

# EGTEI Emerging Technologies sub-Group

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Jean-Pierre RIVRON

# ESTIMATION OF DENOX AND DESOX COSTS FOR A 300 MWeI HARD COAL UNIT ACCORDING VGB POWERTECH DOCUMENTS

Date of the estimation: 2006

- **Reference documents**
- DENOX-kosten var,1,2,4,5 HtKr, entw1,entw2, entw Heit and Heit.K
- Rea kosten O.xls original word document
- FGD overall costs VGB PowerTech E.doc
- Ermittlung der REA kosten Heit/Heit Kr.doc
- **Power unit characteristics**
- LCP capacity: 300 MWeI / 726,4 MWth
- Efficiency (net caloric value): 41,3%
- Net caloric value of coal: 25000KJ/Kg
- Effective full load operation hours per year: 6000h
- Electrical production per year: 1,8TWh
- Coal consumption: 104,6 t/h
- Primary energy input per year: 15690 TJ
- Flue gas emission per coal Kg: 10 m<sup>3</sup>/Kg
- Flue gas flow: 1 046 005 m<sup>3</sup>/h
- Specific energy consumption: 0,9%
- Internal costs of electricity: 0,03 Euro/KWh
- NO<sub>2</sub> concentration at DENOX inlet: 700 mg/m<sup>3</sup>
- NO<sub>2</sub> concentration at DENOX outlet: 200 mg/m<sup>3</sup>
- S content of coal: 1%

# Relation of FGD costs to the unit capacity

REA-Investitionskosten ohne Eigenleistung

(REA kosten 0.xls)

Efficiency 41,3%

Electrical capacity of the unit MWel	Thermal capacity of the unit MWth	Investment MEuro	Investment+10% for additional investor costs: engineering, foudation, connections... MEuro	FGD specific cost MEuro/MWel	FGD specific cost MEuro/MWth
Leitung in MWel					
1000	2421	60	66	0,066	0,027
800	1937	52	57,2	0,072	0,030
600	1453	43	47,3	0,079	0,033
400	968,5	32,5	35,8	0,090	0,037
300	726	27,5	30,3	0,101	0,042
200	484	20	22	0,110	0,045
100	242	12,5	13,8	0,138	0,057

## RELATION OF THE SCR COSTS TO THE UNIT CAPACITY

DENOX kosten var.xls

Efficiency 41,3%

Electrical capacity of the unit MWel	Thermal capacity of the unit MWth	Investment MEuro		SCR specific cost MEuro/MWel	SCRspecific cost MEuro/MWth
Leitung in MWel					
1000	2421	58,5		0,059	0,024
800	1937	47		0,059	0,024
600	1453	35,5		0,059	0,024
400	968,5	24,1		0,060	0,025
300	726	18,3		0,061	0,025
200	484	12,6		0,063	0,026
100	242	6,8		0,068	0,028

# Size effect

Electrical capacity MWeI	Thermal capacity MWth	SCR investment MEuro	FGD investment MEuro	SCR specific cost MEuro/MWth	FGD specific cost MEuro/MWth	SCR size effect	FGD size effect
1000	2421	58,5	66	0,024	0,027	0,86	0,47
800	1937	47	57,2	0,024	0,030	0,86	0,53
600	1453	35,5	47,3	0,024	0,033	0,86	0,58
400	968,5	24,1	35,8	0,025	0,037	0,89	0,65
300	726	18,3	30,3	0,025	0,042	0,89	0,74
200	484	12,6	22	0,026	0,045	0,93	0,79
100	242	6,8	13,8	0,028	0,057	1	1

# REFERENCE POWER PLANT RPP NRW

The following data are extracted from the VGB document « Concept study Reference Power Plant North Rhine-Westphalia (RPP NRW) (February 2004)

## **Brief overview**

The concept of the “Reference Power Plant North Rhine-Westphalia” ( RPP NRW) is based on a hard coal fired 600 MW plant with optimised plant technology and efficiency of 45,9%. Efficiency of over 48% could also be achieved with certain technical measures.

However, that would require different site conditions and also different economic boundary conditions than can currently assume. With efficiency of 45,9%, the NRW reference power plant is clearly above the average of hard coal power plants currently in operation in Germany (average efficiency around 38%). Thus, its use can make a considerable contribution to attaining targets for the reduction of CO<sub>2</sub>.

This NRW Reference Power Plant study was produced with the aim of developing a concept for a sustainable hard coal-fired power plant that takes these challenges into account.

A number of innovative proposals have been included in the plant design. The building of the RPP NRW will involve a total order volume of around Euros 480 million

# RPP NRW

Price basis 2003	Fixed cost ct/KWh	Variable cost ct/KWh	Cost of electricity ct/KWh
RPP NRW Reference case	1,9	1,45	3,35
CCPP gas Combined cycle	1	2,5	3,5
MLP Modern Lignite Plant	Cost of generating power 2,3 No CO2 cost impact Gas price 1,2 ct/KWh Price of hard coal 48 euros/t Lignite price 31 euros/t	1	3,3
700°C Plant	2,5	1,3	3,8
IGCC	2,8	1,3	4,1

# The volume of investments in the reference power plant RPP NRW

Aspect	Unit	Amount
Price of the plant	Euro/KW (gross)	798
Installed gross capacity	MW	600
Order volume	Million euros	478,8
Period of use	Years	35
Owner's own contribution (5% of the order volume)	Million euros	23,9
Flat rate for imponderables (3% of the order volume)	Million euros	14,4
Total sum of investment	Million euros	517,1
Specific sum of investment	Euros/KW	$798 \times 1,08 = 861,8$

# Power plant concept RPP NRW

Gross capacity	600MW
Type of boiler	Tower-type boiler with vertical tubes and steam coil air heater
Heat recovery	Utilization of mill air heat recuperation
Flue gas discharge	Discharge via cooling tower
Turbine model	H30-40/M30-63/N30-2x16m2
Main steam parameters	285 bar/600°C/620°C
Condenser pressure	45 mbar
Generator	Water/hydrogen cooling
Feed water heating stages	8 feed water heaters+external desuperheater
Feed water final temperature	303,4°C
Feed water pump concept	3x50% electric motor-driven feed water pumps, variable-speed drive with planetary gearing

### **Operating concept RPP NRW**

The following major boundary conditions have been specified for the operating concept:

- Service life: 200 000 operating hours
- Base load for the first 15 years at 7500 h/year, then intermediate load at 5500 full load operating hours per year
- 2860 starts over the entire period of usage

### **Preferred variant (§13 and 14)**

A total power plant price of 798 Euros/ KW (gross) was offered for the preferred variant (45,9% of net efficiency) (861,8 Euros/KW in taking into account +8% for owner contribution and imponderables)

	Preferred variant RPP NRW
Gross installed capacity	600MW
Net installed capacity	555,5MW
Net efficiency	45,9%
Main steam parameters	285bar/600°C/620°C
Feed water end temperature	303,4°C
Price of the plant	478,5 MEuros
Boiler type	Benson tower boiler with vertical tubes
Utilization of waste heat	Use of mill air heat
Flue gas cleaning	SRC-DENOX, electrostatic precipitator, flue gas desulphurisation using limestone
Flue gas discharge	Discharge via cooling tower
Steam turbine	Three-casing steam turbine with simple intermediate heating and low-pressure stages made of titanium alloy
Generator stages	Cooled by water/hydrogen
Economiser stages	Eight economisers+external desuperheater
Feed water pump concept	3x50% electric motor-driven feed water pumps , variable-speed drive with planetary gearing
Condenser pressure	45 mbar, wet closed-circuit coming via natural-draft cooling tower
Price of the plant Specific plant price	478,5 MEuros 798 Euros/KWgross

# Increasing of cost in relation with net efficiency RPP NRW

Net efficiency	Total power plant price
Preferred Variant 45,9%	798 Euro/KWbrutto
45,9 to 46,1%	798 Euro/KWbrutto + Appr. 20 Euro/KWbrutto per % pt
46,1 to 46,2%	798 Euro/KWbrutto + Appr. 25 Euro/KWbrutto per % pt
46,2 to 46,5%	798 Euro/KWbrutto + Appr. 30 Euro/KWbrutto per % pt
46,5 to 47,3%	798 Euro/KWbrutto + Appr. 35 Euro/KWbrutto per % pt

# Increasing of cost in relation with net efficiency RPP NRW

Efficiency	Calculation	Specific power price	Total specific power price x1,08	600 MWel plant total price
45,9%		798 Euro/KW	861,8 Euro/KW	517 MEuros
46,1%	+20 Euro/KWx0,2%= +4 Euro/KW	802 Euro/KW	866,2 Euro/KW	520 MEuros
46,2%	+25 Euro/KWx0,1%= +2,5 Euro/KW	804,7 Euro/KW	868,ç Euro/KW	521 MEuros
46,5%	+30 Euro/KWx0,3%= + 9 Euro/KW	903,7 Euro/KW	878,6 Euro/KW	527 MEuros
47,3%	+ 35 Euro/KWx0,8%= + 28 Euro/KW	931,7 Euro/ KW	908,8 Euro/KW	545,3 MEuros

# PLAN COSTS INCREASINGS

## Precautions to take when talking about plant costs

It is always difficult to talk about costs and to compare costs, because a lot of parameters impact plant costs; following are some parameters which have to be taken into account:

- New plant or existing plant***
- Different kinds of costs***
- Conditions and performances of depollution***
- Size effect***
- Series effect***

## Evolutions of costs

Boiler costs (and depollution systems) have multiplied by 1, 5 to 2 between 2003 and 2007; these are two main reasons for the increase:

### ***-Increasing of steel costs***

For example, the increase of the cost of steel was +54% between 2000 and 2007.

### ***-Market tension***

The small number of depollution manufacturers and the proximity of the regulatory term (2015) to apply LCP Directive regulation increase the market tension on the prices of the depollution systems and also on the new plant prices.

## Conclusion

Costs can only be meaningful when fixed in the real context. The costs given in the following tables have to be considered estimated.

### ***-Increasing of steel costs***

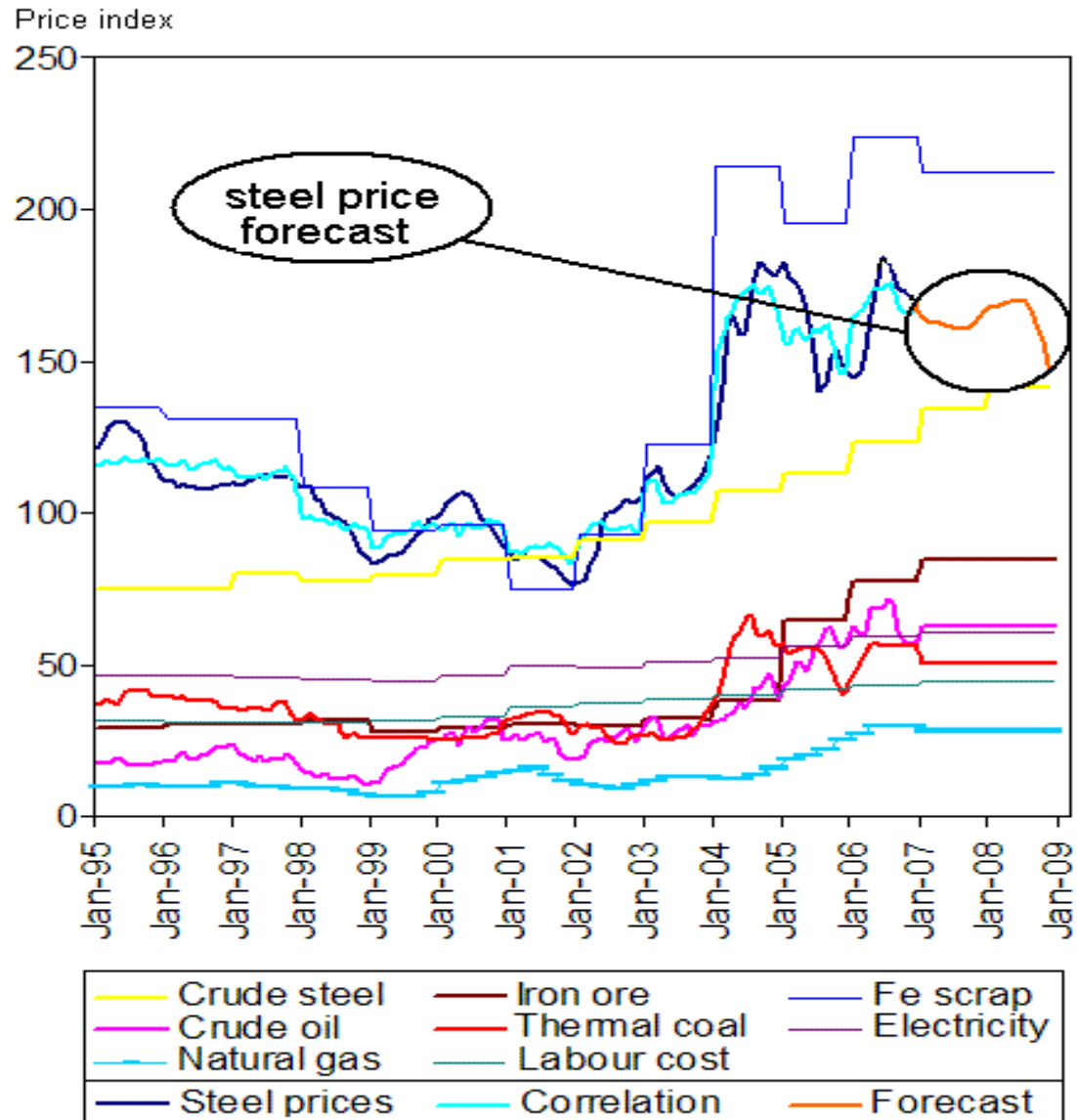
For example, the increase of the cost of steel was +54% between 2000 and 2007. (+58% during year 2007). This steel price is correlated with ferrous scrap prices and energy prices.

The lowest recent price was in January 2002 (price index 80). The price index in January 2008 is 160; steel price has doubled.

Considering that a large part of the cost of a plant is dependant on steel prices, this shows how difficult it is to compare depollution prices at different periods.

An other example of cost increase is the SCR catalyst price which has grown in 2 years at least by +20%.

## World Steel Price Forecast 2007-2008



### ***-Market tension***

The small number of depollution manufacturers and the proximity of the regulatory term (2015) to apply LCP Directive regulation increase the market tension on the prices of the depollution systems and also on the new plant prices.

This market tension explains together with the steel cost increase the global increase of costs of plants and depollution systems at present.

This market tension is felt by different ways: the classical price revision formula are no longer representative; there is no longer reduction in price if you buy several units in series; there is a market saturation until 2014 and even beyond because new countries of the European union are granted a delay in applying the European regulation. The delays to build a plant are becoming very long. Manufacturers are at present free to choose the tenders they wish to answer

# SOME DEPOLLUTION SYSTEM COSTS : FGD

Unit capacity MWe	Unit efficiency %	Unit capacity MWth	Fue	Depollution system	Depollution investment costs MEuros	Estimation year	Specific cost* Euro/Kwe	Specific cost* Euro/Kwth	Existing unit or new unit	Sources Comments
1000	41,3	2421	coal	FGD	66	2006	66	27	new	VGB
800		1937			57,2		72	30		VGB
600		1453			47,3		79	33		VGB
400		968,5			35,8		90	37		VGB
300		726			30,3		101	42		VGB
200		484			22		110	45		VGB
100		242			13,8		130	57		VGB
600	42	1429	coal	Classic FGD	37	2003	62	26	new	EDF Est.
600	42	1429	coal	Flowpac	35	2003	58	24	new	EDF Est.
>600?				FGD		Mid 2006	88			EDF Rybnik
>600				FGD		2007/2008	110			EDF

Est=estimation  
 \*engineering included

# FINE PARTICLES COLLECTOR EMERGING TECHNOLOGIES

Technology name	Manufacturer	Technology description	Aimes	Date of implementation
COHPAC+ TOXECON	Hamon-Research Cottrell (USA) under EPRI licences	Combination of an existing or new electrostatic precipitator with a baghouse precipitator eventually with injection of additives sorbent: )	Reduce significantly mercury, sulphur dioxide and others toxics ( dioxins...)	Tests in 2001 to 2004
INDIGO	Indigo technology LLC ( USA)	Agglomerator located up-stream ESP to agglomerate fine particles with heavy particles to better capture them, with: -a fluidic mechanical agglomeration process -a bipolar electrostatic precipitator	Reduce by about a factor 10 the fine particles emissions	Test in 2004 in Australia

# SO3 INJECTION

- **Short description:** SO3 injection to lower particles emissions in case of combustion of high resistivity coal ashes (Le Havre 4 600MWe/1580 MWth coal fired unit in 2006)
- **Dust abatement efficiency:** average 50% with possibility of 75 to 85%
- **Dust: abated factor:** 6, 2 g/GJ fuel input
- **Electricity consumption:** 0,013 KWh/GJ fuel input
- **SO3 equipment investment** (engineering included): 0, 0007 MEuro/MWth (1, 1 MEuro)
- **Fixed operating costs:** not significant: 0, 0012 Euro/GJ
- **Variable operating cost:** not really significant; 0, 001 Euro/GJ

- **References:**

- Le Havre 4 in 2004
- 2563 GWh (gross)
- 5737 operation hours
- 4202 full capacity equivalent operational hours
- 279 tons dust emissions
- 68 mg/m<sup>3</sup> yearly average dust emission
- 918899 tons of coal
- 24405 KJ/Kg heating value
- 22426 TJ primary fuel input/ year 2004
- **Dust abated emission factor**
- 50% average abatement due to SO3 injection
- 139500 Kg/year
- $139500000/22426000=6, 2$  g/GJ fuel input
- **SO3 system electrical consumption: 50 KW**
- $50KW \times 5737$  hours= 286850 KWh
- $286850/22426000=0,013$  KWh/GJ
- **Fixed costs**
- Maintenance: 2, 5% investment cost (estimation)
- $1, 1MEuro \times 0, 025=27500$  Euros/year
- $27500/22426000GJ=0, 0012$  Euro/GJ
- **Variable costs (sulphur cost)**
- 5100 Euros/1000 full equivalent capacity operational hours
- 21400 Euros for 4202 full capacity equivalent hours (2004)
- $21400/22426000GJ=0,001$  Euro/GJ

# FLOWPAC

- **Description**
- Flowpac process is a wet desulphurisation process developed by ALSTOM. It is a turbulent bubble bed reactor. The flue-gas is injected into a slurry through numerous submerged pipes while limestone slurry is fed into the turbulent bubbled bed reactor and air for oxidation is blown into slurry. The absorber type is a good example of a simplified FGD process. It eliminates the need for recycle pumps, spray nozzles and headers, separate oxidation tanks and thickeners, thereby minimising difficulties as well as power consumption.

# FLOWPAC

- **Performances**
- The process has a compact design and allows to reach high desulphurisation rates (> 99%) with high sulphur content fuels (>1, 5%).
- The electrical consumption is lower in the Flowpac (1, 3% of the power capacity in Karlshamm) than in the classical wet FGD (1, 7 /1, 75%)
- According Alstom, the yearly maintenance costs are lower for Flowpac (1, 2% of the investment costs) than for the classical wet FGD (1, 5%) due to a better accessibility.

# FLOWPAC

- **References**

- Few Flowpac absorbers are built in the world. The prototype was built in 1996 on unit 3 of the Karlshamm power station in Sweden (3 x 340 MWe oil plant). The gas flow is 1080000 Nm<sup>3</sup>/h the design oil sulphur content is 3, 5%.
- 3 other Flowpac (3x150 MWe) have been built recently at Lietuvos Elektrine Power Plant (Lituany) and forecast to start in 2008 ( according to Alstom references). The gas flow is 1800000 Nm<sup>3</sup>/h and the design sulphur content is 3, 5%
- *Lietuvos plant: 4x150MWe+4x300MWe=1800MWe: 5 FGD have been implemented in Lietuvos : boilers 1+ 2 (2x150 MWe);boilers 5A+5B (300MWe); boilers 6A+6B(300MWe); boilers 7A+7B (300MWe); boiler 8A(300MWe); fuel:natural gas, heavy oil( sulphur content up to 3,5%),orimulsion ( sulphur content up to 3%)*
- An other Flowpac will be started in 2009 at Amagervaerket plant in Copenhagen (owner/operator Energi E2) (150MW; 540000 Nm<sup>3</sup>/h; 1, 3% sulphur content)
- There is no reference for capacity > 340 MWe and no operational reference for coal unit. A prototype of 15 MW is in test in Sweden. For a unit of 600 MWe, Alstom proposes 2x300 Flowpac in parallel without reference.
- From the expert point of view, this kind of process is to be advised for oil units < 340 MWe until more experiences.

# FLOWPAC

- **Costs**
- The investments costs desulphurisation of 2 coal units of 600 MWe were estimated in 2003:
- Flowpac: 58 Euros/kWe (70 MEuros for 2x600MWe coal units), 6% lower than
- Classical wet desulphurisation: 61 Euros/kWe (74 MEuros for 2x600MWe coal units)
- **Sources:**
- EDF: “Procédé de désulfuration humide innovant Flowpac: état des connaissances” ( C.Derousseau, I.Gasquet)
- Alstom internet documentation
- IPPC draft reference Document on Best Available Techniques for LCP