# Field Demonstration Study for Heat and Water Recovery at a Coal-Fired Power Plant

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2016 Crosscutting Research & Rare Earth Elements Portfolios Review
Pittsburgh, April 20, 2016

DE-FE0024066

# Overview

- Project Objectives
- Tasks
- Coal industry interviews
- Identification of technologies
- Selection process and scoring
- Discussion of selected technologies
- Going forward

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# Objectives

Advance the path toward a field demonstration of waste (low-grade) heat recovery/use technology (HRUT) for a coal-fired power by:

- Establishing relationships between coal power industry, technology providers, technology experts, and engineering firm
- Comparing cost and benefits of emerging technologies and of commercially available technologies
- Recommending technology(ies) for further analysis
- Developing costs for pilot test at a Southern Company facility
- Developing costs for a conceptual commercial unit

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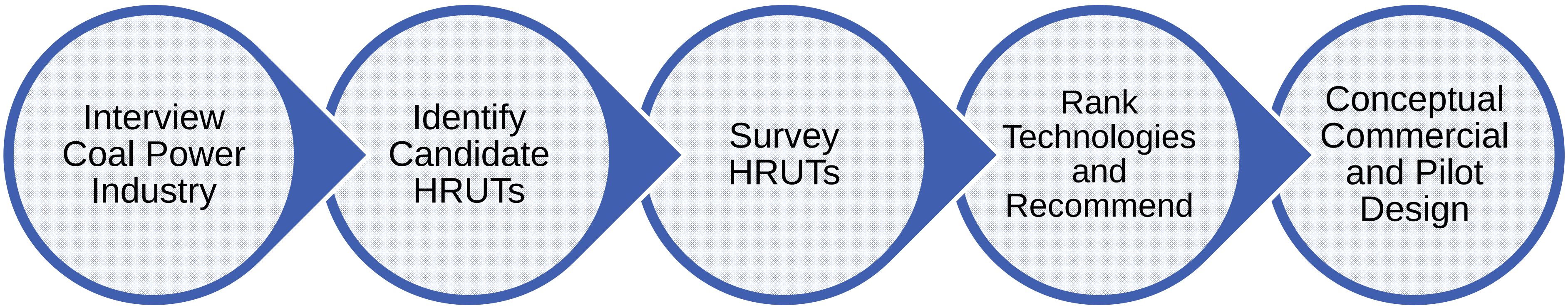
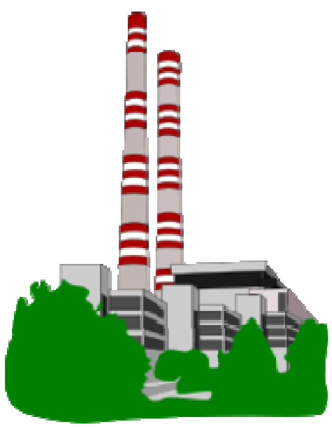
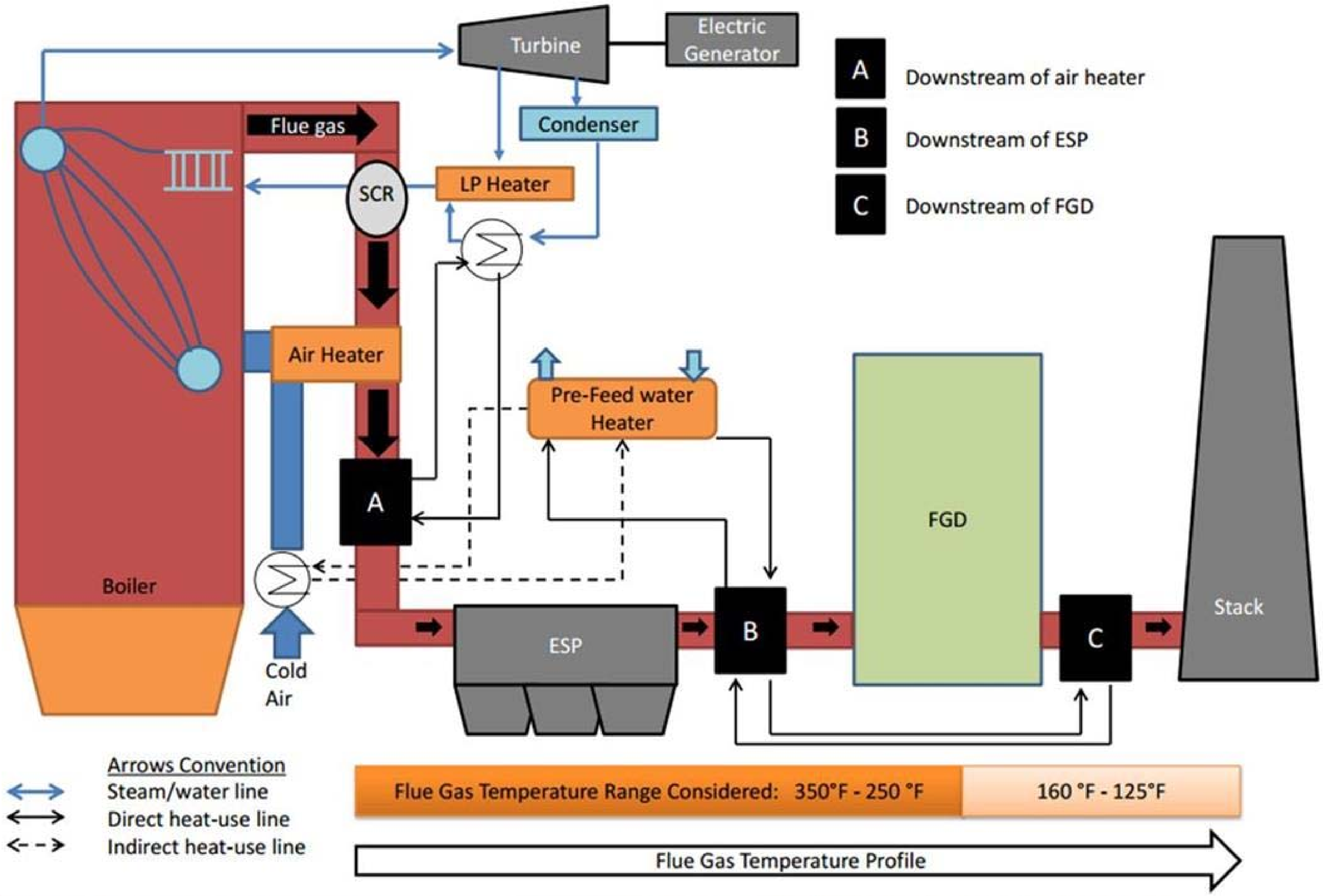
# Project Task Structure



# Heat Recovery Opportunities



# Coal Power Industry Interviews

## Interview topics

- Appetite for low-temp HRUTs
- Previous experience with HRUTs
- HRUT integration flexibility/requirements

## Interview group

- Eight U.S. coal power utilities
- Over 500 GW collectively
- Mostly base load or daily cycling operation

# Interview Results

- Little new build or retrofit planned for coal power in the U.S.
- Only one site uses HRUT (coal drying); all had implemented steam turbine upgrades
- New Source Review (NSR) is a major obstacle for any efficiency/output changes: "NSR is not insurmountable but is a legal and political risk"
- If the efficiency improvement is large or the payback is short, it will be considered
- Most sites do not have space to accommodate new processes
- Reducing the final flue gas temperature may impact plume dispersion
- No district heating opportunities identified; limited industrial possibilities
- Respondents generally not water constrained; reducing FGD or cooling water makeup could be of interest
- Regulations (e.g., 111d) could increase interest in HRUTs

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# Candidate HRUTs

Identified through:

- Conference proceedings
- Industry experts
- Internet searches & literature review
- Similar DOE awards

Resulted in 40 technologies for consideration

- Ranged from commercial to conceptual

Can be categorized into

- Bottoming cycles
- Heat exchangers (incl. condensing)
- Thermoelectric
- Water treatment technologies
- Other (e.g., fuel drying)

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# Screening Process

40 technologies

- High level questionnaire
- Interviews with technology providers
- Eliminated those not feasible, leaving 24
  - Public sharing; uses flue gas; ≤300F; pilot in 2 yrs

Remaining 24

- Detailed questionnaire
  - Organization, design, technology, environmental, costs
- 550MW reference plant for consistency
- Limited response

Final 17 candidate technologies

- Scoring matrix applied

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# Technology Vendors for Scoring

## Bottoming cycles

- Global Geothermal
- Ormat
- Turboden

## Heat exchangers

- ARVOS
- ConDex
- E-Tech
- Flucorrex
- Gas Technology Institute (GTI)
- Mitsubishi Heavy Industries (MHI)
- Wallstein

## Water treatment

- PAX Pure
- Porifera
- Sylvan Source International (SSI)
- Vacom

## Other

- Great River Energy (GRE)
  - DryFining process; coal drying
- Novus
- SSI
  - Heat feedwater

# Scoring Criteria and Weight

Emphasis:

- Costs
- Technology
- Operation
- Design

| Criteria | Weight % | Total % |
|---|---|---|
| **I. Organization Experience** | **10.0%** | **---** |
| A. Tech Experience | *50.0%* | 5.0% |
| B. Organizational Experience | *20.0%* | 2.0% |
| C. Size | *30.0%* | 3.0% |
| **II. Design and Operation** | **25.0%** | **---** |
| A. Design | 30.0% | --- |
| *1. Soundness of Design* | *50.0%* | 3.8% |
| *2. Integration Complexity* | *50.0%* | 3.8% |
| B. Operation | 70.0% | --- |
| *1. Response to Load Changes* | *35.0%* | 6.1% |
| *2. Impact on Startup Times* | *35.0%* | 6.1% |
| *3. Acceptable Flue Gas Composition* | *15.0%* | 2.6% |
| *4. Pressure Drop* | *15.0%* | 2.6% |
| **III. Technology** | **30.0%** | **---** |
| A. Benefits | 70.0% | --- |
| *1. Efficiency* | *40.0%* | 8.4% |
| *2. Water Treatment* | *15.0%* | 3.2% |
| *3. Water Use/Generation* | *15.0%* | 3.2% |
| *4. Environmental* | *30.0%* | 6.3% |
| B. Operations, Maintenance, Availability, and Safety | 30.0% | --- |
| *1. Operations* | *25.0%* | 2.3% |
| *2. Maintenance* | *25.0%* | 2.3% |
| *3. Availability* | *25.0%* | 2.3% |
| *4. Safety* | *25.0%* | 2.3% |
| **IV. Potential for Future Improvements** | **2.5%** | **---** |
| A. Future Technology Improvements | 50.0% | 1.3% |
| B. Future Integration Improvements | 50.0% | 1.3% |
| **V. Costs** | **32.5%** | **---** |
| A. Commercial-Scale Plant Capital Cost | 40.0% | 13.0% |
| B. Cost-Benefit Analysis | 40.0% | 13.0% |
| C. Pilot Plant Capital Cost | 20.0% | 6.5% |
| **Total Score (Out of 100)** | **100.0%** | **100%** |

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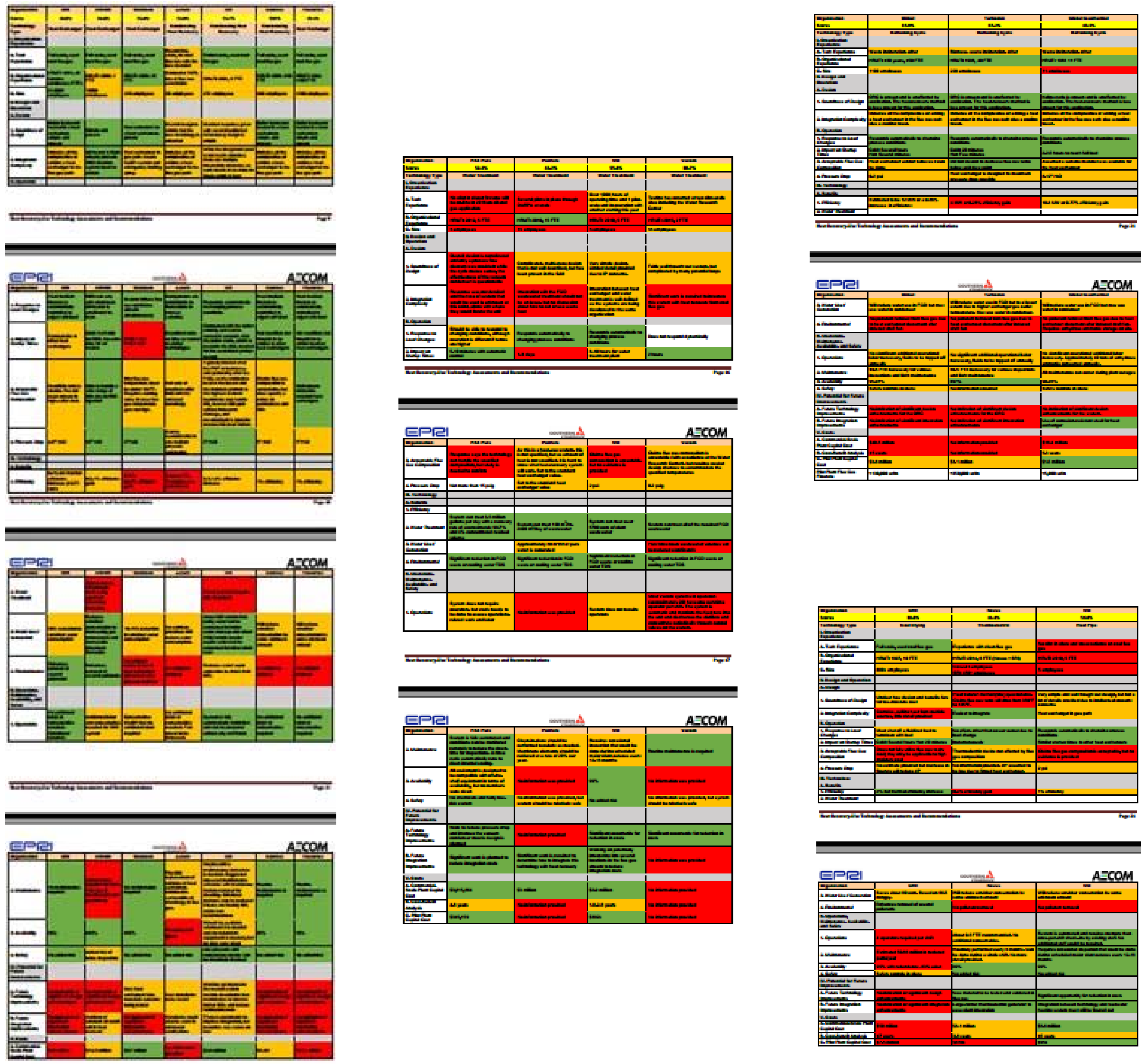
# Detailed Evaluation



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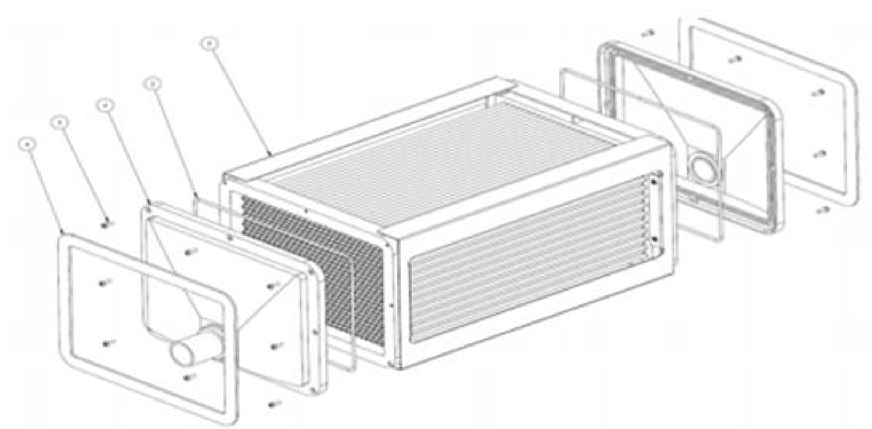
# Rankings

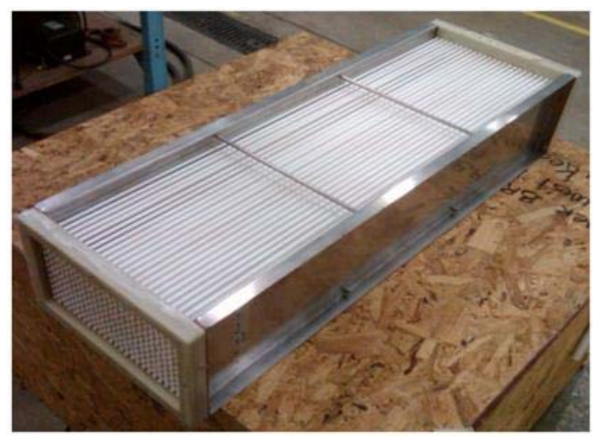
| Organization | Type | TRL |
| --- | --- | --- |
| GTI | Heat Exchanger (Condensing Heat Recovery) | 6 |
| ARVOS | Heat Exchanger | 9 |
| ConDex | Heat Exchanger (Condensing Heat Recovery) | 9 |
| Sylvan Source International (SSI) | Heat Pipe | 4 |
| SSI | Water Treatment | 5 |
| Wallstein | Heat Exchanger | 9 |
| PAX Pure | Water Treatment | 5 |
| Flucorrex | Heat Exchanger | 9 |
| Mitsubishi Heavy Industries (MHI) | Heat Exchanger | 9 |
| Global Geothermal | Bottoming Cycle | 8 |
| Porifera | Water Treatment | 4 |
| Novus | Thermoelectric | 5 |
| Great River Energy (GRE) | Coal Drying | 8 |
| Turboden | Bottoming Cycle | 8 |
| Ormat | Bottoming Cycle | 8 |
| e-Tech | Heat Exchanger (Condensing Heat Recovery) | 7 |
| Vacom | Water Treatment | 8 |

# Selected Technology: GTI

Transport Membrane Condenser

- Uses a nano-porous ceramic membrane to capture waste heat and water vapor downstream of the wet FGD
- Previously demonstrated at a coal plant at ~500 scfm (0.2 MWe) scale
- Recovered heat and water can be used as boiler feedwater
- Some increase in net plant efficiency depending on coal moisture content and ambient temperatures





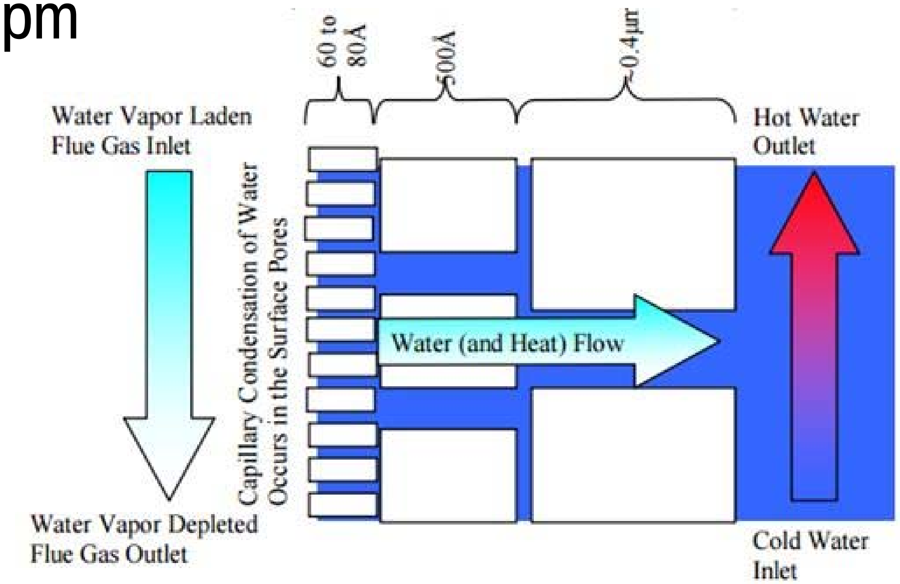
# Selected Technology: GTI

Water is captured via capillary condensation

- Capillary condensation can occur at 50-80% of the saturation vapor pressure
- Significant portion of the thermal energy as latent heat
- Captured water is pure enough to use as boiler feed water

Modules also act as heat exchangers capturing sensible heat

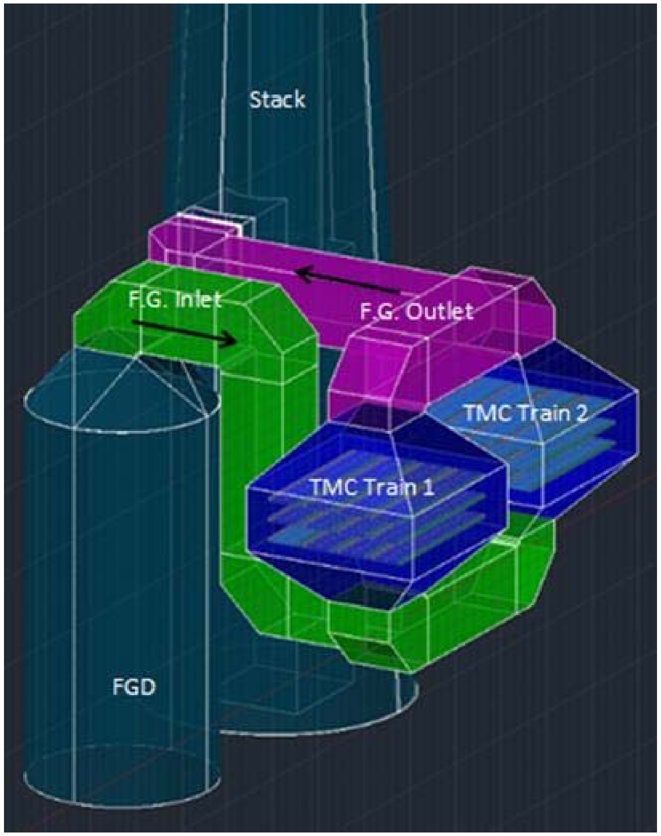
Sulfur resistance of tubes up to 300 ppm

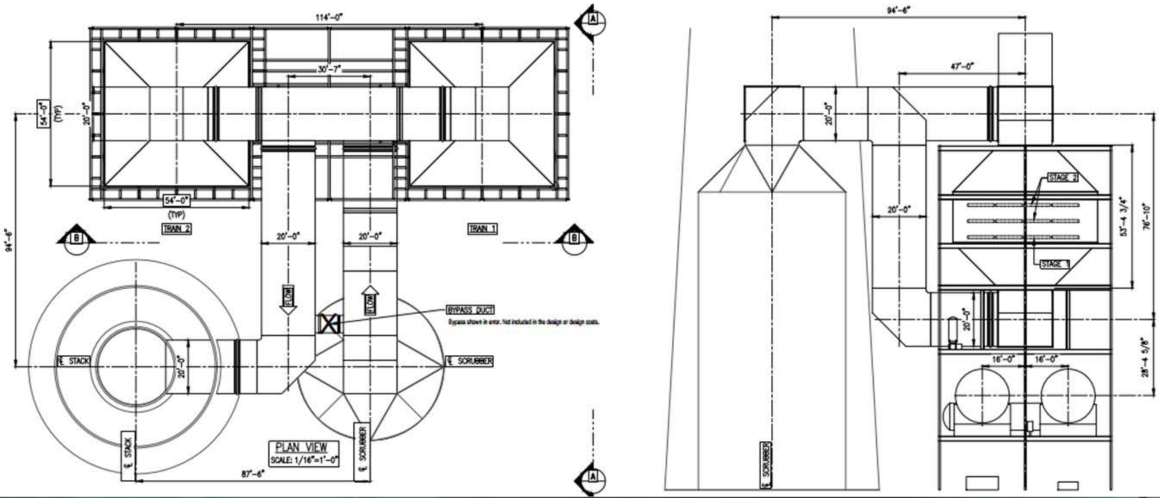


# Commercial & Pilot Conceptual Designs: GTI

Commercial (550MW):

- Early stages of development
- Cost (high) reflects uncertainty
- Integration into FGD vessel – lower $$
- Thermal heat recovery ~ 16 $MW_{th}$
- Minimal plant output increase ~ 1 MW
- Water recovery of ~100 gpm

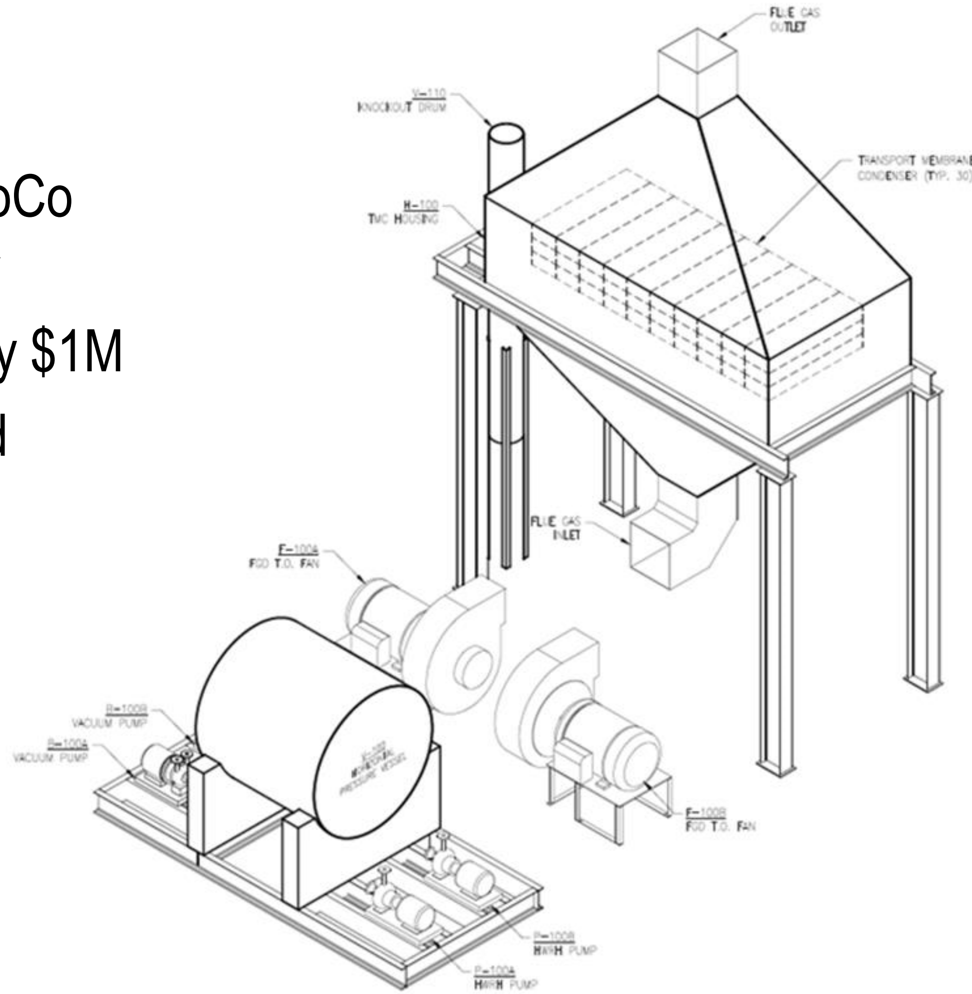


# Commercial & Pilot Conceptual Designs: GTI

## Pilot

- 2 MW slipstream basis
- Potentially located at SoCo Water Research Center
- Skid cost: approximately $1M
- Tie-ins, foundations and operation not included

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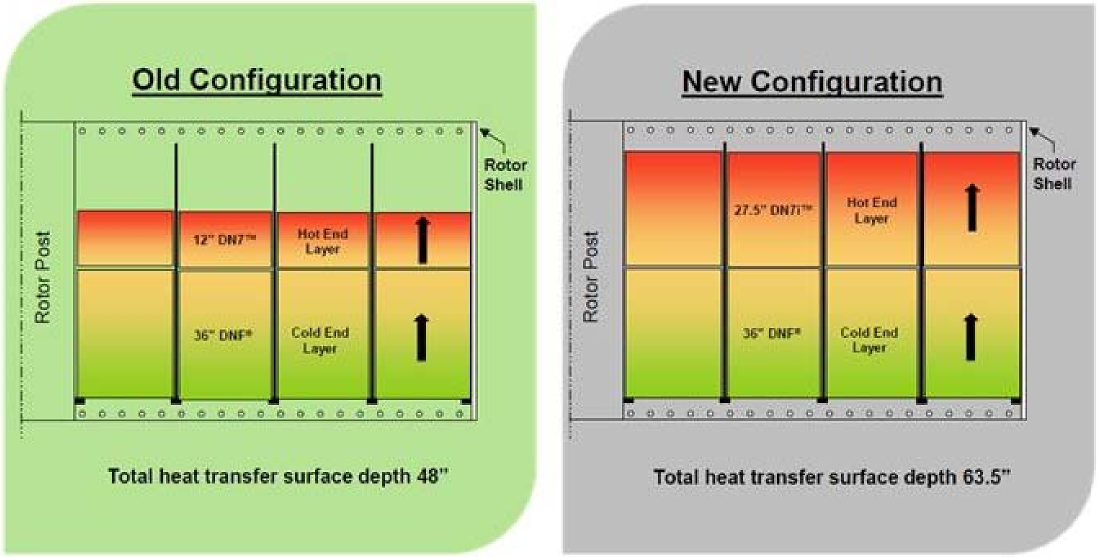
# Selected Technology: ARVOS

## ARVOS: Air Heater Improvements

- Extends and modifies heat transfer surface further decreasing flue gas outlet T
- Sulfuric acid condensation mitigated via SBS$^{TM}$ (sodium-based solution) injection upstream of the air heater
- Increased combustion air temperature improves boiler efficiency by 1-3%
- Decreased flue gas outlet temperature reduces water consumption in wet FGD
- Can be implemented easily as air heater is already present



# Commercial & Pilot Conceptual Designs: ARVOS

Commercial only; no need for pilot

- 550 MW reference - retrofit
- Full air pre heater rotor replacement
- New SBS system
- Total: ~$19M
- At least one system in service

# What's Next

- Final report in preparation
  - Details of evaluation
  - Pilot recommendation & cost
- Funding for pilot?
- Some general takeaways
  - Low grade heat is difficult to recover/use
  - Steam cycle integration is not optimal
  - Space requirements are a barrier
  - Little funding for coal plant upgrades
  - NSR threat

# QUESTIONS?