

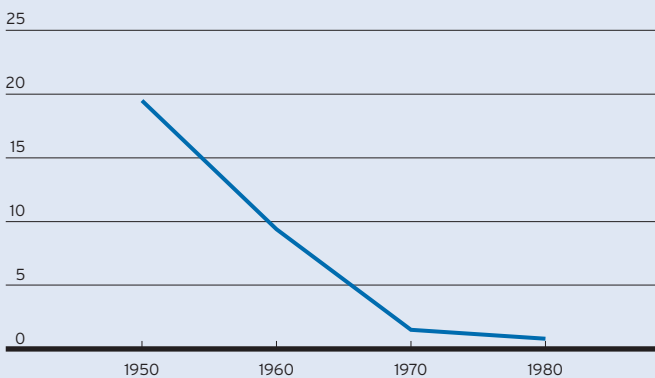
## PROJECTS CONTRIBUTING TO DECREASED EMISSIONS – FROM 1930 INTO THE FUTURE

Many investments and development projects have been carried out to improve the environmental performance of power plants now owned by Vattenfall. The first measures were taken as early as the 1930s, by eliminating particles from the flue gas in coal-fired plants. Here are some examples of investments in plant technology that have virtually eliminated particles and significantly reduced SO<sub>2</sub> and NO<sub>x</sub> emissions from Vattenfall's plants. Opposite are examples of planned projects, especially with the goal of decreasing CO<sub>2</sub> emissions.

### 1930–1980 The history of ESP in Germany

The first verifiable installation of an electrostatic precipitation system (ESP) in Germany was at the Hirschfelde power plant in Saxony in 1935–36, which enabled a reduction of particles by 75%–80%. At around the same time, ESP technology was installed in the Klingenberg power plant in Berlin. During the course of the 20th century, the introduction of flue gas fans led to higher flue gas velocities and increased particulate emissions. The use of pulverised coal burning also contributed to this increase. Therefore, all power plants built after 1945 were fitted with ESP systems as a standard. During the communist era in East Germany, all systems and equipment in the power plants were operated at their capacity limits and beyond. This caused the boilers to leak and resulted in elevated flue gas emissions and relatively low efficiency of ESP systems. Improvements made from 1990 and onwards significantly improved the reduction of particulate emissions without the plants' technology having to undergo any major changes. Today, Vattenfall's power plants in Germany remove up to 99% of particulate emissions.

The amount of particulate emissions relative to the quantities of ash produced during firing %



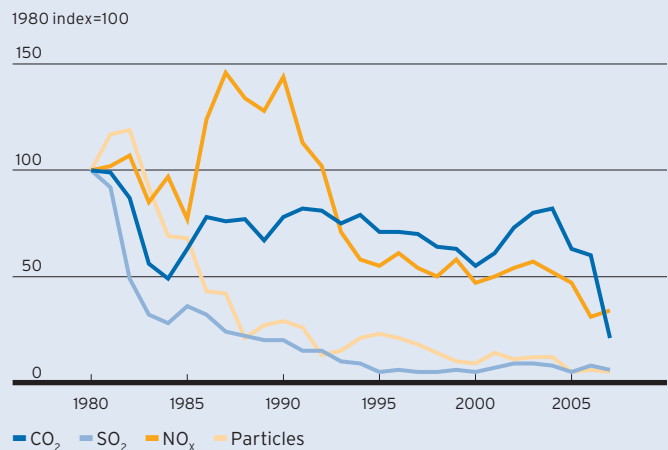
Source: K. Bers, Kraftwerk und Umwelt/Power Plant and Environment (1983)

### 1989–1991 Investments in Danish power plants

In 1989, a 250 MW<sub>e</sub> coal-fired unit at the Amager power plant in Denmark was commissioned. The boiler was equipped with low NO<sub>x</sub> burners and flue gas desulphurisation (FGD) from the onset. The FGD system was the first wet gypsum-producing FGD system installed at a Danish power plant. During the last 10 years, a NO<sub>x</sub> removal degree of approximately 85% has been attained by optimising the low NO<sub>x</sub> burners and retrofitting the boiler with an SCR system. SO<sub>2</sub> emissions have been reduced by lowering the sulphur content of the coal and through technical improvements to the FGD system, resulting in a desulphurisation degree above 97%.

In 1991, a 405 MW<sub>e</sub> coal-fired unit at the Fyn power plant was commissioned. This boiler was equipped with low NO<sub>x</sub> burners and FGD from the beginning. The dry by-product from the FGD is reused as

### 1980–2007 Reduction of emissions at power plants in Uppsala



Vattenfall's facilities in Uppsala, Sweden, generate electricity as well as district heat, cooling and steam. The main fuels are waste, peat, biomass and coal (oil and gas are used in auxiliary devices). A new waste incinerator, Block 5, was commissioned in 2005. Replacing other capacity with the modern Block 5 facility led to reduced emissions of CO<sub>2</sub> as well as SO<sub>2</sub>, NO<sub>x</sub> and particles. All modern flue gas-cleaning technologies are currently used in Uppsala, such as flue gas desulphurisation, low-NO<sub>x</sub> burners, SNCR/SCR technology, ESP and fabric filters.

absorbent in the gypsum-producing FGDs at the Amager and Nordjylland power plants. To further reduce NO<sub>x</sub> emissions, an SCR plant was commissioned in early 2008. Today the Fyn power plant has an estimated desulphurisation degree above 98%, and a NO<sub>x</sub>-removal degree of approximately 85%.

In 1991, block 2 at the Nordjylland power plant was retrofitted with the first full-scale SCR plant in Denmark for reducing NO<sub>x</sub> emissions. The SCR was part of the SNO<sub>x</sub> plant – a combined flue gas cleaning method that reduces both NO<sub>x</sub> and SO<sub>2</sub> from the flue gas. Today the Nordjylland plant, which also includes block 3 from 1998, has an estimated NO<sub>x</sub> removal degree of approximately 82% and a desulphurisation degree above 99% for 2008.



### 2007 and onward Reducing emissions in Poland

Most of the 36 boilers at three plants in Warsaw have been thoroughly modernised or replaced during the past two years. The total cost – nearly EUR 30 million – was covered in part by funding from the EU. The technical solutions not only meet the legal requirement for emission concentrations of 100 mg/m<sup>3</sup>, but highly exceed it – the achieved emission concentration is 50 mg/m<sup>3</sup>.

At the CHP plant in Siekierki, fabric filters together with semi-dry desulphurisation have been installed, leading to particulate emission concentrations that are well below the legal requirement of 50 mg/m<sup>3</sup> (8–12 mg/m<sup>3</sup> lower).

At Vattenfall's second largest plant in Poland, CHP Żerań, most generation is based on fluidised bed technology. The main benefit of combustion in fluidised bed boilers is the reduction of SO<sub>2</sub> and NO<sub>x</sub> emissions to the level required by the EU. Additionally, the environmental impact of the plant has been reduced through optimisation of purchased fuel quality – high calorific value and low sulphur content.

SO<sub>2</sub> and NO<sub>x</sub> reduction efforts in Poland are ongoing. Stricter requirements will be applied in Poland in 2016, and work has begun to equip the Polish facilities with modern installations dedicated to improved flue gas cleaning. Vattenfall's broad base of experience in this area is expected to provide valuable support.



### 2008 CCS pilot plant at Schwarze Pumpe, Germany

On 9 September 2008, Vattenfall's 30 MW<sub>th</sub> Carbon Capture and Storage (CCS) pilot plant at Schwarze Pumpe, Germany, was inaugurated. The pilot plant is an important milestone in efforts to achieve the goal of developing a commercial concept for CCS at coal-fired power plants before 2020. The purpose of the pilot plant is to validate and improve CCS technology. There are three main methods for capturing carbon dioxide. Vattenfall has chosen to test Oxyfuel combustion technology at the pilot plant, since it builds on existing power-cycle technology. It is also currently the most promising method with regard to costs for capturing carbon dioxide at power plants. The initial testing programme will run for three years. Thereafter, the pilot plant will be available for other tests. The plant is planned to be in operation for at least 10 years.



### 2013 Multi-block CCS demonstration plant in Aalborg, Denmark

On 5 February 2008 Vattenfall announced its intention to develop a full-scale Carbon Capture and Storage (CCS) demonstration plant in Denmark. By 2013, the Nordjylland power plant (Nordjyllandsværket) will release only small amounts of CO<sub>2</sub> to the atmosphere. Instead, the CO<sub>2</sub> will be captured and transported to a geological structure where it will be stored in a reservoir at a depth of 1–2 kilometres underground in northern Jutland. In 2008, studies were initiated to ensure that CO<sub>2</sub> storage is a

realistic possibility at Vedsted in northern Jutland. Based on the results of studies of the geological structure, an investment decision is planned for late 2010. If the storage proves feasible, the intention is to establish a full-scale CCS plant in 2013. The demonstration plant is a link between the pilot plant and the commercial concept that is to be developed.