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Air Quality Considerations for Biofuels: Development of Preliminary Estimates of Permitted Potential Emissions for the Bioenergy Supply Chain

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Issues Addressed in This Presentation

- Biorefineries and other biofuel supply chain facilities will require air permits for construction and operation and air emissions are a sustainability issue.
- Except for very recent experience from a select number of cellulosic biorefineries, little is known about the requirements to meet regulations, what are expected air emissions from such facilities and what impact they could have on facility operations and costs.

Context and Broad Goals

Support DOE's BioEnergy Sustainability Program: NREL's sustainability analysis program aims to better understand air emissions from the biofuel supply chain, applicable regulations and implications for cost, operations and sustainability

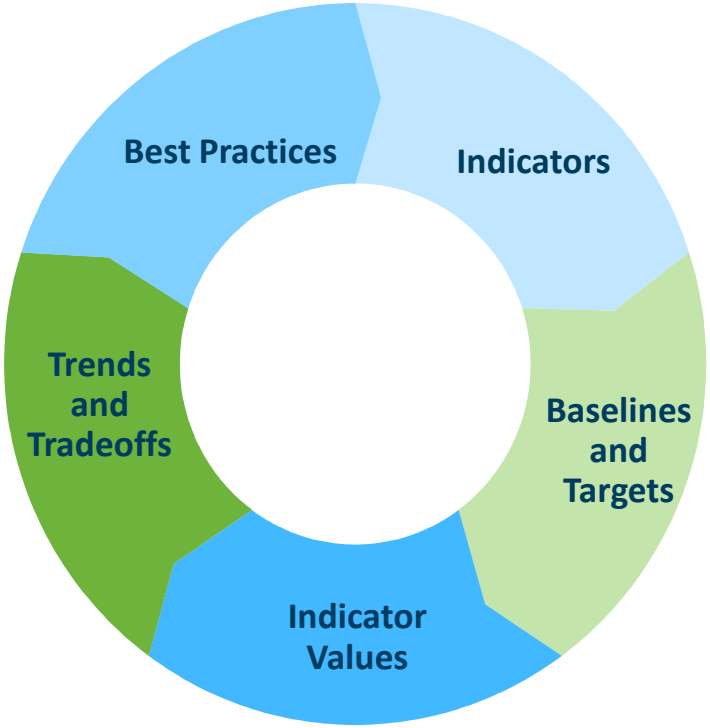
- **Ultimate aim:** to develop tools and analyses that can assess air pollutant emissions and potential health consequences from the cellulosic biofuel supply chain at high spatial, temporal and chemical resolution and can compare results to those from incumbent systems

Address research gaps

1. Lack of updated information linking DOE's stage/pathway advanced designs that enable comparison of estimated emissions to applicable regulatory limits
2. Lack of quantification of life cycle (supply chain) ozone and PM-precursor emissions from different cellulosic biofuel pathways based on DOE advanced designs
3. Lack of spatially, temporally, and chemically resolved life cycle inventories of air pollutant emissions to enable
   a. Examination of source-level emission reduction opportunities
   b. Comparison to existing inventories (e.g., EPA's National Emissions Inventory)
   c. Estimation of air quality and health impacts from large-scale cellulosic biofuel production and use.

Approach

For each life cycle stage, based on inventory



For life cycle impact evaluation, considering all stages and net effects

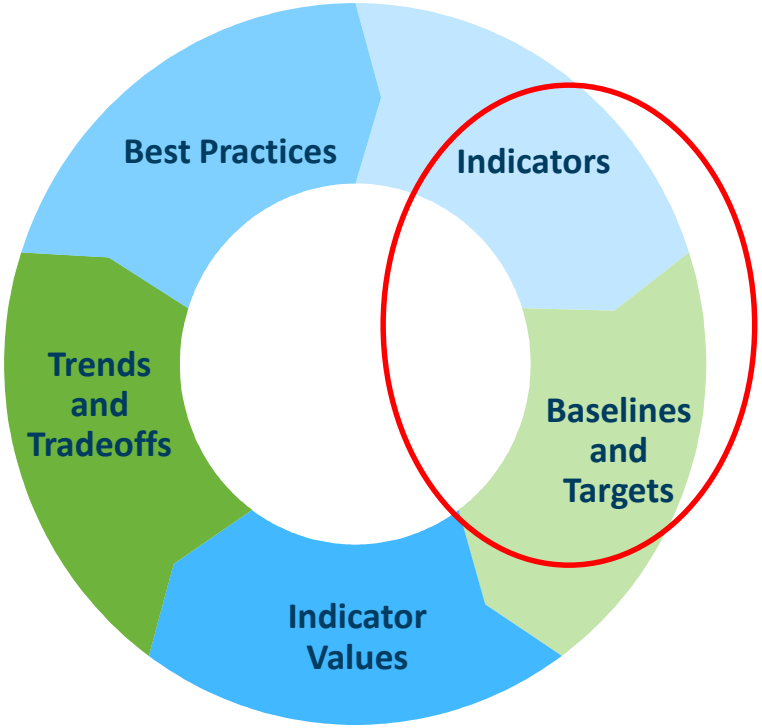
- Spatially, temporally, and chemically explicit inventory
- Air quality modeling
- Exposure assessment
- Health impact assessment and externalities estimation

Life Cycle Stages

Feedstock Production → Logistics → Conversion → Distribution → End Use

Progress

For each life cycle stage, based on inventory



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Life Cycle Stages

Feedstock Production → Logistics → Conversion → Distribution → End Use

FY12-14

FY14-15 (regulations, PTE, controls)

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Sugars-to-Hydrocarbons (HC) Biorefinery Air Emissions

Goals

- Identify air quality regulations applicable to biorefineries
  - Completed: Biological conversion of sugars-to-HCs biorefinery as per the design case described in Davis et al. (2013)
  - Next: fast pyrolysis (PNNL/NREL design: Jones et al. 2013)
- Understand potential air permitting requirements
- Quantify regulatorily-required estimates of permitted *potential* emissions (so-called "potential-to-emit" (PTE)) (*see caveats slide*)
- Provide feedback to the biorefinery design teams to incorporate emission controls if necessary

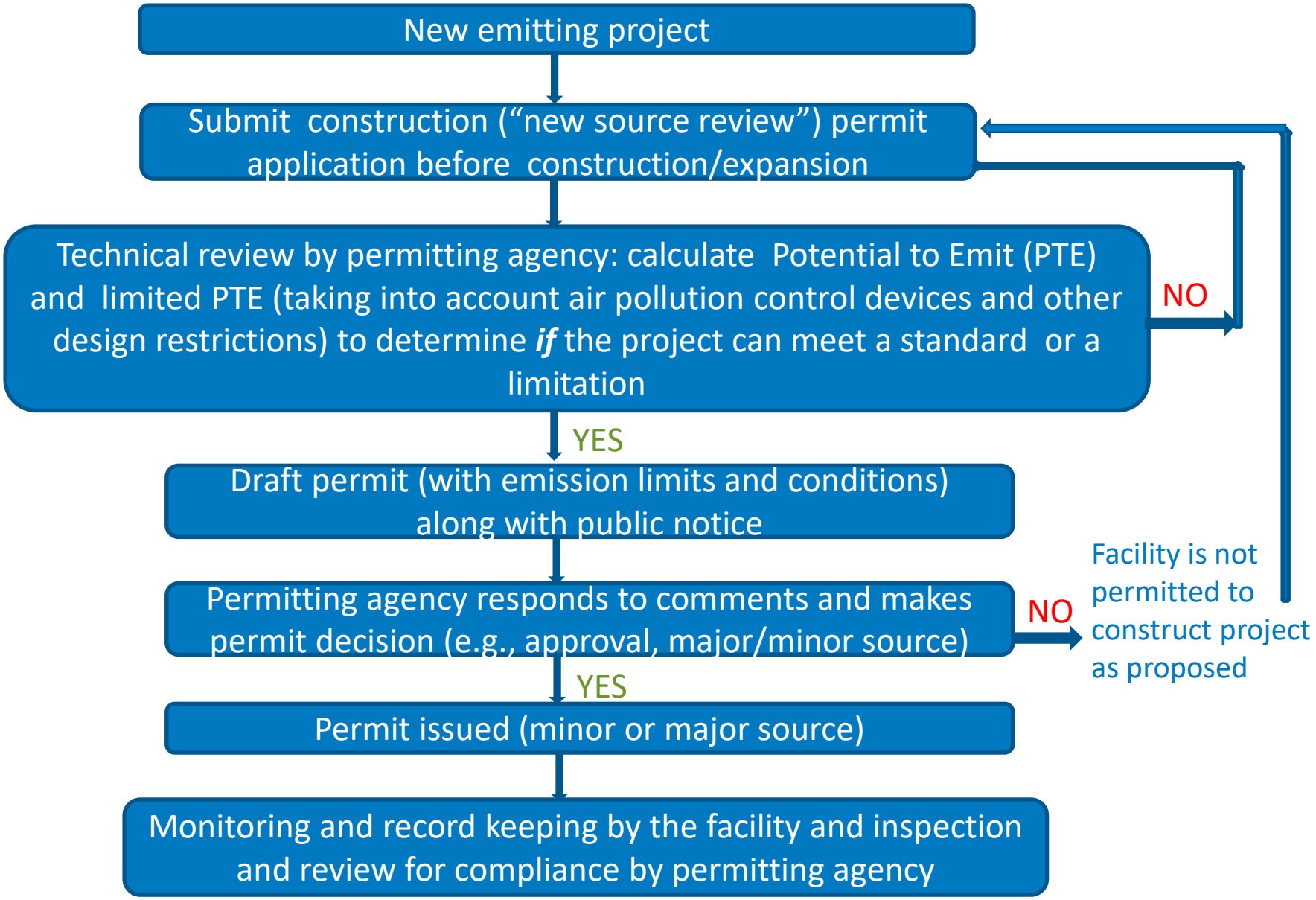
Next:

- Further investigation of strategies to reduce emissions and their potential effect on depot operation, performance and cost
- Collection of available measurements or specific models regarding emissions from depot sources to validate PTE estimates

Caveats on Preliminary Results

- Current design case (Davis et al. 2013) does ***not*** have all necessary information/data needed for making accurate emission estimates for permitting purpose – assumptions are unavoidable, and our results are ***preliminary***.
- Current sugars-to-HC conversion is not designed with the goal of optimizing air emissions.
- Emissions factors are not readily available from literature, EPA guidelines, and existing permits for some novel unit operations – e.g., boiler using a combination of biogas, sludge, lignin and other residues.
- We reviewed only federal regulations and permitting requirements; states or localities may have additional or more stringent requirements.

Overview of construction, aka new source review (NSR), permitting process



Operating permits

- In 1990, Congress established the operating permit program under Title V of the Clean Air Act Amendments.
- Consolidated all air pollutant control requirements into a single “operating permit” that covers all aspects of a source’s year to year air pollution activities.
- Who needs it?

- Any source with a major source permit under NSR

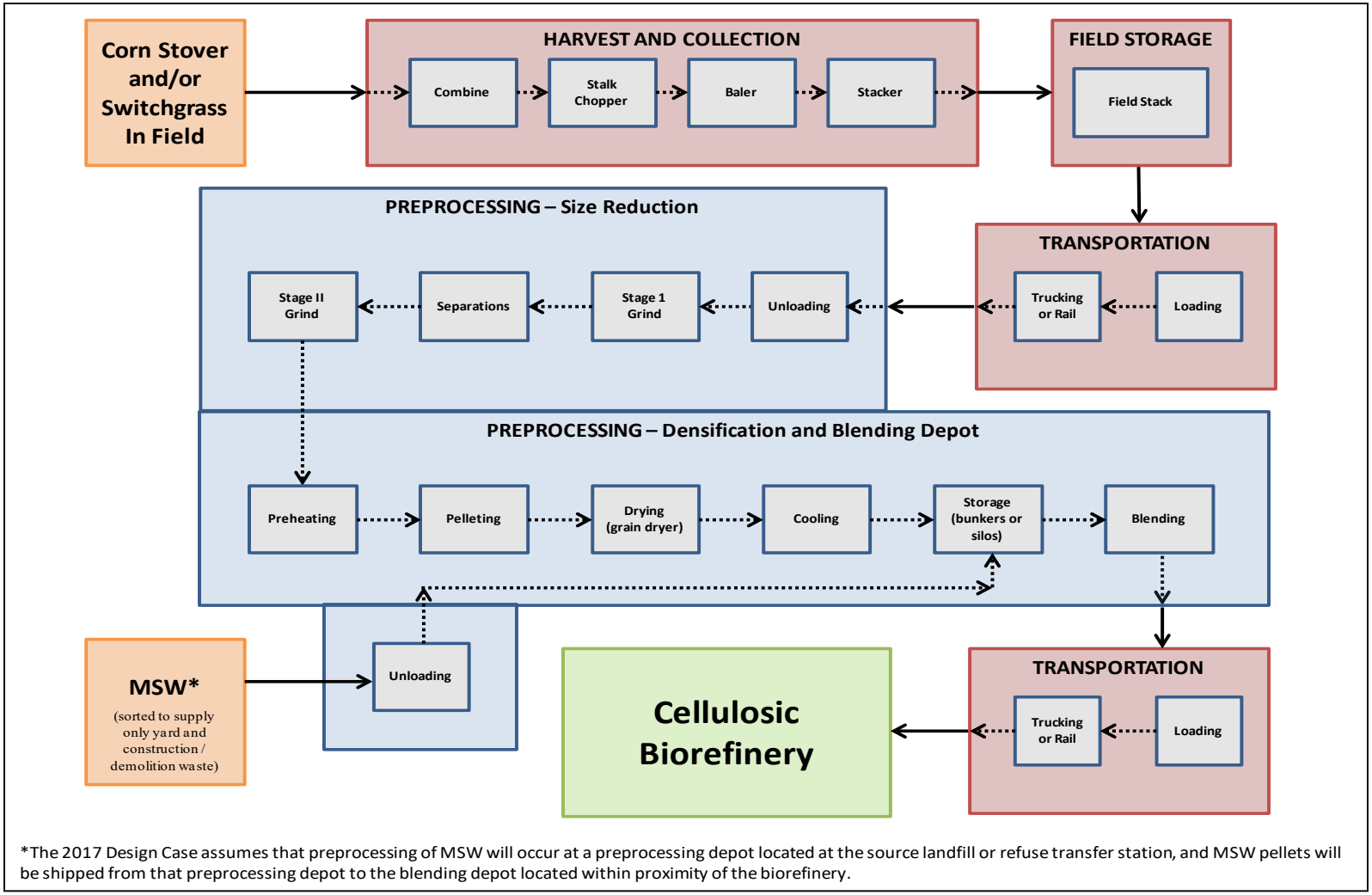
- Major sources for hazardous air pollutants

- Others (e.g., solid waste incineration units, affected sources under Acid Rain Rules)

PTE and limited PTE

- **PTE:** Maximum capacity of a stationary source to emit air pollutants under its physical and operational design (e.g., 24 hours, 365 days) → worst case scenario
- **Limited or post-permit PTE:** takes into account permit limitations (e.g., conditions regarding operational limitations, use of emission control devices), which are federally enforceable.

Biomass logistics systems for sugars-to-HCs

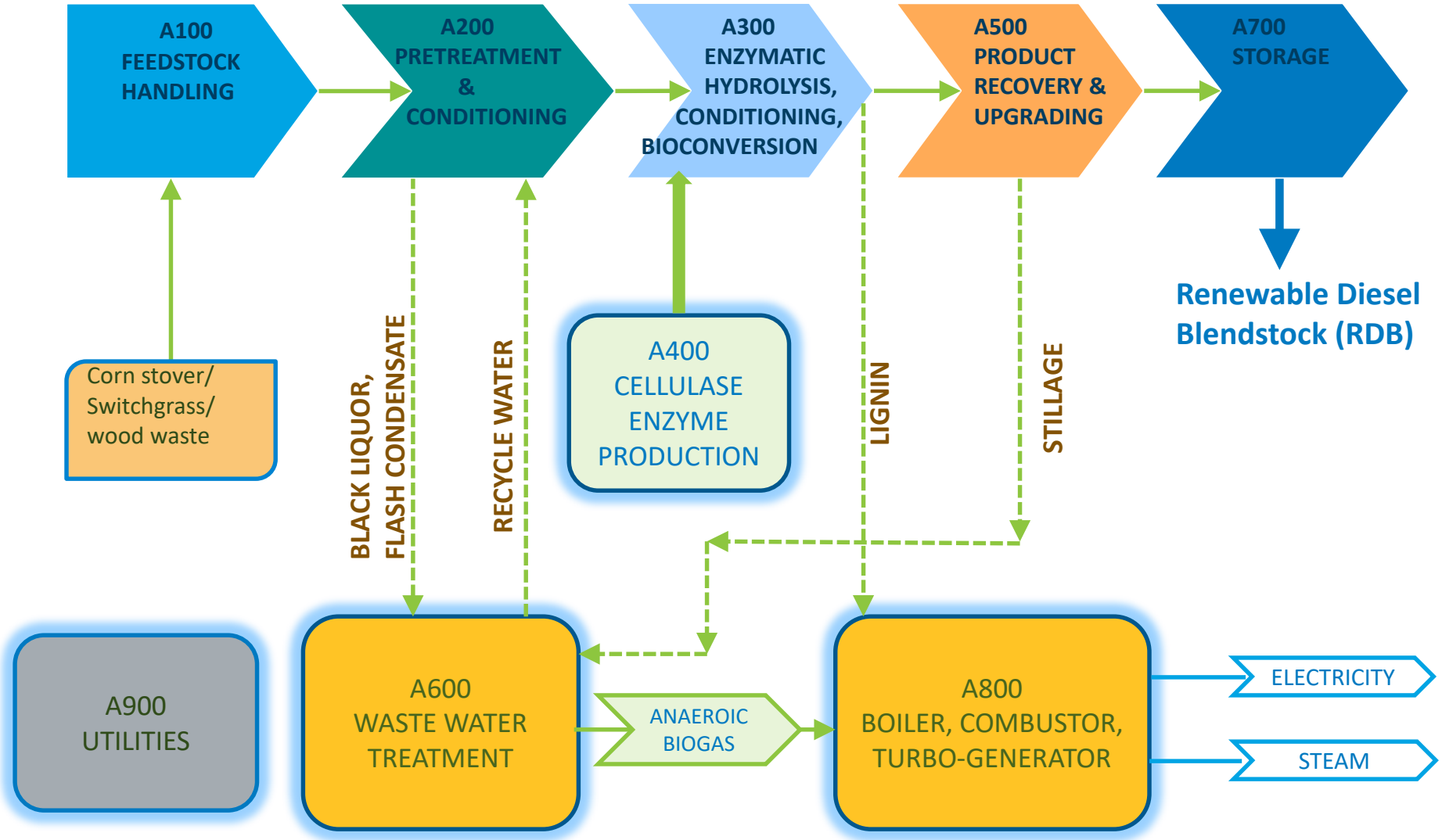


*The 2017 Design Case assumes that preprocessing of MSW will occur at a preprocessing depot located at the source landfill or refuse transfer station, and MSW pellets will be shipped from that preprocessing depot to the blending depot located within proximity of the biorefinery.

- Feedstocks

- System boundary of a biomass depot, where each small box represents individual operation

Simplified process flow diagram for the Sugars-to-HCs biorefinery (based on Davis et al. 2013)



Davis et al. 2013. Process design and economics for the conversion of lignocellulosic biomass to hydrocarbons: Dilute Acid and Enzymatic Deconstruction of Biomass to Sugars and Biological Conversion of Sugars to Hydrocarbons. Available at http://www.nrel.gov/docs/fy14osti/60223.pdf.

Equipment likely to generate air pollutants

Plant Area	Equipment	Air Pollutants
Area 100: Feed handling	Dust collection systems (M-106)	PM, PM_{10}, $PM_{2.5}$
	Dust from trucks hauling feedstock, other raw materials, waste, and product	PM, PM_{10}, $PM_{2.5}$
Area 200: Pretreatment and conditioning	Presteamers (M-204) and Pretreatment Reactors (M-207)	VOC, HAP, SO_2, H_2SO_4 mist
	Flash tank (T-204)	VOC, HAP, SO_2, H_2SO_4 mist
	Ammonia addition tank	NH_3
	Leaking equipment	VOC, HAP
Area 300: Enzymatic hydrolysis, hydrolysate conditioning, and bioconversion	Enzymatic hydrolysis reactors (F-300A)	VOC, HAP
	Filter press (S-205)	VOC, HAP
	Aerobic bioreactors (F-300B) and storage tank (T-306B)	CO_2, VOC, HAP
	Leaking equipment	VOC, HAP
Area 400: Cellulase enzyme production	Bioreactors (F-400, F-401, F-402, and F-403), and tanks (T-405, T-406, and T-410)	CO_2, VOC, HAP
	Leaking equipment	VOC, HAP

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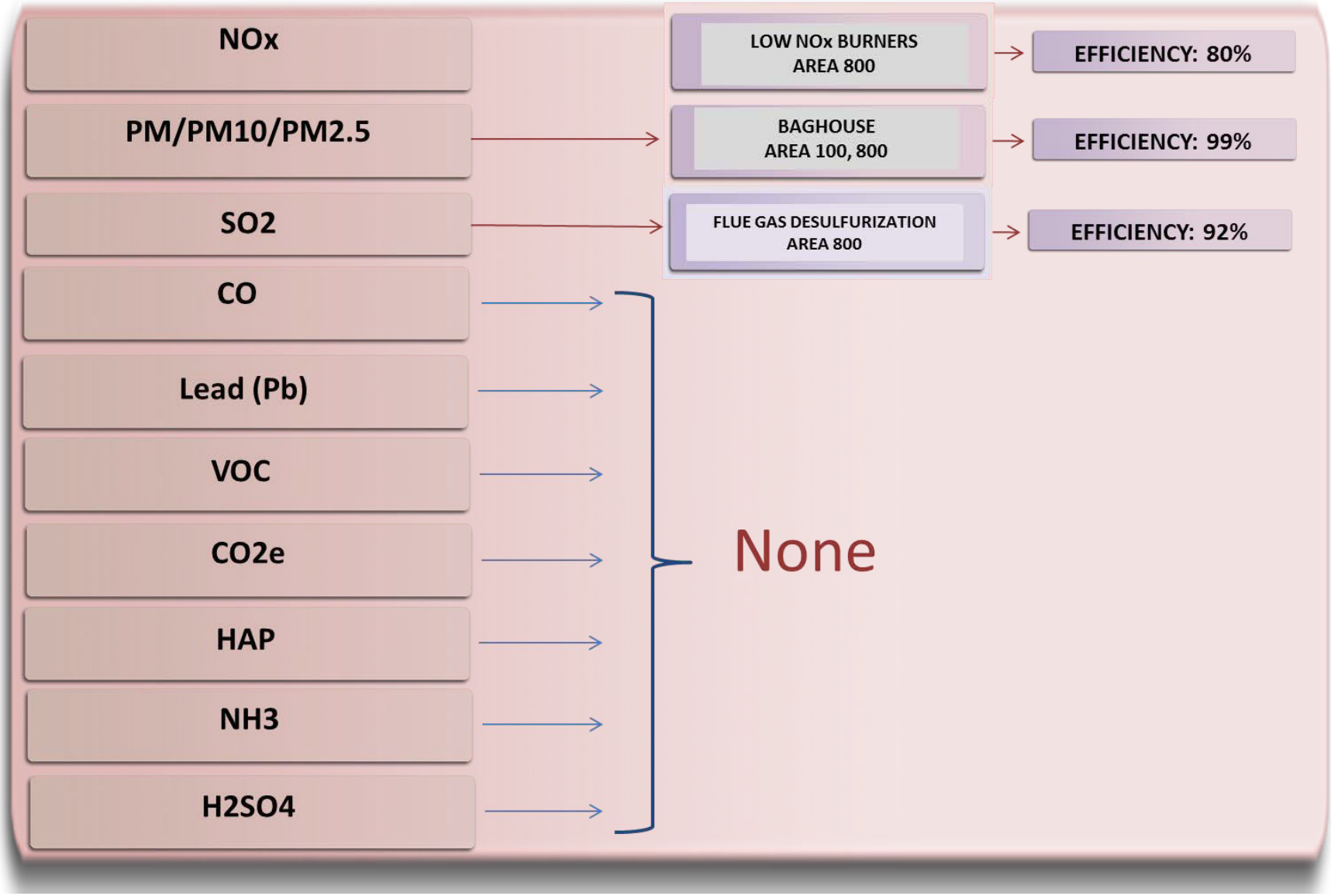
Equipment likely to generate air pollutants (cont'd)

Plant Area	Equipment	Air Pollutants
Area 500: Product recovery and upgrading	Pre-heater (no ID provided)	PM, PM_{10}, $PM_{2.5}$, NO_x, SO_2, CO, CO_2, VOC, HAP
	Hydrotreating process (S-570)	CO_2, VOC, HAP
	Leaking equipment	VOC, HAP
Area 600: Wastewater treatment	Anaerobic digester (T-606)	CH_4, CO_2, VOC, HAP
	Aerobic digester (T-608)	CO_2, VOC, HAP
	Leaking equipment	VOC, HAP
Area 700: Storage	RDB product storage tank	VOC, HAP
	Sulfuric acid tank	H_2SO_4 mist, SO_2
	Two ammonia storage tanks	NH_3
	Loading operations	VOC, HAP
Area 800: Combustor, boiler, and turbogenerator	Boiler (M-803)	PM, PM_{10}, $PM_{2.5}$, NO_x, SO_2, CO, CO_2, VOC, HAP
Area 900: Utilities	Cooling towers	PM, PM_{10}, $PM_{2.5}$, VOC, HAP
	Fire Pump	PM, PM_{10}, $PM_{2.5}$, NO_x, SO_2, CO, CO_2, VOC, HAP
	Emergency generator	PM, PM_{10}, $PM_{2.5}$, NO_x, SO_2, CO, CO_2, VOC, HAP

A technical report by Eastern Research Group

Planned control devices and methods in the design biorefinery (Davis et al. 2013)

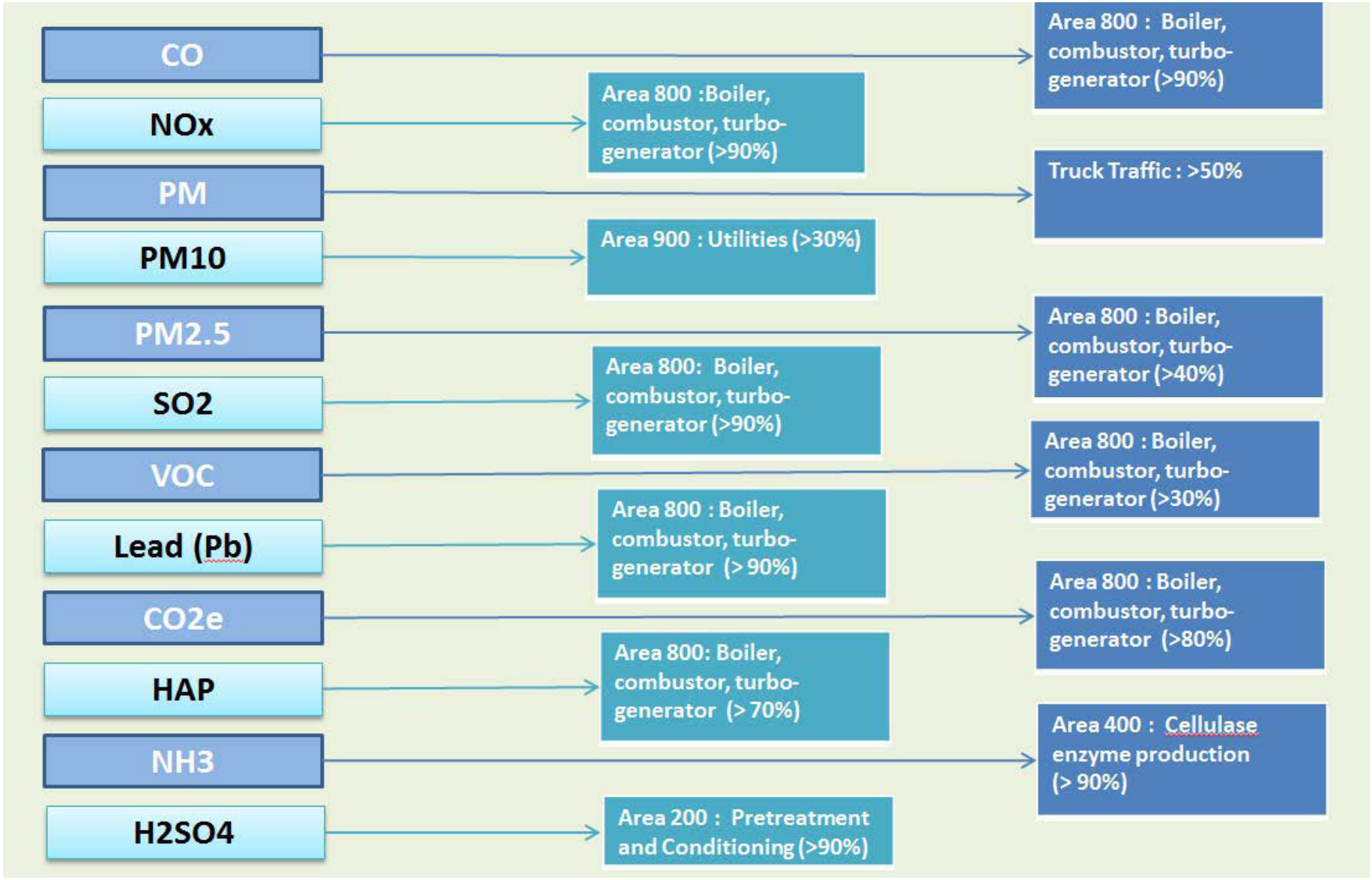


Preliminary, limited PTE estimates

Pollutant	Limited (controlled) PTE (tpy)	Major source threshold (tpy)
Particulate matter (PM)	96	100
Particulate matter with less than 10 micrometers in diameter (PM_{10})	44	100
Particulate matter with less than 2.5 micrometers in diameter ($PM_{2.5}$)	24	100
Sulfur dioxide (SO_2)	74	100
Nitrogen oxides (NO_x)	510	100
Carbon monoxide (CO)	1,400	100
Volatile organic compounds (VOC)	1,900	100
Lead	<1	100
GHG (CO_2 equivalent)	1,400,000	N/A[1]
Hazardous air pollutants (HAP) (total)	390	25 (total)
Ammonia (NH_3)	2.0	Only reporting requirement[2]
Sulfuric acid (H_2SO_4) mist	9.0	100

1. N/A – GHG alone cannot drive major source permitting. However, if a source is a major for non-GHG pollutant, the source will be subject to GHG PSD review if the PTE of GHG emissions exceed a certain threshold. (Some states use 0 and some states use 75,000 tpy. EPA is working on rulemaking to set this value.)
2. NH_3 is not regulated under new source review (NSR) program. If a source has a Title V permit, there is reporting requirement for NH_3.

Major emitting areas by pollutant (*preliminary*)



Key messages

1. A sugars-to-HC biorefinery as per the design case (Davis et al. 2013) will likely be subject to major source review under New Source Review and construction permit procedures, based on current design and our ***preliminary*** PTE estimates.
   - Our preliminary results suggest that NOx, VOC, CO, and HAP will likely exceed the major source thresholds even if the biorefinery is located in an area in attainment of the National Ambient Air Quality Standards for ozone, and CO.
   - Further emission control technologies/devices can be employed to reduce PTE. We are in the process of investigating strategies to reduce emissions and the implications of additional emission controls on cost and performance.
2. Collocating with a biomass (preprocessing) depot could pose additional challenges to air permitting (i.e., making it harder for the biorefinery to reduce its PTE below the major source threshold). These preliminary results are for a ***stand-alone*** biorefinery.
3. Major source review is a greater burden of time and expense in the permitting process, and often results in the acceptance of operational limits or use of additional emission control technologies which can both impact facility economics.
4. The boiler is the single largest emitting source for CO, NOx, $PM_{2.5}$, SO_2, VOC, GHG, and HAP. However, emission factors for similar facilities are not readily available. In FY15, stack test results from analogous unit operations will be collected (*if available)* to verify our estimates and we will also attempt to model combustion devices.
5. These preliminary results need to be validated once test results from newly constructed and operational cellulosic biorefineries are available.