The role of future scenarios to understand deep uncertainty in air quality management

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EXTENDED ABSTRACT

Introduction

The environment and it's interaction with human systems (economic, social and political) is complex and dynamic. Key drivers may disrupt system dynamics in unforeseen ways, making it difficult to predict future conditions precisely. This kind of deep uncertainty presents a challenge to organizations faced with making decisions about the future, including those involved in air quality management. Scenarios represent a key tool that can benefit decision-makers under these conditions (Schwartz 1997; Schoemaker 1991). We propose and demonstrate the application of the future scenarios method to air quality management. Application of scenarios in this context provides a structured means of sifting through and understanding the dynamics of the many driving forces affecting future air quality. Further, scenarios provide a means to identify opportunities and challenges for future air quality management, as well as a platform for testing the efficacy and robustness of particular management options across wide-ranging conditions. While such a scenario approach has been used in practice by industries and government agencies (including for example Ghanadan and Koomey 2005; NPS 2013; GBN 2007), the application of the scenarios is a generally novel approach for air quality management for the U.S.

Approach

An effort to demonstrate the potential utility of scenarios in air quality management kicked off several years ago and culminated with a workshop that was attended by EPA and non-EPA participants representing a wide range of expertise, and was informed by interviews with GBN's network of experts (Gamas 2014). Attendees identified key factors expected to impact pollutant emissions over the coming decades. The group collectively hypothesized the two most important factors to be: (i) technological advancement, and (ii) society's ability to change its long-term behaviors and patterns. The group also agreed on other key driving forces of future air quality including: energy production and use, economic development, and land use and travel patterns.

Using these two factors as the axes of a matrix, four distinct scenarios were identified, as shown in Figure 1.

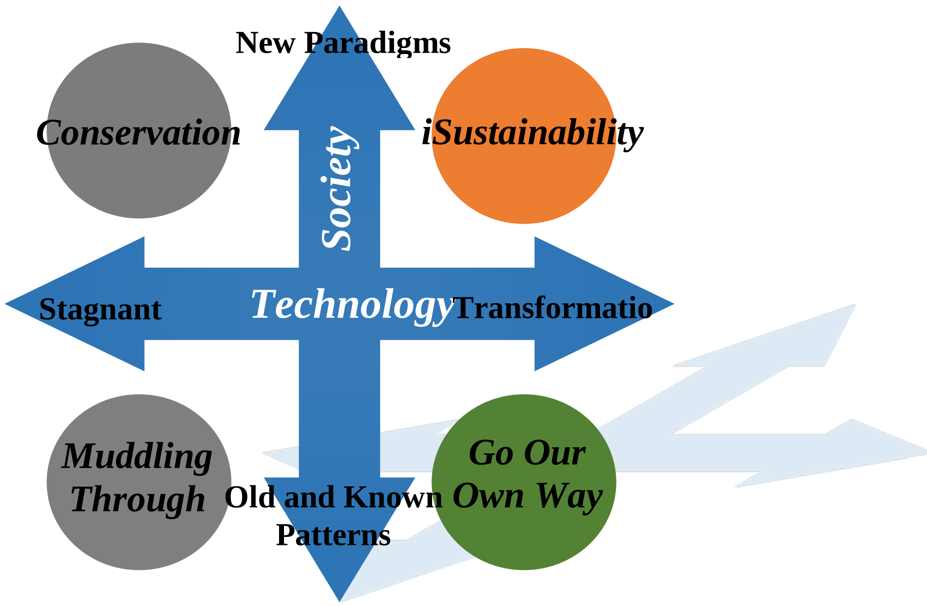

Figure 1. Four scenarios for air quality.

Narratives, summarized briefly below, were developed for each scenario:

- *Conservation* is motivated by environmental considerations. Assumptions include decreased travel, greater utilization of existing renewable energy resources, energy efficiency and conservation measures adopted in buildings, and reduced home size for new construction.
- *iSustainability* is powered by technology advancements, and assumes aggressive adoption of solar power, battery storage, and electric vehicles, accompanied by decreased travel as a result of greater telework opportunities.
- *Go Our Own Way* includes assumptions motivated by energy security concerns. These assumptions include increased use of domestic fuels, particularly coal and gas for electricity production and biofuels, coal-to-liquids, and compressed natural gas in vehicles.
- *Muddling Through* has limited technological advancements and stagnant behaviors, meaning electric vehicle use would be highly limited and trends such as urban sprawl and increasing per-capita home and vehicle size would continue.

Our team then used the MARKet ALlocation (MARKAL) energy system model (Loulou et al., 2004) and U.S. EPA MARKAL database (U.S. EPA, 2013) to evaluate the scenarios and gain further insights into the role of different drivers and their consequences for air quality. MARKAL also helped us uncover inconsistencies in our storylines, and we incorporated this knowledge into refinements to the storylines and their implementations.

Illustrative Results

While the storylines and their implementations are still being refined, early results successfully illustrate important similarities and differences across scenarios. For example, Figure 2 shows how the scenario implementations may differ with respect to national-level NOx and SO_2 emissions, projected through 2040. In the figure, red trajectories indicates low technology development, while blue indicates high technology development. Solid lines represent adoption of new societal paradigms, where dashed lines represent stagnant behaviors. Note that these results do not incorporate the recent Tier III onroad vehicle emission standards or the proposed New Source Performance Standards for new and existing coal-fired power plants.

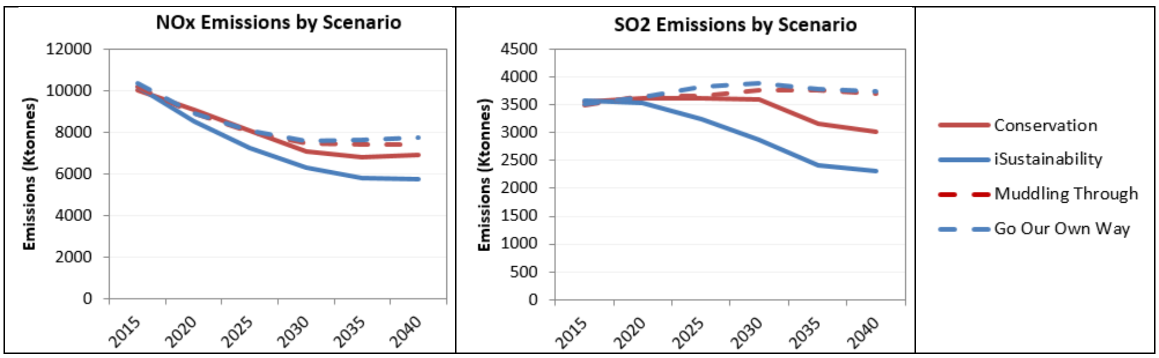

Figure 2. Illustrative result showing the NOx and SO_2 emissions trajectories for preliminary implementations of each scenario in MARKAL.

Despite the wide-ranging differences in assumptions regarding technology development and behavior, all four scenarios indicate that the trend of decreasing NOx emissions will continue, largely driven by air quality regulations. By 2040, NOx emissions across the scenarios are approximately 20% to 40% lower than in 2015. There is considerably more uncertainty related to future SO_2 emissions. Emissions in 2040 range from approximately 6% greater to 35% less than in 2015.

Future Directions

We are re-implementing the scenarios into the latest version of the MARKAL database, EPAUS9r_14, which was released to the public in September, 2014. Based upon our preliminary results, we are exploring how the scenarios can be refined to yield broader coverage of air quality outcomes. We are also exploring alternative ways to implement the scenarios into MARKAL. Our initial effort involved the addition of constraints that forced technological and behavioral changes to match the detailed scenario narratives. In the next implementation, we plan to instead integrate the broader scenario drivers (technological change and changing societal paradigms) in a manner that gives the model more flexibility to respond to changes in model inputs. From the application standpoint, we will begin to explore how the scenarios can be used in a long-term planning context, identifying robust, multi-pollutant management strategies.

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