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MEMORANDUM | 6 SEPTEMBER 2021

TO Shah Dabirian, Ryan Finseth; South Coast Air Quality Management District (SCAQMD)

FROM Henry Roman, IEc

SUBJECT Review of Incidence per Ton Health Benefits Analysis for Proposed Rule 1109.1

INTRODUCTION

The South Coast Air Quality Management District (SCAQMD) is developing Proposed Rule (PR) 1109.1, the purpose of which is to protect human health by reducing emissions of nitrogen oxides (NO_x) from petroleum refineries and related operations. The South Coast Air Basin is currently in non-attainment status with respect to the federal National Ambient Air Quality Standards (NAAQS) for both fine particulate matter ($PM_{2.5}$) and ground-level ozone. A substantial literature base for both pollutants, as documented in U.S. EPA's recent Integrated Science Assessments, associate exposure to these pollutants with adverse health impacts. $PM_{2.5}$ exposure is linked to effects on respiratory and cardiovascular health; ozone is linked to adverse effects on respiratory health; and both can increase the risk of premature death.[1,2] Since NO_x emissions are a precursor to the formation of both ozone and $PM_{2.5}$, rules such as PR 1109.1 are part of SCAQMD's region-wide air quality management plan to help bring the air basin into compliance with the federal standards, and will be expected to result in health benefits to the exposed population in the basin. This particular PR is also anticipated to increase emissions of ammonia (NH_3), another $PM_{2.5}$ precursor, as a result of the use of selective catalytic reduction (SCR) units for emissions control. A proper accounting of the benefits of this PR must address both impacts to identify the net effects on public health.

To support the development of PR 1109.1, SCAQMD conducted a socioeconomic analysis that includes an assessment of the expected net impact on human health resulting from (1) the expected reductions of NO_x emissions; and 2) the expected increase in NH_3 emissions from refineries in the basin.[3] The purpose of this memorandum is to review SCAQMD's human health benefits analysis for PR 1109.1, which employs a reduced-form approach that applies previously estimated impacts of similar rules expressed as a incidence per ton (IPT) of emissions reduced.

The remainder of this memo proceeds as follows. We first provide a summary of SCAQMD's approach to the health benefit analysis and then present our review of that approach for PR 1109.1, considering the reasonableness of applying reduced form

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[1]U.S. EPA. Integrated Science Assessment (ISA) for Particulate Matter (Final Report, Dec 2019). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-19/188, 2019.

[2] U.S. EPA. Integrated Science Assessment (ISA) for Ozone and Related Photochemical Oxidants (Final Report, Apr 2020). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-20/012, 2020.

[3] South Coast Air Quality Management District. 2021. *Draft Socioeconomic Impact Assessment for Proposed Rule 1109.1 — Emissions of Oxides of Nitrogen for Petroleum Refineries and Related Operations*, September.

methods both generally and in this instance, the specific methods and assumptions SCAQMD employed in this analysis, and recommendations to consider that may help improve the approach in future. We emphasize that this review focuses only on the human health analysis of $PM_{2.5}$ included in SCAQMD's socioeconomic analysis of the rule, and not any of the other analyses. In addition, we did not review the illustrative analysis of ozone health impacts, which are less amenable to reduced-form approaches because of ozone's complex chemistry.

OVERVIEW OF SCAQMD APPROACH

SCAQMD employs a reduced-form approach for estimating the health impacts of this PR, which is proposed to help implement one control measure within its overall 2016 air quality management plan (AQMP). A reduced-form method uses tools or data based on less complex representations of the time- and resource-intensive photochemical air quality models (e.g., CMAQ) and health impact models (e.g., BenMAP-CE) used for analysis of large-scale rulemakings. Though less sophisticated, these reduced-form models are typically based on previous runs or series of runs of the "full-form" suite of modeling tools.

In this case, SCAQMD employs an IPT method based on a benefit-per-ton (BPT) method originally developed by U.S. EPA. This method assumes a constant, linear relationship between each ton of a pollutant (and its precursors) emitted and the expected change in the incidence of premature death or other adverse health impacts in the exposed population. Other stated assumptions include:

- Changes in health incidence are proportional to ambient $PM_{2.5}$ concentrations;
- Changes in primary pollutant concentrations are proportional to changes in directly emitted $PM_{2.5}$; and
- Changes in secondary $PM_{2.5}$ are proportional to changes in precursor emissions (NO_x, NH_3).

SCAQMD develops its IPT estimates by dividing the full-scale benefits analysis results in 2023 and 2031 from its Socioeconomic Analysis of the 2016 AQMP by the total modeled reductions in directly emitted (Primary) $PM_{2.5}$ and NO_x associated with the AQMP. Because NO_x contributes to $PM_{2.5}$ through the secondary formation of nitrate $PM_{2.5}$, SCAQMD expresses NOx reductions as a primary $PM_{2.5}$ equivalent. It does so by applying a ratio of 0.03 tons of primary $PM_{2.5}$ per ton NO_x emitted, based on an average of the ratio of U.S. EPA's previously estimated BPT values for NO_x and primary $PM_{2.5}$.

SCAQMD does not develop a specific IPT value for NH_3 emissions, which also lead to secondarily formed $PM_{2.5}$ particles. Instead, they rely on the results of regional air quality modeling simulations previously run for the 2015 RECLAIM NOx Shave rule to estimate the relative impact of NH_3 versus NO_x in generating secondary PM. Based on that modeling, they estimate that one ton of ammonia is equivalent to 7.36 tons of NO_x. Estimated IPT values for NH_3 are negative, denoting negative health benefits associated with increasing NH_3 emissions.

SCAQMD also develops BPT values by multiplying each of the IPT values by the corresponding dollar value per case used in the 2016 AQMP socioeconomic analysis. For benefit years between 2023 and 2031, they apply a linear interpolation for both IPT and BPT. For years beyond 2031, they fix the IPT/BPT estimates at 2031 levels.

REVIEW OF SCAQMD HEALTH BENEFIT ANALYSIS FOR PR 1109.1

We find the approach applied by SCAQMD produces a reasonable first approximation of benefits, though it would benefit from additional characterization of uncertainty to test sensitivity to some of its assumptions. Longer-term, it would benefit from analysis of modeling informed by source apportionment that could support refined IPT estimates that are more source-specific and geographically specific. Despite the uncertainties, the authors have in many cases opted to use conservative assumptions in their analysis, reducing the likelihood that they have overestimated benefits. Below we discuss the factors we considered in our review.

USE OF IPT/BPT FOR BENEFITS ANALYSIS

There is considerable precedent for the use of reduced form tools for air quality benefits analysis, including IPT/BPT. There are a growing set of options available for conducting streamlined air quality and health modeling steps of an analysis where time, resources, and/or data gaps make full-scale modeling challenging. As noted by SCAQMD, the BPT method was first developed by U.S. EPA, and EPA has applied BPT estimates to conduct analyses for the 2011 Mercury and Air Toxics Standards and 2011 Ozone Cross-state Air Pollution Rule.[4,5] This approach has also been used in benefits analyses by CARB.[6] Other reduced tools such as InMAP and AP2 have been used in peer reviewed air quality health benefits analyses.[7]

IPT/BPT values are a function of several factors – the nature of the emissions and their effect on the pollutant of interest (e.g., primary emissions versus precursor emissions); spatial distribution of emission sources, local geography and meteorology; and the size and location of populations potentially exposed. As a result, the ideal IPT/BPT values would be ones that are both source- and location-specific. The SCAQMD approach is

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[4] US EPA. 2011. Regulatory Impact Analysis for the Final Mercury and Air Toxics Standards. Research Triangle Park, NC, Office of Air Quality Planning and Standards. US Environmental Protection Agency. December 2011. EPA-452/R-11-011. https://www3.epa.gov/ttnecas1/regdata/RIAs/matsriafinal.pdf.

[5] US EPA. 2011. Regulatory Impact Analysis for the Federal Implementation Plans to Reduce Interstate Transport of Fine Particulate Matter and Ozone in 27 States; Correction of SIP Approvals for 22 States. Research Triangle Park, NC, Office of Air and Radiation. US Environmental Protection Agency. June 2011. https://www.epa.gov/sites/production/files/2017-07/documents/epa-hq-oar-2009-0491-4547.pdf.

[6] https://ww2.arb.ca.gov/sites/default/files/2019-08/Estimating%20the%20Health%20Benefits%20Associated%20with%20Reductions%20in%20PM%20and%20NOX%20Emissions%20-%20Detailed%20Description.pdf

[7] See for example Tessum, C.W., Apte, J.S., Goodkind, A.L., Muller, N.Z., Mullins, K.A., Paolella, D.A., Polasky, S., Springer, N.P., Thakrar, S.K., Marshall, J.D. and Hill, J.D., 2019. Inequity in consumption of goods and services adds to racial–ethnic disparities in air pollution exposure. Proceedings of the National Academy of Sciences, 116(13), pp.6001-6006; and Jaramillo, P. and Muller, N.Z., 2016. Air pollution emissions and damages from energy production in the US: 2002–2011. Energy Policy, 90, pp.202-211.

specific to the South Coast air basin but is not source-specific and thus reflects an average IPT effect across all sources. On the other hand, U.S. EPA's 2018 published BPT values include refinery-specific estimates, but they are averaged across the entire nation and thus would fail to capture the specifics of refinery issues in this region.[8] EPA also has reported source-specific BPT values for PM-related effects of NO_x and NH_3 emissions by source categories based on modeling in the San Joaquin valley in Fann et al 2009; these estimates are a bit older, however.[9] Given their recency, geographic specificity, and reflection of fine scale local photochemical modeling for the 2016 AQMP, the SCAQMD IPT values are a reasonable choice. SCAQMD should consider, however conducting sensitivity analysis with appropriate estimates from the Fann et al study, given that it would provide source- and geography-specific, if imperfectly matched, estimates.

KEY ASSUMPTIONS IN SCAQMD ANALYSIS

Regarding the key assumptions noted by SCAQMD, the assumption of linearity between changes in $PM_{2.5}$ and health effects generally holds for concentrations in the concentration ranges observed in the South Coast Basin based on the weight of evidence in the U.S. EPA ISA; recent studies such as the Integrated Exposure Response model or the Global Exposure Mortality Model that have fit non-linear functions show changes in the dose-response slope occurring at higher concentrations than those in this analysis.[10,11] The proportionality of $PM_{2.5}$ with primary emissions is also a reasonable assumption, given the lack of complex chemistry involved. In a limited set of policy analyses performed by IEc using various reduced form tools, some tools did show a tendency to predict higher NO_x related PM benefits than those generated using CMAQ-based measurements; however, the BPT estimates generated using the U.S. EPA method tended to be in better agreement with the CMAQ estimates.[12] Future analyses may wish to explore this area further.

The assumption that NO_x contributes 0.03 of a ton of directly-emitted PM is based on an average of the NO_x / Primary $PM_{2.5}$ BPT ratio across all emitting sectors from the published U.S. EPA 2018 values. My calculation of this ratio from U.S. EPA's BPT for refineries specifically is closer to 0.21. Alternatively, a quick analysis using U.S. EPA's COBRA model for the four counties in the South Coast air basin suggests a BPT ratio of NO_3/Primary $PM_{2.5}$ of approximately 0.1, similar to the value SCAQMD notes in footnote

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[8] https://www.epa.gov/benmap/sector-based-pm25-benefit-ton-estimates

[9] Fann, N., Fulcher, C.M. and Hubbell, B.J., 2009. The influence of location, source, and emission type in estimates of the human health benefits of reducing a ton of air pollution. Air Quality, Atmosphere & Health, 2(3), pp.169-176.

[10] Burnett, R.T., Pope III, C.A., Ezzati, M., Olives, C., Lim, S.S., Mehta, S., Shin, H.H., Singh, G., Hubbell, B., Brauer, M. and Anderson, H.R., 2014. An integrated risk function for estimating the global burden of disease attributable to ambient fine particulate matter exposure. Environmental health perspectives, 122(4), pp.397-403.

[11] Burnett, R., Chen, H., Szyszkowicz, M., Fann, N., Hubbell, B., Pope, C.A., Apte, J.S., Brauer, M., Cohen, A., Weichenthal, S. and Coggins, J., 2018. Global estimates of mortality associated with long-term exposure to outdoor fine particulate matter. Proceedings of the National Academy of Sciences, 115(38), pp.9592-9597.

[12] Industrial Economics, Incorporated., 2019. Evaluating Reduced-form Tools for Estimating Air Quality Benefits. Prepared for EPA's Office of Air Quality Planning and Standards. September.

7.[13] The value used of 0.03 seems a reasonably conservative choice that is unlikely to overstate benefits, but an expanded sensitivity analysis spanning 0.21 to 0.1 would aid in characterizing uncertainty in this parameter.

IEc cannot directly comment on the air quality modeling underlying the assumption that one ton of NH_3 emissions in the air basin is equivalent to 7.36 tons of NO_x, as this is outside of IEc's area of expertise. However, we did search for other empirical data points for comparison. We found that NH_3 BPT can differ depending on the source category. The Fann et al, 2009 BPT estimates for San Joaquin valley show quite similar BPT estimates for non-EGU NO_x emissions ($28,000) and area source NH_3 emissions ($36,000), as compared to mobile source NH_3 ($140,000). Dedoussi and Barrett also found larger relative benefits nationwide of NH_3 versus NO_x per unit mass reduced among mobile sources. However, for industrial sources, they found that NH_3 contributed only about twice as much as NO_x nationwide to population exposure.[14] Given the limited points of comparison, this is an area that would benefit from further investigation, but compared to current relevant data, the SCAQMD assumption appears reasonable, and potentially conservative, from a benefits perspective.

The method used to grow the IPT/BPT estimates over time is reasonable; given that it is based on estimates from the 2016 AQMP analysis that include both projections for population and income growth in its 2023 and 2031 estimates, the linear interpolation procedure effectively incorporates these growth factors in the intervening years. Fixing the IPT/BPT estimates post 2031 is a suitably conservative choice reflecting additional uncertainty extrapolating beyond those two modeled years.

The spreadsheet models used to calculate the IPT/BPT values were well-organized, clear, and free of errors. For context, we compared SCAQMD's BPT value for mortality impacts of long-term exposure against the BPT values reported in Fann et al, 2009 for other large cities. Converting the two estimates into common units, the SCAQMD estimate for Primary $PM_{2.5}$ appeared to be about 2.5 times larger than the comparable estimates from Phoenix, Arizona. This difference does not seem unreasonable, given that the population of Los Angeles is roughly 2.5 times larger than Phoenix. The BPT values in the two cities could also be affected by relative differences in baseline mortality rates and geographic patterns of exposure between the two cities, which we did not investigate, but it seems likely that the population difference would be the major contributor to the observed difference.

[13] U.S. EPA CO-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA); https://www.epa.gov/cobra

[14] Dedoussi, I.C. and Barrett, S.R., 2014. Air pollution and early deaths in the United States. Part II: Attribution of PM2. 5 exposure to emissions species, time, location and sector. Atmospheric environment, 99, pp.610-617.

RECOMMENDATIONS FOR FUTURE WORK

If SCAQMD intends to continue applying the IPT approach in the future, potential areas for refinement include the following:

- **Sensitivity Analysis**. Given the assumptions inherent in a reduced-form approach such as IPT, generation of alternative estimates that assess the sensitivity of the benefits model to changes in those assumptions would provide the reader with a better sense of the robustness of the results.
- **Source-apportionment based IPT.** Following the U.S.EPA model, developing a set of BPT values for the South Coast basin that are based on local-scale photochemical modeling of the air quality impacts of emissions from particular source categories will help SCAQMD better tailor its IPT analyses to the sources impacted by future rules.
- **Estimation of secondary $PM_{2.5}$ from precursors using reduced form tools.** Given the importance of NO_x reductions to the AQMP, and the rapidly evolving field of reduced-form air quality modeling, the ability of these tools to estimate PM from precursors such as NO_x and NH_3 will continue to improve. Monitoring these developments will help SCAQMD to evaluate the relative strengths of the IPT approach versus use of reduced-form air models in future assessments.