Marginal abatement cost curves for NOx that account for renewable electricity, energy efficiency, and fuel switching

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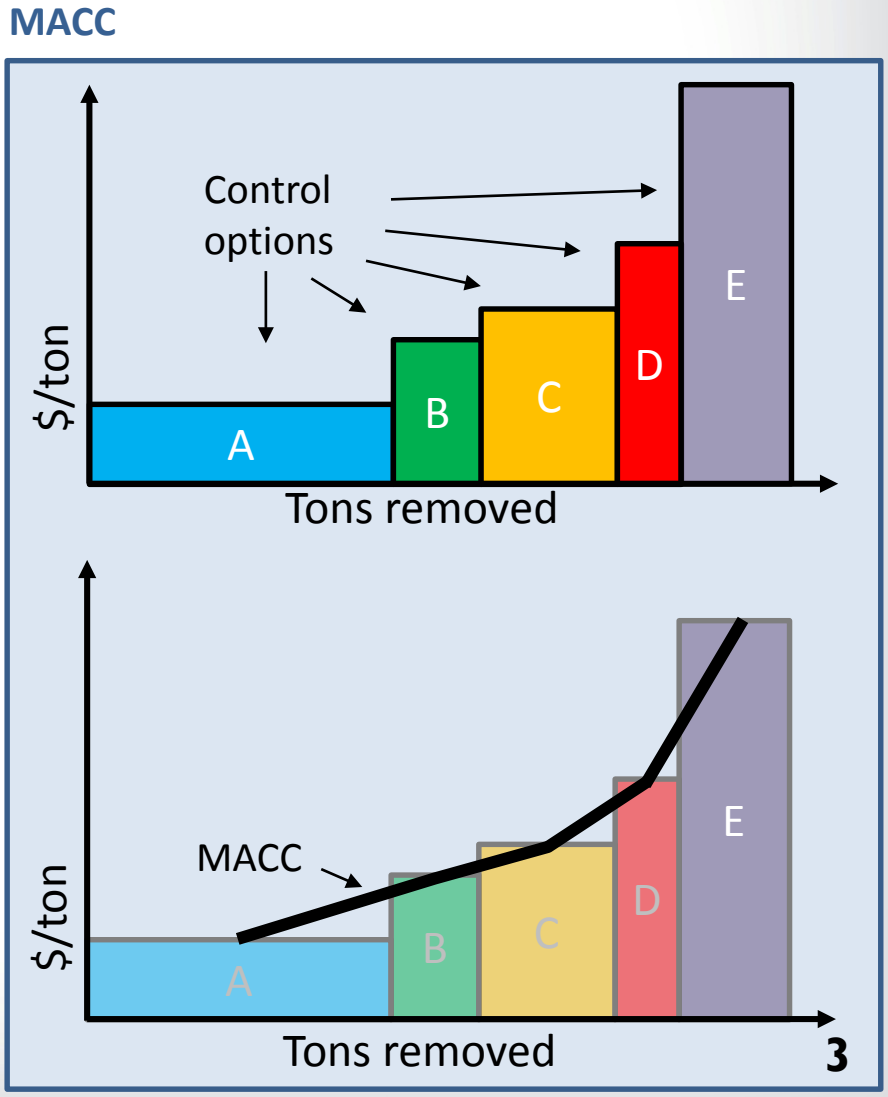
Forward

- Disclaimer: While this presentation has been cleared by the U.S. EPA, the views expressed in this article are those of the authors, and do not necessarily represent the views nor policies of the U.S. Environmental Protection Agency. Mention of companies or products does not constitute endorsement.
- Purpose: The goal of this presentation is to convey research related to a novel approach for developing air pollutant Marginal Abatement Cost Curves (MACCs) using an energy system model.
- Intended audience: Researchers and practitioners working in the area of air quality management.
- Intended use: Results are provided for illustrative purposes only.
- For more details on the methodology presented here, please see:
  - Loughlin, D.H., Kaufman, K.R., Macpherson, A.J. (2015). Marginal abatement cost curve for NOx incorporating controls, renewable electricity, energy efficiency and fuel switching. *Proceedings of the AWMA 108th Conference and Exhibition*, Raleigh, NC, June 22-25, 2015.

Background

- A marginal abatement cost curve (MACC) traces out the relationship between the amount of control and the cost of reducing the next ton of emissions.
- EPA has developed MACCs representing end-of-pipe control measures
  - EPA's Control Strategy Tool (CoST) includes a database of such measures



Research questions

It would be beneficial to have MACCs that also represent alternative measures, such as **renewable electricity, energy efficiency, and fuel switching** (RE/EE/FS).

- What role could RE/EE/FS measures play in compliance strategies?
- What is the cost effectiveness of abatement via RE/EE/FS?
- How might RE/EE/FS change the energy system and influence available end-of-pipe control options?

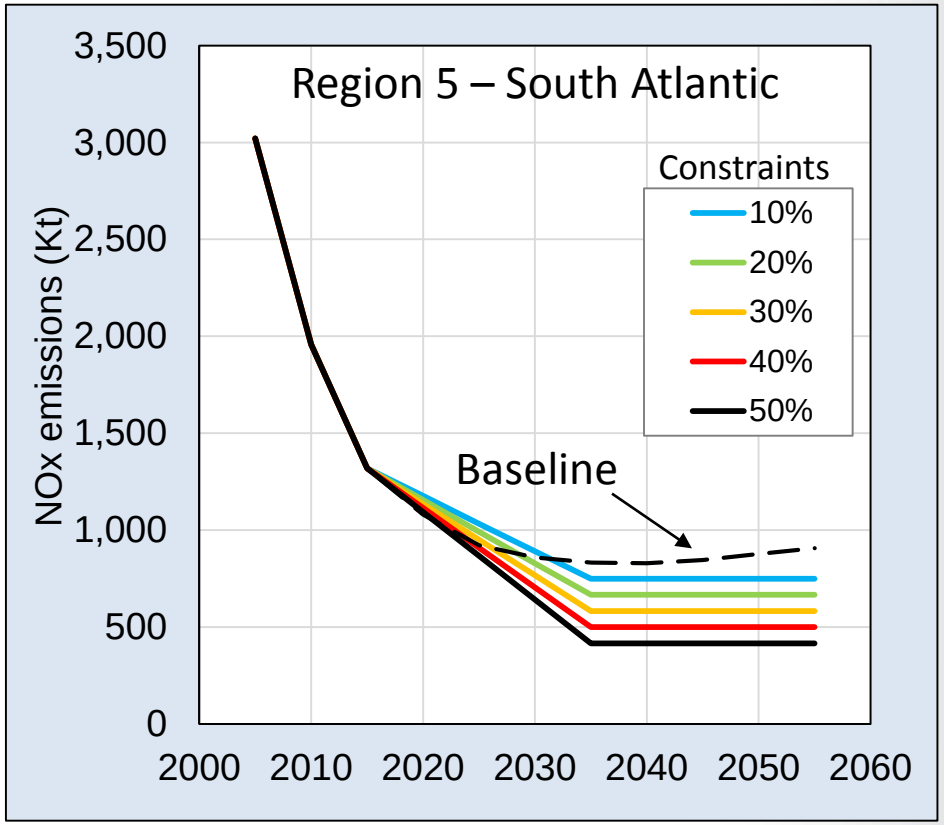
Approach: Model

- Modeling framework:
  - EPA MARKet ALlocation (MARKAL) energy system model and 2014 database
- Sectoral coverage:
  - U.S. energy system, including electricity production, industry, buildings, and transportation
- Spatial scale and resolution:
  - 9 U.S. Census Divisions, 3 to 8 states each
- Temporal resolution:
  - 2005 through 2055 in 5-year increments
- NOx reduction options:
  - Industrial, residential and commercial controls (obtained from CoST)
  - Renewable electricity, energy efficiency, fuel-switching
- Operation:
  - Optimizes the selection of technologies, fuels and controls to meet energy and emission constraints over the 50-yr modeling horizon

Approach: Method

- Iteratively solve MARKAL for increasingly stringent **regional**, energy system-wide NOx trajectories
  - Modeled as upper bounds
- Record the resulting marginal cost of NOx reduction
- Evaluate control, technology and fuel choices to assess their relative roles in NOx reduction
- Initial focus is aggregated national results for 2035

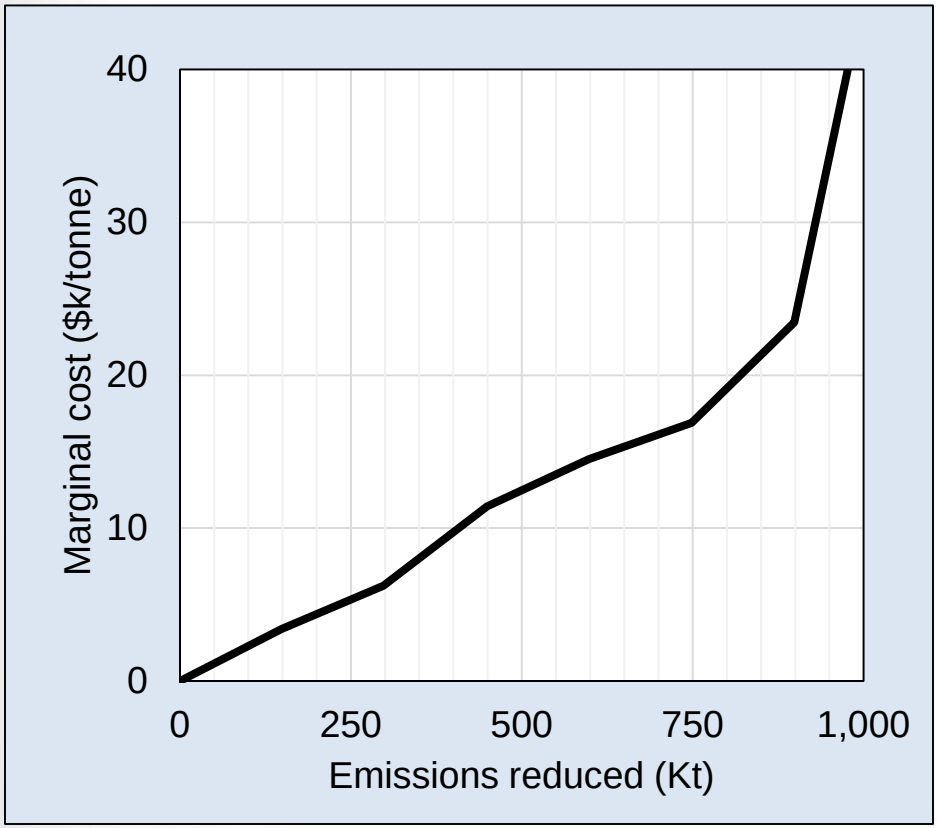
Example:
NOx Baseline and reduction target trajectories



Baseline reflects rules that had been promulgated at the time of this analysis (Jan '15), including CAIR, Tier 3, CAFE, and an assortment of air pollutant New Source Performance Standards. The Clean Power Plan is not included.

Results

National NOx MACC, 2035

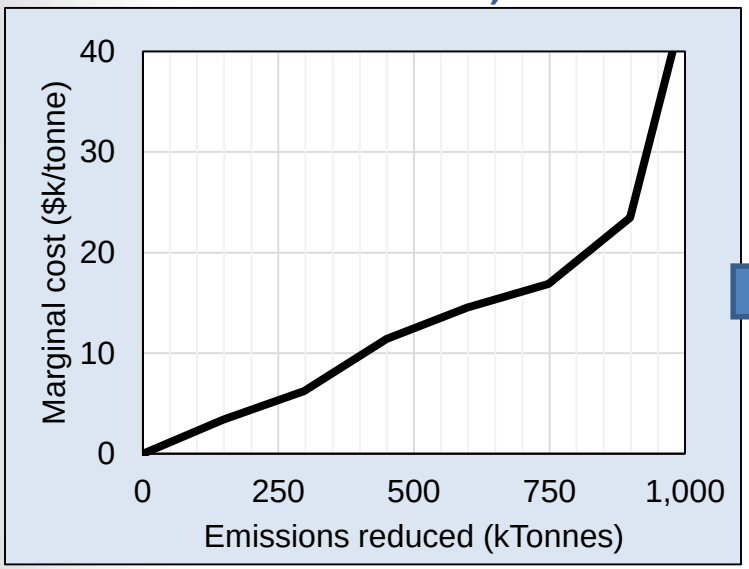


Observations

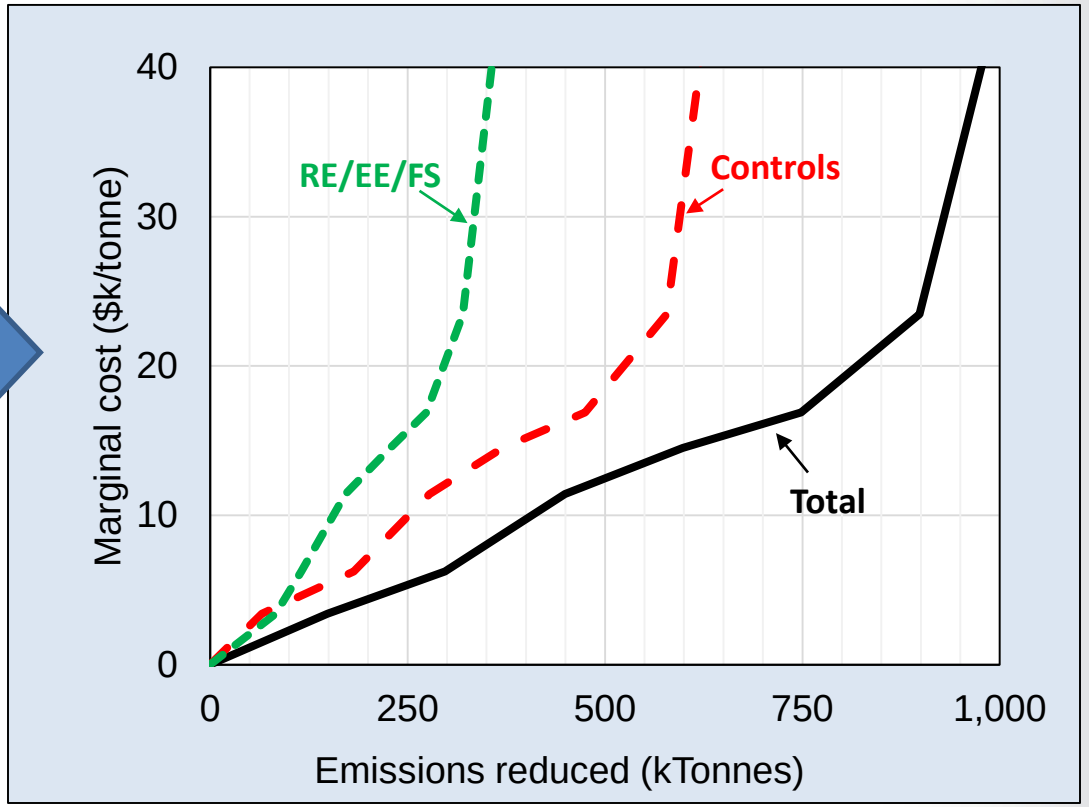
- The response to the increasingly stringent NOx trajectories results in this MACC
- For comparison, baseline NOx in 2035 is 6 Kt
- System-wide NOx reductions:
  7% available for less than $10k/t
  13% available for less than $20k/t
  16% available for less than $40k/t

Results, cont'd

National NOx MACC, 2035



National MACC, decomposed to controls and RE/EE/FS



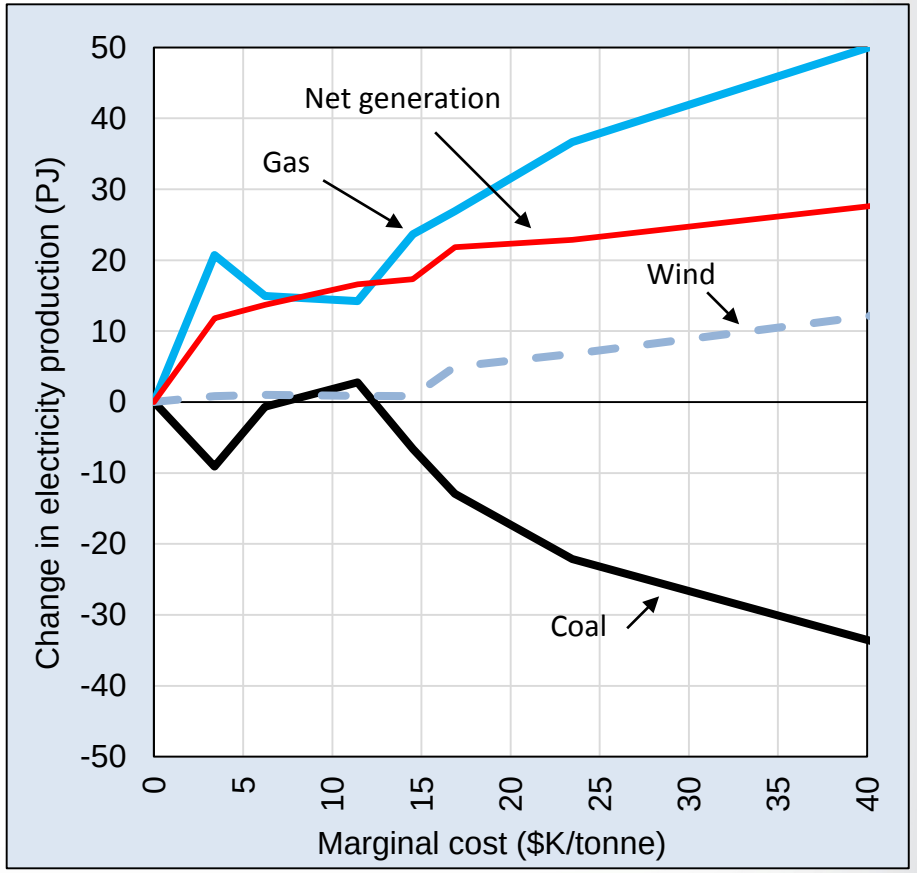
Observations

- Up to $5k/t, RE/EE/FS provide roughly the same NOx reduction potential as controls - For a given dollar-per-ton, NOx reductions are doubled
- Between $5k/t and $40k/t, RE/EE/FS increase the system-wide reduction potential by 50% relative to controls

Results, cont'd

- Changes in electricity production in 2035 provide some indication of how the system is responding
- Up to $4k/t, the model is fuel-switching to natural gas while also electrifying a number of end-uses (reflected by the increased generation)
- Electrification continues between $4k/t and $12k/t, but the increased electricity demand is met by coal
- After $12k/t, coal-fired generation diminishes, replaced by natural gas and wind, to a lesser extent.

Electric sector response to higher marginal costs



Note: The axes are switched to show increasing cost horizontally and corresponding electricity changes vertically.

Conclusions

- This analysis demonstrates that an energy system model can be used to develop a MACC that incorporates both controls and RE/EE/FS
- Furthermore, the following insights are developed:
  - RE/EE/FS have the potential to reduce NOx significantly beyond what is possible with end-of-pipe control technologies
  - Some RE/EE/FS are cost-competitive with end-of-pipe controls
- An important implication of the results is that:
  - All else equal, a control cost estimate that considers only end-of-pipe controls can be reduced by introducing consideration of RE/EE/FS

Caveats

- MARKAL is a linear optimization model, so the constructs within the model (e.g., supply curves, costs functions) have been linearized.
- Our cost estimates are intended to approximate "engineering costs" and do not imply broader "economic costs"
- We do not consider how economic growth or demands for energy services could be affected by changes in energy prices.
- We analyze MARKAL results at the *national* level, based upon regional-scale modeling. There are a variety of associated caveats and considerations, including:
  - MACCs are likely to differ from one region to another as a function of existing technology stock, access to low cost natural gas and renewables, and a wide variety of intra- and inter-sectoral interactions.
  - There may be important regional tradeoffs, resulting in trade of electricity and other fuels from one region to another.
  - Representing state and regional policies at the U.S. Census Division resolution requires simplifications and approximations.
  - Attainment is a local issue, affected both by emissions within the local region and by emissions (and ozone) transported into the region from a broader area. MARKAL's spatial resolution does not provide insights regarding spatially-explicit considerations.
  - MARKAL does not have the spatial or temporal resolution associated with regulatory models such as IPM and MOVES.

Future directions

- Develop and evaluate region- and sector-specific MACCs
- Explore multi-pollutant considerations:
  - How might the role of RE/EE/FS change if we consider co-benefits such as SO_2 and CO_2 emission reductions?
- Evaluate if and how the updated MACCs may most effectively benefit:
  - RIAs
  - SIPs
  - Other modeling efforts (e.g., Integrated Assessment Models) that make use of MACCs

Contact and references

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- Lead author: Dan Loughlin Loughlin.Dan@epa.gov

Several relevant references regarding the EPA MARKAL framework and applications:

- Lenox, C., Dodder, R., Gage, C., Kaplan, O., Loughlin, D., and Yelverton, W. (2012). *EPA U.S. nine-region MARKAL database: Database documentation*. (EPA600/B-13/203). Washington, D.C.: National Technical Information Service.
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