

REINHOLD ENVIRONMENTAL[®]



2023 Reinhold/PCUG Round Table Presentation

Cohosted by Duke Energy and Vistra in The Westin Hotel,
Cincinnati, OH on June 26-27, 2023

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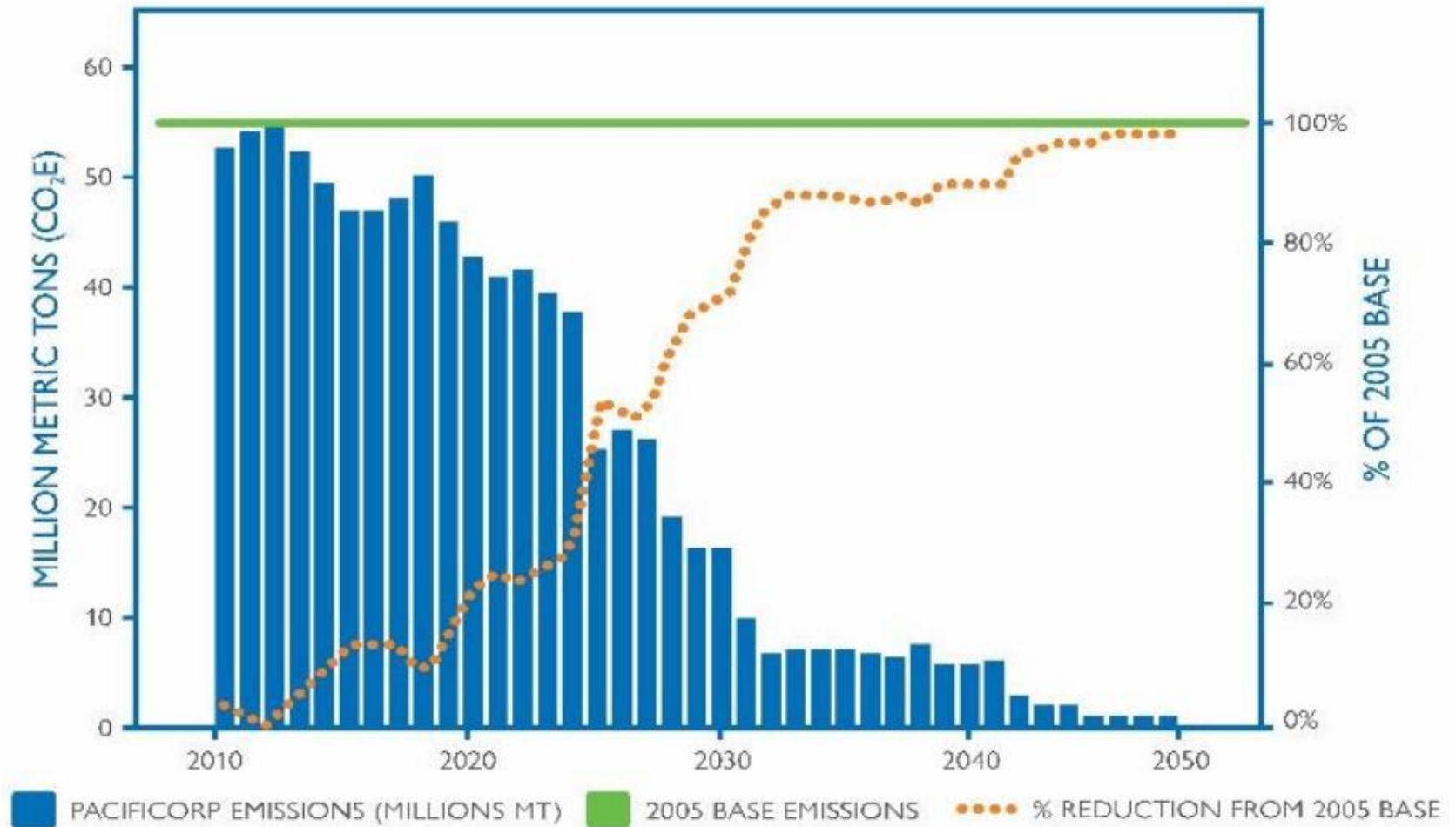
SNCR in an OTR World

Joseph Betenson, PE
Reinhold Conference
Cincinnati, OH
June 27, 2023



2023 IRP – Path to Net Zero

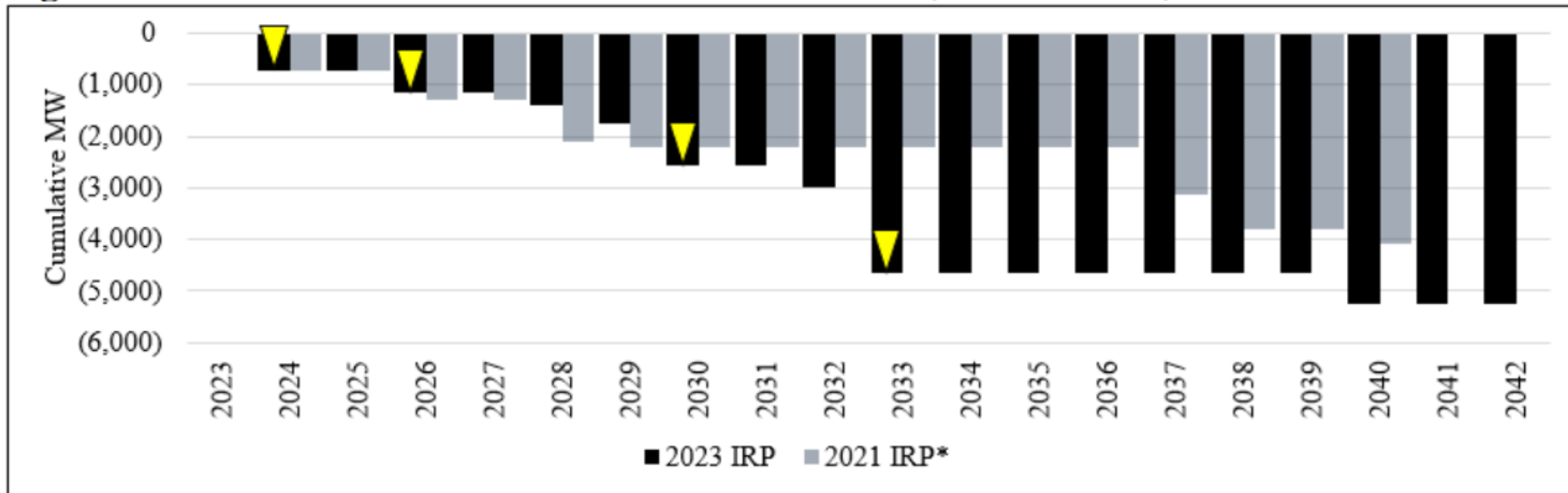
PACIFICORP CO₂E EMISSIONS TRAJECTORY



*California, Oregon and Washington are on an accelerated greenhouse gas emissions reduction trajectory as compared to the systemwide emissions reduction trajectory.

2023 IRP – Portfolio Changes

Figure 1.11 – 2023 IRP Preferred Portfolio Coal Exits, Retirements, and Gas Conversions*



* Note: Coal exits and retirements are assumed to occur by the end of the year before the year shown in the graph. The graph shows the year in which the capacity will not be available for meeting summer peak load. All figures represent PacifiCorp’s ownership share of jointly owned facilities.

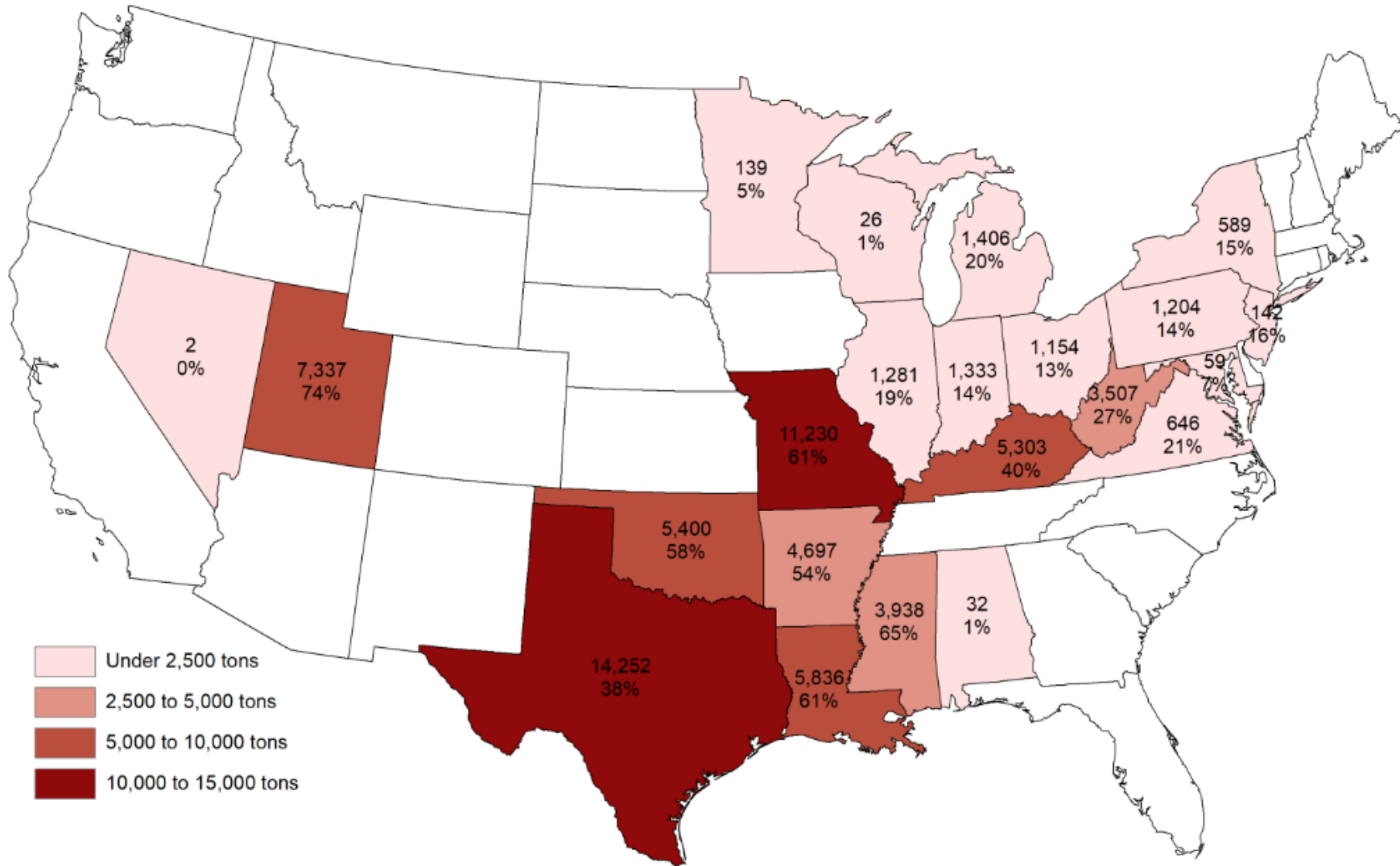
2023 IRP – Natural Gas Conversions

- 2024 – Jim Bridger Units 1 & 2
 - Retire 2037
- 2026 – Naughton Units 1 & 2
 - Retire 2036
 - Sodium Nuclear Facility 2030
- 2030 – Jim Bridger Units 3 & 4
 - SCRs installed 2015
 - Retire 2037

2023 IRP – Coal Retirements

- 2027 – Dave Johnston Unit 3 (220 MW)
- 2028 – Dave Johnston Units 1 & 2 (99 MW, 106 MW)
- 2031 – Hunter Unit 1 (445 MW)
 - SNCR by 2026
- 2032 – Hunter Units 2 & 3 (448 MW, 471 MW)
 - SNCR by 2026
 - Natrium Nuclear Facility 2032 (335 MW Base / 500 MW Peak)
- 2032 – Huntington Units 1 & 2 (459 MW, 450 MW)
 - SNCR by 2026
 - Natrium Nuclear Facility 2032 (335 MW Base / 500 MW Peak)
- 2039 – Wyodak Unit 1 (335 MW)
 - SNCR by 2026

Good Neighbor Plan



OTR – Utah NO_x Emission Budget

| CSAPR NO _x Ozone Season Group 3 Preset State Emissions Budgets for the 2023 through 2029 Control Periods (tons) | | | | | | | |
|--|----------------------------------|----------------------------------|----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|
| State ▲ | Final Emissions Budgets for 2023 | Final Emissions Budgets for 2024 | Final Emissions Budgets for 2025 | Preset Emissions Budgets for 2026 | Preset Emissions Budgets for 2027 | Preset Emissions Budgets for 2028 | Preset Emissions Budgets for 2029 |
| Utah | 15,755 | 15,917 | 15,917 | 6,258 | 2,593 | 2,593 | 2,593 |

- 15,917 tons in 2025
- 6,258 tons in 2026
- 2,593 tons in 2027

Excerpt from Final Rule in Federal Register

~~they ignored key aspects of the proposed rule.~~ First, the final rule does not directly require implementation of SCR; rather, it requires reductions commensurate with SCR installations based on a rigorous assessment of SCR retrofit potential. ~~Implementing the reductions through a trading program~~

PacifiCorp Compliance Strategy

- More Renewables
- Reduce Thermal Load
- Install SNCR
- Introduce Nuclear in 2030's

SNCR vs SCR

| | <u>SNCR</u> | <u>SCR</u> |
|-----------------------------|--------------------|------------------|
| • NO _x Reduction | 20 - 30% | 80 - 90% |
| • Catalytic | No | Yes |
| • Temperature | 1600 F - 2000 F | 480 F - 800 F |
| • Reagent Usage | More | Less |
| • Capital | Low | High |
| • O&M | Higher | Lower |

SNCR Technology Development

- Exxon 1975 Patent 3,900,554
 - NH₃
 - California legislative mandates led to demonstration at Haynes.
 - Highlighted flaw: only works in small temperature windows.
 - Dynamic load changes location of temperature windows.

- EPRI 1980 Patent 4,208,386
 - Urea
 - San Diego Gas & Electric's Encina Plant (110 MW)
 - Delays release of Urea
 - 30% NO_x Reduction at NSR of 2 and ammonia slip under 20 ppm

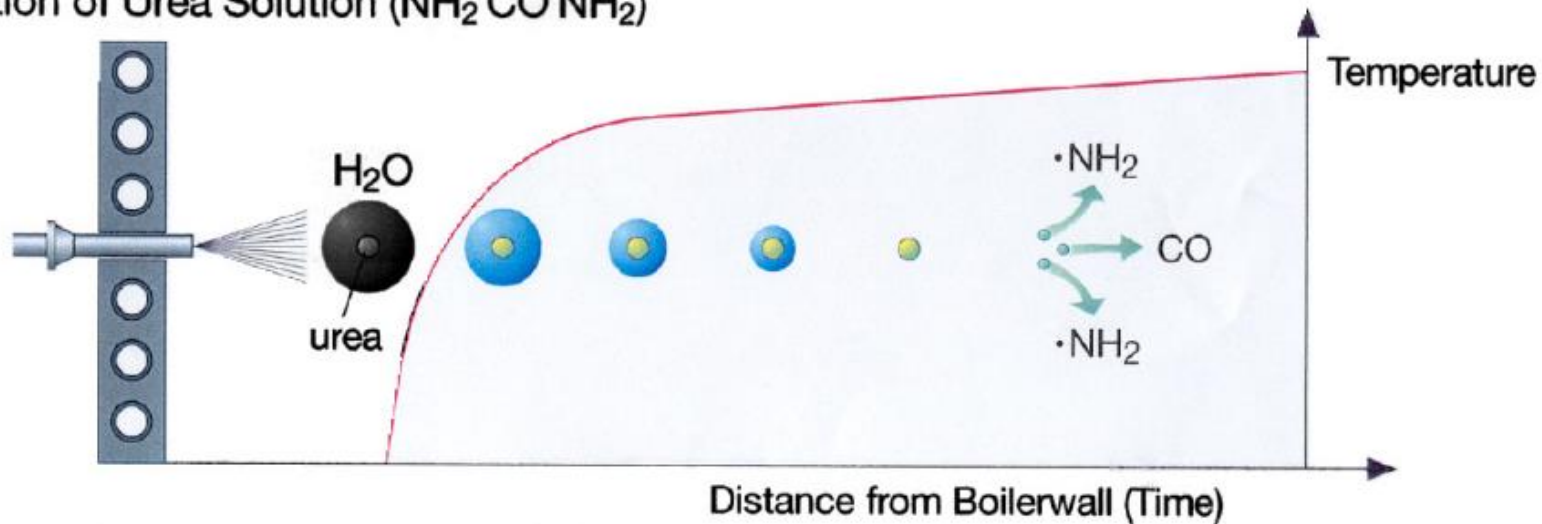
Urea vs Ammonia

- Urea
 - Lower volatility (vapor pressure) allows reagent to stay in the droplet allowing it to treat locations deeper in the boiler.

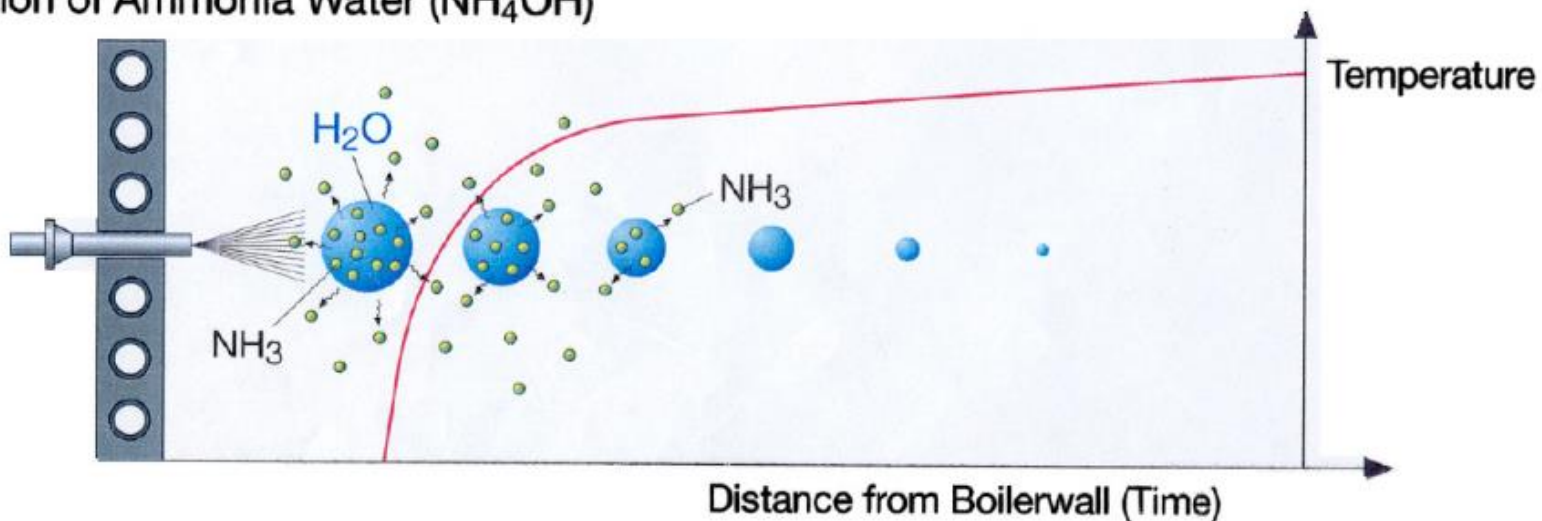
- Ammonia
 - Higher volatility (vapor pressure) can cause reagent to leave droplet before reaching temperature window.

Urea vs Ammonia

Injection of Urea Solution ($\text{NH}_2\text{CO NH}_2$)



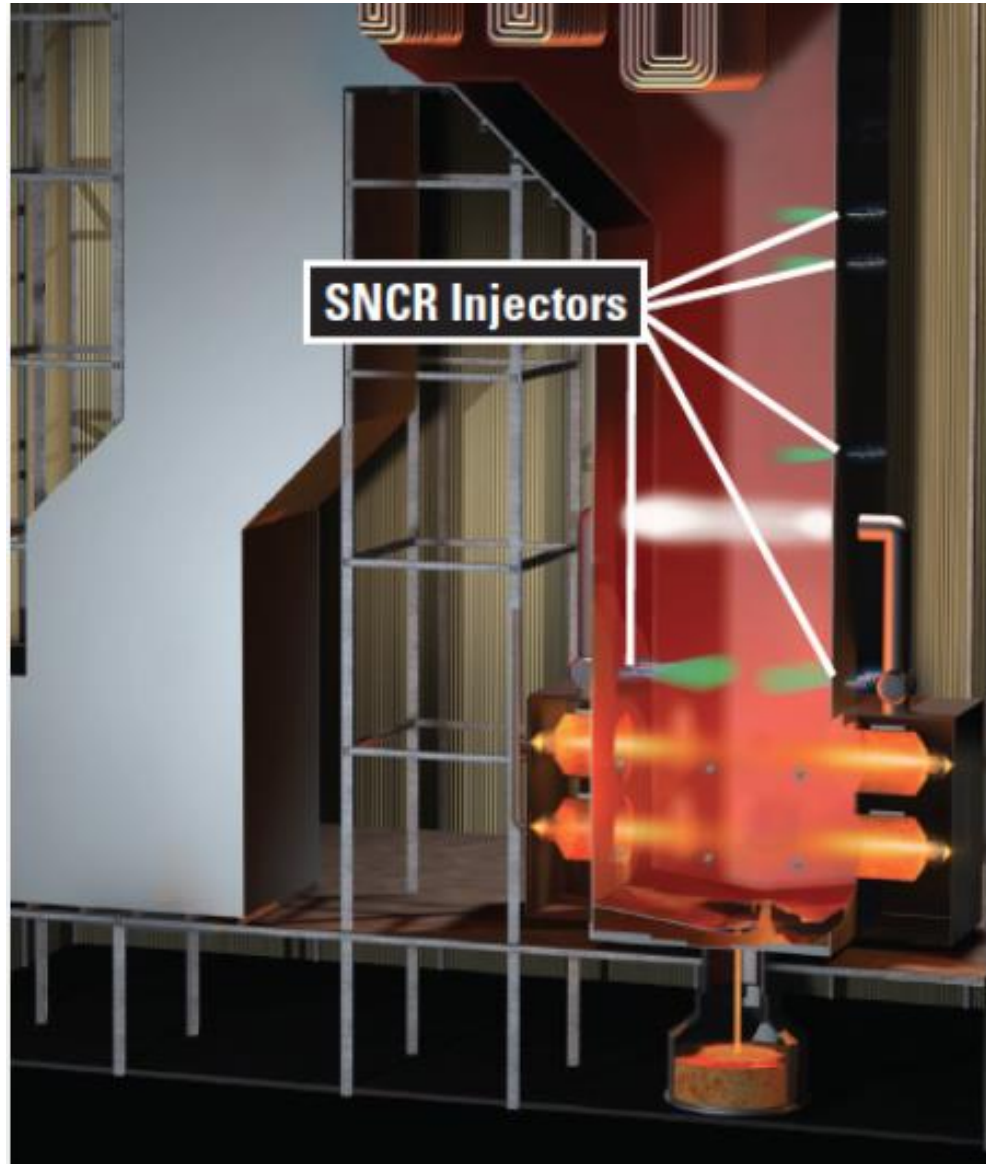
Injection of Ammonia Water (NH_4OH)



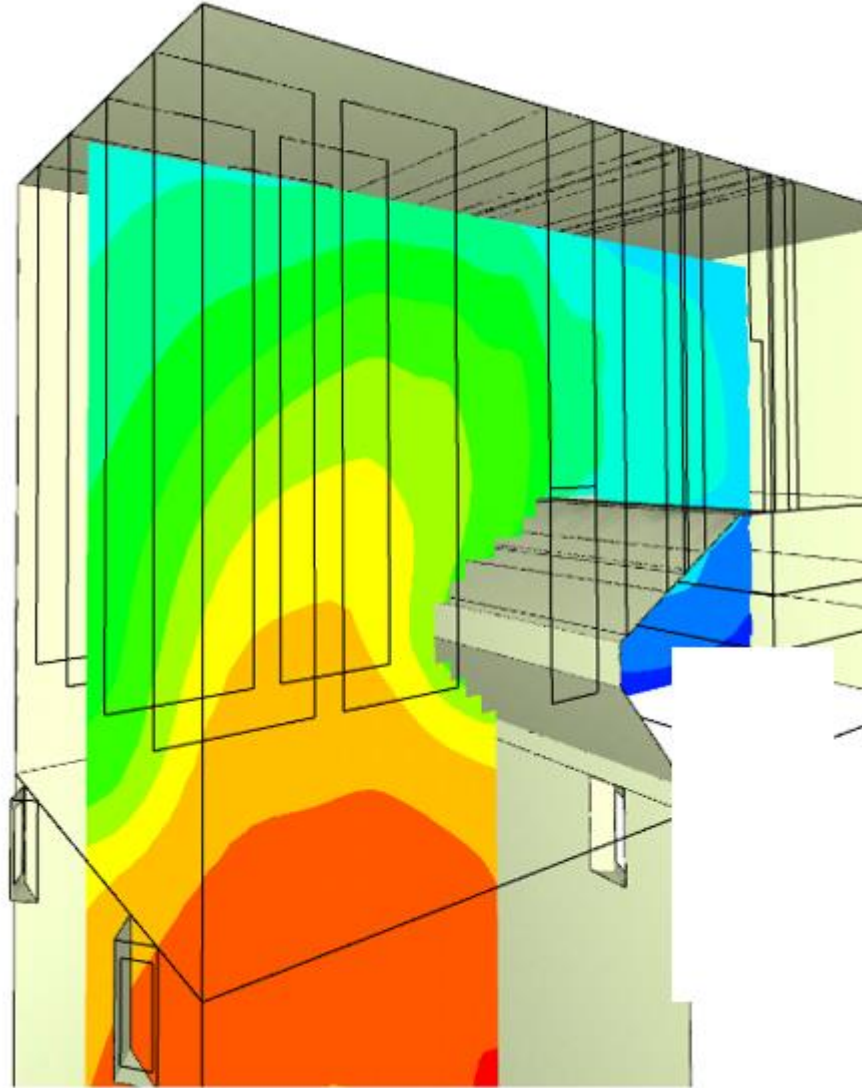
SNCR Timeline

- No commercial SNCR utility installations in 1980's
- Limited installations in 1990's
- Low NO_x burners become available
 - More cost effective than SNCR
- 1990 Clean Air Act – NO_x reductions
- Ozone Transportation Corridor (OTC) established
- Multiple large scale demonstrations in 2000's

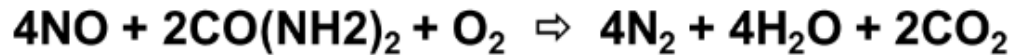
Reagent Delivery



Boiler Temperature Profiling



SNCR Chemical Reactions



Urea Decomposition

- $\text{CO}(\text{NH}_2)_2 \rightleftharpoons \text{NH}_3 + \text{HNCO}$
- $\text{CO}(\text{NH}_2)_2 + \text{H}_2\text{O} \rightleftharpoons 2\text{NH}_3 + \text{CO}_2$

Activation

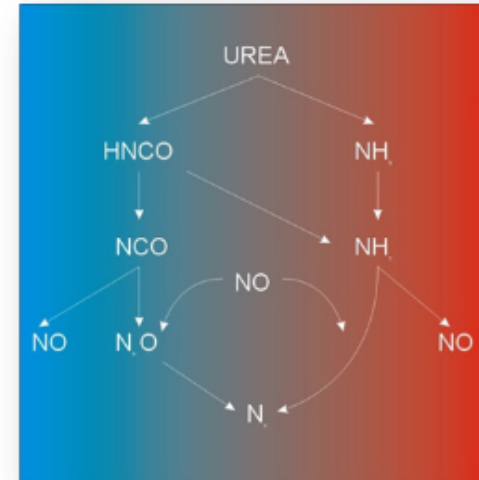
- $\text{NH}_3 + \text{OH} \rightleftharpoons \text{NH}_2 + \text{H}_2\text{O}$
- $\text{HNCO} + \text{OH} \rightleftharpoons \text{NCO} + \text{H}_2\text{O}$

NOx Destruction

- $\text{NH}_2 + \text{NO} \rightleftharpoons \text{NNH} + \text{OH}$
- $\text{NH}_2 + \text{NO} \rightleftharpoons \text{N}_2 + \text{H}_2\text{O}$
- $\text{NCO} + \text{NO} \rightleftharpoons \text{N}_2\text{O} + \text{CO}$
- $\text{N}_2\text{O} + \text{M}^1 \rightleftharpoons \text{N}_2 + \text{O} + \text{M}$
- $\text{NNH} \rightleftharpoons \text{N}_2 + \text{H}$

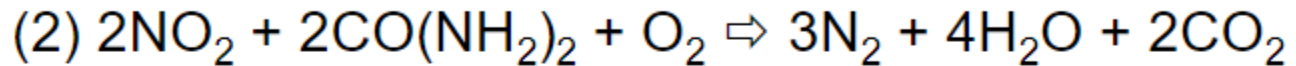
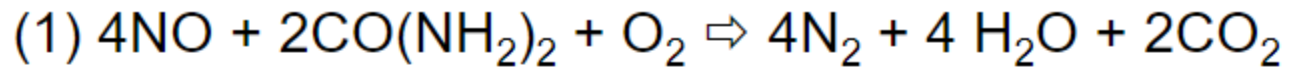
NOx Formation

- $\text{NH}_2 + \text{OH} \rightleftharpoons \text{NH} + \text{H}_2\text{O}$
- $\text{NH} + \text{OH} \rightleftharpoons \text{HNO} + \text{H}$
- $\text{HNO} + \text{OH} \rightleftharpoons \text{NO} + \text{H}_2\text{O}$
- $\text{NCO} + \text{OH} \rightleftharpoons \text{NO} + \text{CO} + \text{H}$



Note 1: "M" is referred to as the third body. It is not a product of the reaction but it changes the reaction rate. For example, $\text{A} + \text{B} + \text{M} \rightarrow \text{D} + \text{M}$. The reaction rate is $C_a \cdot C_b \cdot (P/RT)^{-1} \cdot k_{exp} \cdot \exp(-E/RT)$, where (P/RT) is the concentration of M expressed from the ideal gas law.

Normalized Stoichiometric Ratio



Urea + Nitrogen Oxide + Oxygen \rightleftharpoons Nitrogen + Carbon Dioxide + Water

Equation 1 Typically Accounts for 95% of NOx

$$\text{NSR} = \frac{\text{Actual Molar Ratio of Urea to Baseline NOx}}{\text{Theoretical Ratio to Reduce One Mole of NOx}}$$

SNCR Process Parameters

Temperature

Ammonia 1,600 – 1,900 F; Peak: 1,750 F

Urea 1,700 – 2,000 F; Peak: 1,850 F

- Optimum temperature zone location changes with load
 - Injections above upper temperature limit **increase** NO_x
- Multiple Reagent Injection Elevations
- Tailor release of reagent as function of flue gas time-temperature profile.

SNCR Process Parameters

Residence Time

- More Residence Time = More NO_x Removal
- Increases at lower loads
- Performance Degradation if <200 msec

Amount of Reagent

- Overfeeding leads to APH fouling
- Risks fly ash contamination

Ammonium Bisulfate Formation

- ABS is sticky and adheres to air heater surfaces
- Forms in intermediate sections of regenerative air heaters
 - Less severe in tubular air heaters
- 300 – 430 F
- Regenerative evidence: increased air heater pressure drop
- Tubular evidence: decreased heat transfer performance

Manual operation can foul an air preheater in 8 hours!

How to avoid ABS

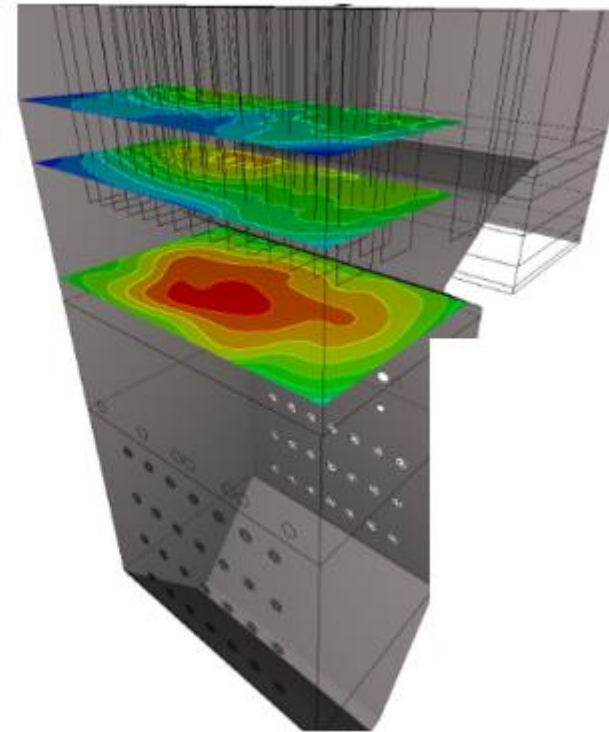
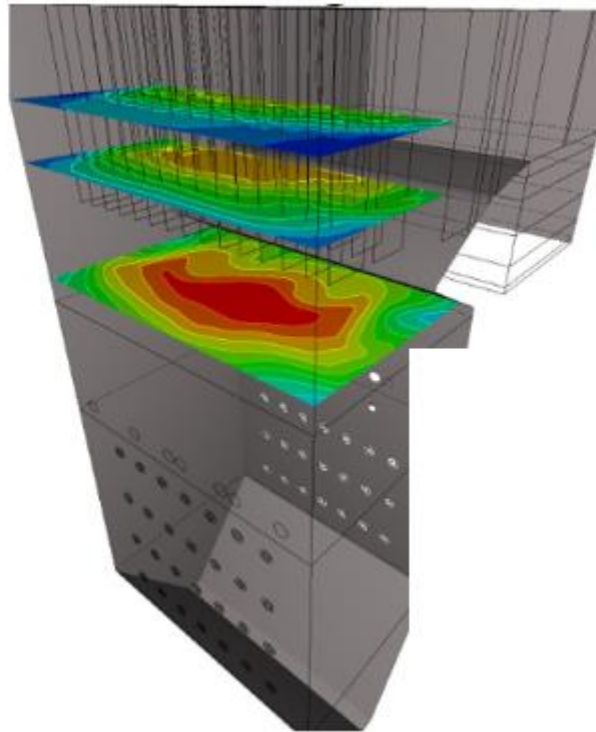
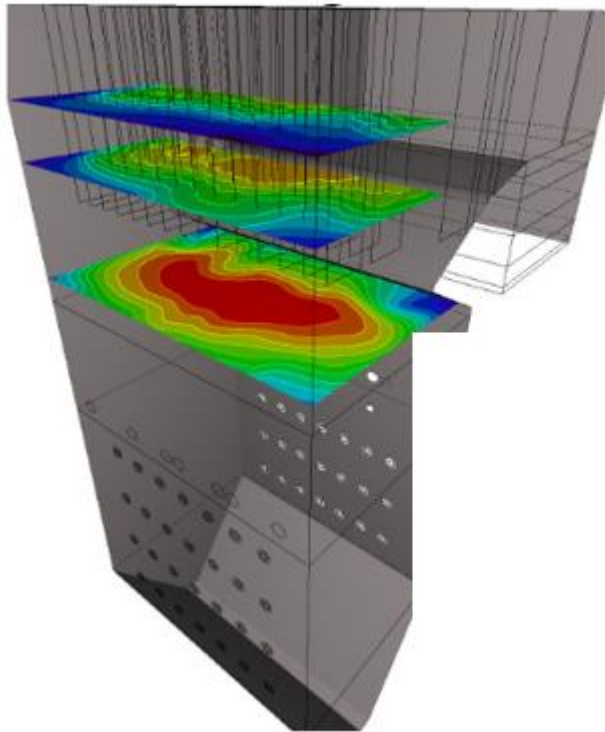
- Operate at lower ammonia slip levels
- Install higher pressure soot blowers
- Reduce SO₃ levels
- Washing air heaters offline/online more frequently
- Converting air heater from three layer to two layer system with deep cold end baskets

CFD & Chemical Kinetic Modeling

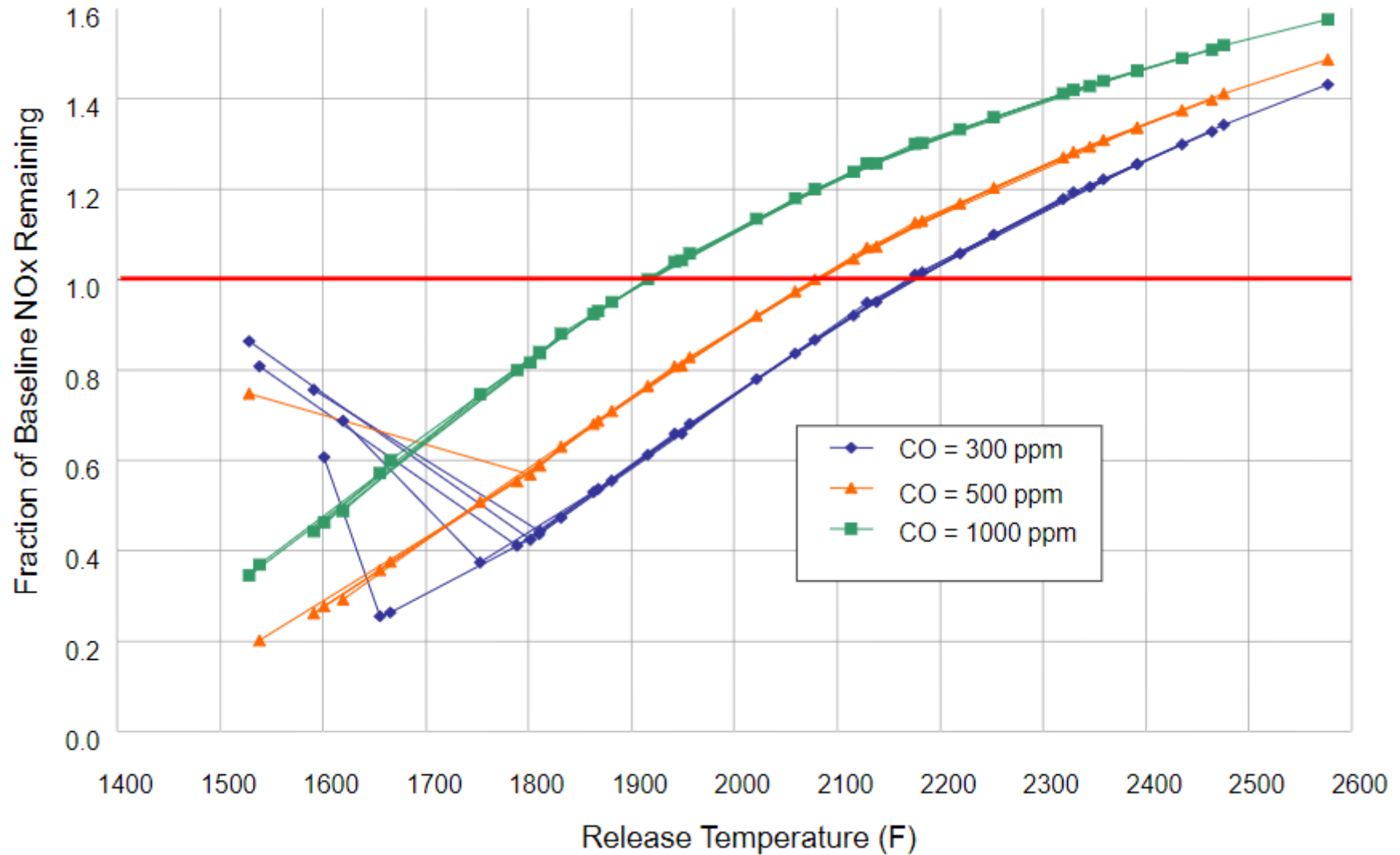
High Load

Mid Load

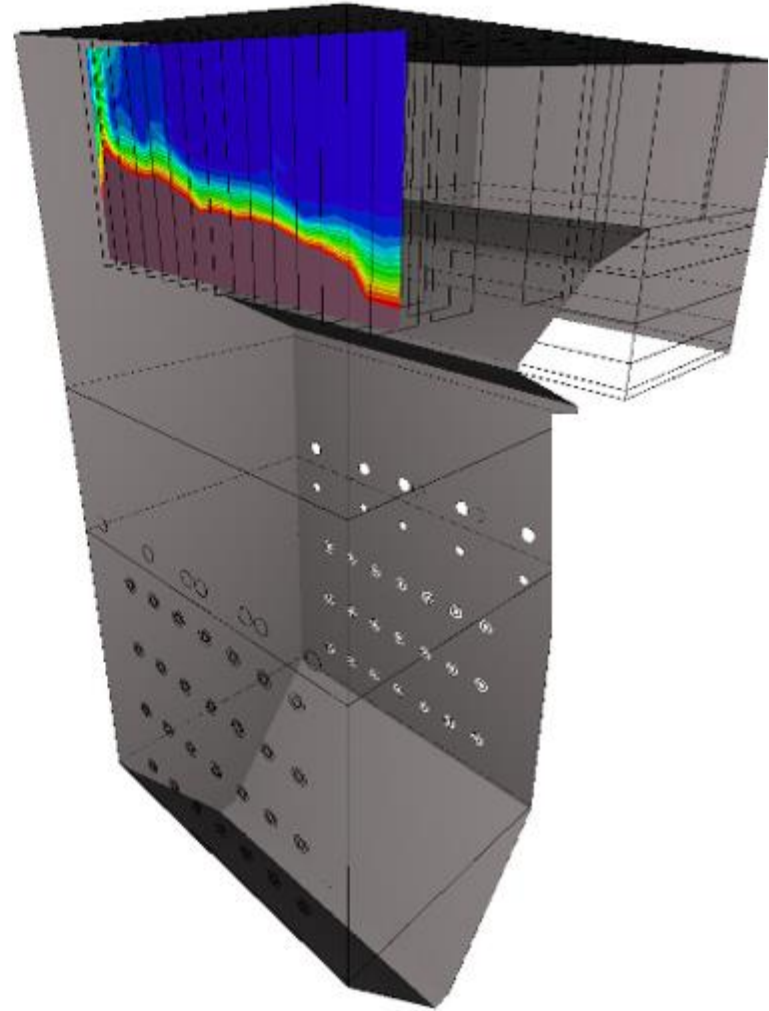
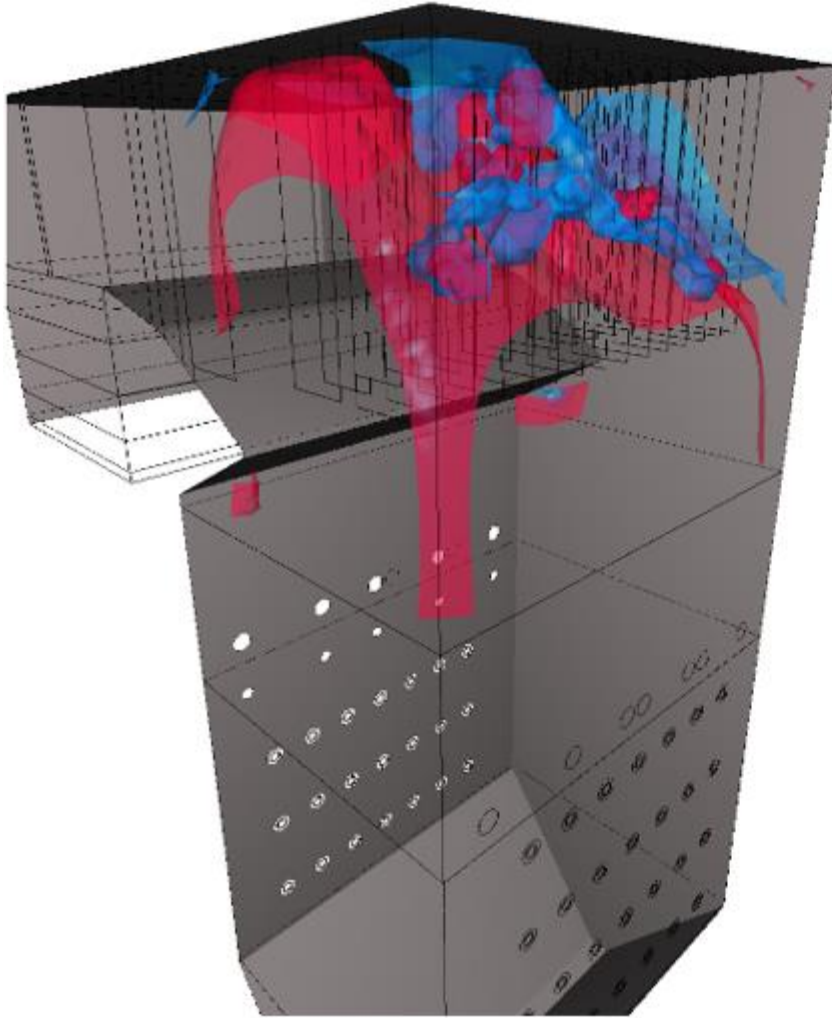
Low Load



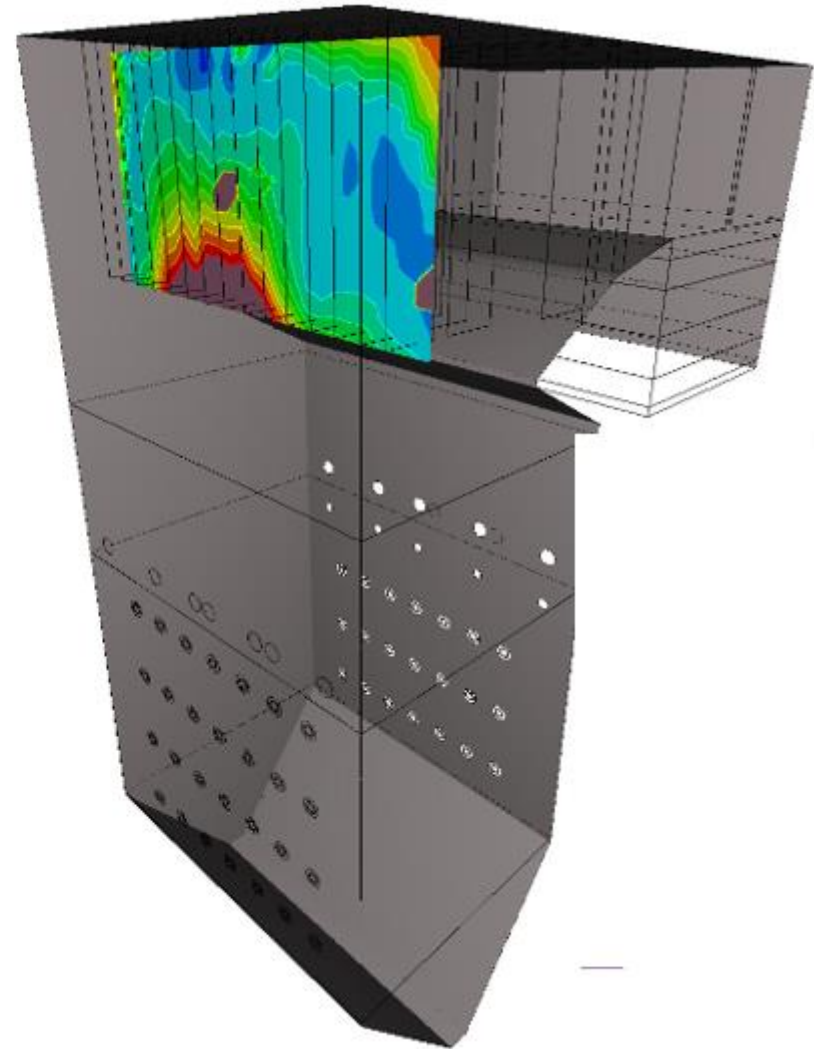
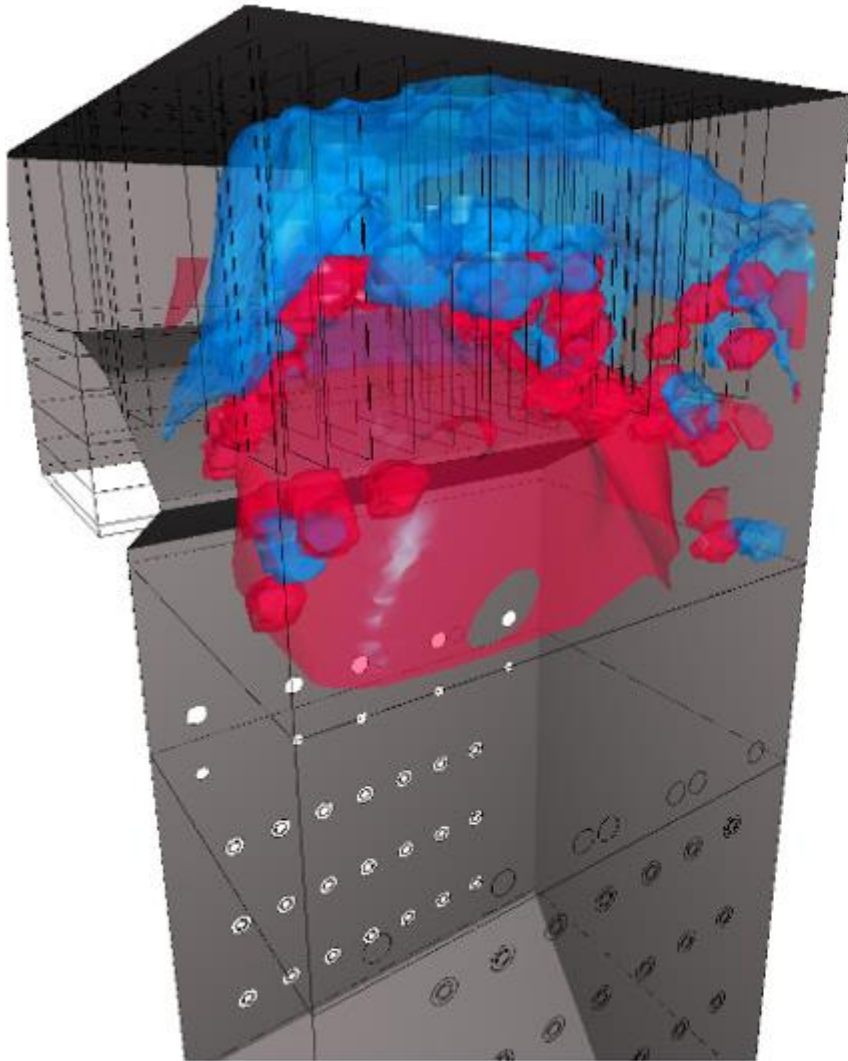
SNCR Process Parameters - CO



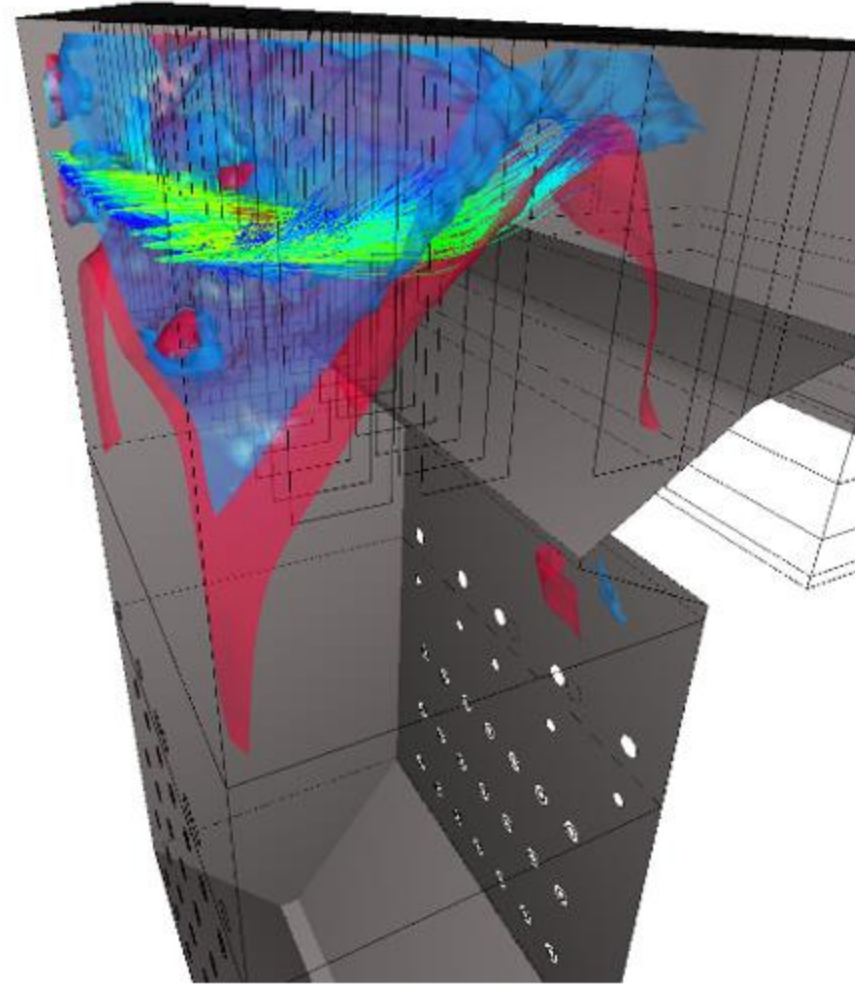
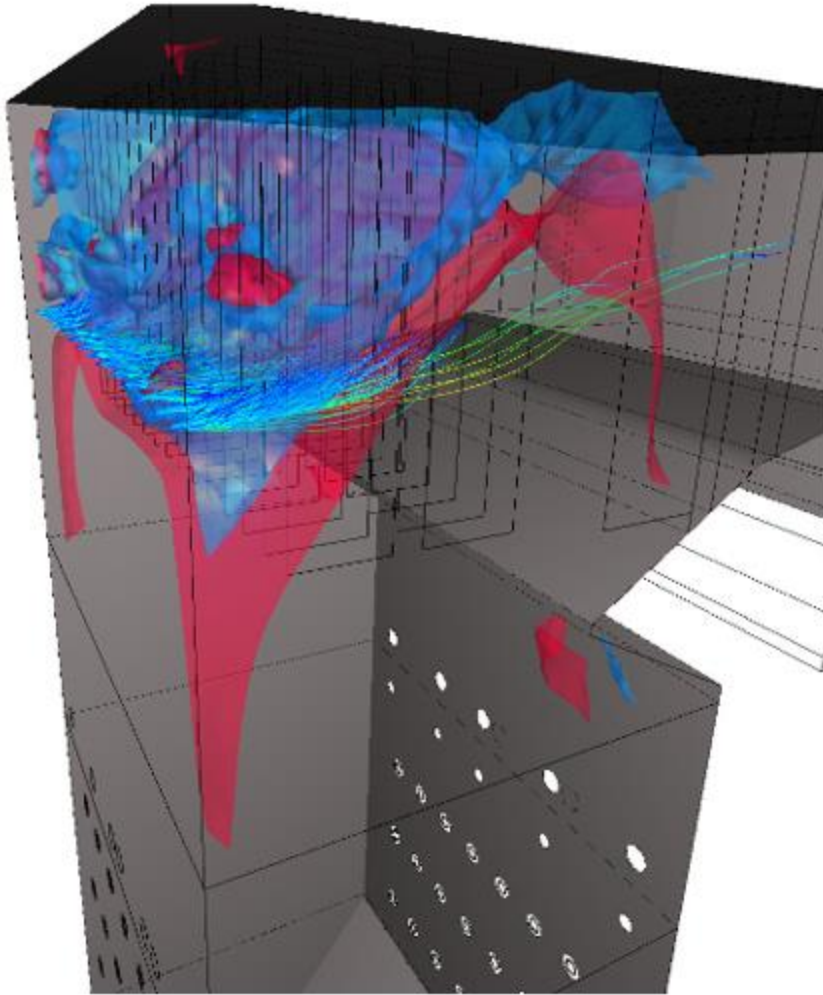
Temperature Window & NO_x Concentration



Temperature Window & NO_x Concentration



Reagent Droplet Trajectories



Reagent Mixing Skid



Questions?
