Rule 1109.1 – NOx Emission Reduction for Refinery Equipment

Working Group Meeting #9

December 12, 2019

Call-in Information

Call-in Number: 1-866-705-2554

Meeting Number: 677695

Agenda

- Summary of Working Group Meeting #8
- Progress of Rule Development
- Technology – John Zink Hamworthy Combustion
- Baseline Emissions and Reductions
- U.S. EPA Cost Spreadsheet (updated cost curve) & Cost Information
- BARCT Assessment and Limits
- Next Steps

Progress of Rule Development

Summary of Working Group #8 (6/27/19)

- CEMS data evaluation: Operational Peak determination
- U.S. EPA SCR cost spreadsheet revision and requested additional cost information
- Requested additional costs for SCR installations

Since Last Working Group Meeting

- Norton Engineering meetings to discuss preliminary BARCT assessment and limits
- Fossil Energy Research Corporation (FERCo) finishing up site visit to facilities
- Cost estimates submitted by facilities
- U.S. EPA SCR cost spreadsheet updates
- Continued discussions with control technology suppliers
- Considering establishing SOx BARCT emission limits and removing exemptions for RECLAIM

SOx RECLAIM

- Last RECLAIM meeting considering the need to address SOx RECLAIM to address concerns for co-pollutant
- Some permits cannot be issued due to co-pollutant issue until sulfur is removed from fuel gas
- One option is to sunset SOx RECLAIM to conduct BARCT Assessment
  - SOx BARCT reassessment has not been conducted since 2010
- Assembly Bill 617- Requires the implementation of BARCT for market-based programs

Engineering Consultants

FERCo — Fossil Energy Research Corporation

- Completing site visits to major facilities
- Compiling assessment
- Space constraints challenges account for the majority SCR costs
- Despite challenges, some facilities have undergone elaborate engineering designs and implementations
- Reviewing cost data

Norton engineering

- Engineering assessment of NOx control technologies
- Meeting and discussions with vendors
- Reviewing NOx control cost data and information from refinery projects in other regions such as the Gulf and East Coast
- Reviewing staff's analysis

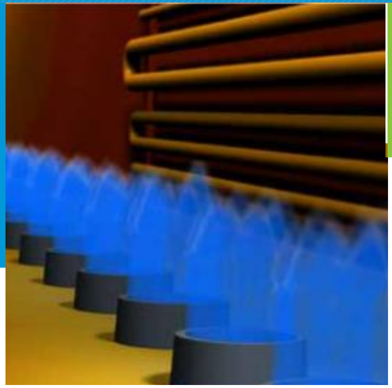
John Zink Hamworthy

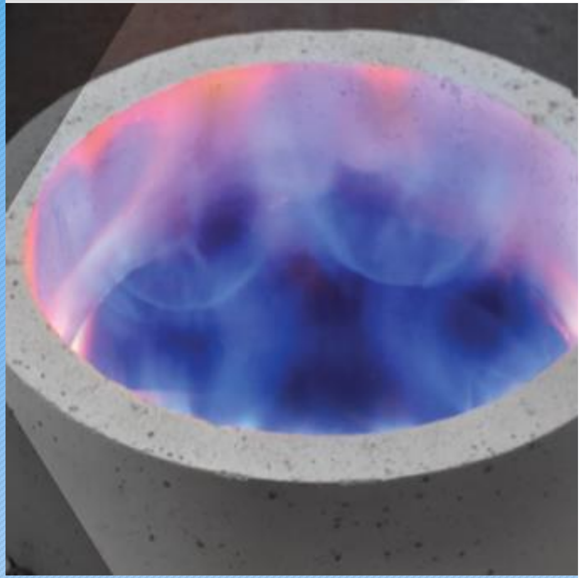
SOLEX™ Burner by John Zink

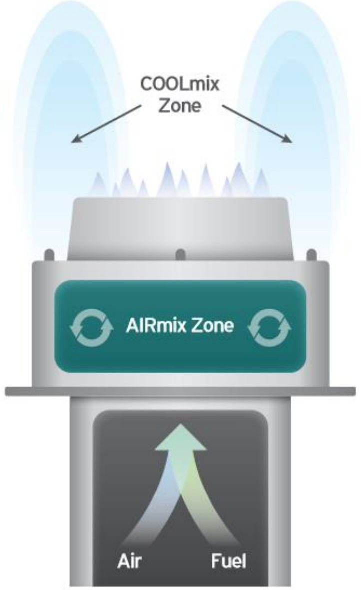
JOHN ZINK HAMWORTHY COMBUSTION®

SOLEX™ Burner

5 ppm NOx Performance







*The SOLEX burner achieves **5 ppm NOx and near-zero CO at start-up,** all with a short flame length.*

Performance

+ NOx emissions
  - Can replace the need for SCR or other NOx reducing technology
  - Independent of: fuel compositions >75% H_2, air preheat, furnace temperature, operation range, firebox heat density
  - High predictability and repeatability
+ CO emissions
  - Decoupled from cold furnace temperatures
  - Near-zero CO emissions at start-up and turndown conditions
+ Flame
  - Lengths less than half of ultra-low NOx staged fuel burners
  - Solution for tight burner spacing arrangements
  - Round or flat flame options
+ Retrofits
  - Fits traditional ultra-low NOx burner footprints
  - Upfired, downfired, horizontally fired

System Requirements

+ Two fuel zones
+ Air-fuel ratio controls and supporting hardware
+ Heat releases ranging between 1 MMBtu/hr (0.3 MW) and +20 MMBtu/hr (+5.9 MW)
+ Advanced combustion controls to enable a burner-only solution that achieves SCR level NOx emissions

Updated Emission Evaluations (CEMS Review)

Baseline Year Considerations

Survey

- Included 4 years of Data (Facilities Indicated Representative Year)
- Some representative years were as old as 2012

EPA Recommendation

- Use most recent valid data
- Represent current activity

Staff Recommendation

- 2017 Reported Mass Emissions Data

Baseline Emissions Evaluation for Cost-Effectiveness Calculation

- Last Working Group Meeting
  - Staff evaluated CEMS data for 134 heaters and boilers and discussed a methodology of determining operational peak
  - Considered using operational peak as substitute for units without a permit limit
- Stakeholders expressed concern that operational peak may overestimate the emissions inventory and did not support using operational peak for cost-effectiveness calculations
  - Requested staff use annual average reported in surveys as more representative of unit operations for cost-effectiveness calculations

Emission Evaluations

- After last working group meeting staff reviewed and compared emission data:
  - NOx emissions reported in survey *– NOx concentration*
  - Operational peak determined from CEMS *– NOx concentration*
  - Annual Emission Report/RECLAIM Report *– NOx mass emissions*
- Staff concluded the annual mass based emissions most accurately reflected the emission of each unit
- Staff used the U.S. EPA cost spreadsheet to back calculate the NOx concentration based on the annual reported mass emissions
  - Back-calculated NOx value generally higher than the average value reported in the survey and below the operational peak

Revisiting Example Analysis of 52 MMBtu/hr Heater Using Refinery Gas

	Reported in Survey	Staff Estimated Operational Peak	Annual Emissions Report
NOx Emissions	23.3 ppm	56 ppm	30 ppm
Annual Emissions	4.03 tons/year	9.83 tons/year	5.31 tons/year

Emissions Determination

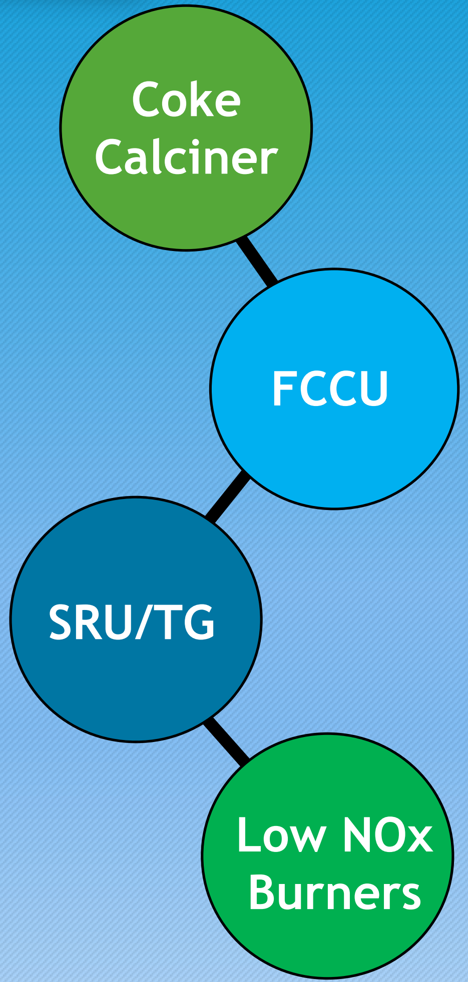
- Staff proposing to use actual NOx emissions to back-calculate NOx concentration
  - 2017 reported emissions will be used as baseline year
  - Actual NOx emissions will be used for cost-effective calculation
  - Other metric may be used for emission reduction calculation
- Evaluation of all heater CEMS/reported emissions data shows:
  - Reported NOx concentration in survey underestimates emissions
  - Annual mass emissions most accurately characterize the emissions of each unit
    - Emission data continuously tracked (CEMS)
    - Audited (RECLAIM)
    - Reported (AER)
  - Operational peak NOx concentration represent potential to emit and can be used to approximate a permit limit

Cost Updates

Discounted Cash Flow (DCF)

- South Coast AQMD uses Discounted Cash Flow
  - Cost-Effectiveness = Present Value/Emissions Reduced Over Equipment Life
  - Present Value = Capital Costs + (Annual Operating Costs*Present Value)
  - Present Value = $(1-1/(1+ r)^n)/r$
    - $r = (i - f)/(1 + f)$
    - i= nominal interest rate
    - f = inflation rate

- DCF used for units where NOx emissions are dependent on feedstock and not fuel usage such as FCCU, coke calciner, SRU/TG incinerators, and flares



U.S. EPA Cost Spreadsheet

- Cost-effectiveness is a cost-benefit analysis comparing relative cost and outcomes
- Measured in cost per ton of pollutant reduced
- For SCR installations, staff will use the U.S. EPA cost spreadsheet
  - Size and costs of SCR based on unit size, fuel usage, NOx removal efficiency, catalyst cost, energy and reagent consumption
  - Capital Costs annualized over 25 years at 4% interest rate
    - One SCR is 31 years old
    - One low NOx burner is 40 years old
  - 2017 annual reported emissions used to estimate reductions and baseline emissions
  - Modifications required to U.S. EPA spreadsheet to reflect cost of the refinery sector

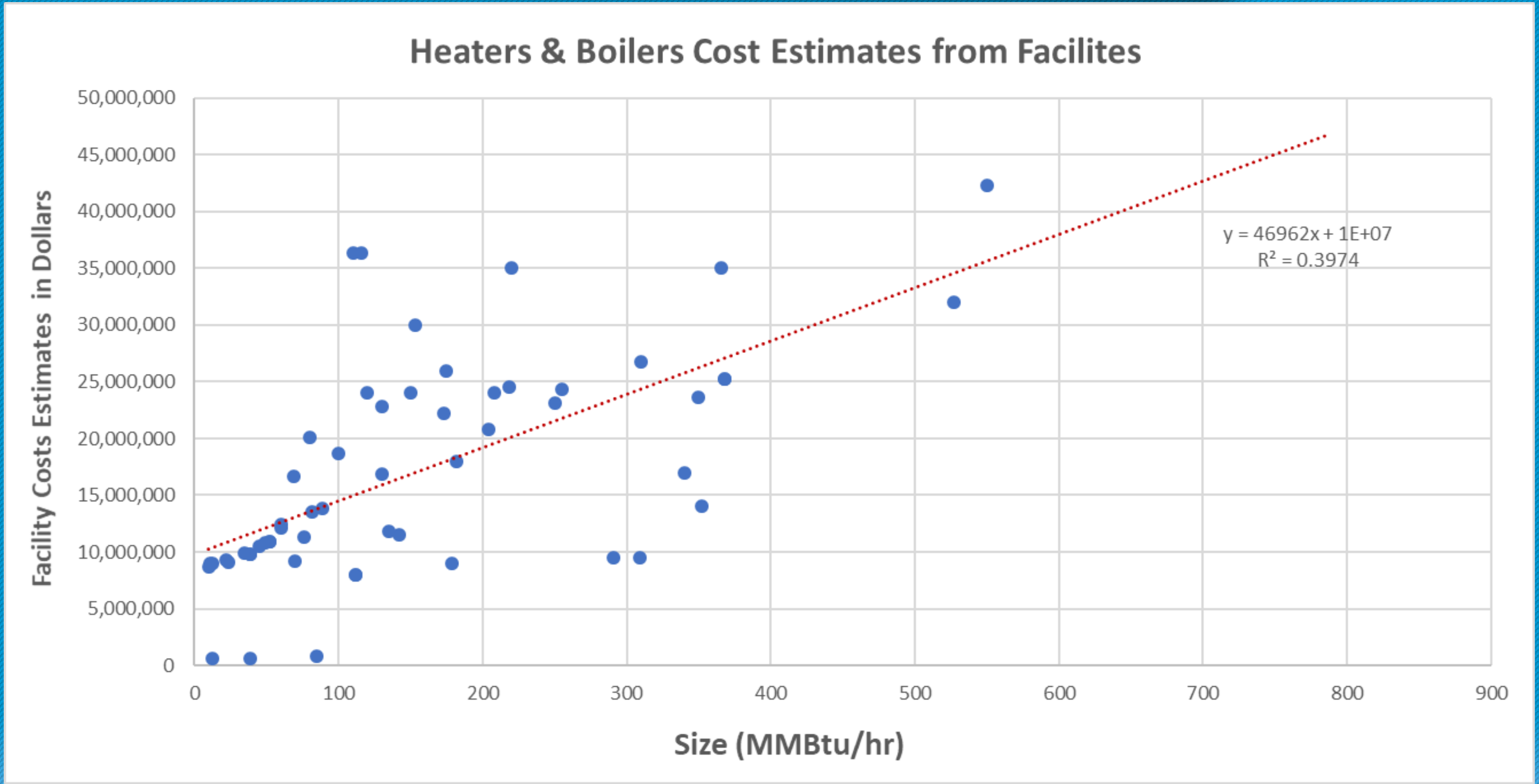
U.S. EPA cost spreadsheet (*cont.*)

- Staff agrees the model was designed for electric power sector, not the refinery sector
- Will modify model with actual costs from refinery stakeholders
- Norton Engineering 2015 BARCT assessment costs were factors based on material costs by one SCR manufacturer for a FCCU
  - Heaters and boilers cost based on process calculations then using 0.6 power law to prorate costs

SCR Cost Estimates from Stakeholders

- Facilities provided costs for 58 SCR projects
  - Some costs were project scope or conceptual estimates (+/- 50 %)
  - Some detailed costs estimate were provided which included a breakdown of engineering, material, electrical upgrades, and labor (+/- 10%)
  - Assumed costs received from facilities include equipment, tax, shipping, engineering, construction labor, and installation
  - Excluded any costs provided that were for catalyst replacements only
  - Escalated cost at 4% inflation for those not reported in 2018 dollar year

Facility provided SCR Cost Estimates



U.S. EPA SCR Cost Curve Update

- EPA cost calculations based on 0.6 power factor rule
- From facility submitted cost estimates, a new cost curve was generated and used to revise U.S. EPA SCR cost spreadsheet
- Cost more reflective of affected refineries
- Cost curve
  - $ per MMBtu/hr vs. heater size
  - Power curve fit
- Some cost were for multiple heaters venting to common SCR
  - For these heaters, summed the heat input for all heaters and divided by total costs
- New cost curve generated provides:
  - "N" the size exponent
  - "C_A" the known cost of equipment of corresponding size

$$C_B = C_A \left(\frac{S_B}{S_A} \right)^N$$

C_B = approximate cost of equipment having size S_B (MMBtu/hr, hp, scfm, etc.)

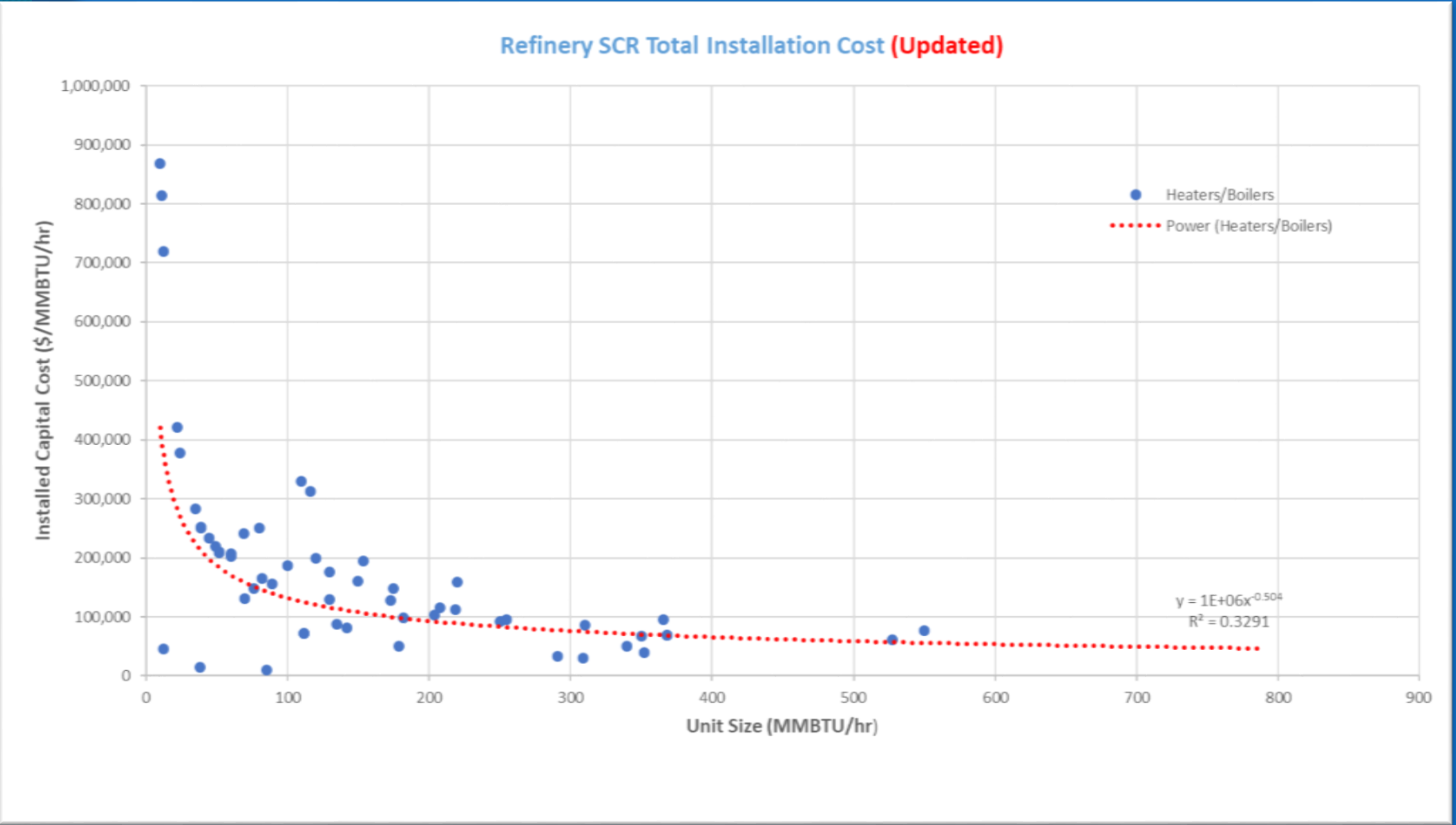
C_A = known cost($) of equipment having corresponding size S_A (same units as S_B)

(S_B/S_A) = ratio size factor

N = size exponent (varies 0.3 to >1.0, but average is 0.6)

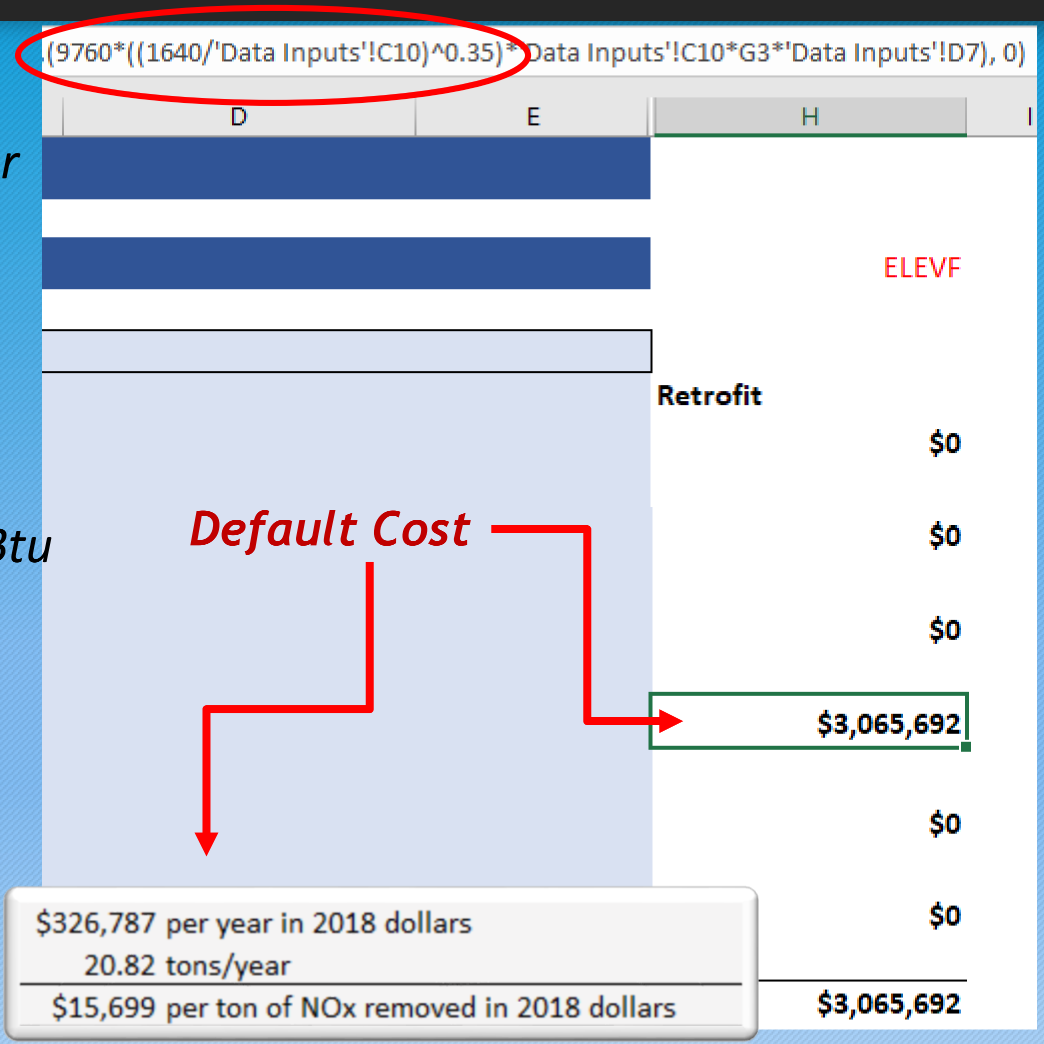
EPA SCR Model -Updated Cost Curve

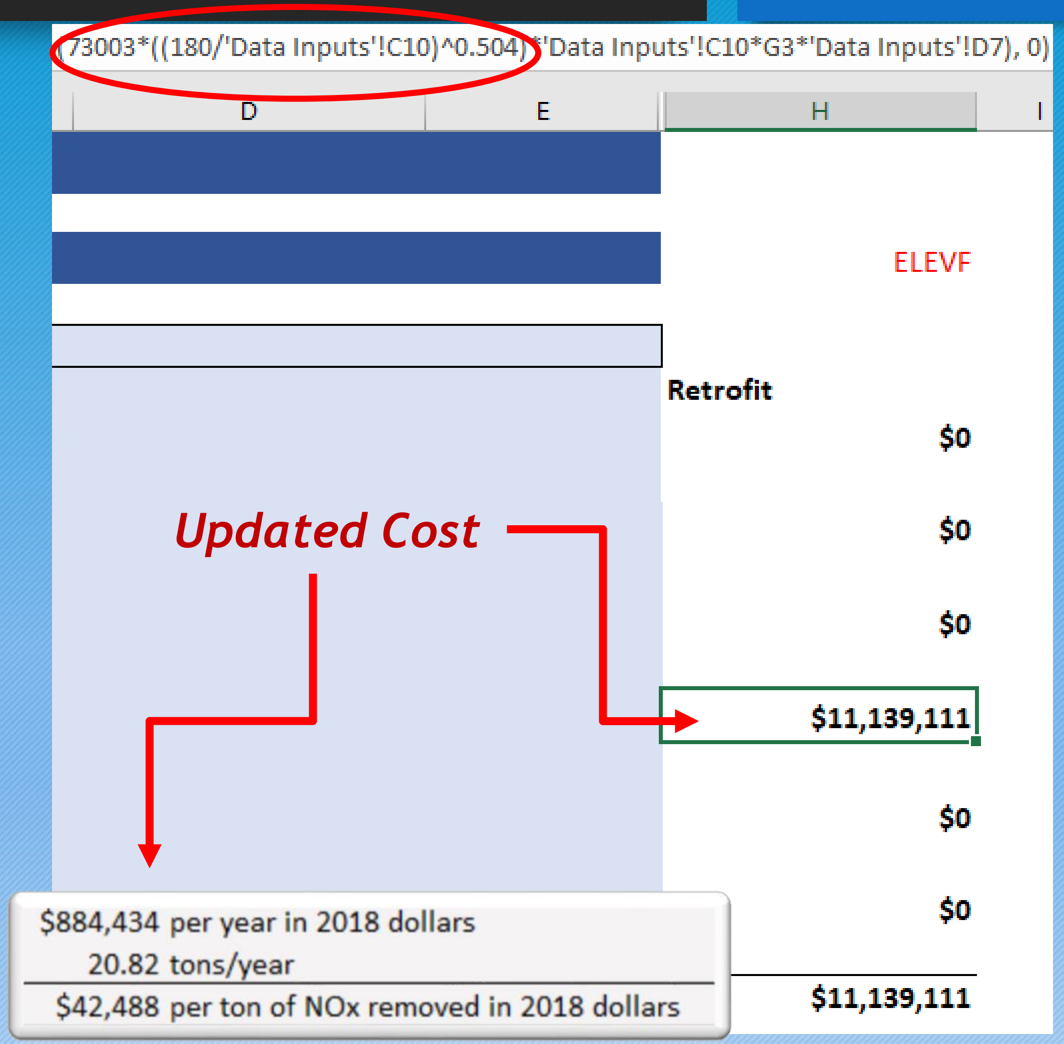
- From new cost curve,
  - Equation of trendline
    $y = 1{,}000{,}000x^{-0.504}$
    - Choose base heater size "x"
      180 MMBtu/hr
    - Solving equation for "y"
      $y = \$73{,}003$ per MMBtu/hr
    - *N* exponent
      $N = -0.504$
    - **New equation**
      $C_B = 73{,}003(180/C_B)^{0.504}$



EPA SCR Cost Model Example

Heater:
130 MMBtu/hr
Fuel:
Refinery Gas
HHV:
1,227 btu/scf
NOx:
0.062 lb/MMBtu
23 tons/year
Reduction:
95% (2 ppm)
Run time:
8,760 hours

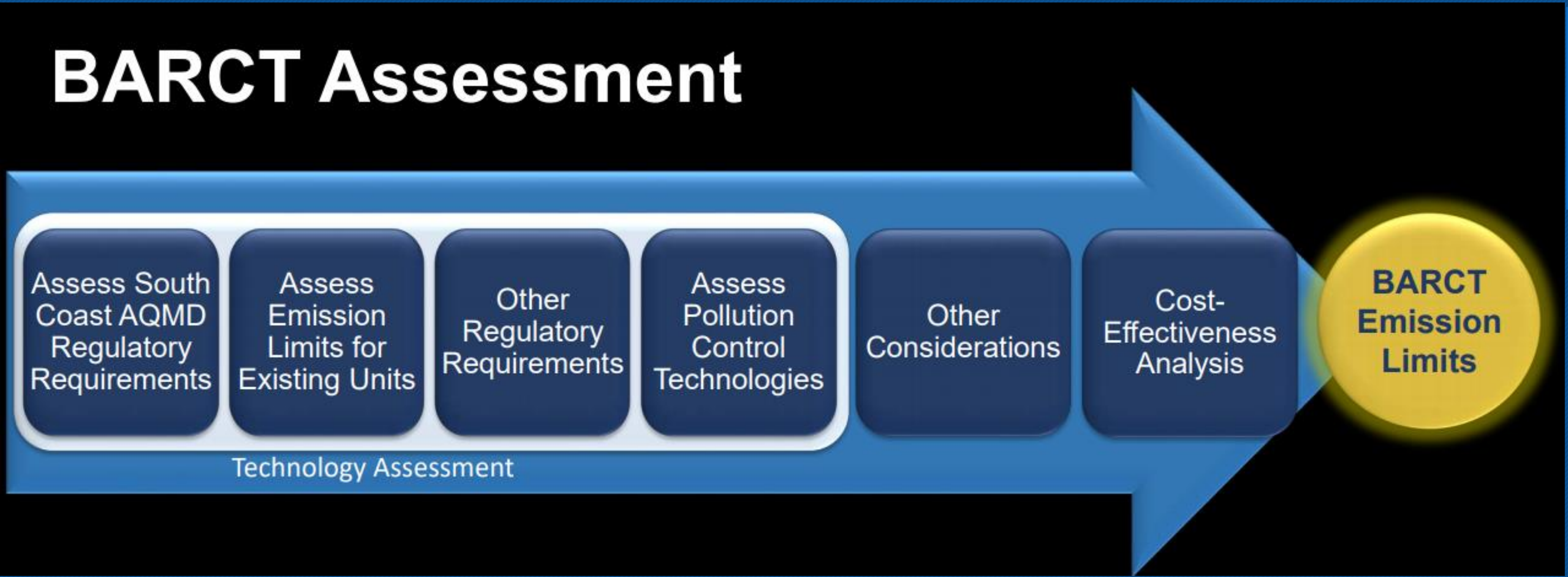




BARCT Assessment

BARCT

As defined by Sections 40406 and 40952, Chapter 10, Part 1, Division 26 of the Health and Safety Code, BARCT "means an emission limitation that is based on the maximum degree of reduction achievable, taking into account environmental, energy, and economic impacts by each class or category of source."



- BARCT analysis will be conducted for each equipment category
    - Equipment size
    - Fuel type
- Cost-effectiveness will look at outliers

NOx Control Technology

Revised

BARCT Assessment

Size (MMBTU/hr)	Equipped with LNB/ULNB	NOx Range (ppm)
<20	88%	20 to 40
20 to <40	90%	15 to 80
40 to 110	83%	17 to 70
>110	97%	22 to 70

- Burner control and SCR technology have advanced over the last 30 years
- Combination of burner control and SCR achieves the greatest NOx removal efficiency
  - Newer generation burner technology will reduce inlet NOx to SCR (< 30 ppm)
  - Latest SCR technology with proper design can achieve up to 96% removal efficiency (recent permit applications)
- Many units with an existing SCR installed can achieve further reductions through optimization
- Majority of units already have low-NOx (LNB) or ultra-low NOx (ULNB) burners installed
  - Recognize not all heaters are suitable for LNB/ULNB retrofitting, considerations may be needed for units that cannot be retrofitted with LNBs

Revised

Burner Technology Assessment

Current Burner Control Technology Observations (Refinery Gas)	
Premix or Raw Gas Burners	Highest NOx (75 to 134 ppm)
>25 years old (LNB/ULNB)	High NOx (60 to 80 ppm)
<25 years old (LNB/ULNB)	Low NOx (20 to 47 ppm)

- Since most units currently have LNB/ULNB, assume they are designed within API-560 (Fired Heaters) and API-535 (Burners) recommended guidelines for general refinery service
- Retrofitting or upgrading to latest generation LNB/ULNB should not require major modifications
- There may be some exceptions for burner upgrade
- Latest LNB/ULNB performance have improved overtime (achieve < 30 ppm)
- Based on recent retrofit installations, latest ULNB technology on refinery gas can achieve as low as 19 ppm (recent compliance test)

Revised

Emerging Technologies has potential to achieve even lower NOx emissions

ClearSign

ClearSign Core™ (formerly Duplex)

- <5 ppm achieved in practice using natural gas
- <5 ppm achieved in practice using refinery gas (<20 MMBtu/hr process heater)
- Natural and forced draft

JOHN ZINK HAMWORTHY COMBUSTION®

SOLEX

- ~5 ppm* demonstrated at test facility using natural gas
- Designed for refinery applications

Emerging Technology

*Refinery fuel gas may have higher emissions

SCR Technology Assessment

- SCR achieves the highest NOx removal efficiency
- Most mature and commercially available
- Proven control technology utilized throughout various types of industries
- Combined with proper engineering design, high NOx removal efficiency can be achieved
- Based on recent permit applications, retrofits with proper design can achieve up to 96% removal efficiency with one layer of catalyst
- Catalyst technology and performance has advanced over the last 30 years
- Existing SCR units can be upgraded to achieve greater reduction
  - System upgrades and/or optimizations
  - Cost will be less than installing new SCR
- Additional catalyst layers can help increase NOx removal efficiency if necessary

Managing Ammonia from SCRs

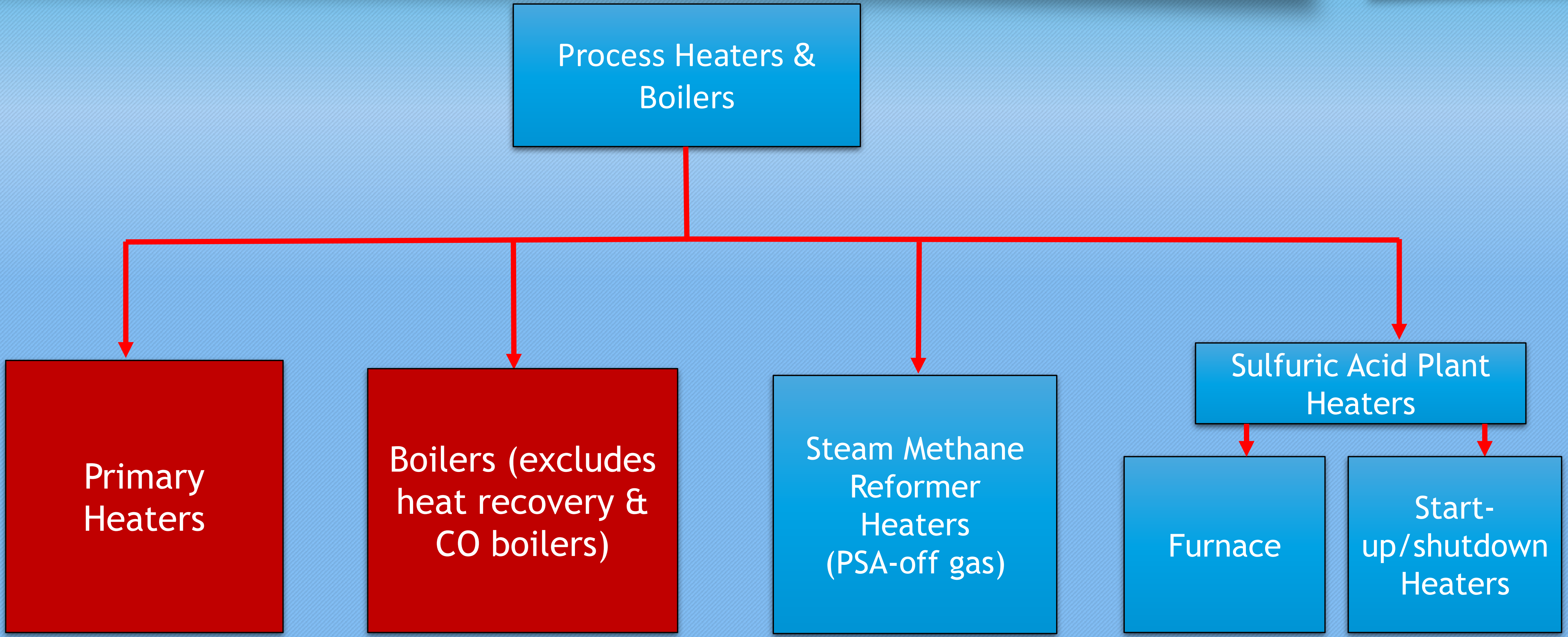
Catalyst manufacturers and system designers are utilizing flow modeling to improve ammonia injection and mixing design to achieve maximum NOx removal with minimal ammonia slip

Understanding and knowledge of ammonia injection design, tuning, and optimization have advanced over the last 30 years

Ammonia destruction catalyst is available and could be utilized if necessary

Heaters & Boilers BARCT Assessment

Heaters & Boilers by Category



BARCT Assessment Heaters <40 MMBtu/hr Using Refinery Gas

Technical Feasibility for Heaters <40 MMBtu/hr Using Refinery Gas

- Combination of SCR (95% reduction) and ULNB (< 30 ppm) can achieve 2 ppm
  - One equipped with burners and SCR achieving < 3 ppm NOx (shared SCR)
  - Burner control feasible for most units and will reduce inlet NOx emission to SCR
    - Existing heaters <40 MMBtu/hr already achieving between 14 to 40 ppm (2 units at 58 and 81 ppm)
    - 90% of existing heaters currently have LNB or ULNB, so spacing not anticipated to be major issue
- Emerging technology (ClearSign and SOLEX) has potential to achieve significant NOx reductions
  - < 9 ppm achievable using refinery gas

Initial BARCT NOx Limit for Heaters <40 MMBtu/hr Using Refinery Gas

	RECLAIM 2005 BARCT	Existing Units	Other Regulatory	Technology Assessment	Initial BARCT NOx Limit	Proposed BARCT NOx Limit
<20 MMBTU/hr	12 ppm	3 - 58 ppm	9 - 30 ppm	2 ppm	2 - 9 ppm	Need to conduct cost-effectiveness on initial BARCT NOx limit
20 to 40 MMBtu/hr	9 ppm	3 - 81 ppm	9 - 30 ppm	2 ppm	2 - 9 ppm	Need to conduct cost-effectiveness on initial BARCT NOx limit

Initial BARCT NOx Limits for Cost-Effectiveness Analysis (Heaters <40 MMBtu/hr Using Refinery Gas)

2 ppm

Combination of SCR (95% reduction) and ULNB (< 30 ppm)

9 ppm

Emerging Ultra-Low NOx Burners

Potential NOx BARCT Emission Limits

30 ppm

Commercially Available Ultra-Low NOx Burners

Potential Interim NOx Emission Limits

Emissions from this category are low:
Total NOx emission for heaters <40 MMBtu/hr is 0.55 tpd

Cost-Effectiveness Analysis for 2 ppm (Heaters <40 MMBtu/hr Using Refinery Gas)

Cost-Effectiveness at 2 ppm	
Heater Category	2 ppm
<20 MMBtu/hr	$307,808
20 to 40 MMBtu/hr	$84,476

- Combination of SCR (95% reduction) and ULNB (< 30 ppm) can achieve 2 ppm
- Evaluated two heater sizes:
  - < 20 MMBtu/hr
  - 20 to 40 MMBtu/hr
- Based on the U.S. EPA cost spreadsheet, NOx concentration limit of 2 ppm is not cost-effective at this time

Staff Recommendation

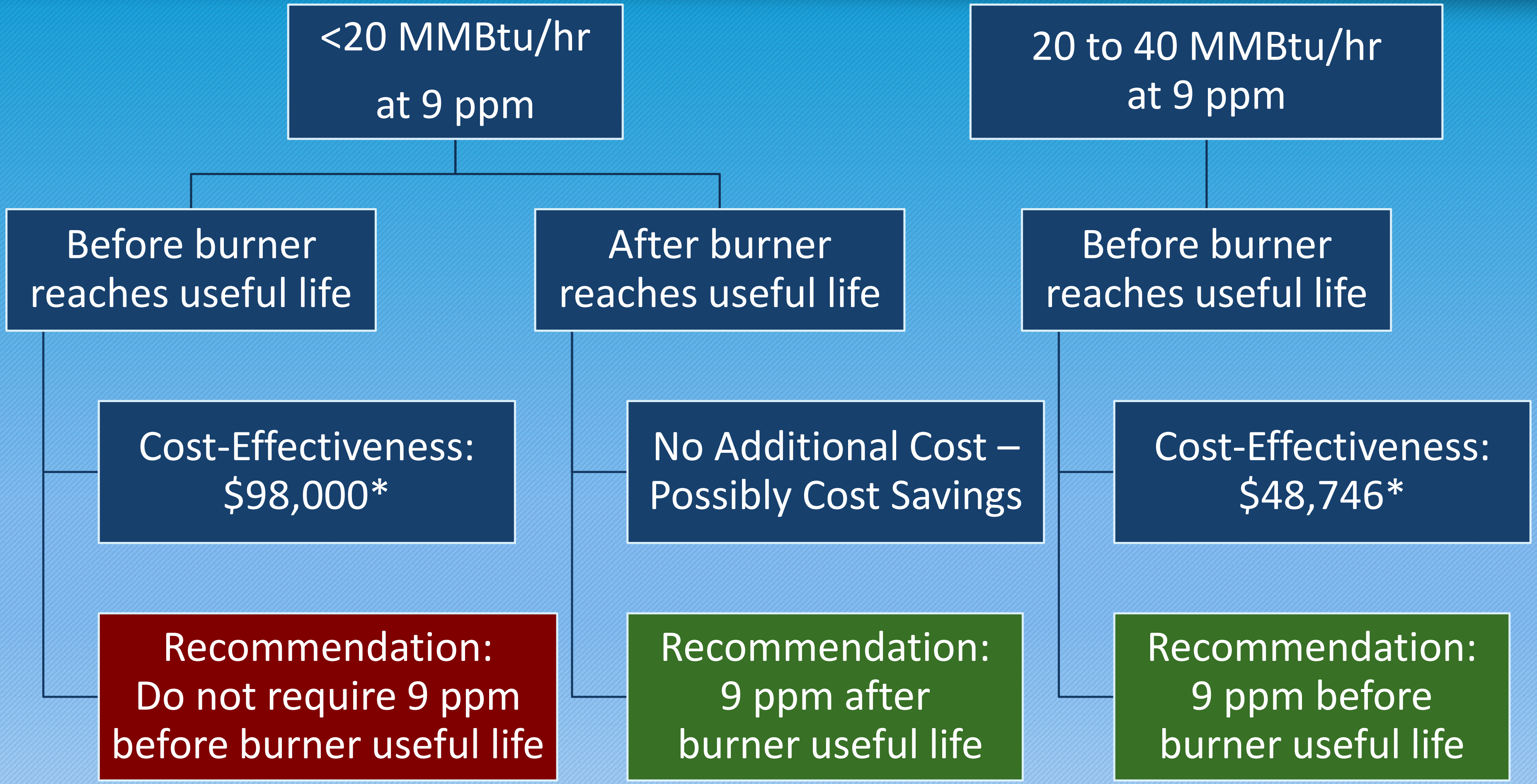
- 2 ppm is not cost-effective for heaters < 40 MMBtu/hr using refinery gas

Cost-Effectiveness Analysis for 9 ppm (Heaters <40 MMBtu/hr Using Refinery Gas)

Cost-Effectiveness at 9 ppm		
Heater Category	Burners Replaced Before Useful Life	Burners Replaced After Useful Life
<20 MMBtu/hr	$98,017	No cost increase, possibly savings
20 to 40 MMBtu/hr	$48,746	

- Evaluation of 9 ppm using refinery gas
  - Based on emerging technologies: ClearSign or SOLEX
  - Implementation schedule will need to account for technology development
- Evaluated two heater sizes:
  - < 20 MMBtu/hr
  - 20 to 40 MMBtu/hr
- For each of the heater sizes, evaluated two scenarios:
  - Burner replacement before useful life
  - Burner replacement after useful life, if replacement before useful life is not cost-effective
- Assumptions
  - ClearSign is <$1 MM
  - Used cost based on traditional low-NOx burner ~$2.2 MM (conservative assumption)
  - Assumed 25 years useful life

Staff Recommendation Regarding 9 ppm for Heaters <40 MMBtu/hr Using Refinery Gas



*Cost per ton of NOx reduced

Staff Recommendation

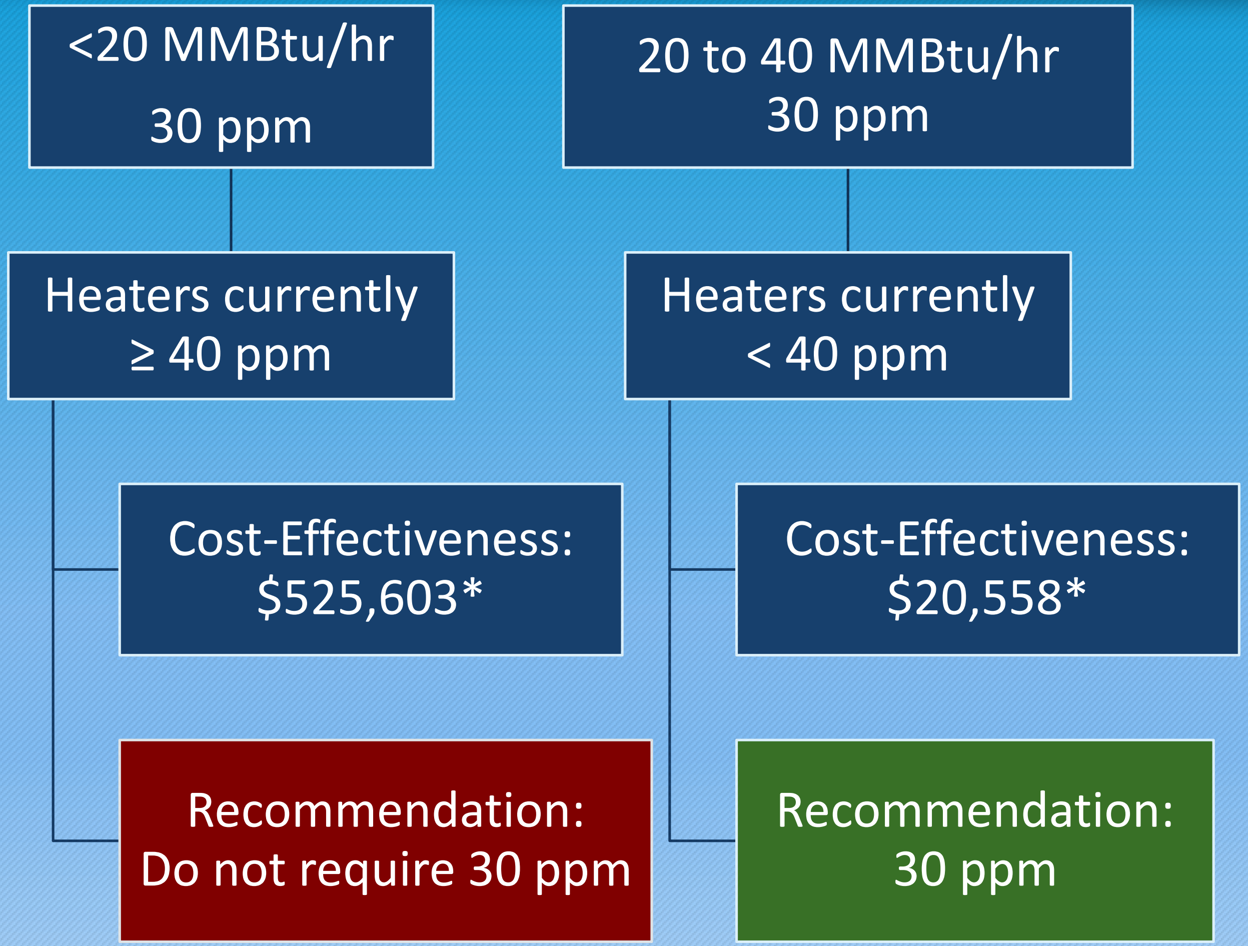
- 9 ppm *after* burner reaches useful life for heaters < 20 MMBtu/hr
- 9 ppm *before* reaches useful life for heaters 20 to 40 MMBtu/hr
- Need to establish effective date (9 ppm is emerging technology)

Cost-Effectiveness Analysis for 30 ppm (Heaters >40 PPM, <40 MMBtu/hr Using Refinery Gas)

Cost-Effectiveness at 30 ppm	
Heater Category	NOx Limit 30 ppm
<20 MMBtu/hr	$525,603
20 to 40 MMBtu/hr	$20,558

- Most heaters are achieving NOx concentration <40 ppm
- Three heaters with NOx concentrations > 40 ppm
  - 2 heaters are < 20 MMBtu/hr
  - 1 heater is 20 to 40 MMBtu/hr
- Commercially proven low-NOx burners can achieve < 30 ppm
  - Burner manufacturers will guarantee 30 ppm using refinery gas
- Evaluated cost-effectiveness of interim NOx concentration limit of 30 ppm for heaters currently > 40 ppm for two heater sizes:
  - < 20 MMBtu/hr
  - 20 to 40 MMBtu/hr
- Assumptions
  - Average cost for burners is $2.2 MM
  - Assumed 25 years useful life

Staff Recommendation Regarding Interim 30 ppm limit for Heaters Currently > 40 ppm, < 40 MMBtu/hr Using Refinery Gas



Staff Recommendation

- 30 ppm for heaters 20 to 40 MMBtu/hr that are > 40 ppm
- Interim limit would delay implementation of 9 ppm NOx limit
  - Additional discussion is needed

*Cost per ton of NOx reduced

Proposed BARCT NOx Limit for Heaters <40 MMBtu/hr Using Refinery Gas

	RECLAIM 2005 BARCT	Existing Units	Other Regulatory	Technology Assessment	Proposed BARCT NOx Limit*	
<20 MMBTU/hr	12 ppm	3 - 58 ppm	9 - 30 ppm	2 ppm	9 ppm* after burner useful life	23 heaters
20 to 40 MMBtu/hr	9 ppm	3 - 81 ppm	9 - 30 ppm	2 ppm	30 ppm for heaters > 40 ppm	1 heater
					9 ppm* before burner useful life	45 heaters

* Further discussion needed on implementation timeframe since 9 ppm is based on emerging technologies.

BARCT Assessment Heaters ≥40 MMBtu/hr Using Refinery Gas

Technical Feasibility for Heaters ≥40 MMBtu/hr Using Refinery Gas

- Combination of SCR (95% reduction) and ULNB (< 30 ppm) can achieve 2 ppm with proper engineering and design
  - Additional catalyst layers can help achieve further reductions
- Burner control feasible for most units and will reduce inlet NOx emission to SCR
  - 83% of heaters from 40 to 110 MMBtu/hr
  - 97% of heaters >110 MMBtu/hr
  - Moderate modifications required for burner upgrades

Initial BARCT NOx Limit for Heaters ≥40 MMBtu/hr Using Refinery Gas

	RECLAIM 2005/2015 BARCT	Existing Units	Other Regulatory	Technology Assessment	Initial BARCT NOx Limit	Cost-Effectiveness
≥40 to 110 MMBtu/hr	25/2 ppm	1.4 - 134 ppm	9 - 30 ppm	2 ppm	2 ppm	Need to conduct cost-effectiveness on initial BARCT NOx limit
>110 MMBtu/hr	5/2 ppm	1.5 - 70 ppm	9 - 30 ppm	2 ppm	2 ppm	Need to conduct cost-effectiveness on initial BARCT NOx limit

Initial BARCT NOx Limits for Cost-Effectiveness Analysis for Heaters ≥ 40 MMBtu/hr Using Refinery Gas

2 ppm

Combination of SCR (95% reduction) and ULNB (< 30 ppm)

Potential NOx BARCT Emission Limits

Emissions from this category are high:
Total NOx emission for heaters ≥ 40 MMBtu/hr is 5.24 tpd

Cost-Effectiveness Analysis for 2 ppm (Heaters ≥40 MMBtu/hr Using Refinery Gas)

Cost-Effectiveness at 2 ppm	
Heater Category	2 ppm
≥40 to 110 MMBtu/hr	$48,892
>110 MMBtu/hr	$40,682

- Burner costs included for units requiring >95% reduction from SCR
  - $2.8MM/unit for installation of ULNB
  - ULNB can achieve < 30 ppm
  - 14 units will require burner upgrades
- Cost-effectiveness calculated using U.S. EPA cost spreadsheet
  - Average cost-effectiveness of all heaters >40 MMBtu/hr < $50,000/ton NOx reduced
  - Units with existing SCR (37) not included in cost-effectiveness calculation
    - Assume new catalyst(s), ammonia injection grid upgrades, and tuning can improve removal efficiency
    - Will not require complete SCR retrofit installation
    - Cost will be less than a complete retrofit installation
    - Staff still evaluating costs and potential reductions for units with existing SCRs

Staff Recommendation Regarding 2 ppm for Heaters ≥40 MMBtu/hr Using Refinery Gas

≥40 to 110 MMBtu/hr at 2 ppm
- Cost-Effectiveness: $48,892*
  - Recommendation: 2 ppm

>110 MMBtu/hr at 2 ppm
- Cost-Effectiveness: $40,682*
  - Recommendation: 2 ppm

Staff Recommendation

- 2 ppm for heaters ≥ 40 MMBtu/hr

*Cost per ton of NOx reduced

Proposed BARCT NOx Limit for Heaters ≥40 MMBtu/hr Using Refinery Gas

	RECLAIM 2005 BARCT	Existing Units	Other Regulatory	Technology Assessment	Proposed BARCT NOx Limit	
≥40 to 110 MMBtu/hr	12 ppm	1.4 - 134 ppm	9 - 30 ppm	2 ppm	2 ppm	64 Units
>110 MMBtu/hr	9 ppm	1.5 - 70 ppm	9 - 30 ppm	2 ppm	2 ppm	50 Units

Heaters Summary (≥40 MMBtu/hr Using Refinery Gas)

- Staff proposing an initial NOx limit of 2 ppm
  - Challenging, but cost-effective
  - Technically feasible with proper engineering and design
- Considerations:
  - Units near proposed BARCT limit will not be required to retrofit at time of rule adoption (high cost/low emission reductions)
    - Retrofits at a future effective date or at end of control device’s useful life
  - Averaging time
  - Breakdown/start-up/shutdown provisions
  - Ammonia limit assessed during permitting process

BARCT Assessment for Boilers

BARCT Assessment Boilers <40 MMBtu/hr Using *Natural Gas*

Technical Feasibility for Boilers <40 MMBtu/hr

- Combination of SCR (95% reduction) and ULNB (< 30 ppm) can achieve 2 ppm
- Burner control feasible for most units and will reduce inlet NOx emission to SCR
  - All four natural gas boilers equipped with LNBs
    - Two <20 MMBtu/hr ~30 ppm NOx
    - Two 20 to <40 MMBtu/hr ~6.5 ppm NOx
- Emerging technology (ClearSign and SOLEX) has potential to achieve significant NOx reductions
  - <5 ppm achievable on natural gas
- One <40 MMBtu/hr boiler using refinery gas – not in service for past 5 years
  - Not included in this analysis

Initial BARCT NOx Limit for Boilers <40 MMBtu/hr Using Natural Gas

	RECLAIM 2005 BARCT	Existing Units	Other Regulatory	Technology Assessment	Initial BARCT NOx Limit	Cost-Effectiveness
<20 MMBTU/hr	12 ppm	32- 36 ppm	9 - 25 ppm	2 ppm	2 to 9 ppm	Need to conduct cost-effectiveness on initial BARCT NOx limit
20 to 40 MMBtu/hr	9 ppm	6 - 8 ppm	9 - 25 ppm	2 ppm	2 to 9 ppm	Need to conduct cost-effectiveness on initial BARCT NOx limit

Initial BARCT NOx Limits for Cost-Effectiveness Analysis for Boilers <40 MMBtu/hr Using Natural Gas

2 ppm	5 ppm	9 ppm
Combination of SCR (95% reduction) and ULNB (20 – 30 ppm)	Emerging Ultra-Low NOx Burners	Commercially proven LNB for Natural Gas

Emissions from this category are low:
Total NOx emission for natural gas boilers <40 MMBtu/hr is <u>0.13 tpd</u>

Cost-Effectiveness Analysis for 2, 5, and 9 ppm (Boilers <40 MMBtu/hr, Natural Gas)

Cost-Effectiveness at 2, 5, and 9 ppm			
Boiler Category	2 ppm	5 ppm*	9 ppm
<20 MMBtu/hr	$167,149	No additional Cost	$55,563
20 to 40 MMBtu/hr	$42MM	No additional Cost	$0 Achieved

* After burner useful life

- Combination of SCR (95% reduction) and ULNB (< 30 ppm) can achieve 2 ppm
  - SCR cost-estimates based on U.S. EPA cost spreadsheet with adjustments (previous slides)
- Evaluation of 5 ppm based on burner replacement after burner reaches useful life
- Evaluation of 9 ppm using natural gas based on use of LNB
- Evaluated two heater sizes:
  - < 20 MMBtu/hr
  - 20 to 40 MMBtu/hr
- Assumptions
  - Used cost based on traditional LNB burner ~$2 MM
  - Assumed 25 years useful life

Staff Recommendation Regarding 2, 5, and 9 ppm for Boilers <20 MMBtu/hr Using Natural Gas

<20 MMBtu/hr

- **2 ppm**
  - Cost-Effectiveness $167,000*
  - Recommendation Do not require 2 ppm
- **5 ppm (After burner reaches useful life)**
  - Cost-Effectiveness No Additional Cost – Possibly Cost Savings
  - Recommendation 5 ppm after burner reaches useful life
- **9 ppm**
  - Cost-Effectiveness $55,563*
  - Recommendation 9 ppm

Staff Recommendation

- 9 ppm for < 20 MMBtu/hr boilers using natural gas
- 5 ppm *after* boiler reaches useful life
- Need to establish effective date (5 ppm is emerging technology)

*Cost per ton of NOx reduced

Staff Recommendation Regarding 2, 5, and 9 ppm for Boilers 20 to 40 MMBtu/hr Using Natural Gas

20 to 40 MMBtu/hr

- 2 ppm
  - Cost-Effectiveness $42MM*
  - Recommendation Do not require 2 ppm
- 5 ppm (After burner reaches useful life)
  - Cost-Effectiveness No Additional Cost – Possibly Cost Savings
  - Recommendation 5 ppm after burner reaches useful life
- 9 ppm
  - Cost-Effectiveness $0, Achieved
  - Recommendation 9 ppm

Staff Recommendation

- 9 ppm for 20 to 40 MMBtu/hr boilers using natural gas
- 5 ppm *after* boiler reaches useful life
- Need to establish effective date (5 ppm is emerging technology)

*Cost per ton of NOx reduced

Proposed BARCT NOx Limit for Boilers <40 MMBtu/hr Using Natural Gas

	RECLAIM 2005 BARCT	Existing Units	Other Regulatory	Technology Assessment	Proposed BARCT NOx Limit*	
<20 MMBTU/hr	12 ppm	32- 36 ppm	9 - 25 ppm	2 ppm	9 ppm	2 Units
					5 ppm at burner replacement	
20 to 40 MMBtu/hr	9 ppm	6 - 8 ppm	9 - 25 ppm	2 ppm	9 ppm	2 Units
					5 ppm at burner replacement	

* Propose initial BARCT limit of 9 and future limit of 5 ppm at end of burner useful life

Boilers ≥40 MMBtu/hr BARCT Assessment

Technical Feasibility

- Combination of SCR (95% reduction) and ULNB (~ 30 ppm) can achieve 2 ppm
  - 2 ppm is a challenge, but is achievable with proper engineering and design
- Boilers can typically accommodate burner upgrades
  - Number of burners range from 1 to 5 (less than heaters of similar size)
  - Larger burners than those found in heaters
- 3 boilers (> 40 to 110 MMBtu/hr)
  - No NOx control
  - One primary and one stand-by (<5% capacity)
  - One not in service
- 20 Boilers (>110 MMBtu/hr)
  - 12 are currently equipped with LNB or ULNB.
  - 6 with SCR (one achieving <5 ppm)

Boilers Assessment (≥40 MMBtu/hr)

	RECLAIM 2005/2015 BARCT	Existing Units	Other Regulatory	Technology Assessment	Initial BARCT NOx Limit	Cost-Effectiveness
≥40 to 110 MMBtu/hr	25/2 ppm	68 - 80 ppm	5 - 9 ppm	2 ppm	2 ppm	Need to conduct cost-effectiveness on initial BARCT NOx limit
>110 MMBtu/hr	5/2 ppm	4.2 - 117 ppm	5 - 9 ppm	2 ppm	2 ppm	Need to conduct cost-effectiveness on initial BARCT NOx limit

Initial BARCT NOx Limits for Cost-Effectiveness Analysis for Boilers ≥ 40 MMBtu/hr Using Refinery Gas

2 ppm

Combination of SCR (95% reduction) and ULNB (< 30 ppm)

Potential NOx BARCT Emission Limits

Emissions from this category are high:
Total NOx emission for heaters ≥ 40 MMBtu/hr is ~2.5 tpd

Cost-Effectiveness Analysis for 2 ppm (Boilers ≥40 MMBtu/hr Using Refinery Gas)

Cost-Effectiveness at 2 ppm	
Heater Category	2 ppm
≥40 to 110 MMBtu/hr	\$36,578
>110 MMBtu/hr	\$31,461

- Burner costs included for units requiring >95% reduction from SCR
  - \$2.8MM/unit
  - NOx reduced to 30 ppm
  - 8 boilers will require burner upgrades
- Cost-effectiveness calculated using U.S. EPA cost spreadsheet
  - Average cost-effectiveness for all boilers ≥ 40 MMBtu/hr < \$50,000/ton NOx reduced
  - Units with existing SCR (7) not included in cost-effectiveness analysis
    - Assume new catalyst(s), ammonia injection grid upgrades, and tuning can improve removal efficiency
    - Will not require complete SCR retrofit installation
    - Cost will be less than a complete retrofit installation
    - Staff still evaluating cost and potential reductions for units with existing SCR

Staff Recommendation Regarding 2 ppm for Boilers ≥40 MMBtu/hr Using Refinery Gas

≥40 to 110 MMBtu/hr at 2 ppm

Cost-Effectiveness: $36,578*

Recommendation: 2 ppm

>110 MMBtu/hr at 2 ppm

Cost-Effectiveness: $31,461*

Recommendation: 2 ppm

<u>Staff Recommendation</u>

- 2 ppm for boilers ≥ 40 MMBtu/hr

*Cost per ton of NOx reduced

Boilers Assessment (≥40 MMBtu/hr)

	RECLAIM 2005/2015 BARCT	Existing Units	Other Regulatory	Technology Assessment	Proposed BARCT NOx Limit	
≥40 to 110 MMBtu/hr	25/2 ppm	68 - 80 ppm	5 - 9 ppm	2 ppm	2 ppm	3 Units
>110 MMBtu/hr	5/2 ppm	4.2 - 117 ppm	5 - 9 ppm	2 ppm	2 ppm	20 Units

Boilers Summary (≥40 MMBtu/hr Using Refinery Gas)

- Staff proposing an initial NOx limit of 2 ppm
  - Challenging, but cost-effective
  - Technically feasible with proper engineering and design
- Consideration:
  - Units near proposed BARCT limit will not be required to retrofit at time of adoption (high cost/low emission reductions)
    - Retrofit at a future effective date or at end of control device's useful life
  - Averaging time
  - Breakdown/start-up/shutdown provisions
  - Ammonia limit assessed during permitting process

Next Steps

- Working Group Meeting #10 to present proposed BARCT Limits for other categories
- Discussion of proposed BARCT Assessment and Limits
- Final Assessment Report from Consultants
- Rule Concepts
- Finalize BARCT Limits
- Draft Rule Language
- Public Workshop
- Governing Board (forecast for September 2020)

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