Research Statement

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Overview

Despite advances in the development of alternative fuels, there is still a long way to go to meet the nation's goals of energy independence and to develop the suite of carbon neutral fuel sources needed to replace existing fossil fuels and mitigate climate change. Solving these problems will involve a multidisciplinary approach since the hurdles we face as a nation are not purely scientific in nature. Some of the challenges that we face are the development and analysis of potential new fuel sources, minimizing cost of including new and existing alternative fuels sources in energy production, and increasing efficiency when using fossil fuels to lower our demand. The skills needed to do this include a mixture of laboratory work, economic analysis, analysis of societal acceptance of specific fuels, and fundamental research. This will take a concerted effort by a large number of scientists with interdisciplinary skill to analyze the multiple variables that will determine the success of specific alternative fuels to meet our current and future energy needs.

My research goals are fairly broad but to summarize I would like to be to analyze alternative fuel sources for potential use in electricity generation and mobile vehicles. I am deeply interested in the development of alternative fuel sources, implementing new technologies, and the effect of fuels on the air quality and global warming. I am very interested in collaborating with other scientists to perform more holistic analysis of potential fuels.

Current and Past Research

My past work has focused on the study of combustion properties and characterizing emissions from industrial and mobile sources. I have developed experience in a wide range of engineering fields that I believe would make me a valuable asset. The experience in several engineering fields including specialized instrument fabrication, gas chromatography/ mass spectrometry, health risks analysis, source apportionment, and framing complex problems to make a substantive contributions to:

Combustion Research

The main source of energy and electricity is combustion and that will likely continue to be the case for the foreseeable future even as the fuels we burn evolve. Fuel combustion is a complex chemical interaction involving numerous chemical species. The properties of the chemical interaction determine pollutant emissions and efficiency of the system. One of the most important properties of any flame is flame temperature as this governs the relative rates of reactions of the fuel and oxidant. Determining temperatures within flame, especially turbulent or low strain flames, is extremely difficult due to the rapidly varying flame temperatures in turbulent flame or laminar flame instabilities.

As a part of my master's work and research experience, I have extensively worked researching combustion and flame properties and developing novel methods for making measurements in flame. While working at the National Institute of Technology I worked on a project to explore extinction properties of laminar low strain flames in 1-g and μ-g. As a part of this work I developed a computational model to determine flame temperature based on the luminosity of a silicon carbide fiber in the visual spectrum[1].

At the University of Maryland, I developed a computational model to determine the viability of using the infrared emissions from seed particles to determine flame temperature of high strain turbulent counter-flow flames. When seed particles proved to have too much thermal inertia for the needed measurements,

I worked on extrapolating the silicon carbide temperature measuring technique to the turbulent flames using infrared imaging.

Characteristics of Air Toxics Exposure, Risks, and Sources

My thesis work focused on determining air toxics exposure, risks, and sources by analyzing measured air toxics concentrations in diverse exposure regimes including a mobile dominated site, a residential site heavily influence by industry, and a regional background site using traditional and novel techniques. The project was a multi-year field study to evaluate the concentrations, risks, and sources of air toxics, a specific subcategory of air pollutants, in Allegheny County, PA.

The first stage of this work was to perform a thorough health risks analysis including traditional methods and more advanced models including performing synergistic/antagonistic health risk analysis of air pollution. It was determined that particle phase pollutants dominated the cancer risks.

As a major part of this study, I developed an automated inlet for a commercially available Gas Chromatograph/Mass Spectrometer/Flame Ionization Detector (GC/MS/FID) to take high time resolved measurement of gas phase toxics for use in field studies[2]. Air toxics are difficult to measure due to low ambient concentrations and the diverse properties of the 187 pollutants. The standard approach for measuring air toxics is to use manually collected time-integrated cartridge or canister samples. The samples are then sent to laboratories for analysis often taking weeks or months. The end result is one average concentration, usually over a 24-hr period, for each species. However, ambient air toxics concentrations can vary greatly over a given 24-hr period [3]. While daily averaged data are useful for traditional methods of quantifying chronic health risks, high temporal fluctuations in pollutant concentrations are not resolved.

Deploying the instrumentation that I developed aided in more advanced risk analyses, assessment of acute risks, development of better estimates of exposure, and identification of air toxics sources. Receptor modeling, specifically Positive Matrix Factorization[4], using the high time resolved data was used to apportion air toxics risks to sources at each of the three exposure regimes. Knowing the sources of air toxics is vital enacting policy to effectively reduce risks. The results of the work provided technical support for decisions makers at the Allegheny County Health Department and were also used to evaluate Environmental Protection Agency (EPA) modeling of gas phase air toxics for use in policy making.

Determining the concentrations, risks, and sources of air toxics at three sites allowed for a comprehensive evaluation of the EPA modeling of gas phase air toxics, the National Air Toxics Assessment (NATA), for use in policy making. An initial assessment of NATA showed that in Allegheny County correctly identified the risks drivers but that mobile source contributions to air toxics concentrations are over-predicted and contributions from non-mobile and backgrounds sources are, on average, under-predicted.

Future Research Interests

Health effects of combustion emissions

Switching to alternative fuels, such as biodiesel, on a large scale will have a substantial effect on emissions and subsequent health effects both from primary and secondary emissions. I would like to conduct measurement and modeling work to explore the effects that these variations in pollutant concentrations will have on human health, the environment, and ecological systems. The first step to this work would be laboratory work to sample fresh and aged emissions from specific fuel types, with emphasis on pollutants that have been determine to be potentially damaging to people or the environment or precursors of those pollutants. Dispersion models can be used to look at how wide spread use of alternative fuels would affect outdoor concentrations of both persistent and non-persistent pollutants.

Outdoor concentrations can be used to extrapolate health risks from criteria pollutants and air toxics, affects on crop yields, the global warming potential of the fuel, and other adverse affects.

Multivariate analysis of alternative energy sources

There are multiple variables to explore when deciding which sources of alternative energy are appropriate for a given region including the state of the technology, emissions, cost, and availability. It is necessary to compare alternative energy sources across all of these variables to determine the technologies that best fit the needs. Mandating one type of renewable fuel when another would be cheaper and as effective can cost large amounts of money. Determining effective metrics for comparing between energy types and providing decision making tools to policy makers can aid in making the right decisions for each state/region. I am very interested in comparing energy sources for use in diverse climates and developing metrics that will aid decision makers.

Exploring Engine and Turbine Configurations that Increase Efficiency and Minimize Emissions

Increasing the efficiency of engines and turbines burning fossil fuels can go a long way to reducing fossil fuel demand. A study by the Rocky Mountain Institute showed that 62% of coal fired power plants could be done away with if the 40 worst performing states did as well as the 10 best performing state using current technology[5]. Developing new materials and configurations of turbines and engines could increase that number. The efficiency of engines is a function of temperature, fuel mixing, and properties within the engine or turbine. Designing turbines and engines that increase efficiency without increasing pollutant emissions could drastically reduce our demand for fossil fuels.

Mitigating climate change

One of the greatest challenges facing our nation is reducing greenhouse gases in the atmosphere whether that is by reducing green house gas emissions or removing carbon dioxide from the air. As carbon dioxide levels increase in the atmosphere, simply reducing emission may not be enough to avoid catastrophic climate change. There is a need to explore alternative methods of reducing the effect of climate change on the planet. Potential alternatives include economically removing carbon dioxide from the atmosphere and increasing particle concentrations in the upper atmosphere. Developing these technologies means that we can do something to mitigate climate change even if we do not reduce emissions in time to avoid harmful effects. In addition we will have a safeguard if current carbon reducing technologies, such as sequestration, do not contain carbon as we hope.

Adapting to climate change

Without drastic change in our energy consumption patterns, there will increasing impacts from climate change in the coming years especially for those living in low lying areas and areas prone to natural disasters. Increasing global temperatures will lead to sea level risks, increased storm activity, and increased natural disaster, such as wild fires. Living with these changes will mean adapting current cities to these environmental stressors. Doing so will take a combination of new technologies and effective planning. Waiting until we start to see the effects of climate change is too late. There is a need to start developing potential scenarios now. In the United States most of our major cities are on only a few meters about sea level. They represent huge investments in capitol and resources and it is important to explore methods of preserving them now.

References

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