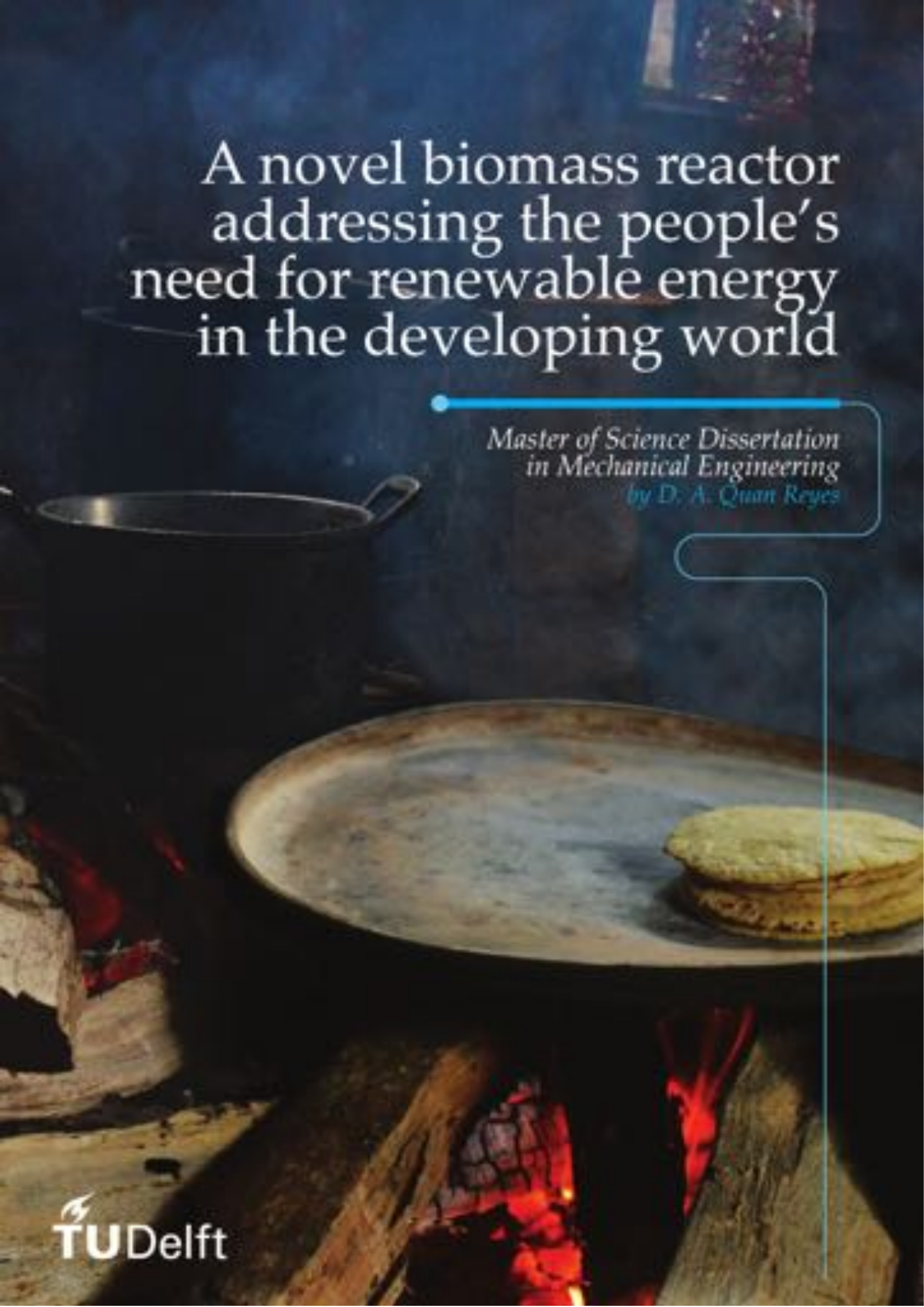

A novel biomass reactor addressing the people's need for renewable energy in the developing world

Master of Science Dissertation in Mechanical Engineering

by D. A. Quan Reyes

TUDelft

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To the legacy of Isabel Gutiérrez de Bosch

Abstract

The current economic-development system based on fossil fuels can no longer sustain itself and is incapable of satisfying the needs of the global population. Nearly one third are unable to meet even their most basic needs that involve harnessing energy for everyday essential tasks such as maintaining livable shelter and food preparation.

Models of *development* have exacerbated the problem by promoting and subsidizing fossil fuel based solutions that require those struggling to survive to do so at the expense of the environment and other species. This is a self-defeating trap, whereby the urgent needs of the most vulnerable are pitted against climate change and the mass extinction of complex life forms. The only way to break this contradiction is through the creation of a new development system that removes incentives for short-term, destructive profit and puts people and other forms of life at its center. Healthy, sustainable development must be rooted in the fair and democratic allocation of resources. Prioritization of truly life-focused progress would allow for human beings to shape their own destinies through the use of locally available, renewable energy resources that do not contribute to mass extinction or climate catastrophe.

While the downward spiral towards extinction may seem unstoppable, in reality, the biggest obstacle is simply coming to accept that the old view of what constitutes positive development – an extractive, hierarchical philosophy powered by fossil fuels - must be replaced with the new paradigm based on sustainability and cultural realism. Once that understanding has been reached, it is a matter of targeting key areas for change that will make the most difference in the shortest amount of time. The project outlined herein is a contribution to that new development system. My carefully selected target will address the energy needs for clean cooking and heating for the one third of the world population that relies on low-efficiency biomass combustion technology. Although such technology may at first seem too modest to make a difference, the impacts of making this simple change would have profound, worldwide implications. If that vulnerable one third of the world's population could access clean domestic technology, there would be enormous improvements in health and environmental conditions.

The *Kulkan* reactor is a biomass gasifier coupled to a burner that optimizes the combustion process and heat transfer by means of heat recovery using an air pre-heater and partially premixed laminar combustion of the syngas. The novel design was founded on three hypotheses that addressed the optimization of efficiency, pollution minimization by flame quenching prevention, and reduction of ultra-fine alkali particle emissions. The first two were investigated using an algebraic model (0-D), and computational fluid dynamics of reacting flow for 1-D, 2-D and 3-D. The algebraic model predicts an efficiency of $[60 - 65\%]$ which is 4-8 times higher than traditional cooking technology and 25% higher than the best improved cookstove ever reported. The 1-D and 2-D simulations show reduction feasibility of laminar pre mixed combustion and a reduction of flame length of up to 50% compared to non-premixed, supporting the idea of more compact combustion chambers and prevention of flame quenching.

The 3-D simulations show essential information on the importance of the pressure drop calculations necessary for the design process of a *Kulkan* reactor, particularly for the burner. Furthermore, arguments for the third hypothesis are presented which invite further investigation to reduce the ultra-fine particles containing highly toxic alkali metals, which are produced during high efficiency biomass combustion.