After stabilizate curing (long-time lasting stabilization process) the material - stabilizate is significantly different by it's technical parameters to the originally untreated products. Stabilizate has favorable ecological properties

SOME TYPICAL PROPERTIES OF STABILIZATE FOR VARIOUS USE

Properties	Unit	Value
Volume mass of freely poured mixture, wet	$Kg.m^{-3}$	1000 – 1200
Volume mass of wet mixture after compacting	$Kg.m^{-3}$	$\geq$ 1350
Volume mass of dry substance after compacting	$Kg.m^{-3}$	$\geq$ 1100

BY-PRODUCTS; UTILIZATION; TYPES; SPECIFICATION; PARAMETERS – cont.

Microspheres/ Characteristic:

- **Particular solid phase with granulometry 0 to 500 □m;**
- **particles of ball form filled by flue gas;**
- **Having a high pouring density of 380 kg/m3;**
- **Chemically inert material, composition mainly SiO_2 and Al_2O_3;**
- **Good noise and heat insulation properties;**
- **Temperature of softening is 1000 to 1200 °C.**

SUGGESTED LOCAL MARKETS FOR BY-PRODUCTS

- **Bottom ash**:
  - For building of land filling protection walls;as the winter road/ pavement maintaining material;and for the production of bricks-like products;
- **Fly ash**:
  - In a process of poro-concrete production; for production of mortars, asphalt hydro-insulation strips, cement; it use to be certified
- **Gypsum**:
  - Manufacturing of gypsum plates; at poro-concrete preparation; use to be certified for cement production
- (Gypsum must not contain any disvaluating impurities as bottom ash, clay, stones, brick parts, wooden parts, metal particles, etc).
- Gypsum use to be delivered in wet form (humidity 6 – 15% mass).

SUGGESTED LOCAL MARKETS FOR BY-PRODUCTS - continuation

- **Stabilizates**:
  - Product in compliance with applicable local standards,
  - various utilization in civil industry
  - use to be certified as a product for countryside relief adjustments during the cultivation work and also during asanation works of deposit areas
  - use to be used for sealing of land-filling protection walls; as a stabilizate for road laying
- **Stabilizate is being delivered usually in wet state directly from mixing centre silo**
- **Microspheres**:
  - As material for increase of heat and noise insulation product utilized also under high temperatures. In plastics in automotive and aircraft industry, into tiles, floor covers, as filling into façade products, as filling into paints, etc.