Integrated Gasification Combined Cycle (IGCC) Air Permitting: Overcoming Obstacles, Maximizing Flexibility

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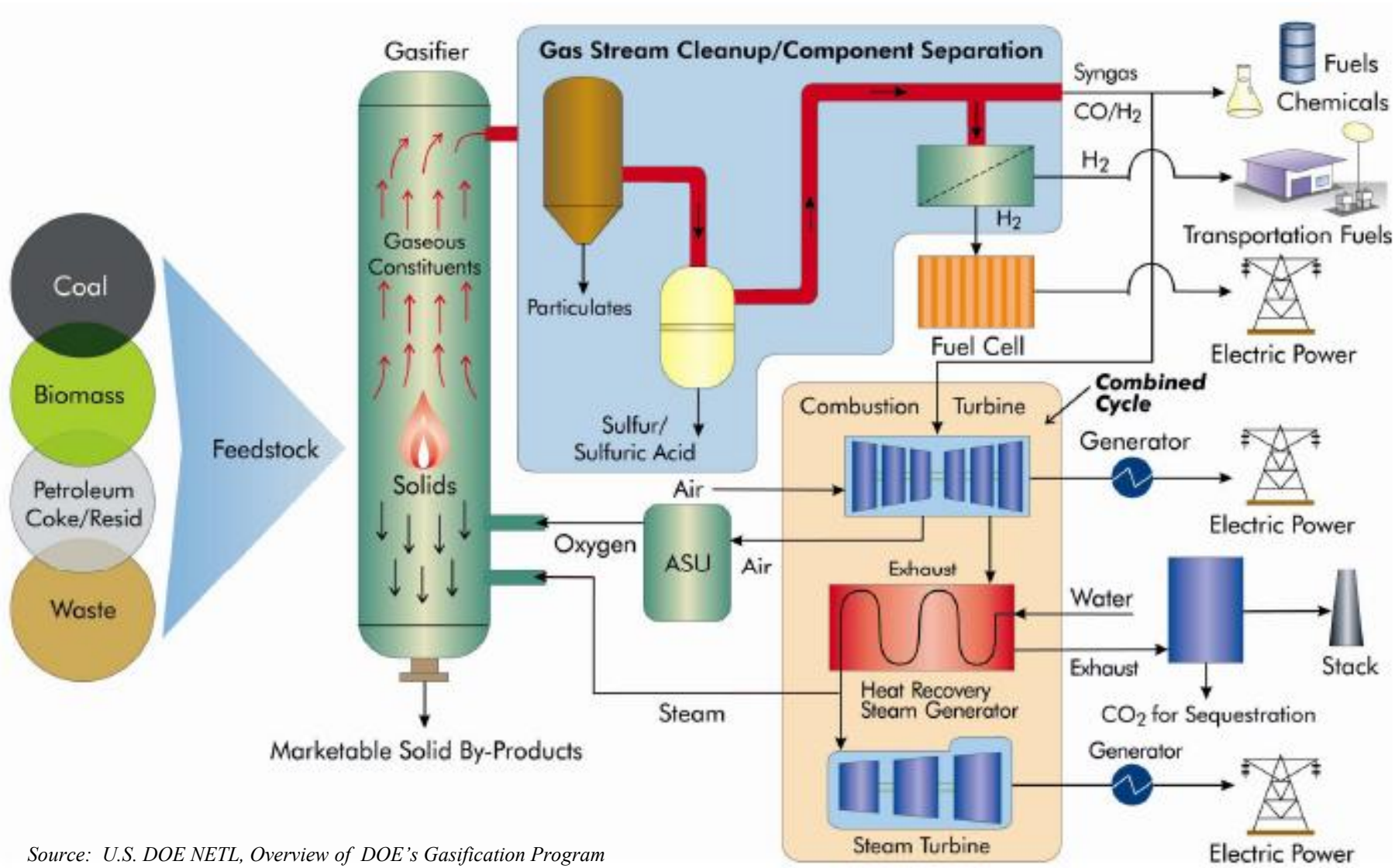
Source: U.S. DOE NETL

Agenda

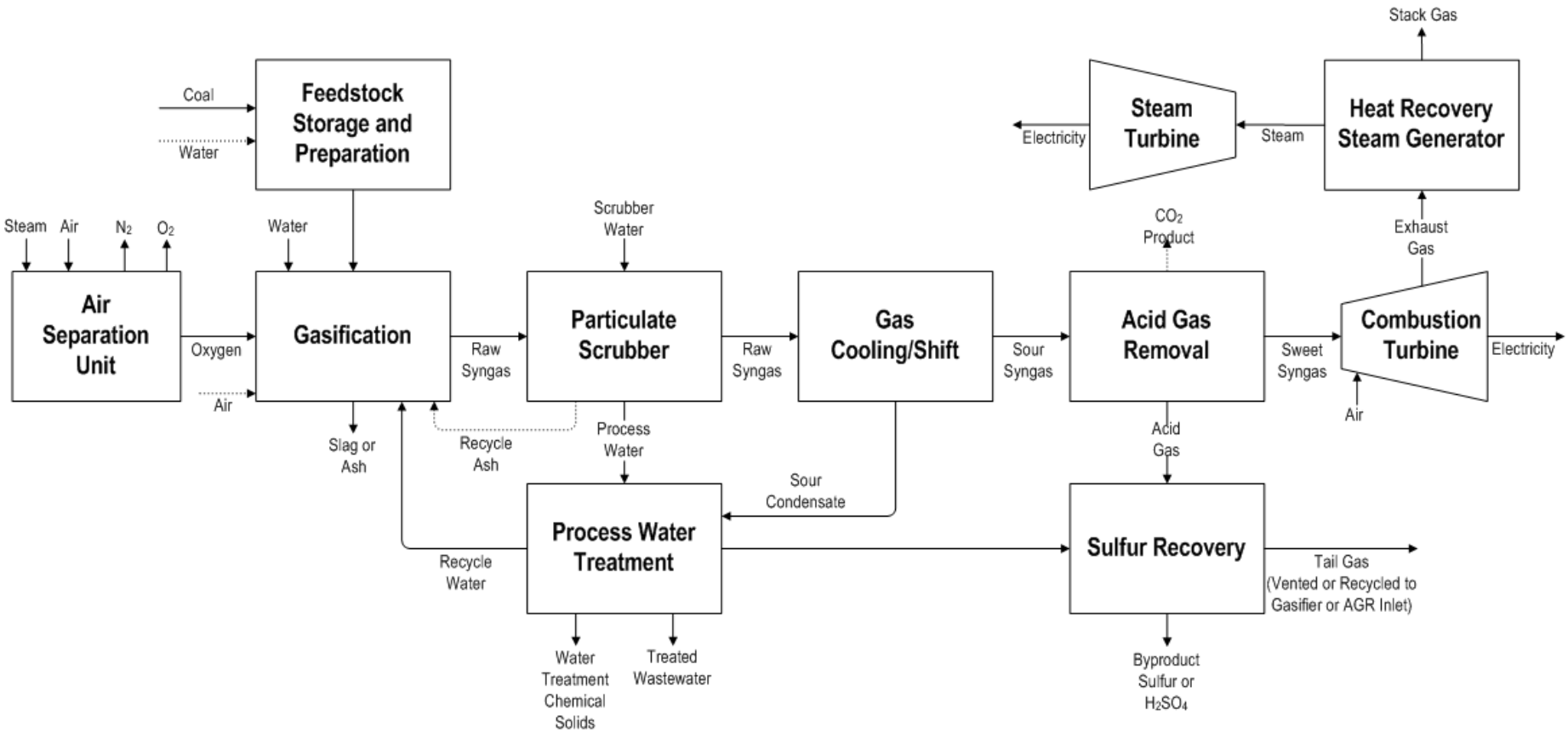
1. IGCC Process Overview
   - Gasification system options and process flow diagram
   - Process area and plant-wide air emissions summary
2. Gasification Block Sources
   - Emission points and operating scenarios (OS)
   - Short-term and annual emissions summary
3. Permitting and Compliance Strategies
   - Permitting considerations for startup, shutdown, gasifier rotations, and malfunctions (SSM) emissions
   - BACT, air dispersion modeling, and other permitting considerations

Gasification System Options



Source: U.S. DOE NETL, Overview of DOE's Gasification Program

IGCC Process Flow Diagram



IGCC Facility-Wide Process Flow Diagram

Flow Legend
Process Stream
Optional Process Stream

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Air Emissions – Process Areas

Area 1: Air Separation Unit(s)

- Not typically a significant source of criteria pollutant emissions, but a significant power load (thus impacting emissions per KW produced)

Area 2: Material Storage and Preparation

- Fugitive (e.g., storage piles and roads) and stack (i.e., dust collector) $PM/PM_{10}/PM_{2.5}$ emissions from gasifier feedstock and by-product (waste coal, solid sulfur, slag, etc.) storage and handling activities
- Emission points similar to coal, ash, and limestone handling at PC plants except that scope of handling system may be more complex and may involve more materials
- Potential emissions vary widely from project to project depending on raw materials, method for receiving feedstock, and ability to store or dispose of by-products onsite

Air Emissions – Process Areas

Area 3: Gasification and Syngas Scrubber

- Emissions sources typically include gasifier startup vents (CO and NO_X), gasifier feed system vents (CO, VOC, and HAPs), and equipment leak components (CO , VOC, and HAPs)
- Off-specification raw syngas may be vented to the flare during startup, shutdown, gasifier rotations, and malfunction (SSM) events

Area 4: Gas Shift and Acid Gas Removal (AGR)

- Sour syngas may be vented to the flare during SSM.
- Shift units are typically installed only if CO_2 capture is desired or if facility will co-produce substitute natural gas (SNG), transportation fuels, or chemicals
- CO_2 selective AGR units produce a CO_2 product vent typically routed to a catalytic or regenerative thermal oxidizer (CO, SO_2, NO_X, VOC, and HAPs)

Air Emissions – Process Areas

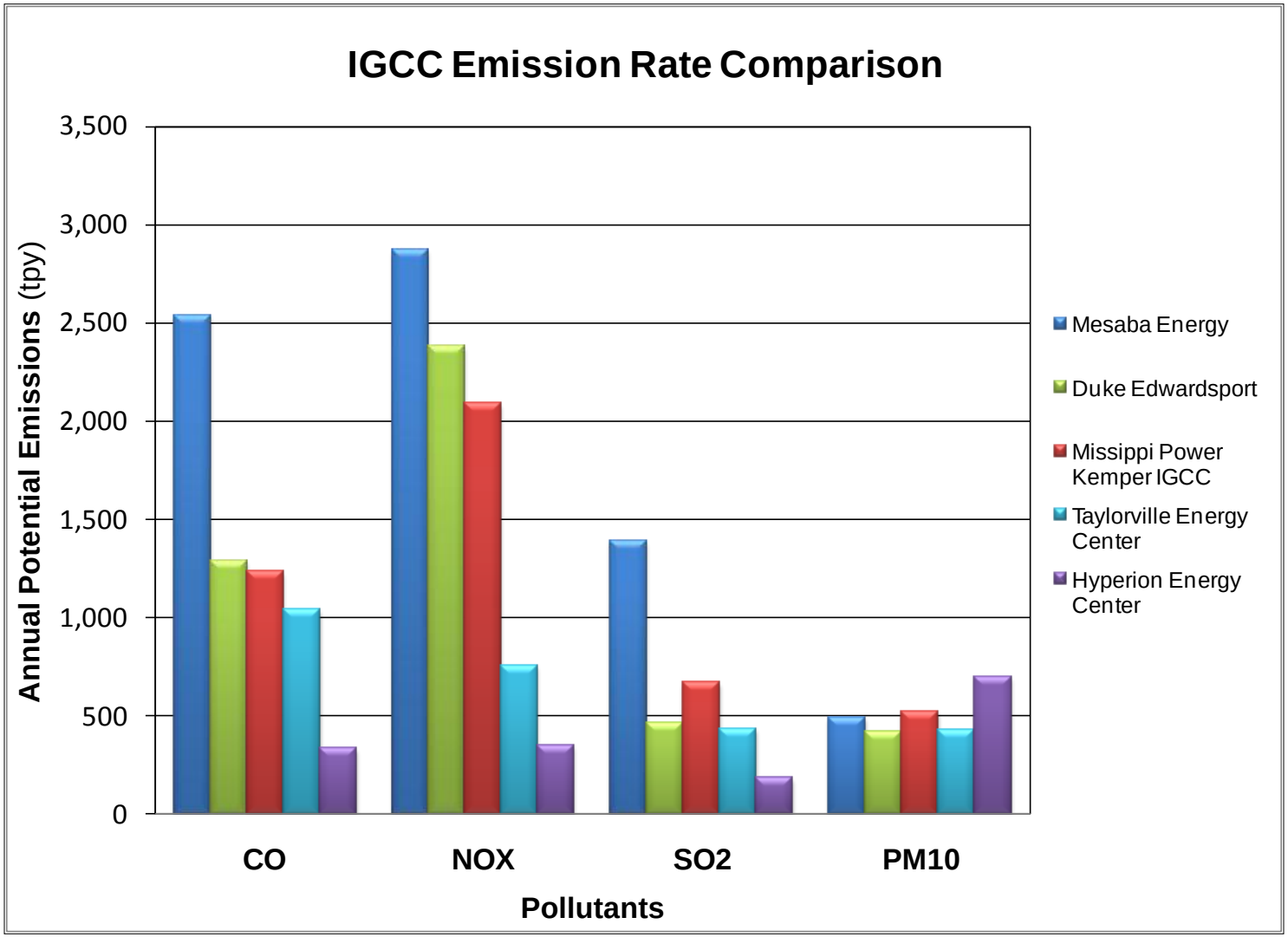
Area 5: Sulfur Recovery Process

- Most common applications are conventional refinery-type Claus Sulfur Recovery Unit (SRU) or wet sulfur acid (WSA)
- SRU tailgas is either routed to a tail gas treatment unit and thermal oxidizer (SO_2, NO_X, and CO) or hydrogenated and recycled to the AGR inlet or gasifiers

Area 6: Power Block

- Most common combined cycle configuration is 2 on 1 with two (2) “F” frame combustion turbines equipped with heat recovery steam generators (HRSGs)
- Combustion turbine emissions typically comprise the vast majority of plant-wide annual CO and NO_X emissions and contribute a smaller percentage of SO_2 emissions

Plant-wide Air Emissions



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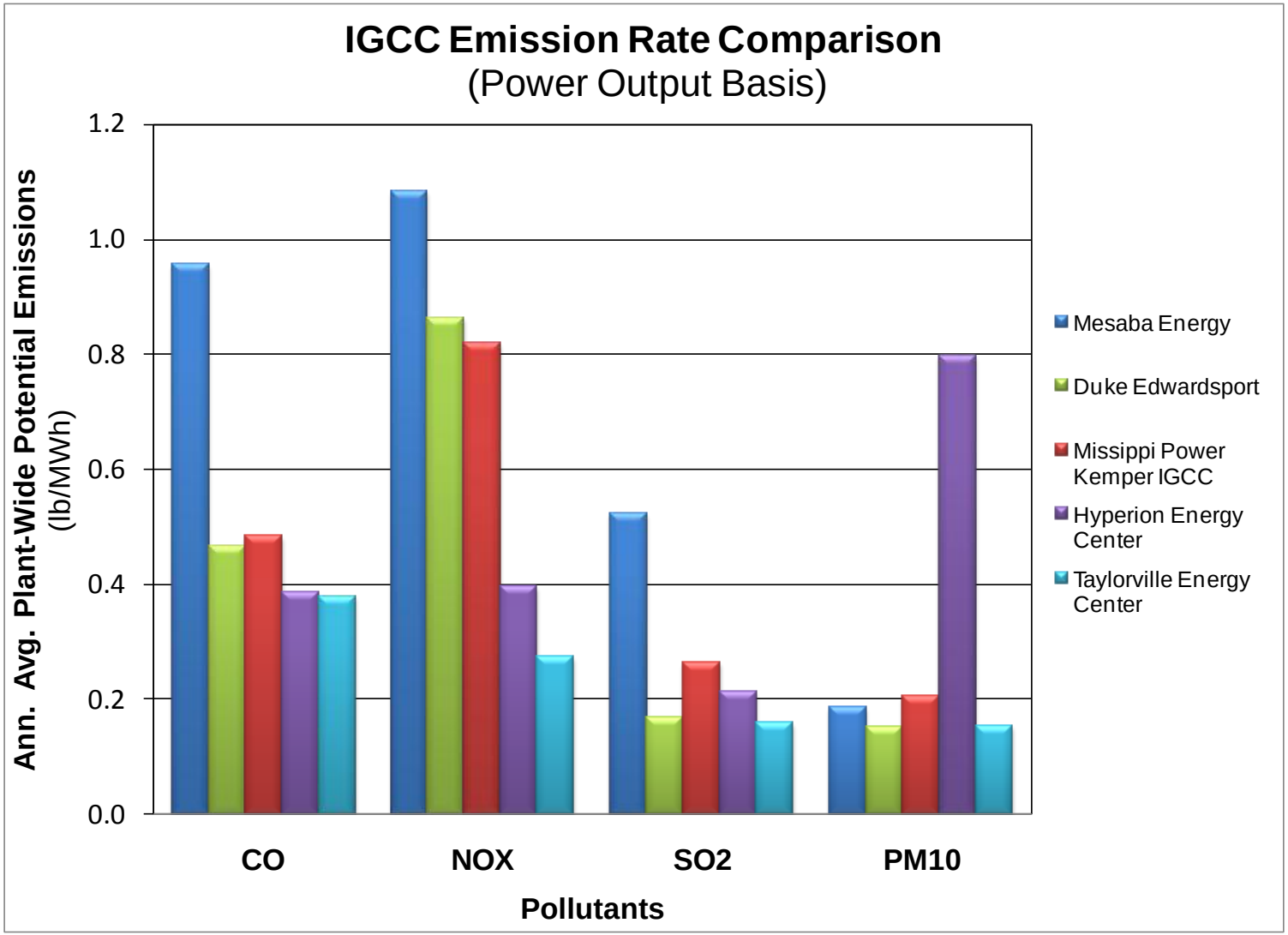

Gasification Block - Emission Sources

OS 1 - Emissions Sources During Steady-State Operations

- Gasification block typically acts as a closed system with no routine emissions

OS 2 - Emissions Sources During Startup

- Gasifier preheating process typically requires venting of combustion byproducts to the flare or through gasifier vent system
- Switch to solid fuels after preheating can require venting of raw/sour/sweet syngas to the flare if syngas processing equipment is not up to operating pressure when fuel switching occurs
- For multi-train configurations, subsequent gasifier/syngas processing train startups can also require syngas flaring

OS 3 - Emissions Sources During Gasifier Swaps/Rotations

- A small stream of syngas is typically drawn off the processing train to avoid upsetting syngas production for the power block

Gasification Block - Emission Sources

OS 4 - Emissions Sources During Shutdown

- Phased shutdown typically begins with power block and cascades towards gasifiers through the syngas processing train
- Syngas and vessel purge gas flaring typically occur during plant shutdowns

OS 5 - Emissions Sources During Malfunctions

- Power block upset leads to sweet syngas flaring at the AGR outlet
- SRU/WSA upset leads to acid gas or sour syngas flaring
- AGR upset leads to sour syngas flaring from syngas processing train outlet
- Syngas scrubber/shift unit upset or gasifier feed system malfunction leads to raw syngas flaring from gasifier outlet

Gasification Block - Emissions Summary

1. Flare Emissions

OS 1-4 - Normal Operations

- CO Emissions – Primary CO present in syngas and secondary CO formed from incomplete combustion of methane and other hydrocarbons (30 to > 500 tpy, 200 to >5,000 lb/hr)
- SO_2 Emissions - A function of flared syngas quality and flow rate (<1.0 to >300 tpy, 1.0 to >300 lb/hr)
- NO_X Emissions - Only small quantities of thermal NO_X emissions typically occur from syngas flaring

OS 5 - Malfunctions

- CO and SO_2 Emissions - Location of malfunction in the process dictates syngas quality and flow rate to flare during these events and determines CO and SO_2 emission rates
- Emergency gasifier shutdowns can occur relatively quickly (typically <1 hour) so durations of malfunction events can be minimized

Gasification Block - Emissions Summary

2. AGR Emissions
   - CO and SO_2 Emissions - CO and H_2S/COS are absorbed into CO_2 stream often requiring control in an oxidizer (CO: 100 to 500 tpy, SO_2: 15 to >150 tpy)
   - CO_2 vent flow rate determined by syngas processing rate in AGR so startup and shutdown emissions are typically not addressed
3. SRU Emissions
   - SO_2 Emissions - Vary depending on tailgas treatment configuration (0 to >50 tpy)
   - Claus unit design dictates sulfur content of tailgas
   - Startup and shutdown emissions are typically addressed since tailgas may not be fully treated or recycled
4. Equipment Leak Component Emissions
   - Number of components and service type must be determined to quantify emissions from all process streams containing VOC

Permitting and Compliance Strategies

- Are SSM emissions from the gasification block required to be included when determining source classifications, permit limits, modeled emission rates, and BACT level controls?
- What is BACT for a first of its kind multi-train IGCC facility that has not been commercially demonstrated in the U.S.?
- How should the various operating scenarios for the plant be evaluated in air dispersion modeling analysis?
- What are the other key modeling considerations?
- What work practice standards should be proposed to minimize emissions from flaring?
- What gasification block control measures are required to ensure the plant stays below the HAP major source threshold?

SSM Permitting Considerations

- For excess emissions occurring during malfunctions, states may chose to exercise “enforcement discretion” when penalizing (or choosing not to penalize) the offending source
- Additionally, in areas where a single source or small group of sources do not have the potential to cause an exceedance of the NAAQS or PSD increments, states may include in their SIPs affirmative defenses for excess emissions
- In order to exercise an affirmative defense, a source must generally demonstrate excess emissions were caused by a sudden, unavoidable equipment breakdown, beyond the operator’s control and the amount and duration of the excess emissions were minimized to the maximum extent practicable

SSM Permitting Considerations

- Gasification block emissions during malfunctions and emergency shutdowns may not be reasonably quantifiable for state-of-the-art multitrain IGCC facilities
- Despite the difficulty in quantifying malfunction emissions, EPA Region 8 adversely commented on the Hyperion Energy Center draft permit by stating that:
  - *"(South Dakota) DENR should consider and evaluate as potential BACT for refinery and IGCC flare emissions the imposition of annual limits, which include malfunction periods."*
- Establishing short-term and/or annual flare BACT permit limits to cover startups, shutdowns, and normal steady-state operation is appropriate. BACT limits that include malfunction emissions are not appropriate.

BACT Considerations

- Power block, AGR vent, and SRU/WSA BACT determinations are straight-forward and follow the top down procedure recommended by EPA
- Flare is both an emission unit and control device, so BACT must address both flare controls (i.e., good combustion practice, pilot and assist gas design, etc.) and pre-flare control options (i.e., minimizing venting during SSM, use of low sulfur fuels during startup, sulfur absorption technologies, etc.)
- Flare malfunction emissions should be addressed through work practice standard alternatives (flare minimization plan and root cause analysis) rather than emission limitations
- Selecting an annual averaging period for flare BACT limits may be appropriate given extreme variability in short-term emission rates

Modeling Considerations

- Per the *Guideline on Air Quality Models*, the maximum allowable emission limit or federally enforceable permit limit should be modeled in the NAAQS/PSD Increment analyses
  - Malfunction emissions **should not** be addressed in the modeling analysis
  - *"Malfunctions which may result in excess emissions are not considered to be a normal operating condition. They generally should not be considered in determining allowable emissions." – Guideline Section 8.1.2.a.*
  - Ambient impacts from malfunctions are more appropriately addressed as part of an incident investigation where ***actual*** emissions, duration, and meteorology during the event are used as model inputs
- Between power block loads and gasification block operating scenarios the "load analysis" portion of the modeling analysis can be very complex

Modeling Considerations

- AERMOD routinely over predicts ambient impacts from ground level fugitive PM sources at low wind speeds
  - Detailed refinements to material storage, handling, and hauling emission calculations and source characterization may be required
  - The large number of sources required to characterize long haul road segments and complex material storage and handling schemes can greatly increase PM model run times
- Characterize the flare under each operating mode
  - Requires detailed heat and material balance data for vented process gas
  - Peak hourly flare emissions can greatly exceed 3-hr, 8-hr, or 24-hr average emission rates
  - Determining emission rates over various averaging periods for each operating mode may be required

Other Permitting Considerations

- Integrating enforceable work practice standards for minimizing flaring (i.e., flare minimization plan, root cause analysis, etc.) into permit can drastically increase compliance burden
- Selecting appropriate flare compliance monitoring systems can be difficult without detailed site-specific engineering
- Developing plant-wide HAP emissions estimates can require detailed site-specific HAP emissions data from heat and material balance data and technology suppliers
- Pre-flare controls, AGR vent oxidizer, and leak detection and repair (LDAR) program for equipment leak components may be required to reduce HAP emissions below major source levels (thus avoiding MACT requirements)

Questions?

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