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Advancing Methane Mitigation by Understanding the Physics and Chemical Kinetics of Ultra-lean Combustion Dynamics

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The recent climate change discussions between Canada and the United States of America and other international agreements target methane a potent GHG. The U.S. Environmental Protection Agency will begin developing regulations for methane emissions from existing oil and gas sources while Environment and Climate Change Canada will publish proposed initial phase regulations by early 2017. Although goals are set for anthropogenic methane emissions they should not be the only target for mitigation, thus technology to mitigate naturally occurring methane is required. At present the wetlands emissions, 150–180 TgCH4 per year, are thought to dominate, but the levels of permafrost emissions are potentially much greater. It has been estimated that the methane stored in the permafrost and clathrates may be greater than all other fossil fuels combined and may be poised to be atmospherically released as the Arctic temperature increases. Methane is typically quoted as having about 25 times the forcing factor of carbon dioxide, but that is over a century, it can be more than 84 times that of carbon dioxide over 20 years. The impact is immediate, which may accelerate a positive Arctic feedback loop causing much greater temperatures and rapid release of the stored methane. As reported in Nature, the cost of this methane release could be $60 trillion and the outcome could be disastrous for the climate and world economy.

The impetus of this work is on modelling and simulation of ultra-lean methane oxidation/combustion. The challenges associated with ultra-lean methane oxidation are the conditions for ignition of the ultra-lean mixture and sustainability of the combustion process. The interest in MILD combustion has been mainly driven by the need for low emission combustion technology, but methane capture and energy utilisation requires a deeper understanding of ultra-lean combustion. The fundamental studies of the chemical kinetics, physical process and reliable kinetic schemes of ultra-lean methane combustion are sparse, but are required to do proper computational fluid dynamics studies in support of designing and developing advanced mitigation systems. Ultra-lean methane combustion cannot be achieved using traditional combustion technologies because the thermal energy available in the system may not be sufficient to ignite the fuel or even sustain the chemical reactions; thus, the concept of moderate or intense low-oxygen dilution (MILD) combustion is of great relevance. A discussion of the modelling approach in the context of low concentration methane oxidation/combustion is provided. A brief review of anthropogenic emissions of methane and some combustion mitigation and utilisation technologies will be discussed with the view toward developments focused on innovative technologies to achieve sustainable oxidation/combustion and energy capture is discussed.

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