

Acid gas removal and heat recovery

Hot topic hour June 16

Mcilvaine Company

Proposed carbon emission standards rely on generation-side efficiency

- *Proposed U.S. standards for reducing carbon emissions from existing coal-fired power plants rely heavily upon generation-side efficiency improvements. Fuel, operations, and plant design all affect the overall efficiency of a plant, as well as its carbon emissions.*
- *The beneficial use of more flue gas heat can substantially contribute toward meeting these goal.*
- *FGD and sorbent injection can all play a role in reducing the emissions. Presently FGD increases the emissions by adding pressure drop and increasing fan energy consumption*

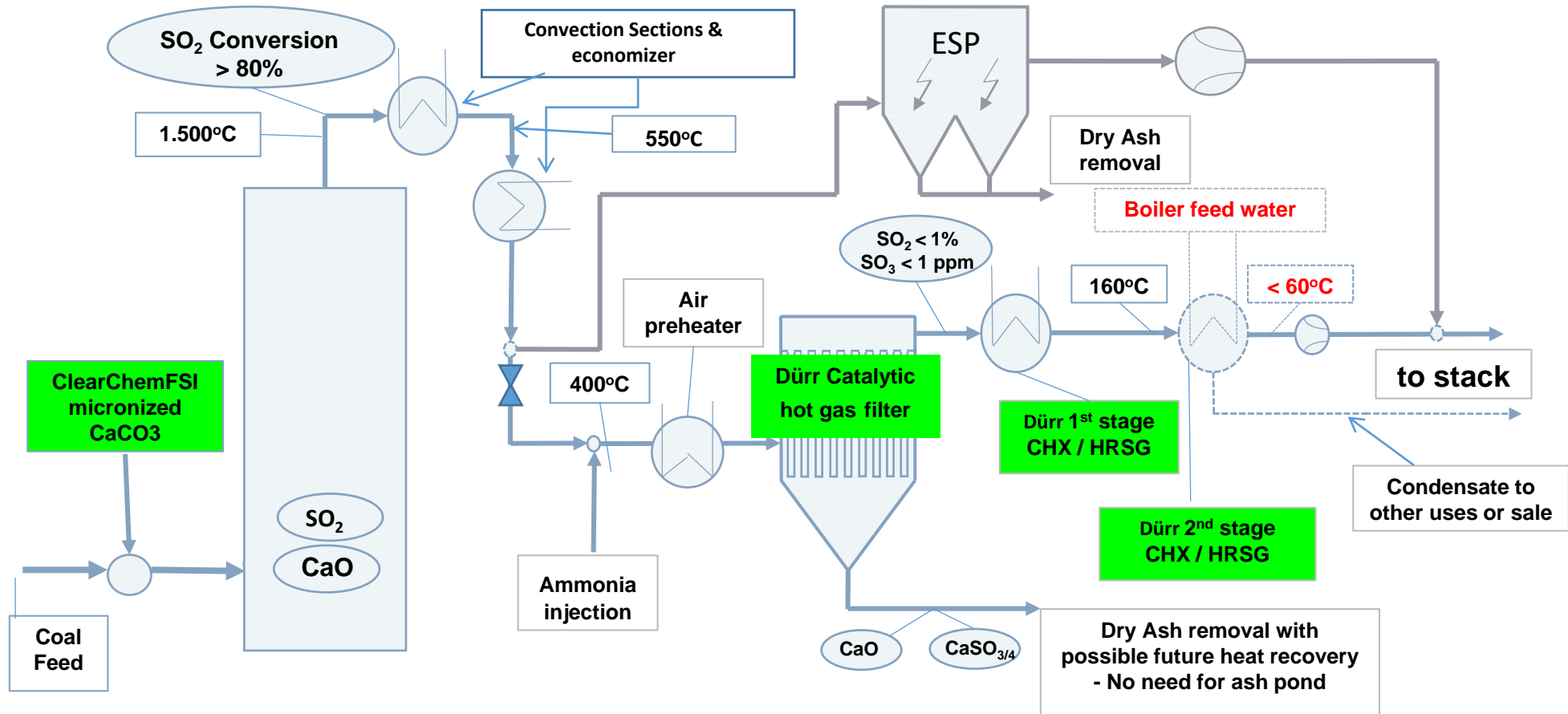
Boiler feedwater heating at Anqing

Shenhua Shenwan Energy Company's Anqing Power Plant Phase II's 2×1000-MW expansion project

- An approach to saving energy was capturing the waste heat in the flue gas and using it to preheat the boiler feedwater. Operating at the designed full load, the flue gas heat exchanger recovers 44,000 kW of heat, which reduced heat consumption by 45 kJ/kWh, and reduced the plants' standard coal consumption by 1.65 g/kWh.
- This seems to show a 2% efficiency improvement. Could the heat transfer take place in a tubular heat exchanger in the exhaust duct?

Durr system with powdered Lime

Side Stream Application – Example existing ESP



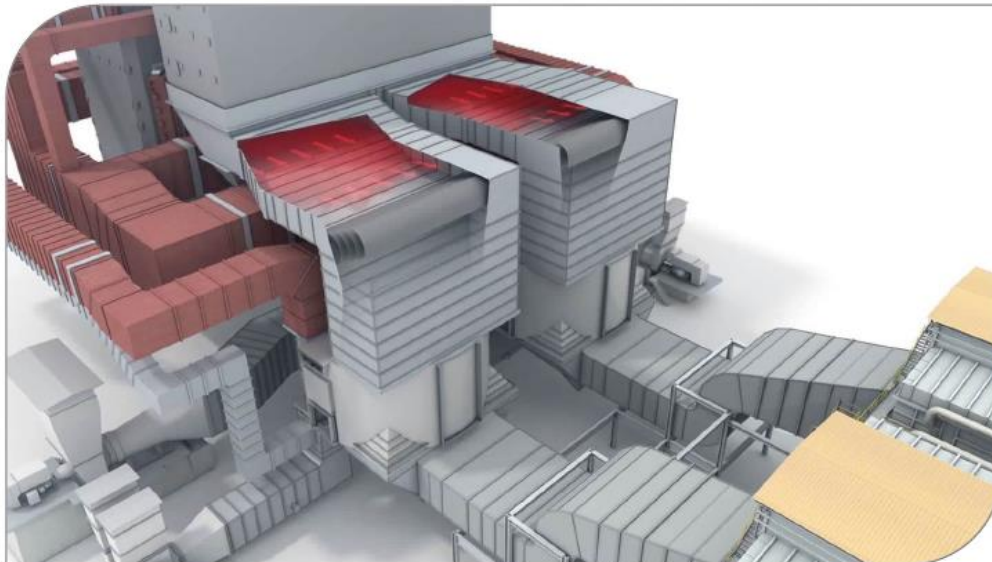
Air pre heater concept

4

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Air Heater Equipment

- Common to all coal-fired power plants
- Large rotating heat exchanger
- Transfers heat/energy from exhaust gas to inlet air
- Improves overall plant energy efficiency



Ljungström[®]
AIR PREHEATER

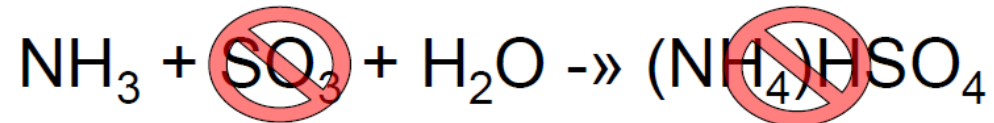
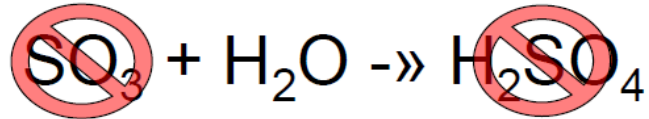
Inject sorbent to prevent acid formation and then lower air heater outlet temperature

6

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Strategy: APH Performance Improvement

1) *Inject Sorbent to Remove SO₃ Prior to Air Heater*



2) *Change Air Heater to Reduce Exit Gas Temp*

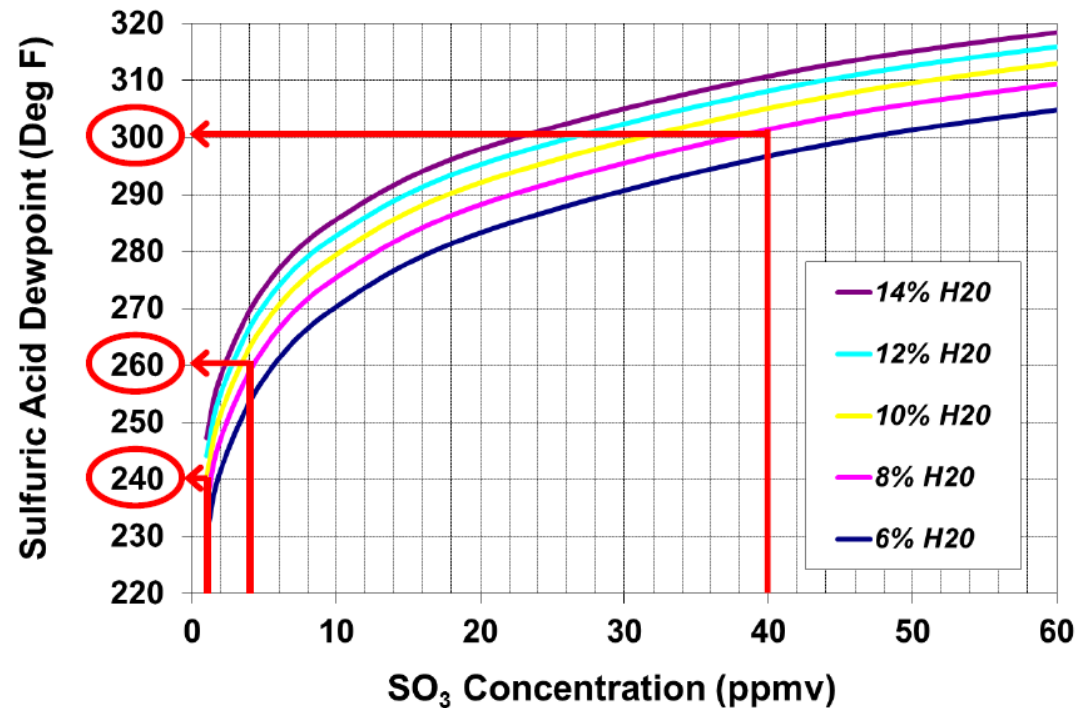
- *Reduce or eliminate air pre-heat*
- *Modify air heater internals*

Reduce SO₃ to 5 ppm and reduce acid dewpoint to 240F

7

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Strategy: Acid Dewpoint Reduction

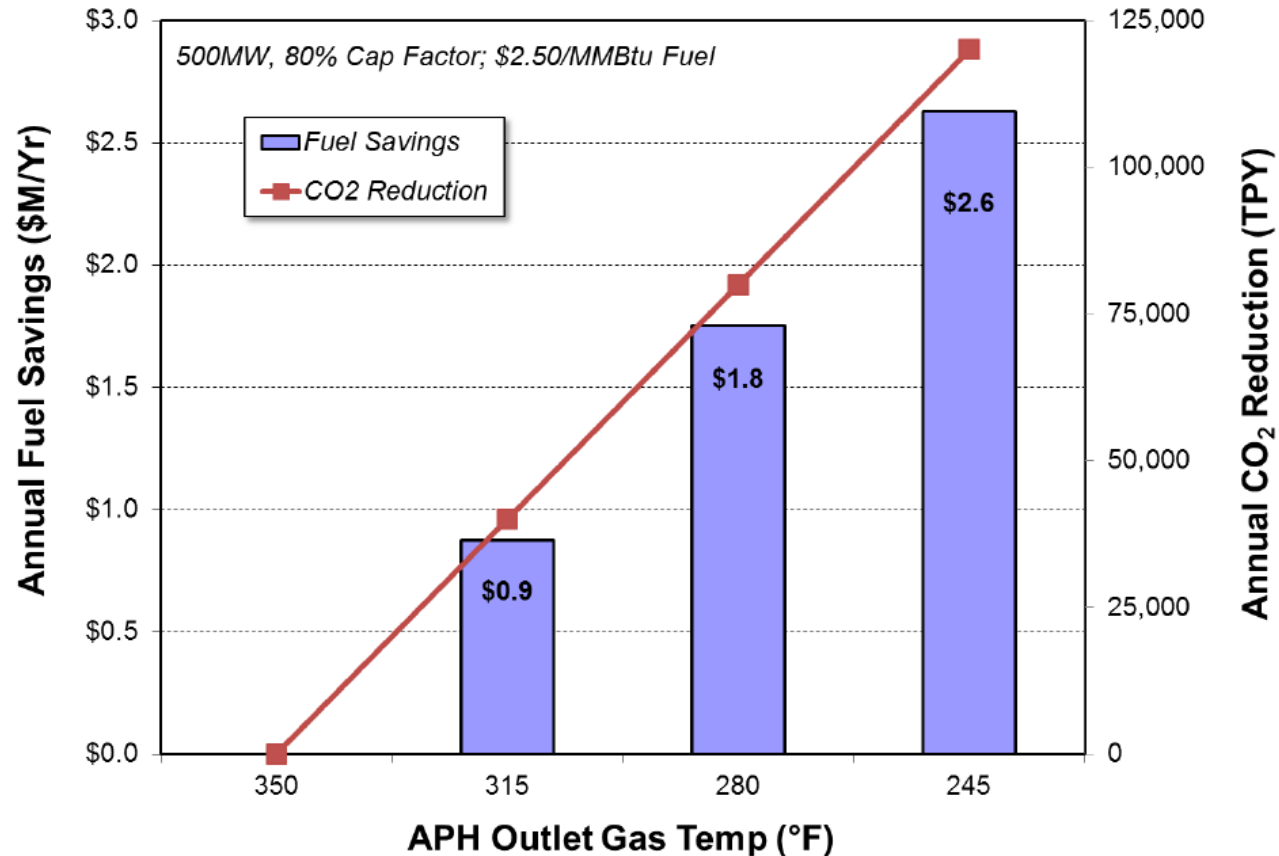


Fuel savings of \$ 2.5 million/yr for 500 MW plant

9

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Strategy: Heat Rate Benefit



Higher efficiency and lower emissions

10

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Strategy: Other Co-Benefits

- Reduced CO₂ Emissions
 - higher unit energy efficiency
- Enhanced Mercury Capture
 - greater carbon absorption capacity
 - less SO₃ interference
- Enhanced ESP Performance
 - lower gas volumetric flow (higher SCA)
 - lower ash resistivity (temp and SO₃ effect)
- Reduced Fan Aux Power Consumption
 - reduced gas flow and gas path pressure drop
- Reduced WFGD Water Usage
 - cooler inlet flue gas temp
- Reduced Unit Derates
 - higher PA temp and greater fan margin

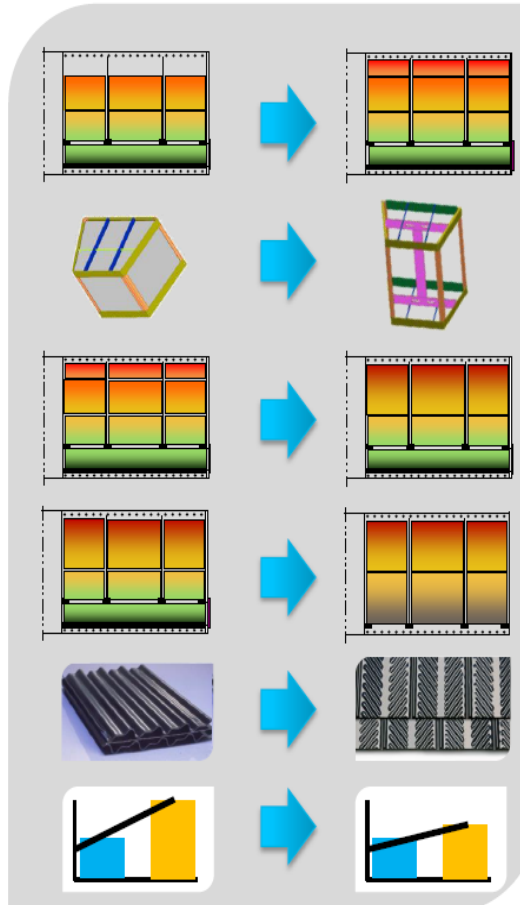
Temperature reduction approaches

14

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APH Temperature Reduction Approaches

1. Fill empty voids in APH rotor with additional basket layers
2. Utilize special basket designs to maximize useable space for heat transfer surface
3. Consolidate shallow basket layers into single deeper layers
4. Modify APH rotor to more efficiently support basket layers
5. Switch to more efficient types of heat transfer surface
6. Reduce pre-heat of air at inlet of APH

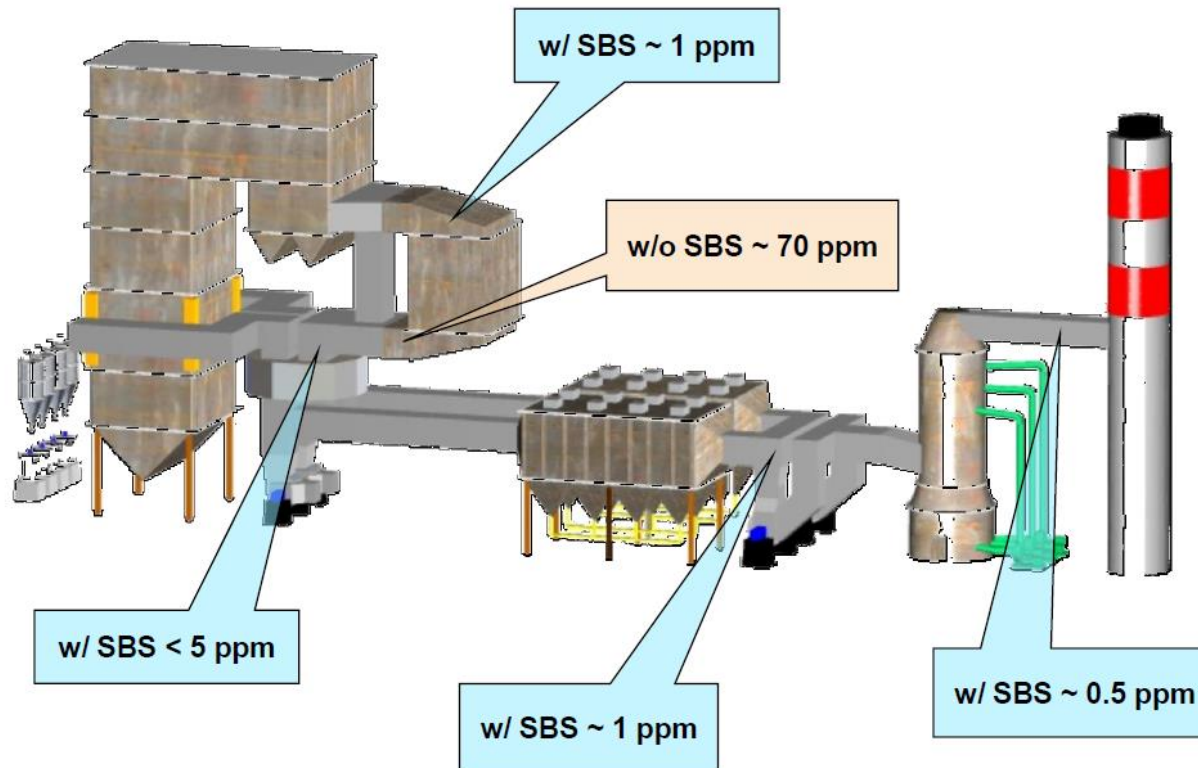


500 MW high sulfur coal 2014 air heater upgrade

17

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Relative SO₃ Levels Thru Gas Path

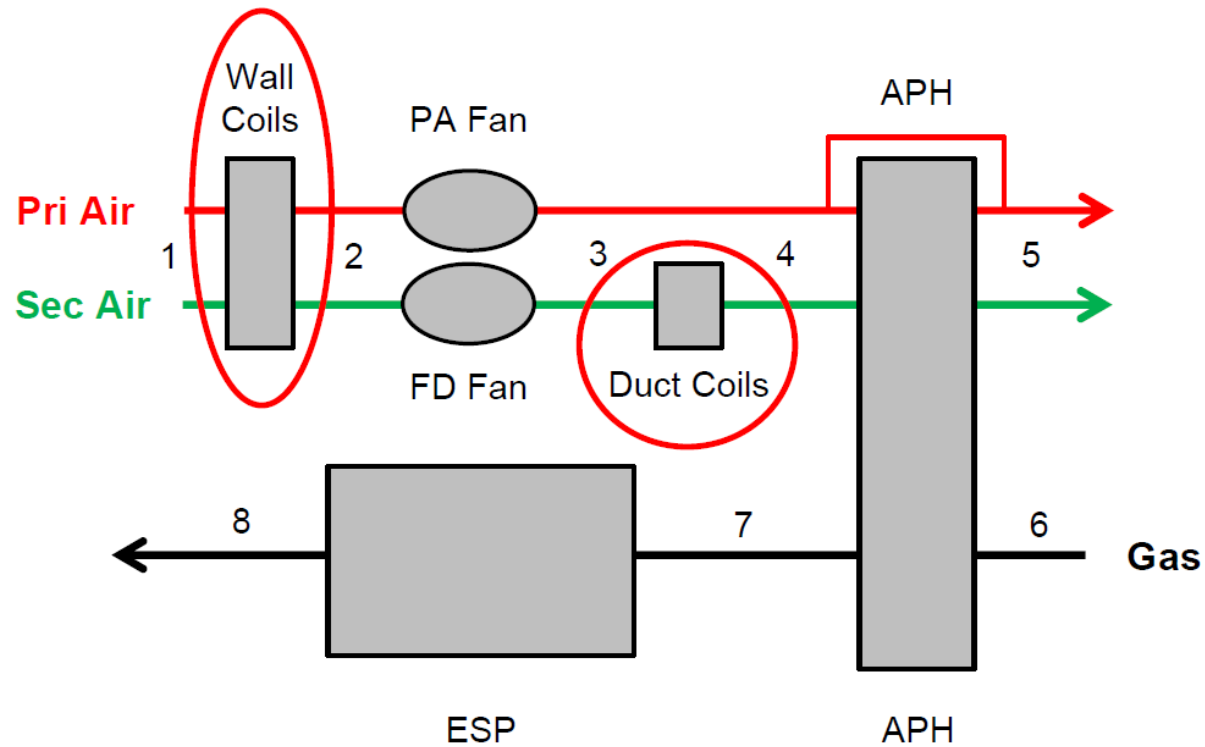


APH configuration

18

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APH Configuration and Operation

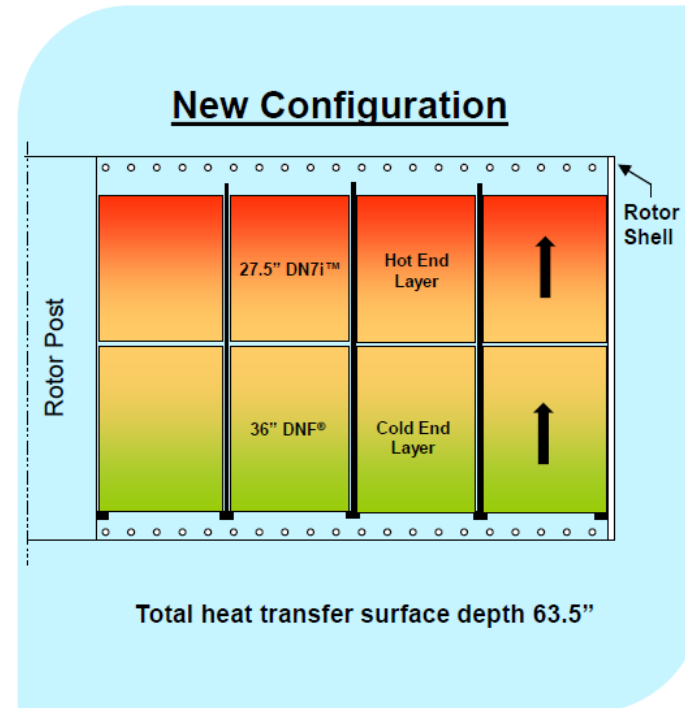
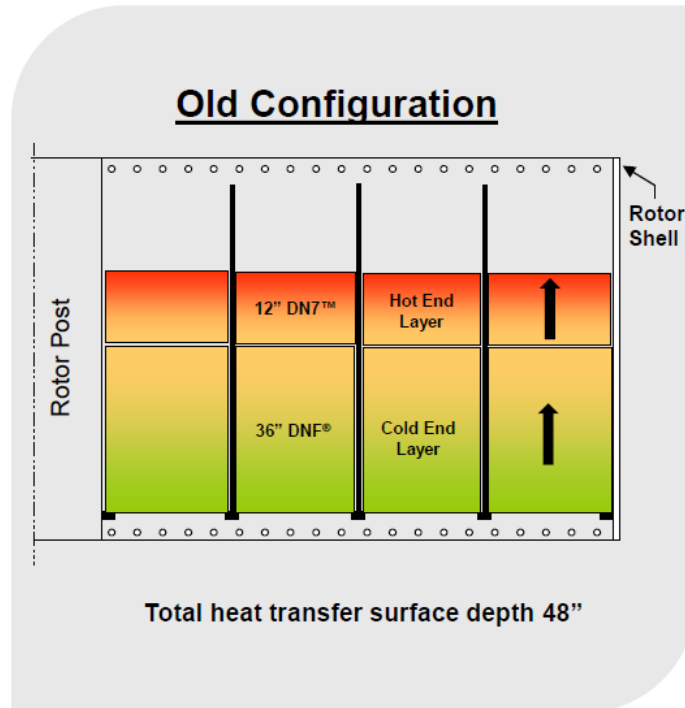


Rotor post expansion

19

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APH Upgrade Modifications

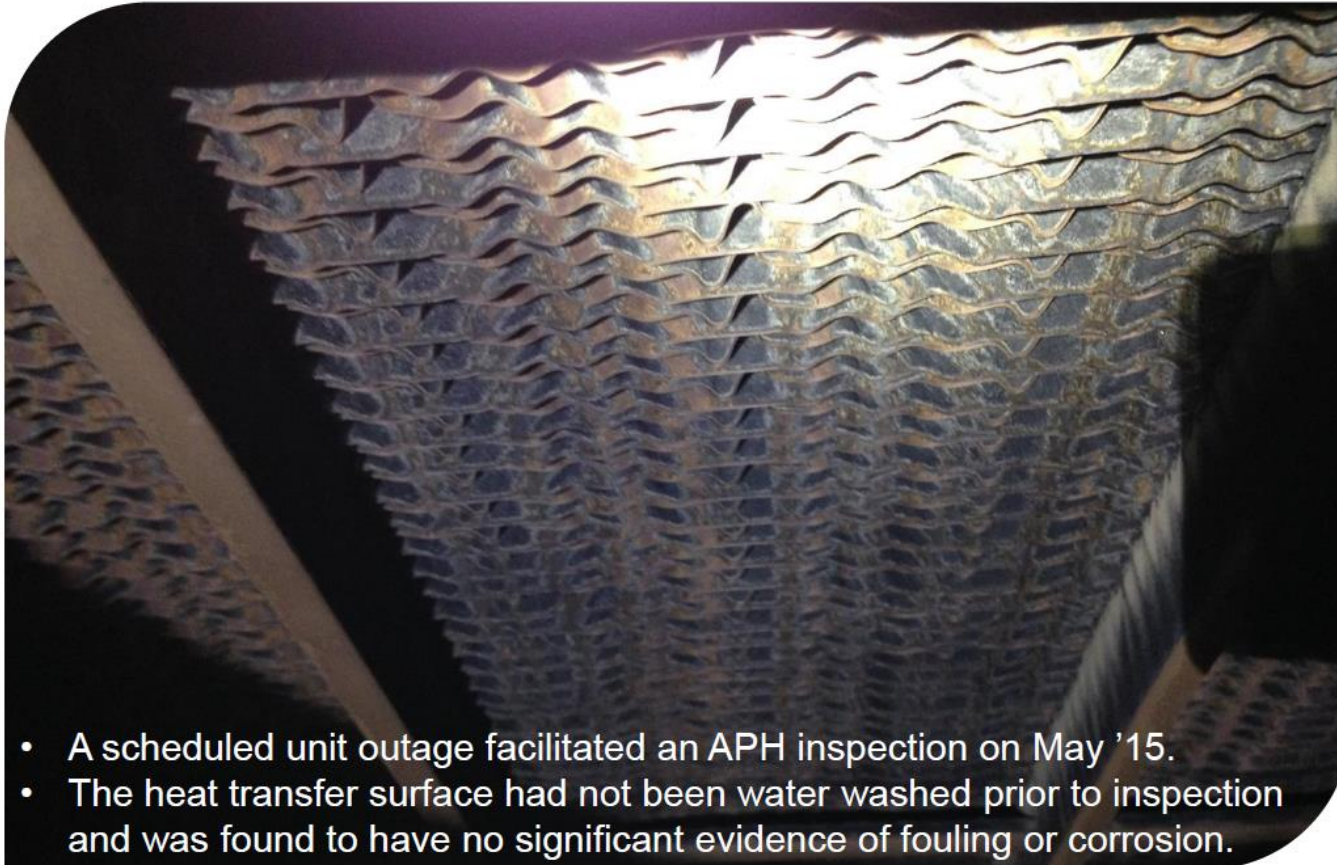


Heat transfer service stays clean

24

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APH Inspection After Demo



- A scheduled unit outage facilitated an APH inspection on May '15.
- The heat transfer surface had not been water washed prior to inspection and was found to have no significant evidence of fouling or corrosion.

Successful 70F temperature reduction

27

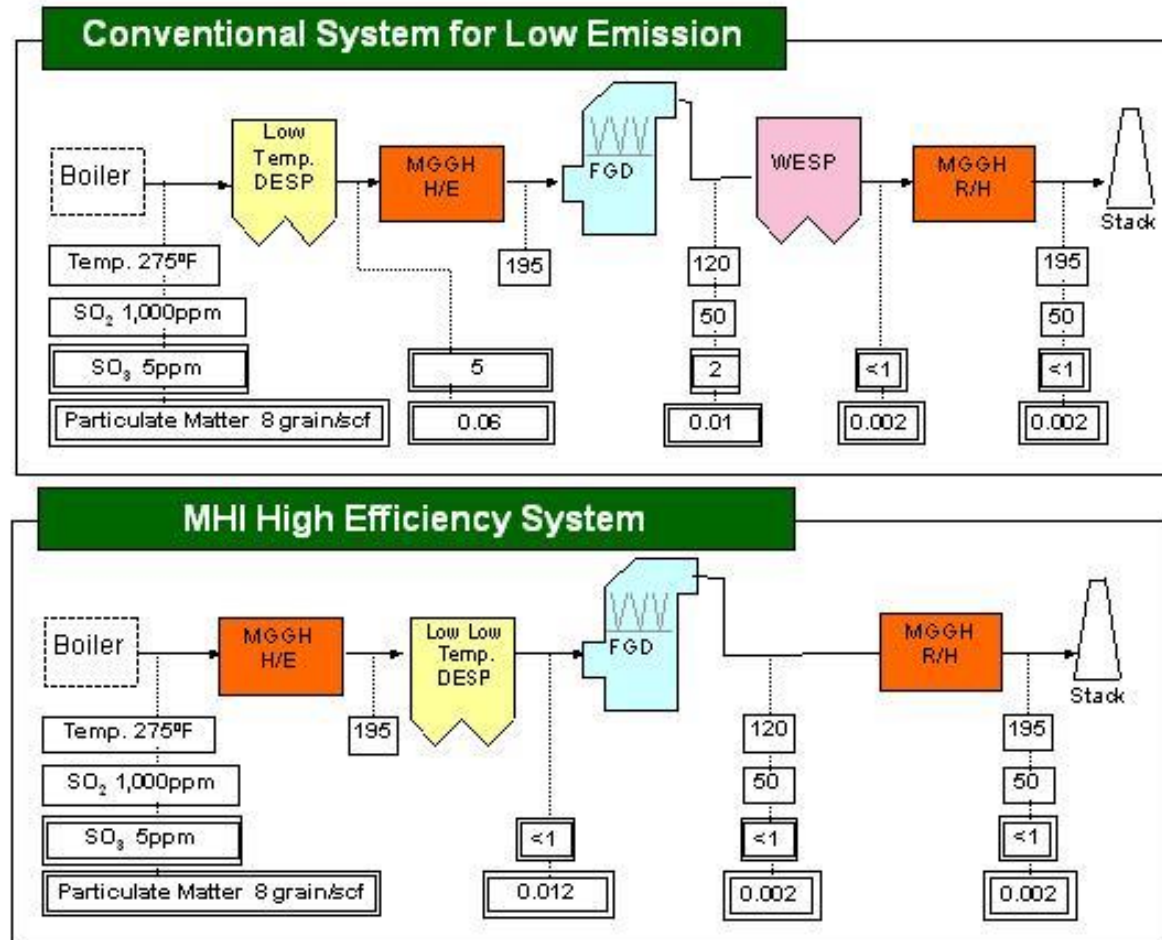
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Summary and Conclusions

- SBS Injection™ highly effective for SO₃ removal
- APH protection requires <5 ppm SO₃ at inlet
- Utility APH upgrade demonstration successful
 - ✓ Gas outlet temperature reduced by ~ 70°F
 - ✓ No APH fouling or pressure drop increase
 - ✓ No APH corrosion
- Utility benefits realized:
 - ✓ Heat rate improvement (O&M fuel savings)
 - ✓ CO₂ reduction (Clean Power Plan)
 - ✓ Enhanced mercury capture (MATS)
- Utility evaluating even more efficient APH design

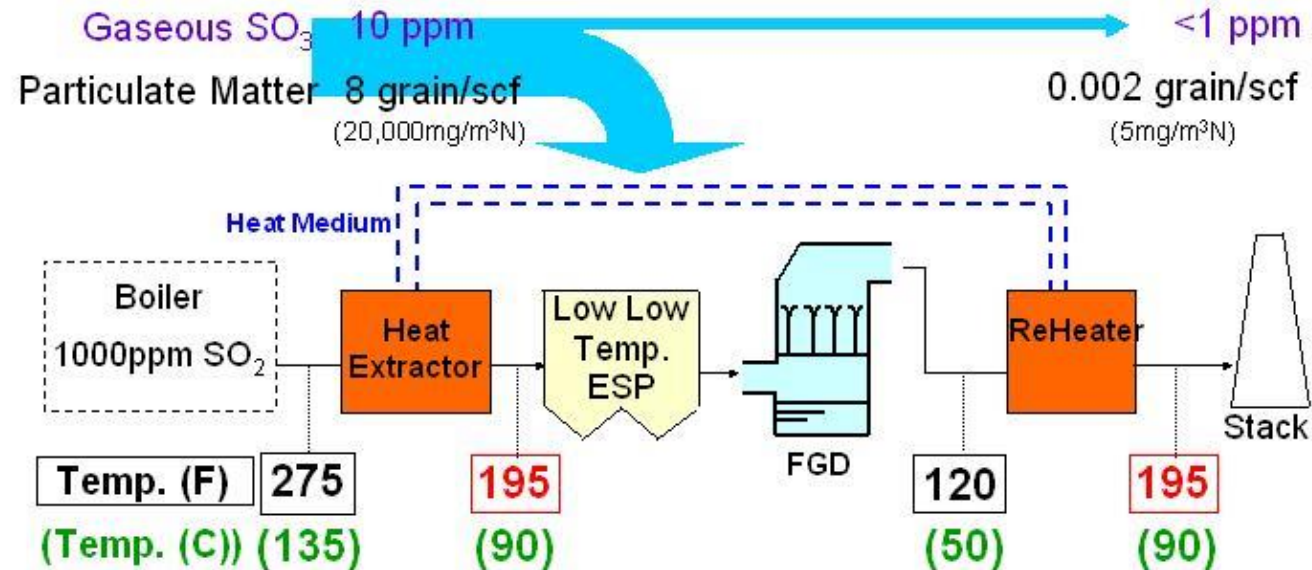
MHI – benefits to reduce to 195 F

MHI High efficiency system



MHI (but not use heat to reheat flue gas)

MHI High efficiency system



- SO₃ gas through air heater condensed with fly ash at ESP
- No plume caused by SO₃ mist at stack
- High particulate matter removal performance

- Patent -
* The U.S. Patent No.5282429
* The U.S. Patent No.6149713

MHI savings with heat reduction vs WESP

MHI High efficiency system

Feasibility study for Japanese 600MW boiler

	WESP	Alkali Injection	High Efficiency System
Initial Cost *1) (million US\$)	27	2	10
Operational Cost (million US\$ / year)	0.8	2.0	△0.7 *2)
Total (3 years Evaluation)	29.4	8.0	7.9 *3)

* 1) Including engineering, procurement and construction fee

* 2) 40 US\$/MW

* 3) Equivalent of 2MW (Increase of turbine output)

**High Efficiency System:
The most economical system
from the 3rd year**

MHI installations

MHI High efficiency system

MHI experiences in Japan

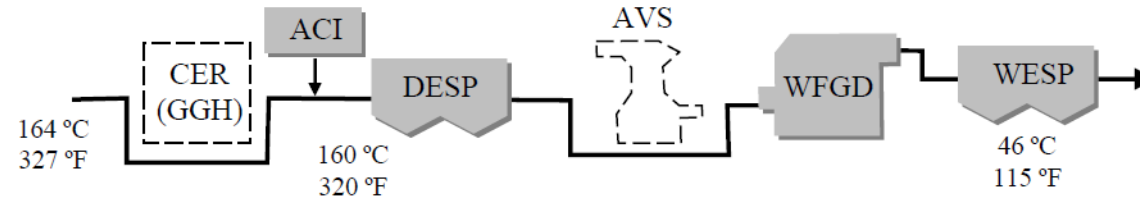
Year	Customer (Location)	Capacity (MW)	Fuel	PM Conc. (stack inlet) (grains/scf-dry)	SO ₂ Conc. (stack inlet) (ppm -dry)
1997	Tohoku Electric Power Co.,Inc. (Haramach#1,Japan)	1,000×1	Coal-Fired	0.010	<1
1998	Chugoku Electric Power Co., Inc.(Misumi,Japan)	1,000×1	Coal-Fired	0.004	<1
2000	Electric Power Development Co.,Ltd. (Tachibanawan,Japan)	1,050×1	Coal-Fired	0.002	<1
2000	Shikoku Electric Power Co.,Ltd. (Tachibanawan, Japan)	700×1	Coal-Fired	0.002	<1
2002	Hokkaido Electric Power Co.,Inc. (Tomatoh-atsuma #4, Japan)	700x1	Coal-Fired	0.003	<1
2003	Sumitomo Joint Thermal (Nyuugawa, Japan)	250x1	Coal-Fired	0.005	<1
2004	Tokyo Electric Power Company (Hirono, Japan)	600x1	Coal-Fired	0.002	<1
2004	Kobe Steel, Ltd. (Kobe, Japan)	700x1	Coal-Fired	0.002	<1
2007	Sumitomo Metal Mining Co., Ltd. (Kashima, Japan)	500x1	Coal-Fired	0.002	<1

Hitachi CER

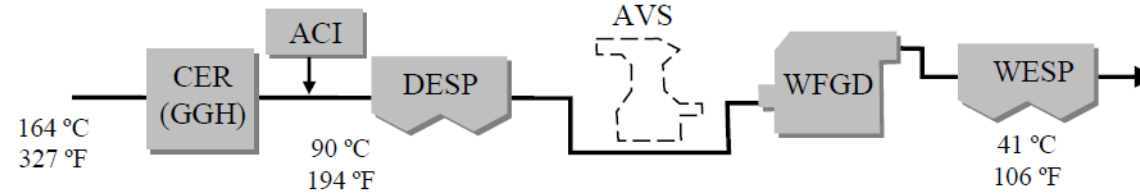
- Effective control of these pollutants requires careful consideration of their behavior across the whole Air Quality Control System (AQCS). In the case of mercury, it is necessary to evaluate how much elemental mercury (Hg_0) can be converted to oxidized mercury (Hg_2^+) in the SCR reactor¹⁻³. Hg_2^+ , which is mostly present as water-soluble mercuric chloride (HgCl_2), can be removed in downstream equipment such as the dry electrostatic precipitator (DESP) and the wet flue gas desulfurization (WFGD)^{4,5}. Flue gas temperature and chlorine concentration affect the oxidation and removal of mercury. Generally, coals containing high levels of chlorine, such as most eastern bituminous coals, produce high concentrations of Cl in flue gas and contribute to high oxidation and removal of mercury. Activated carbon injection (ACI) also can be effective to obtain further mercury removal. However, for high-sulfur bituminous coal applications mercury capture by activated carbon is inhibited by the SO_3 in flue gas⁶. It is necessary to remove SO_3 upstream of the activated carbon injection point for the carbon to work effectively.
- To solve this problem, Hitachi's advanced AQCS uses a Clean Energy Recuperator (CER). The CER is a finned tube gas cooler located upstream of the DESP to reduce flue gas temperature and remove gas phase SO_3 . The CER in the gas to gas heater (GGH) configuration has been applied successfully by Hitachi to five large coal-fired utility power plants in Japan⁷.

An Evaluation at CILCO showed substantial benefits for the CER

<a> Conventional System



 Advanced AQCS



<c> Advanced Venturi Scrubber (AVS) System

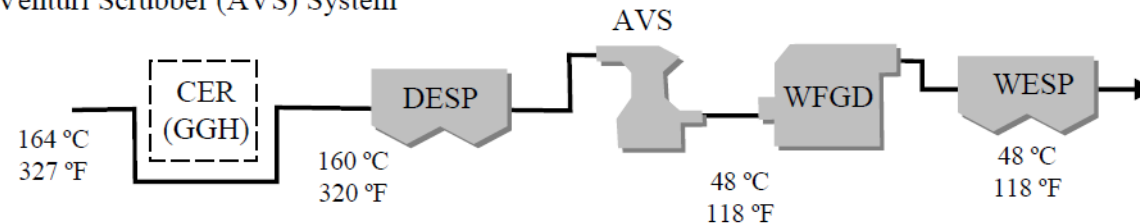


Fig.2 AQCS configurations tested

Ethanol –cogeneration plant

- The Blue Flint plant is co-located with Coal Creek Station, a GRE-operated plant near Underwood, ND. The synergistic relationship carries additional benefits in that the ethanol plant needs no boilers or their supporting infrastructure, maintenance, water treatment, and fuel costs.
- This concept can incorporate beneficial use for the remaining flue gas heat.
- The Spiritwood plant of GRE was built with the concept of co generation for a grain drying operation and several other operations which could use waste heat.
- Should operators of older plants consider converting their facilities into a manufacturing complex rather than shutting them down?

Can heat be beneficially used in forward osmosis ZLD

Forward Osmosis (FO) holds lots of promise for many applications. Whether FO should be considered for any specific project will depend on:

- Application specific details such as the solids content of the slurry and the availability of waste heat
- Approaches to regenerating the draw solution
- Process design and integration with RO and other sub-processes
- Membrane quality
- Product quality considerations

There has been considerable effort to apply FO in direct competition to RO. To-date most of the success has come where FO has unique performance advantages such as use with high solids wastewater in power plant FGD systems and Frac flow-back. Food applications where FO uniquely impacts product quality are also examples.

Oasys Water is transforming high salinity wastewater at the Changxing Power Plant. Oasys Water and its Chinese partner were selected to deliver the world's first commercial application of Forward Osmosis (FO)-based ZLD at the state-of-the-art Changxing coal-fired power plant. Oasys provided its ClearFlo MBC system and pre-concentrating reverse osmosis (RO), while Beijing Woteer supplied physic-chemical filtration, ClearFlo Complete ion exchange pretreatment, and a crystallizer package.

- **Feed Water:** The feed water at Changxing is a complex combination waste stream that includes flue gas desulfurization (FGD) blowdown wastewater and cooling tower blowdown (CTBD).
- **Results:** Oasys Water's patented technology is now transforming 630 m³/day of complex FGD wastewater at the Changxing Power Plant, reducing both the intake of local surface water and the outflow of industrial wastewater. This project has allowed Oasys to introduce an innovative FO-based brine concentration and water reuse process to treat desulfurization wastewater.
- **Economics:** The draw solution recovery at Changxing was designed to use steam as the energy source, thus reducing overall energy requirements and overall cost. The Changxing system's typical energy requirement is 90 kWh_t per m³ of processed wastewater.

In the FO decision guide we want to explore ways which energy for the FO can be supplied with waste heat from the power plant

What about using a direct gas to liquid heat exchanger in the exhaust stack and pump the draw solution through this exchanger. It would reduce flue gas temperature as well as provide the FO energy

What about using water in the exchanger and add MVR to bring it up to the right temperature?

Much older research on aquaculture before RAS

- An aquaculture system capable of rejecting all the waste heat from a 1000-MW(e) power station in winter can accommodate about half the summer heat rejection load. The aquaculture facility would require approximately 133 ha and would produce 4.1×10^5 kg/year of fish, 1.5×10^6 kg/year of clam meat, and 1.5×10^4 kg/year of live crayfish. The estimated annual pretax profit from this operation is one million dollars. Several possible problem areas have been identified. However, technical solutions appear to be readily available to solve these problems. The proposed system shows considerable economic promise

IBIS project to use power plant waste heat for RAS

- Power plants can only reach 50/60% production efficiency, which results in a great deal of energy wasted in the form of heat;
- Past research and aquaculture facilities tried to harness the waste heat of the cooling waters of power plant without much success;
- The main cause of failure of these type of aquaculture systems was due to unregulated discharges of pollutants in the cooling waters or unplanned shut down of the plant resulting in sudden lack of heated water
- Modern technology is approaching the concept of using waste heat through the use of heat exchangers
- The use of waste heat in Recirculating Aquaculture Systems (RAS) for the culture of warm water species such as tilapia, perch, turbot, seabass, and eel could decrease running costs and increase the profitability of the venture
- Harnessing of waste heat decreases environmental impact of power plants and reduces the energy need of RAS facilities.
- Waste heat might be successfully coupled with integrated aquaculture to achieve a environmentally, socially and financially sustainable enterprise.
- A partnership between the Loughs Agency, Queen's University Belfast, and the University of Glasgow, supported by the EU's INTERREG IVA Programme, managed by the [SEUPB](#).

Air conditioning and maybe even ice

- It appears that justifying the heat recovery is easy in the winter in cold climates but what about Indonesia, Vietnam and India where it is hot most of the year
- Co-generation with air conditioning would be one answer
- But what about areas which do not even have enough electricity to run air conditioners and are too distant to consider district cooling. . Why not generate ice and deliver it by truck? This is the way much of the U.S. dealt with the heat a century ago?
- Many deaths in India recently were attributed to the extreme heat. So there is a life saving potential to this approach. Water is already being delivered by truck , why not ice?

Ice for energy storage already researched

- This report describes a bulk energy storage and power peaking concept that is coupled to a Supercritical
- CO₂ (SCO₂) Waste Heat Recovery (WHR) power plant. The waste heat source could be the exhaust from
- a 25 MWe class gas turbine or hot gases from manufacturing process such as a metal smelter. The SCO₂
- power system is configured either as a supercritical Brayton cycle (off-peak power production) or as a
- transcritical Rankine cycle (on-peak). Energy is stored as ice in the “charging cycle” and then discharged
- by melting the ice during the on-peak demand time period. The ice is produced in a transcritical CO₂
- refrigeration cycle (heat pump) from CO₂ at –5 C. The power to run the CO₂ refrigeration cycle can
- come from either the grid or directly from the SCO₂ Brayton cycle. The charging cycle operates for
- approximately 8 hours during the night and early morning when the demand and the price of electricity
- are low. The stored thermal energy is recovered, or “discharged”, over a period of about 4 hours during
- the early evening when peak power demands and the price of electricity are high.

Waste heat for air conditioning

- The Experimental Power Grid Center (EPGC) at Singapore's Agency for Science, Technology and Research (A*STAR) and Japanese electronics company Hitachi have now completed and commissioned a Combined Heat and Power (CHP) pilot plant to harness waste heat, and convert it to energy to power air-conditioning. The CHP system will control heat and power facilities as the operating point to best minimize costs and energy consumption. The plant marks the successful completion of a milestone in the three-year research collaboration project between EPGC and Hitachi. CHP systems are not widely adopted in Singapore as most buildings obtain power from the grid to provide electricity for air-conditioning, mechanical ventilation systems, water pumps, lights and other services such as lifts and escalators. These needs account for up to 54 percent of total electricity consumption in a commercial building. With the large electricity consumption, there is a need for an energy efficient system that decreases reliance on fossil fuels and reduces carbon dioxide emissions. This is crucial as buildings are estimated to contribute almost 14 percent of Singapore's carbon emissions by 2020. : <http://www.asianscientist.com/2014/08/tech/turning-waste-heat-air-conditioning-2014/>

Air conditioning with waste heat

