Proposed Rule 1150.3
Emissions of Oxides of Nitrogen from Combustion Equipment at Landfills

Working Group Meeting #3

November 6, 2019

Teleconference Information

Dial-In Number: 1-866-705-2554

Participant Passcode: 185381

Agenda

- Summary of Working Group Meeting #2
- Stakeholder Comments
- BARCT Assessment
  - Technology Assessment
    - Assessment of Pollution Control Technologies
  - Initial NOx Emission Limits and Other Considerations
  - Cost Effectiveness Analysis

Summary of Working Group Meeting #2

- Summary of Working Group Meeting #1
- Summary of Individual Stakeholder Meetings
- Proposed Rule Structure and Applicability
- BARCT Assessment
  - Assessment of Emission Limits for Existing Units
  - Other Regulatory Requirements

Stakeholder Comments

Engines

Comment: PR 1150.3 should include landfill gas engines that are currently regulated under Rule 1110.2; prefer all combustion equipment at landfills in one rule

Response:

- Rule 1110.2 has a provision that exempts landfill gas engines from Rule 1110.2 if a Regulation XI rule applicable to landfill gas engines is amended/adopted
- If landfill gas engines are included in PR 1150.3, then staff proposes to copy provisions and limits for landfill gas engines from Rule 1110.2 into PR 1150.3
  - New submittals and application fees will be required for equipment permits, I & M plans, and Title V permit revisions to update references from Rule 1110.2 to PR 1150.3 and respective requirements

Engines *(continued)*

Current Fiscal Year Permit Application Processing Fees		
Change	Non-Title V	Title V
Engine Permit *(per equipment)*	$962.75 - $4,319.40*	$1,206.41 - $5,412.63*
I & M Plan *(per plan/per facility)*	$725.60	$909.25
Title V Revision *(per facility)*	N/A	$1,518.26

Examples of Permit Application Processing Fees		
Change	Facility A (Non-Title V): Two Engines	Facility B (Title V): Seven Engines
Engine Permit	$1,925.50 - $8,638.80*	$8,444.87 - $37,888.41*
I & M Plan	$725.60	$909.25
Title V Revision	N/A	$1,518.26
Total Per Facility**	**$2,651.10 - $9,364.40***	**$10,872.38 - $40,315.92***

* Low end estimate represents fee for administrative change and high end estimate represents fee for change of condition

** Estimated fees only includes moving engines from Rule 1110.2 to PR 1150.3, does not include fees for any other equipment subject to PR 1150.3

- Staff will survey each facility on their preference of moving landfill gas engines from Rule 1110.2 to PR 1150.3
  - Each facility has their own unique financial limitations

Landfill Gas Equipment at Other Air Districts

Comment: Are there any existing landfill gas turbines or boilers located in other air districts that have a lower NOx emission limit?

Response:

- Researched equipment at San Joaquin Valley Air Pollution Control District (SJVAPCD) and Sacramento Metropolitan Air Quality Management District (SMAQMD), and found no existing landfill gas turbines or boilers
- In 2009, SMAQMD had a landfill gas boiler
  - Complied with SMAQMD Rule 411 limit of 15 ppmv*
  - 2009 source test result: 6.9 ppmv*
  - Boiler equipped with flue gas recirculation and ultra-low NOx burner
  - In 2010, boiler switched to 100% natural gas due to low landfill gas volume

*NOx concentrations are corrected at 3% $O_{2,}$ dry

Stranded Assets

Comment: PR 1150.3 should factor in stranded assets as landfill gas volume decreases when applying cost analysis

Response:

- Cost analysis will take into consideration the decommissioning of boilers and turbines due to landfill gas volume decreasing to levels in which equipment is no longer operational

Source Test Results

Comment: Consider high load versus low load when evaluating source test results

Response:

- Source test results presented in previous working group meetings were performed only at full or maximum achievable load for turbines and only at normal loads for boilers
- Staff will work with stakeholders on how to address low load operations

Transitional Period

Comment: Consider including a transitional time period for facilities to meet new rule requirements

Response:

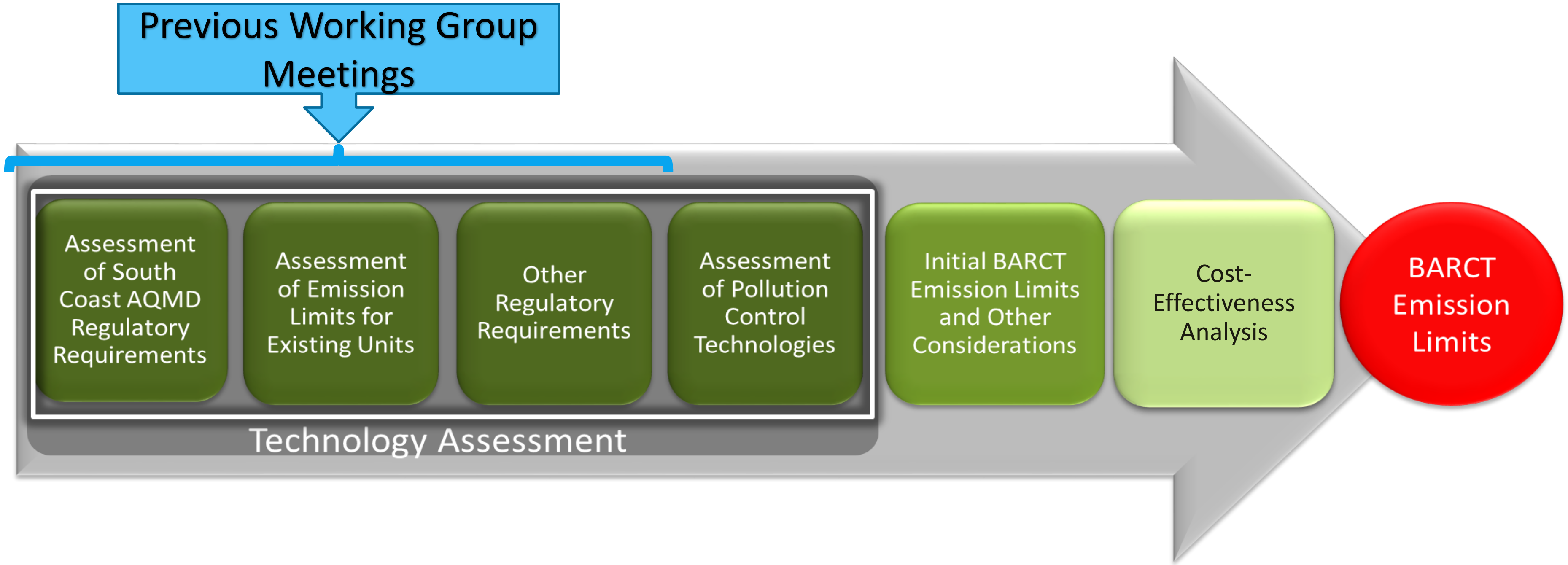
- Staff will work with stakeholders to develop the implementation timeframe
  - In addition to a final compliance date, PR 1150.3 may establish deadlines for submission of permits, source tests, etc.
  - Implementation dates will take into consideration the complexity of control technologies, unit size, the number of units at one facility, etc.

- Staff encourages stakeholders to reach out and discuss unique facility challenges that may affect implementation

Continuing BARCT Assessment: Technology Assessment

BARCT Assessment: Technology Assessment

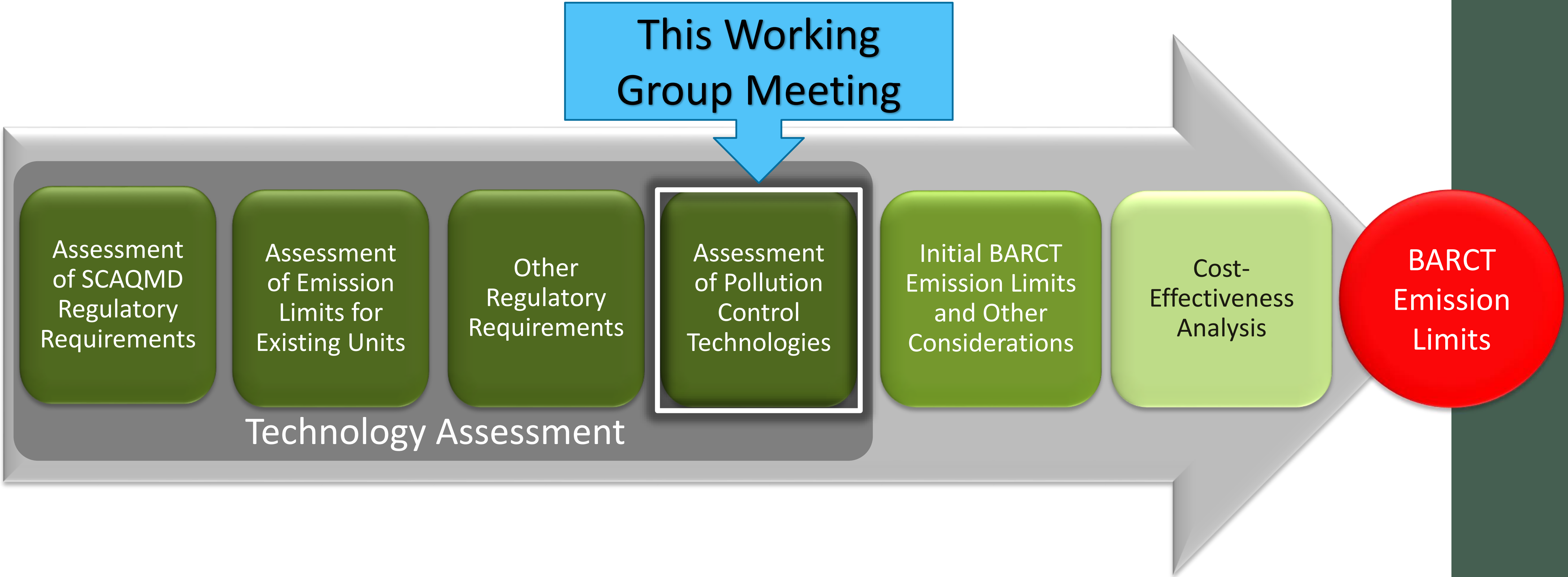
- Four steps in the BARCT technology assessment, each step works towards identifying possible BARCT emission limits, steps include assessment of:
  1. South Coast AQMD regulatory requirements
  2. Emission limits for existing units
  3. Other regulatory requirements
  4. Pollution control technologies



BARCT Assessment: Technology Assessment

- Technology assessment is specific to the equipment category, fuel type, and may take into account size and application of the equipment
- An initial BARCT emission limit is recommended based on the technology assessment and other considerations
  - A cost-effectiveness analysis will be performed for each initial BARCT emission limit
  - Based on cost-effectiveness, the recommended BARCT emission limit may be revised from initial BARCT emission limit

BARCT Assessment



*BARCT analysis is conducted for each equipment category and fuel type

Assessment of Pollution Control Technologies

- Assessed siloxane removal technology for gas treatment systems
- Assessed NOx controls and technological feasibility for:
  - Landfill gas boilers
  - Landfill gas turbines
  - Landfill gas microturbines
- Sources used for researching pollution control technologies
  - Scientific literature
  - Vendor information
  - Systems used in practice

Landfill Gas Treatment System

- Gas treatment technology removes siloxanes, moisture, hydrogen sulfide, and other undesirable contaminants
- Removal of siloxanes from landfill gas is important for equipment and control technology to work efficiently and to prevent damage

Three primary types of systems for siloxane removal		
Consumable Media	Regenerative Media	Chiller/Adsorption
Each system can utilize different media or a combination of media		

Characteristics of Media

- Effectiveness of siloxane removal depends on media characteristics and contaminants in gas stream
- Common types of media
  - Activated carbon
    - Versatile adsorbent with highly porous and large surface area, suitable to adsorb organic molecules (e.g. siloxanes)
  - Molecular sieve
    - Adsorbent with pores of uniform size, capable of performing selective removal of contaminants at low concentrations (e.g., water molecules, siloxanes, CO2, and/or H2S)
  - Silica gel
    - Shapeless and porous adsorbent, with siloxane adsorption capacity about 10 times greater than activated carbon and has high affinity for water

Consumable Media

- Commonly used with activated carbon as media and stored in a series of parallel canisters
  - Activated carbon media adsorbs siloxanes and many other contaminants
  - Canisters are changed out after carbon is saturated and siloxanes begin to break through
  - Activated carbon media is quickly saturated due to adsorption of the many other contaminants, causing frequent change
    - Frequency of media change depends on gas treatment system design
    - Initial installment and maintenance cost are typically less than regenerative and chiller media systems due to the lack of complex machinery
    - Removal and disposal of media can have a significant cost[1]
- Removal efficiency depends on gas content and system design

[1]https://www.aqmd.gov/docs/default-source/rule-book/support-documents/rule-1110_2/aqmd-contract-13432-final-report-2014---revised.pdf?sfvrsn=2

Regenerative Media

- Different types of regenerative media may include molecular sieve, silica gel, clay, and zeolite
  - System consists of at least two media canisters in parallel – one canister remains online and processes the landfill gas while one canister remains offline to regenerate media with hot purged air (typically above 300˚F)
  - Typical online and purge cycle times vary
  - Media change out varies based on gas treatment system design
    - Spent media is non-hazardous and may be landfilled
  - Due to media being regenerative, size of canisters and quantity of adsorbent is far less than required if using consumable media

Regenerative Media *(continued)*

- Regenerative media can be enhanced by applying polymeric resins
  - Increases service life
  - Higher adsorbent capacity
  - Contaminants removed more quickly from during regeneration
  - Regenerates at a lower temperature
- Higher installation cost than consumable system due to complex system design[1]
  - Disposal and removal costs are similar to consumable media
- Removal efficiency depends on gas content and system design

[1] https://www.aqmd.gov/docs/default-source/rule-book/support-documents/rule-1110_2/aqmd-contract-13432-final-report-2014---revised.pdf?sfvrsn=2

Chiller/Adsorption

- System consists of reducing temperature of the landfill gas to below dew point to condense out any moisture and siloxanes
  - Adsorbent media can then be used as a polishing filter to remove remaining traces of siloxanes and other contaminants
- Initial installation and maintenance costs are similar to regenerative media systems[1]
  - Chiller/adsorption system is used in combination with consumable media system
  - Disposal and removal costs are similar to consumable media
- Chiller/adsorption systems (40˚F) can remove 30 to 50% of siloxanes (case study)
- Advanced chiller/adsorption systems (lower temperature) can remove up to 95% siloxanes (case study)

[1] https://www.aqmd.gov/docs/default-source/rule-book/support-documents/rule-1110_2/aqmd-contract-13432-final-report-2014---revised.pdf?sfvrsn=2

Current Applications of Landfill Gas Treatment Systems

- Gas treatment systems may be combined to increase siloxane removal efficiency
  - Silica gel with chiller/adsorption system has shown a siloxane removal efficiency of ≥ 98%
- Facilities that use selective catalytic reduction (SCR) would require the removal of siloxanes down to levels that can allow SCR catalyst to be sustained
- Currently 14 landfill gas turbines are using at least one of the three primary system types for siloxane removal
- Currently no landfill gas boilers are using any type of gas treatment system
  - Landfill gas boilers with a SCR unit would require the use of a gas treatment system

Gas Treatment Systems Currently Utilized				
Facility	Number of Turbines	Consumable Media	Regenerative Media	Chiller/ Absorption
A	2		√	
B	3	√		√
C	4		√	√
D	5	√	√	

NOx Control Technologies for Landfill Gas Boilers

Combustion Controls	Post-Combustion Controls
Flue Gas Recirculation*	Selective Catalytic Reduction (SCR) with Gas Treatment System
Low-NOx Burners*	Selective Non-Catalytic Reduction
Ultra-Low NOx Burners*	
Overfire Air	

* Primary control approach for landfill gas boilers

NOx Control Technologies for Landfill Gas Turbines

Combustion Controls	Post-Combustion Controls
Lean Premixed Combustion*	Selective Catalytic Reduction (SCR) with Gas Treatment System*
Steam/Water Injection*	

* Primary control approaches for landfill gas turbines

NOx Control Technologies for Landfill Gas Microturbines

Combustion Controls	Post-Combustion Controls
Lean Premixed Combustion*	Selective Catalytic Reduction (SCR) with Gas Treatment System
Steam/Water Injection**	

* Primary control approach for landfill gas microturbines

** For a recuperated microturbine system only

Flue Gas Recirculation (Boilers)

- Hot combustion exhaust products are taken out of the flue and recirculated back into the furnace
  - Helps to preheat incoming combustion air and lowers combustion zone temperature; reduces NOx formation
  - Reduces NOx by 30 – 55% (~ 24 ppmv*)
- Considerations
  - Deliberate replacement of combustion air with low oxygen flue gases, reduces efficiency (capacity loss)
  - Potential flame instability can make flame shape difficult to adjust in furnaces, causing damage to boiler or burner

* At 3% O_2, dry

Low-NOx/Ultra-Low NOx Burners (Boilers)

- Controls fuel and air mixing at the burner reducing the peak flame temperature and therefore, less NOx is formed
  - Low-NOx burners reduces NOx by 60% (~ 15 ppmv*)
  - Ultra-low NOx burners reduces NOx by 80% (~ 9 ppmv*)
- Considerations
  - Retrofits to an existing boiler may require complex engineering and design

* At 3% O_2, dry

Lean Premixed Combustion (Turbines and Microturbines)

- Prior to combustion, gaseous fuel and compressed air are premixed, minimizing localized hot spots that produce elevated combustion temperatures and therefore, less NOx is formed
- Reduces NOx to ~ 9 ppmv*
- Considerations
  - Requires that the combustor becomes an intrinsic part of the turbine design
  - Not available as a retrofit technology; must be designed for each turbine application

* At 15% O_2, dry

Water/Steam Injection (Turbines)

- Injection of water or steam into high temperature flame zone, lowering combustion zone temperature and reducing NOx formation
  - Water injection reduces NOx by 80 – 95% (~ 25 ppmv*)
  - Steam Injection reduces NOx by 70 – 85% (~ 25 ppmv*)
- Addition of water or steam increases mass flow through the turbine and creates a small amount of additional power
- Considerations
  - Water needs to be demineralized, which adds cost and complexity
  - Imprecise application leads to some hot zones with higher NOx levels
  - Increases CO and VOC emissions
  - Increased fuel use

* At 15% O_2, dry

Selective Catalytic Reduction (Boilers and Turbines)

- Selective catalytic reduction (SCR) is primary post-combustion technology for NOx reduction[1]
  - Used in turbines, boilers, internal combustion engines (including heavy duty trucks), and other NOx generating equipment for all gas types including landfill gas and natural gas
  - Ammonia is injected into the exhaust gas, which passes through the catalyst reactor, resulting in the reduction of NOx
    - Reduces NOx by 90 – 95%
      - ~ 5 ppmv* for landfill gas boilers
      - ~ 2.5 ppmv** for simple cycle landfill gas turbines
      - ~ 2 ppmv** for combined cycle landfill gas turbines
- May be used simultaneously with combustion control technologies

[1] https://www.epa.gov/sites/production/files/2017-12/documents/scrcostmanualchapter7thedition_2016revisions2017.pdf

* At 3% O_2, dry

** At 15% O_2, dry

Selective Catalytic Reduction *(continued)*

- Considerations
  - Gas treatment system is needed to remove siloxanes and other contaminants
    - Catalyst susceptible to fouling if flue gas contains contaminants (e.g. particulates, sulfur compounds, siloxanes, etc.)
  - Requires on-site storage of ammonia, a hazardous chemical
    - Pure anhydrous ammonia is extremely toxic and no new permits issued
    - Aqueous ammonia is somewhat safer but requires vaporization of water
    - Urea is safer to store, but requires conversion to be used
  - Potential for ammonia slip where unreacted ammonia is emitted from control device
  - Limited by its range of optimum operating temperature conditions (e.g. 400 to 800˚F for conventional SCR)
  - Facilities may be space constrained to add more catalyst modules

Summary of Control Technologies

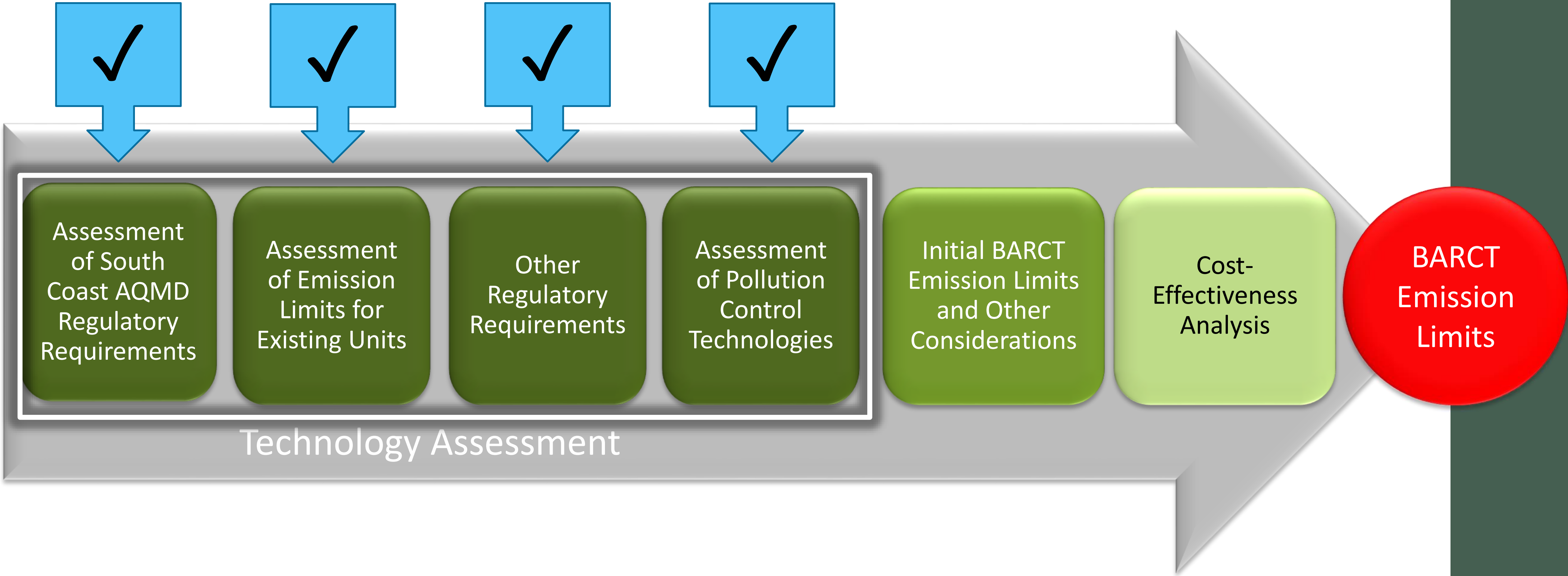
Five major strategies identified to reduce NOx emissions from gas boilers, turbines, and microturbines

- Combustion controls for boilers
  - Flue gas recirculation
  - Low-NOx/Ultra-low NOx burners
- Combustion controls for turbines
  - Lean premixed combustion
  - Steam/water injection
- Exhaust controls
  - Selective Catalytic Reduction
    - Biogas (landfill and digester gas) turbines using SCR require substantial gas pretreatment to remove trace contaminants that can poison the catalyst[1]
    - Catalytic control technologies may be inappropriate for landfill and digester gas turbines[1]

[1]https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s01.pdf

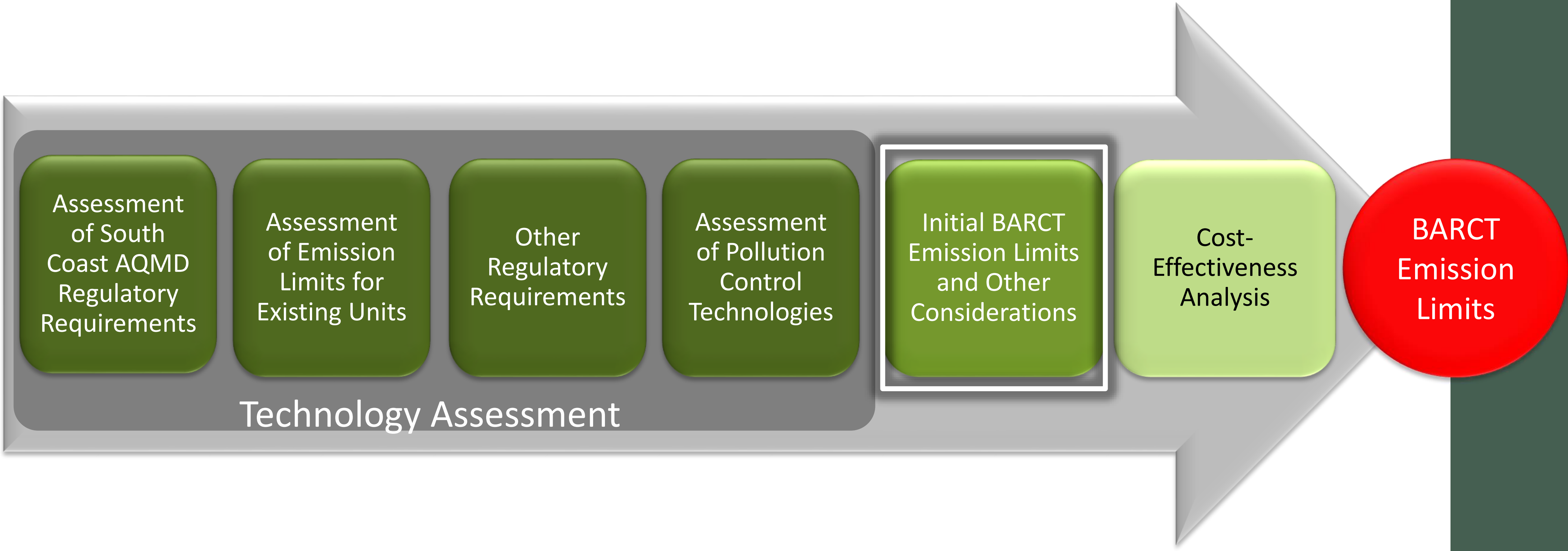
BARCT Assessment: Initial BARCT Emission Limits and Other Considerations

BARCT Assessment



*BARCT analysis is conducted for each equipment category and fuel type

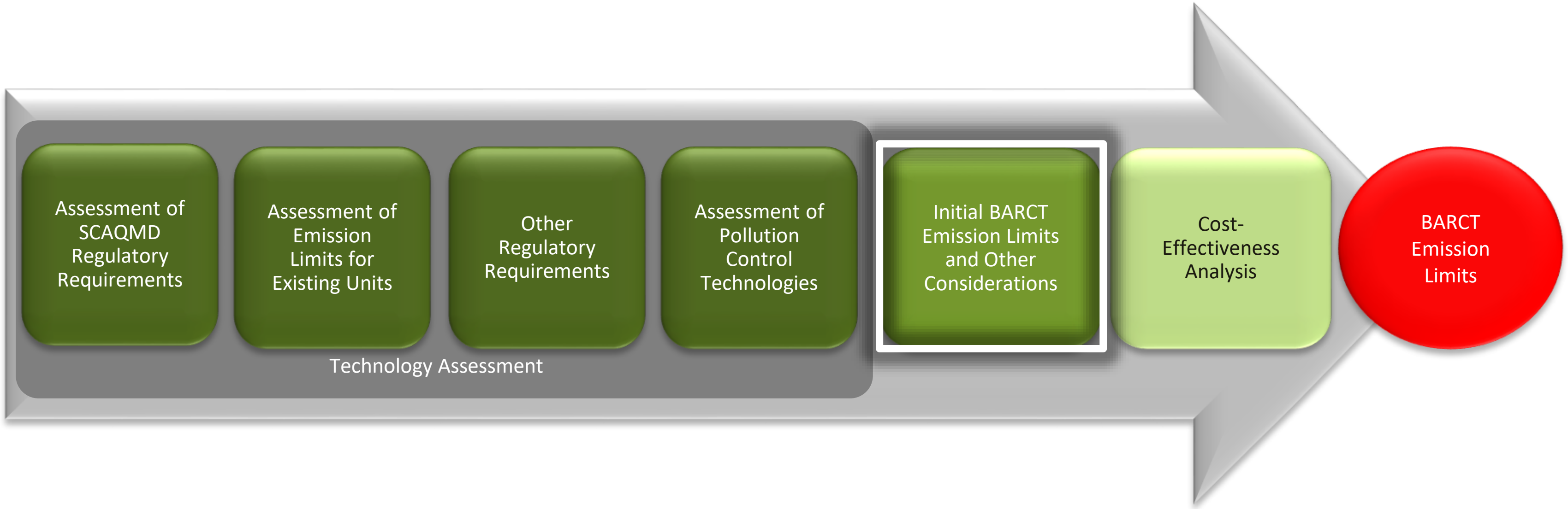
BARCT Assessment



*BARCT analysis is conducted for each equipment category and fuel type

Initial BARCT Emission Limits and Other Considerations

- Each step of the technology assessment works towards identifying possible BARCT emission limits
- An initial BARCT emission limit is recommended based on the technology assessment and other considerations
    - A cost-effectiveness analysis will be performed for each initial BARCT emission limit
    - Based on cost-effectiveness, the recommended BARCT emission limit may be revised from initial BARCT emission limit



Landfill Gas Boilers

	South Coast AQMD Regulatory Requirements	Source Test Results	Other Regulatory Requirements	Pollution Control Technologies	Initial BARCT Emission Limits
Retrofit*	21 – 24 ppmv	N/A	5 – 15 ppmv	5 ppmv	5 ppmv**
New Install*	21 – 24 ppmv	16.8 – 22 ppmv	5 – 15 ppmv	5 ppmv	5 ppmv**

* At 3% O_2, dry

** Cost effectiveness analysis will take into consideration cost of landfill gas treatment system and operating and maintenance of the SCR

Updated

Landfill Gas Simple Cycle Turbines

	South Coast AQMD Regulatory Requirements	Source Test Results	Other Regulatory Requirements	Pollution Control Technologies	Initial BARCT Emission Limits
Retrofit*	12.5 – 18.5 ppmv	N/A	5 – 25 ppmv	2.5 ppmv	2.5 ppmv**
New Install*	12.5 – 18.5 ppmv	3.1 – 7.6 ppmv	5 – 25 ppmv	2.5 ppmv	2.5 ppmv**

* At 15% O_2, dry

** Cost effectiveness analysis will take into consideration cost of landfill gas treatment system and operating and maintenance of the SCR

Updated

Landfill Gas Combined Cycle Turbines

	South Coast AQMD Regulatory Requirements	Source Test Results	Other Regulatory Requirements	Pollution Control Technologies	Initial BARCT Emission Limits
Retrofit*	25 ppmv	N/A	5 – 25 ppmv	2 ppmv	2 ppmv**
New Install*	25 ppmv	22.5 – 23.8 ppmv	5 – 25 ppmv	2 ppmv	2 ppmv**

* At 15% O_2, dry

** Cost effectiveness analysis will take into consideration cost of landfill gas treatment system and operating and maintenance of the SCR

Landfill Gas Microturbines

	South Coast AQMD Regulatory Requirements	Source Test Results	Other Regulatory Requirements	Pollution Control Technologies	Initial BARCT Emission Limits
Retrofit*	9 ppmv	N/A	N/A	9 ppmv	9 ppmv
New Install*	9 ppmv	N/A	N/A	9 ppmv	9 ppmv

* At 15% O_2, dry

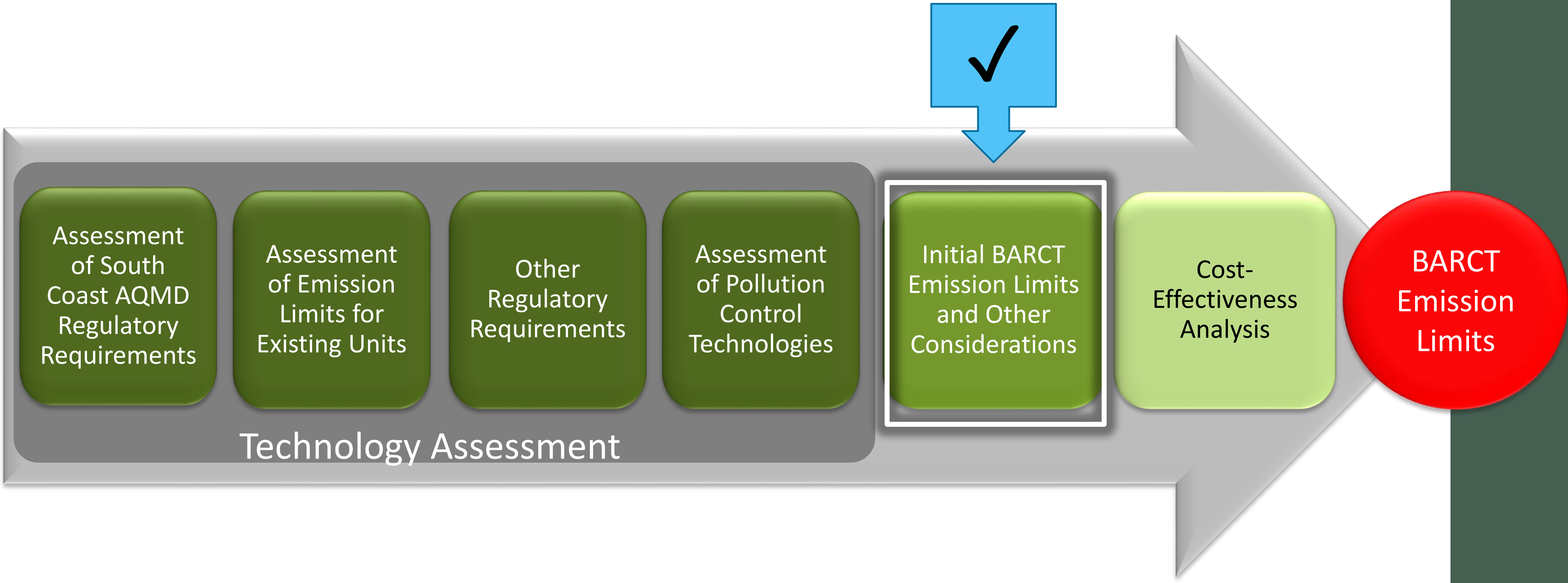
Initial BARCT NOx Emission Limits

- Initial BARCT NOx emission limits based technology assessment:

Boilers	Simple Cycle Turbines	Combined Cycle Turbines	Microturbines
5 ppmv @ 3% O_2	2.5 ppmv @ 15% O_2	2 ppmv @ 15% O_2	9 ppmv @ 15% O_2

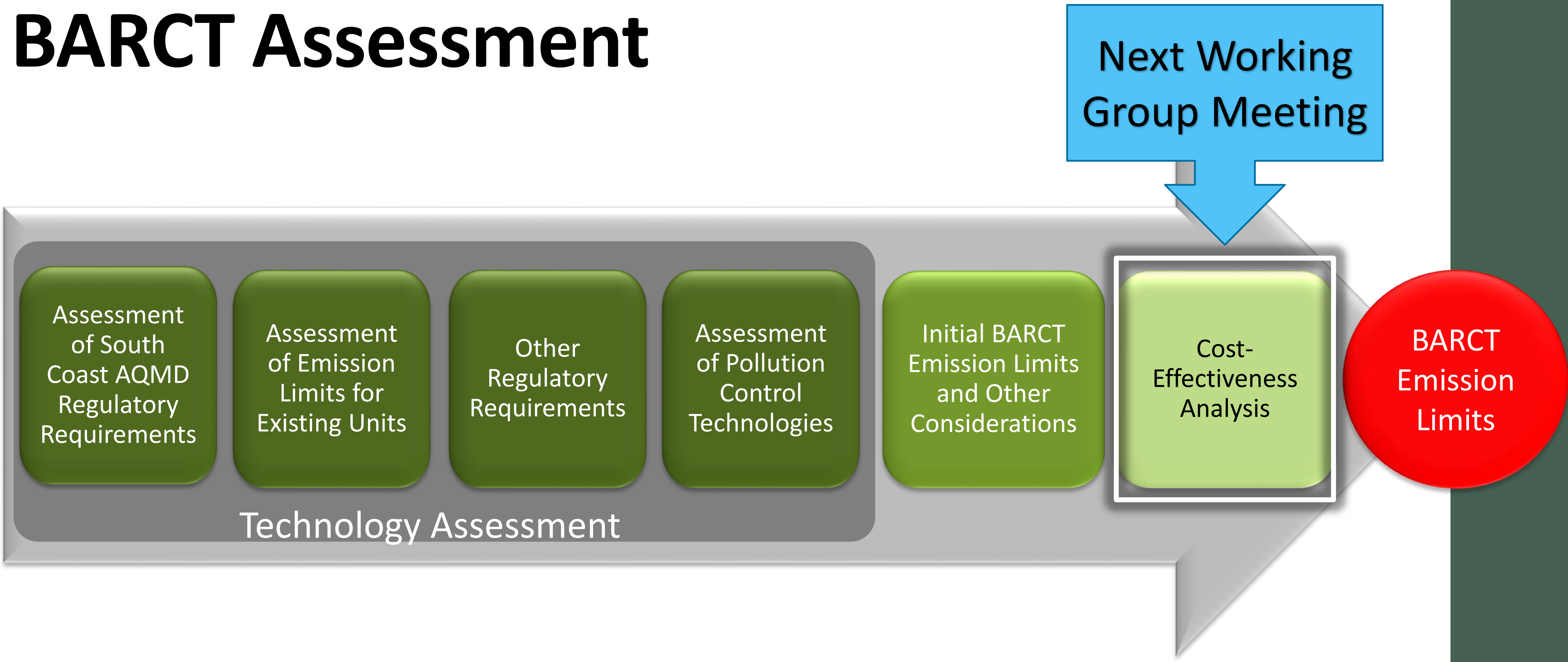
- Cost effective analysis is still needed to determine final BARCT emission limit
  - Landfill gas treatment costs will be included, if needed

BARCT Assessment



*BARCT analysis is conducted for each equipment category and fuel type

BARCT Assessment



*BARCT analysis is conducted for each equipment category and fuel type

Cost Effectiveness Analysis

Updated

Cost Effectiveness Analysis

- Cost-effectiveness analysis includes:
  - Annual fuel usage, NOx emissions, and emission factors based on annual emission reports submitted to the South Coast AQMD
- Costs to be estimated using:
  - U.S. EPA's Air Pollution Control Cost Calculation Spreadsheet for Selective Catalytic Reduction[1]
    - Used to estimate the capital and annual costs for SCRs
  - South Coast AQMD's Biogas Cleanup System Cost Estimator Tool Kit Training and User Instruction Manual[2]
    - Used to estimate the capital and annual cost for gas treatment systems
  - Costs from stakeholders and vendors shared with staff
    - Staff encourages stakeholders to reach out and discuss costs pertaining to their facilities

[1]https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-reports-and-guidance-air-pollution

[2]http://www.aqmd.gov/docs/default-source/rule-book/support-documents/rule-1110_2/biogas-toolkit-cost-estimator.xls?sfvrsn=2

Schedule

Rule Schedule

Action	Target Dates
Next Working Group Meeting	4 – 6 Weeks
Public Hearing	1st Quarter of 2020

Contacts

Contacts

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