US ENVIRONMENTAL PROTECTION AGENCY
SCIENCE ADVISORY BOARD
INTEGRATED NITROGEN COMMITTEE
October 20-22, 2008

Charges for Breakout Groups on October 20 and 21

October 20

Breakout Group 1: *NOx Emissions from Combustion*

Breakout Group 2: *Managing Ammonia Emissions*

Breakout Group 3: *Urban and Aquatic Nr Discharge*

Breakout Group 4: *Agricultural Aquatic Discharge*

October 21

Breakout Group 5: *Impacts of Land Use on Accumulation and Effects of Reactive Nitrogen in the Environment*

Breakout Group 6: *Integrated Reactive Nitrogen Policies*

Breakout Group 7: *Agroecosystems, Food Security, and Bioproducts*

Breakout Group 8: *Energy and the Cascading Costs of Reactive Nitrogen*

Breakout Group #1: NOx Emissions from Combustion

Russ Dickerson and JoAnn Lighty
co-chairs

The largest sources of reactive nitrogen (Nr, e.g., NH_3, N_2O, NOx) created by human action in the USA are fossil fuel combustion and food production. The Nr that comes from fossil fuel combustion is chiefly in the form of NOx emissions into the atmosphere; this introduces about 5.5 Tg N per year into the environment. Largest sources for these emissions are from the electrical generation and transportation sectors.

The Clean Air Act (1970) and its Amendment (1990), have resulted in NOx emissions that are <50% of what they would have been without the controls. While this is an admirable accomplishment, NOx emissions are still an order of magnitude greater than at the beginning of the 20th century and, as a consequence, there are negative impacts on both people and ecosystems. Thus we recommend that the EPA expand its NOx control efforts from the current reductions of emissions of passenger cars and power plants to include other important unregulated mobile and stationary sources. Notable NOx emitters include heavy-duty on-road and all off-road mobile sources (including rail and marine), as well as currently uncontrolled electricity generation and industrial processes. Instituting reductions for the major, currently uncontrolled sources would reduce annual emissions by about **2** Tg N per year. However, it is vitally important that the implementation of these controls not result in additional emissions of N_2O and NH_3 to the atmosphere, which would just change one N-related problem to another.

During this breakout session, NOx Emission Breakout Group will address the following questions:

1. Are the NOx inputs identified by the committee sufficiently accurate? If not, what other inputs need to be considered?

2. Are the implied control strategies identified by the committee correct, accurate, and practicable? What are the best control strategies?

3. Are the recommended actions suggested by the committee ones that would be the most effective, without further degradation of the environment?

4. Are there other actions that should be taken to decrease NOx emissions?

5. Should there be a standard that combines both NOy and NHx, instead of the current NO_2 standard?

Breakout Group #2: Managing Ammonia Emissions

Viney Aneja and Arvin Mosier
co-chairs

The gains made over the last several decades in lowering the amount of NOx emitted from stationary and mobile combustion sources have been offset by the essentially unregulated release of ammonia from livestock operations (largely due to increasing poultry and swine production), which have expanded significantly. Ammonia emissions from livestock production have increased ~30% since 1970. In 2002 an estimated 1.6 Tg of NH_3-N was emitted from U.S. livestock production and another 0.9 Tg was emitted from U.S. agricultural fields. We suggest a goal of decreasing livestock-derived ammonia emissions to approximately 80% of 1990 emissions, a decrease of **0.5** Tg N per year (by a combination of Best Management Practices and engineered solutions). This will reduce PM2.5 by ~0.3 $\mu g/m^3$ (2.5%) and improve health of ecosystems by achieving progress towards critical load recommendations. Additionally we recommend decreasing ammonia emissions derived from fertilizer applications by 20% (decrease by ~**0.2** Tg N per year).

During this breakout session the "Managing Ammonia Emissions" group will address the following questions:

1. Are there other important sources of NH_3?
2. Is it possible to decrease agricultural NH_3 emissions by 20-30% without harming the U.S. agricultural (livestock and crop production) industry? Why and How?
3. What can be done to decrease the uncertainty in the dry deposition rate of agriculturally emitted NH_3?
4. Do current air quality models simulate both the short-range dispersion and deposition of NH_3 near the ground and the long-range transport and fate of NH_4^+ downwind of sources, and are the observations of emissions, concentrations, and deposition of ammonia suitable for model verification and evaluation?
5. Should NHx be treated as a criteria pollutant, i.e. do NH_3 emissions and their role in PM2.5 pose a human health risk?
6. Should there be a standard that combines both NOy and NHx, instead of the current NO_2 standard?

Breakout Group #3: Urban and Aquatic Nr Discharge

Don Hey and Paul Stacey
co-chairs

Populated (urban/suburban/developed) land areas provide significant loads of reactive nitrogen (Nr) to the environment, both by generation (e.g., deposition of NOx emissions) and by transfer (e.g., domestic sewage from imported food). Categorical sources include sewage treatment plants (STP), industries, subsurface (septic) systems, atmospheric deposition, domestic animal and wildlife waste, and fertilizers used on lawns, gardens and landscapes. Infrastructure (e.g., storm sewers) and landscape conditions (e.g., increased impervious cover) more efficiently move Nr associated with surface runoff to receiving waters and may also inject or infiltrate Nr into ground water. Landscape changes, primarily increases in impervious cover, soil disturbance and compaction, and wetland/hydric soil losses, have also reduced the capacity for natural systems to treat Nr inputs by recycling or denitrification. Other disruptions in chemical condition (e.g., acidification), biology (e.g., vegetative cover), and physical character (e.g., temperature increase) alter the nitrogen cycle, which may have both negative and positive consequences for Nr amelioration on the populated landscape and in air and water. Populated lands are estimated to export as much as 10 times the total nitrogen that was exported under pre-development conditions.

There are several ways in which the release and control of reactive nitrogen in the environment can be approached. In general these can be classified as follows:

- Transformation—in which one form of nitrogen is converted to another form (e.g. nitrification of wastewater, denitrification in engineered or natural systems),
- Removal—in which reactive nitrogen is sequestered from impacting a particular resource (e.g. ion exchange)
- Source limitation—in which the amount of reactive nitrogen introduced into the environment is lowered (e.g. lower fertilizer application rates, controls on NO_x generation)
- Improved use or reuse efficiency—in which the efficiency of production that is dependent on reactive nitrogen is improved (e.g. increased grain yields for lower Nr applied), or Nr wasted from one source is reused in another (e.g. algal farming).
- Improved practices—in which the flux of reactive nitrogen that creates an impact is lowered through better management practices (e.g. on-field agricultural practices, controlled combustion conditions)
- Product substitution—in which a product is developed or promoted which has a lower dependency on, or releases less, reactive nitrogen (e.g. N-bearing wastes instead of corn grain as a feedstock for biofuels, development of alternative power sources such as wind and solar)

Effective management of Nr requires combinations of these approaches; none is a perfect alternative for controlling Nr in the environment. At the same time, care needs to be taken that the control, in and of itself, does not produce more Nr than it eliminates (e.g.

removing dilute concentrations of Nr from secondary waste water requires considerable energy, which may result in the release of increased masses of reactive nitrogen to the air).

The INC estimates that landscape management could reduce excess flows of Nr into the aquatic environment by 20%, or about 1 Tg N per year although, nationally, urban runoff is a relatively small percentage of that reduction and the 4.8 Tg national surface water flux. Further urban gains, though not quantified, are possible through improved turf fertilizer management, stormwater programs, and pollution prevention techniques associated with landscaping and land management. More aggressive management of STPs could reduce Nr loading to aquatic systems by another 0.5 to 0.8 Tg N per year. These sources are especially important to the urbanized watersheds on the east and west coasts where they can dominate local estuarine nitrogen loading. Municipal sewage and industrial point sources, atmospheric deposition, non-farm fertilizer use, and nitrogen fixation from vegetation are primary contributors. Delivery from those sources are exacerbated by changes in the landscape, including surface hardening and drainage systems as well as loss of natural nitrogen removal functions that might be afforded by wetlands, for example.

During this breakout session the group will address these questions, among others.

1. Related to urban and aquatic discharge, has the committee adequately defined the effects and scope of the Nr problems—their sources, and the strategies to address them, including the costs and benefits of the plausible solutions?

2. In regard to non-point sources of reactive nitrogen, have we given enough consideration to runoff management? If not, what is missing?

3. Are there existing programs and management practices that could decrease the introduction of Nr into aquatic systems? Are there new innovative technologies and approaches that warrant additional investigation and application?

4. Are voluntary and social marketing approaches, including pollution prevention, effective and do they have advantages over traditional regulatory mechanisms?

5. What are the role and benefits of economic market-based approaches, such as pollutant trading, tax levies and tax breaks, that provide incentives/disincentives?

Breakout Group #4: Agricultural Aquatic Discharge

Ken Cassman and Hans Paerl
co-chairs

The key findings of the EPA Integrated Nitrogen Management Scientific Advisory Board related to agriculture, biofuels, and aquatic ecosystems include:

- About 29 Tg N of new Nr enters USA terrestrial ecosystems each year; crop and livestock agriculture accounts for 64% of this Nr input load with about 11 Tg N coming from N fertilizers applied used in crop, turf, and livestock production, and 8 Tg N from biological N_2 fixation by cultivated legume crops.
- Agriculture accounts for +80% of NHx-N and +60% of N_2O-N losses emissions to the atmosphere, and for a majority of the NOx-N losses to aquatic systems.
- Because nitrogen is both a critical resource and also a contributor to a number of environmental problems, it is imperative to understand how to reduce the risks to society while also providing the materials, food and energy required by society.
- An integrated approach to the management of Nr must of necessity use a combination of mechanisms, each most appropriate to the nature of the problem at hand, that are supported by critical research on reducing the risks of Nr, and reflective of an integrated policy that recognizes the complexities and tradeoffs associated with the nitrogen cascade. Control at one point in the cascade may be more efficient and cost effective than control or intervention at another point. This is why understanding the nature and dynamics of the N cascade is so critically important.

Recommendations based on these findings include:

1. There is a pressing need to encourage reductions in Nr losses to the environment through capture and recycling of agricultural and urban runoff. It is possible to reduce excess flows of Nr into streams, rivers, and coastal systems by approximately 20% **(~1** Tg N per year.**)** through improved landscape management without undue disruption to agricultural production and human lifestyles and economies. This would include activities such as using wetland management (e.g., USDA Wetlands Protection Program), improved tile-drainage systems and riparian buffers on crop land, and implementing storm water and nonpoint source management practices (e.g., EPA permitting and funding programs).

   It is also possible to increase crop N-uptake efficiencies by up to 25% over current levels through a combination of knowledge-based practices and advances in fertilizer technology (such as controlled release). The net reduction would be somewhat less as some duplication of efforts is represented in reducing excess Nr flows and increasing N-uptake efficiencies. However, the critical conclusion is that crop output can be increased while reducing total Nr by up to 20% of applied artificial Nr, amounting to ~**2.4** Tg N per year below current levels of Nr additions to the environment. These are appropriate targets with today's available technologies and further progress is possible.

2. Acreage devoted to corn production has increased about 10% for corn based ethanol production, and nearly one-third of the crop is being devoted to bioethanol

production. Current policy calls for bioethanol to expand to 15 billion gallons for corn-based ethanol and 36 billion gallons of bioethanol from all sources by 2022. We expect fertilizer nitrogen to increase by at least 10% **(0.5** Tg N per year**)** initially to meet biofuel feedstock crop demand. Strategies to increase N-uptake efficiencies and strategies to reduce N losses must be implemented across corn and other N intensive biofuel crops.

In the absence of significant progress to increase N fertilizer uptake efficiencies to achieve increases in crop yields while, at the same time, reducing Nr losses, current biofuels policies will make it extremely difficult to reduce Nr releases to soils, water and air. In this regard, we endorse Section 204 of EISA which requires that after 3 years and then every 3 years thereafter, the EPA Administrator, the Secretary of Agriculture, and the Secretary of Energy shall report to Congress on the impact of the Clean Air Act requirements related to environmental issues, resource conservation issues, and the growth and use of cultivated invasive and noxious plants. The impact of expanded biofuel production on Nr load and environmental impact should be a critical component of this impact assessment.

3. There is an urgent need to improve and maintain foundational data required to track sources of Nr and Nr loads in the environment. Specific data needs include: rationalized and geospatially defined fertilizer use data; improved estimates of nitrogen fertilizer efficiency and its variation based on estimates from production-scale fields for the major crops and cropping systems; improved monitoring and estimates of wet/dry Nr deposition and its transformation/transport on land and water.

4. What is managed depends on what is measured, and because Nr undergoes multiple chemical transformations as it cascades through multiple media and ecosystems, impacts and intervention points are difficult to determine. There are multiple metrics for evaluating and prioritizing Nr impacts. Traditionally the measure has been tons of nitrogen by chemical species, but one can also measure damage costs of impacts, or replacement and mitigation costs or human health measures. The use of multiple metrics may provide a fuller picture of the impacts of reactive nitrogen and improve the setting of priorities.

During this breakout session, the breakout group will address the following questions:

1. Are there any questions, comments or concerns about the above findings?
2. Are the estimates of Nr inputs and fluxes and their sources reasonable? Do they reflect best current available science? Are the specified reduction targets reasonable and will they be effective in reducing detrimental atmospheric, terrestrial and aquatic impacts?
3. Are the identified approaches for mitigation of Nr load from agriculture the best options? Are there other options that have been overlooked?
4. To establish a transparent and equitable framework for possible regulations and incentives on Nr use, how important will it be to have accurate data on Nr use in agriculture and its geospatial distribution? What government agencies need to be involved, how to coordinate among them, and should responsibility be given to a lead agency?

Breakout Group #5: Impacts of Land Use on Accumulation and Effects of Reactive Nitrogen in the Environment

Beth Boyer and Ellis Cowling
co-chairs

During its deliberations during the past 24 months, the SAB's Integrated Nitrogen Committee determined (among other things) that:

1. Nr inputs to the land, air, and water have been increasing in essentially all regions of the United States -- mainly due to human activities associated with food production and fuel combustion. Despite the obvious benefits of a plentiful supply of food and energy, the adverse consequences associated with the *accumulation* of Nr in the environment are large, with important implications for both human health and environment.
2. The larger the inputs of Nr to the landscape, the greater the potential for detrimental negative *effects,* including greenhouse gas production, ground level ozone, degradation of soils and vegetation, acidification of surface and ground waters, nutrient enrichment, coastal hypoxia, and eutrophication.
3. Nr inputs to land, air, and water are tightly linked to *land use* (e.g., agriculture, residential, industrial, transportation, forest, rangeland). Changes in land use from forest to other types are typically associated with increased Nr inputs to the environment. Thus, efforts to mitigate Nr pollution are linked to land management.
4. The total amounts of new Nr currently introduced to the environment from crop and animal agricultural operations in the United States are substantially (~ 4 times) larger than the total amounts of new Nr being introduced to the environment from all the power plants, transportation vehicles (including cars, trucks, aircraft, boats, and marine shipping vessels) and from industrial and commercial sources in and around the United States.
5. EPA should take a leading role among other federal agencies and university scientists in coordinating approaches to the several reactive nitrogen problems, and should join with other organizations in developing and maintaining a national nutrient information/accounting system that includes all chemical and physical forms of reactive nitrogen.

During this breakout session, the breakout group will address the following questions:

1) How does land use relate to Nr inputs to the landscape, and losses to air and water?

2) How can EPA best assess and influence the multiple issues (including policies, controls, and management) associated with land use decisions that affect Nr accumulation and release into the environment?

3) What are the most promising means by which the USEPA (and other federal, state, and private research, educational, and regulatory organizations) can facilitate new land use policies that take into account the need to control total Nr releases to the environment.

4) How can EPA best integrate policies which require understanding of the spatial heterogeneity of terrestrial and aquatic ecosystems and recognize that both regionally- and locally-specific target loads rather than nationally uniform approaches may be more effective in decreasing Nr pollution problems in the environment?

Breakout Group #6: Integrated Reactive Nitrogen Policies

Arvin Mosier and Paul Stacey
co-chairs

Fossil fuel combustion and food production have significantly increased the introduction of Nr into the US environment and, while there are tremendous benefits, there are also tremendous damages to the health of both ecosystems and people. Some problems from excess Nr (associated with sewage, fossil fuel combustion, crop/animal production, etc.) are well recognized and addressed. EPA has taken an impact-by-impact approach to Nr regulation, which, with few exceptions, addresses specific forms of nitrogen in a single system (aquatic, atmospheric, or terrestrial). The principal regulatory authorities pertaining to nitrogen are the Clean Water Act (CWA) and the Clean Air Act (CAA). Because such approaches rarely consider and impact more than a small part of the nitrogen system, and are reactionary in nature, i.e., they are largely aimed at fixing problems rather than preventing them, they often merely delay larger scale and sometimes unanticipated impacts. Optimizing the benefits of Nr while minimizing its problems will require an integrated nitrogen management strategy that not only involve EPA authorities under the CAA and CWA, but also other federal agencies (e.g., USDA, DOE, NOAA), state agency managers, the private sector and a strong public outreach program.

There are several ways in which the release and control of reactive nitrogen in the environment can be approached. In general these can be classified as follows:

- Transformation—in which one form of nitrogen is converted to another form (e.g. nitrification of wastewater, denitrification in engineered or natural systems),
- Removal—in which reactive nitrogen is sequestered from impacting a particular resource (e.g. ion exchange)
- Source limitation—in which the amount of reactive nitrogen introduced into the environment is lowered (e.g. lower fertilizer application rates, controls on NO_x generation)
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Effective management of Nr requires combinations of these approaches; none is a perfect alternative for controlling Nr in the environment. At the same time, care needs to be taken that the control, in and of itself, does not produce more Nr than it eliminates (e.g. removing dilute concentrations of Nr from secondary waste water requires considerable energy, which may result in the release of increased masses of reactive nitrogen to the air).

Generally speaking, US environmental policy employs four mechanisms for the management of contaminants, including Nr, in the environment that may be implemented at federal, state and local levels:

- Command-and-Control—in which permitted limitations on emissions, as promulgated under various statutes, are issued. Violations may result in the assessment of penalties.
- Government-based programs for effecting a policy, such as directed taxes, price supports for a given commodity, subsidies to bring about a particular end, and grants for capital expansion or improvement.
- Market-based instruments for pollution control in which cap and trade markets are used to bring about a desired policy end, often at reduced overall cost.
- Voluntary programs in which desired ends are achieved using private or government-initiated agreements or through outreach and education.

Just as strategies for the release and control of Nr require a combination of approaches, an integrated approach to the management of Nr must also use a combination of mechanisms, each most appropriate to the nature of the problem at hand, that are supported by critical research on reducing the risks of Nr, and reflective of an integrated policy that recognizes the complexities and tradeoffs associated with the nitrogen cascade. Control at one point in the cascade may be more efficient and cost effective than control or intervention at another point. This is why understanding the nature and dynamics of the N cascade is so critically important. Comprehensive actions implemented through the four mechanisms identified above could decrease the amount of Nr entering the environment by ~7 Tg N/yr, or about 25% of the anthropogenic Nr created each year. Additional actions could be taken, but all actions need to take into consideration an over-arching finding of the committee—as the amount of reactive nitrogen released to the environment grows, more effective integration of strategies that work across media, address multiple problems and avoids unintended adverse consequences is necessary to reduce costs and create more enduring solutions.

During this breakout session, the Integrated Nr Policies breakout group will address the following questions:

1. What are recommendations for policies on integration and multimedia management of Nr?

2. Is there a widely perceived need for an integrated Nr policy?

3. Are the INC suggestions for initially decreasing Nr entering the environment by 25% appropriate (i.e. too little, too much, wrong apportionment)?

4. Are there appropriate technical and regulatory mechanisms in place to facilitate an integrated Nr management policy? If not, what is needed create such a policy?

Breakout Group #7: Agroecosystems, Food Security, and Bioproducts

Ken Cassman and Rick Kohn
co-chairs

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Recommendations based on these findings include:

5. There is a pressing need to encourage reductions in Nr losses to the environment through capture and recycling of agricultural and urban runoff. It is possible to reduce excess flows of Nr into streams, rivers, and coastal systems by approximately 20% **(~1** Tg N per year.**)** through improved landscape management without undue disruption to agricultural production and human lifestyles and economies. This would include activities such as using wetland management (e.g., USDA Wetlands Protection Program), improved tile-drainage systems and riparian buffers on crop land, and implementing storm water and nonpoint source management practices (e.g., EPA permitting and funding programs).

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6. Acreage devoted to corn production has increased about 10% for corn based ethanol production, and nearly one-third of the crop is being devoted to bioethanol production. Current policy calls for bioethanol to expand to 15 billion gallons for corn-based ethanol and 36 billion gallons of bioethanol from all sources by 2022. We

expect fertilizer nitrogen to increase by at least 10% **(0.5** Tg N per year**)** initially to meet biofuel feedstock crop demand. Strategies to increase N-uptake efficiencies and strategies to reduce N losses must be implemented across corn and other N intensive biofuel crops.

In the absence of significant progress to increase N fertilizer uptake efficiencies to achieve increases in crop yields while, at the same time, reducing Nr losses, current biofuels policies will make it extremely difficult to reduce Nr releases to soils, water and air. In this regard, we endorse Section 204 of EISA which requires that after 3 years and then every 3 years thereafter, the EPA Administrator, the Secretary of Agriculture, and the Secretary of Energy shall report to Congress on the impact of the Clean Air Act requirements related to environmental issues, resource conservation issues, and the growth and use of cultivated invasive and noxious plants. The impact of expanded biofuel production on Nr load and environmental impact should be a critical component of this impact assessment.

7. There is an urgent need to improve and maintain foundational data required to track sources of Nr and Nr loads in the environment. Specific data needs include: rationalized and geospatially defined fertilizer use data; improved estimates of nitrogen fertilizer efficiency and its variation based on estimates from production-scale fields for the major crops and cropping systems; improved monitoring and estimates of wet/dry Nr deposition and its transformation/transport on land and water.

8. What is managed depends on what is measured, and because Nr undergoes multiple chemical transformations as it cascades through multiple media and ecosystems, impacts and intervention points are difficult to determine. There are multiple metrics for evaluating and prioritizing Nr impacts. Traditionally the measure has been tons of nitrogen by chemical species, but one can also measure damage costs of impacts, or replacement and mitigation costs or human health measures. The use of multiple metrics may provide a fuller picture of the impacts of reactive nitrogen and improve the setting of priorities.

During this breakout session, the breakout group will address the following questions:

5. Are there any questions, comments or concerns about the above findings and recommendations?
6. What types of programs (i.e. research, extension, incentives, penalties, etc) will be most effective for minimizing N runoff from agricultural and urban areas through investments in wetland management and artificial wetlands development, improved tile-drainage systems and riparian buffers on existing crop land, and exclusion of livestock from sensitive streams and rivers? Which federal agencies will need to be involved? How to achieve coordination across federal agencies; is there a basis for an integrated policy framework for reactive nitrogen?
7. What types of research and extension programs will be needed to achieve the required increase in N fertilizer use efficiency while sustaining increases in crop yields? How much will it cost? Which federal agencies will need to be involved? How to achieve coordination amongst programs across federal agencies?
8. What are the commendations for integration and multimedia management?

Breakout Group #8: Energy and the Cascading Costs of Reactive Nitrogen

Otto Doering and Bill Moomaw
co-chairs

We have a sense of the amount of reactive nitrogen involved in current energy production, but we are just beginning to realize that the damage cascades through air, land and water. This has profound implications for managing these releases of Nr, as current media focused and technology-based regulations are unable to address the full impacts in many regions.

Furthermore, the U.S. is entering a period of energy transition. The concerns here are what is the future likely to hold both with respect to changes in existing energy infrastructure and reactive nitrogen utilization and emission and what kinds of changes are most likely as we change from the existing infrastructure. In addition, new sources of energy, particularly bio-based energy, potentially involve important trade-off with respect to reactive nitrogen – both as a potent greenhouse gas and as a nutrient for plant growth and component of bio-based materials. These may be especially important in several phases of the nitrogen cascade.

Neither the Clean Water Act nor the 1990 amendments to the Clean Air Act deal fully with the kinds of changes in reactive nitrogen that may result from the movement to bio-based energy that will likely be largely non-point in nature.

Finally, there are many suggestions for market based regulation that involve such things as carbon trading schemes. Part of the move to market based management depends upon the ability to value things like ecological services as well as provide the cap or regulatory framework that allows market based regulation to function effectively. One important question here is how economic damage and mitigation metrics interact with or supplement the more traditional metrics of pollution abatement, toxicity, etc.

During this breakout session some of the following questions will be critical for this breakout group to address:

1. How can our understanding of the reactive nitrogen cascade help us to identify opportunities for lowering the damage costs of reactive nitrogen?
2. What kind of transition are we likely to see from traditional energy systems and how will these affect reactive nitrogen forms and amounts – comparing traditional to new sources?
3. What specific concerns should we have for reactive nitrogen with new bio-based energy systems?
4. What kind of policies or institutional structures lead to effective market based solutions for reactive nitrogen control?
5. When does the economic or dollar metric make the most sense in considering concerns of reactive nitrogen? What are its limitations and advantages? How is a dollar metric successfully juxtaposed with physical/biological or health metrics?