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# A cost-benefit analysis of livelihood, environmental and health benefits of a large scale water filter and cookstove distribution in Rwanda

Christina Barstow[a], Randall Bluffstone[b], Kyle Silon[c], Karl Linden[a], Evan Thomas[a,*]

[a] University of Colorado Boulder, Mortenson Center in Global Engineering, 4001 Discovery Drive, Boulder, CO 80205, United States
[b] Portland State University, Institute for Economics and the Environment, 1825 SW Broadway, Portland OR 97201, United States
[c] DelAgua Health, The Old Dairy, Lower Fyfield, Marlborough, Wiltshire, SN8 1PY, United Kingdom

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ABSTRACT

Public health interventions targeting contaminated drinking water and indoor air pollution may help to reduce two of the leading causes of death among children under 5 in Rwanda - diarrhea and pneumonia. These interventions also have the potential to provide economic benefits, including reduction in expenditures on fuelwood and time spent on fuelwood collection, environmental benefits through reductions in deforestation and greenhouse gas emissions, and additional economic benefits attributable to health impacts. We evaluate one such large scale intervention, the *Tubeho Neza* program in Western Rwanda using a cost-benefit analysis. This paper estimates monetized program benefits related to fuelwood savings, time savings, environmental and health benefits, which are then compared to the overall program cost, over a 5 year project year period. The total program cost is estimated at over $11.91 million, and total benefits at the means valued at over $66.67 million, for an estimated mean cost-benefit ratio of over 5.6. A sensitivity analysis of the major factors indicated a cost-benefit ratio range of approximately 1–16. The primary benefit identified is the environmental impact of woodfuel savings attributable to the improved cookstoves. This study estimates 118,000 tonnes of annual woodfuel savings in the Western Province may be attributable to the program in year 1, decreasing to 65,000 tonnes in year 5. These estimates suggest that this program may help to compensate for the government of Rwanda's projected regional woodfuel deficit of 106,000 tonnes per year by 2020. Overall, this study suggests that the *Tubeho Neza* program provides benefits in excess of the program costs.

## 1. Introduction

Public health interventions designed to address contaminated drinking water and indoor air pollution hazards in developing countries may under some circumstances deliver additional benefits. Importantly, the economic and environmental benefits can also contribute to the overall suitability and sustainability of an intervention. For example, advocacy of household water treatment methods replacing boiling can both reduce fuelwood consumption and provide time savings (Clasen et al., 2008; Peletz et al., 2012). Similarly, implementation of improved cooking stoves has the potential to reduce expenditures on purchasing fuelwood, and time from the collection of fuelwood. Additionally, reduction in fuelwood consumption can result in significant environmental benefits both locally through reduced deforestation and globally through reduced greenhouse gas emissions (Hutton et al., 2007a; García-Frapolli et al., 2010; Habermehl, 2007, 2008). Furthermore, the health improvements realized may translate into economic benefits to countries and communities.

In the Republic of Rwanda, where two of the largest contributors to mortality among children under five are pneumonia (18%) and diarrhea (8%) (United Nations International Children's Emergency Fund, 2012), interventions that can improve access to clean drinking water and reduce exposure to harmful indoor air pollution have the potential to provide significant health benefits. Additionally, Rwanda's 10.5 million people may benefit from the livelihood and environmental benefits from these programs. With over 80% of Rwandans relying on firewood as their primary fuel and over 40% boiling their water for treatment prior to drinking (National Institute of Statistics of Rwanda, 2012), decreased firewood demand from water filters and high efficiency cookstoves could help reduce the shortage in availability of firewood. Additional

* Corresponding author.
*E-mail addresses:* barstow@colorado.edu (C. Barstow), bluffsto@pdx.edu (R. Bluffstone), kyle.silon@delagua.org (K. Silon), karl.linden@colorado.edu (K. Linden), ethomas@colorado.edu (E. Thomas).

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cost and time savings from reduced fuelwood consumption could help curb some of the economic burden on the approximately 80% of Rwandans who live on less than $2 per day (World Bank, 2011).

A cost-benefit analysis can provide insight into the relative contribution of these livelihood, environmental and health benefits. Public health programs advocating water treatment methods and improved cookstoves can vary greatly in quality, scale and impact, from small community driven projects to large scale government programs, from non-profit to for-profit models, and from subsidized to market based funding mechanisms. Because of the high degree of variability of impacts between these program models, understanding a particular program's ability to deliver benefits to the target population in a cost effective and sustainable way is essential to inform future interventions. This paper analyzes one such program, the DelAgua Health and Ministry of Health *Tubeho Neza* program in rural Rwanda, through the comparison of the program costs, and the potential benefits of the program related to fuelwood savings, time savings, environmental and health impact.

### 1.1. Program setting and population

The *Tubeho Neza* ("Live Well") program is a partnership between the Rwanda Ministry of Health (MOH) and the social enterprise, DelAgua Health (DelAgua), designed to deliver environmental health technologies to some of these poorest of Rwanda's households. An initial pilot phase of the program (Phase 1) was implemented in October of 2013 among approximately 2000 households (Barstow et al., 2014). Following the completion of several studies in Phase 1, including a health impact randomized controlled trial (Rosa et al., 2014), a large-scale (Phase 2) program among approximately 102,000 households was implemented between September and December of 2014 in Rwanda's Western Province. The program included the distribution of the EcoZoom Dura improved wood burning cookstove and the Vestergaard Frandsen LifeStraw Family 2.0 household gravity-fed water filter. In 2015, a further 250,000 cookstoves were distributed primarily in the Eastern Province (Phase 2). The intervention includes household level education and behavior change messaging to each household through MOH Community Health Workers. Currently, the program includes educational promotion activities as well as repair and replacement services throughout program households (Barstow et al., 2016). This paper considers only the costs and benefits attributable to the Phase 2 program.

Baseline woodfuel and water collections practices are shown in Fig. 1 and the cookstove and water filter interventions are shown in Fig. 2.

## 2. Materials and methods

The analysis here examines the costs and benefits of the *Tubeho Neza* program over a projected period of 5 years and is informed by field survey data, kitchen performance tests and controlled cooking tests, as well as two years of experience with the program implemented at-scale. Similar studies have been conducted on cookstove programs (Hutton et al., 2007a; García-Frapolli et al., 2010; Habermehl, 2007, 2008) and drinking water interventions (Hutton et al., 2007b) separately, but the authors are not aware of any cost-benefit analysis of a combined program. The cost-benefit model was designed based on the methodology outlined in the aforementioned referenced studies, with additional guidance from World Health Organization documents for conducting cost-benefit analyzes of household energy, and water and sanitation interventions (World Health Organization, 2004, 2006). Potential benefits include those related to livelihood and environmental impacts associated with the water filter and improved cookstove technologies implemented within the *Tubeho Neza* program. Further, health impacts were estimated based on experimental trials conducted within the program, and projected using emergent models. In this analysis, we consider only the operational phase of the water filters and stoves. We do not consider the full lifecycle costs or environmental impacts of the product production, transportation, or disposal.

### 2.1. Cost estimation

The cost of the program was quantified through an incremental cost analysis where intervention costs are separated into capital costs and recurrent costs. Investment costs describe all intervention costs incurred at the beginning of the intervention, including the cost of the hardware and the administrative and implementation costs. Recurrent costs are those which occur periodically throughout the lifetime of the program, including product maintenance and educational outreach activities. Given both technologies have an estimated lifetime of five years and replacements are not currently planned by the government of Rwanda or the implementer, this study considered only the capital and operating costs for an initial distribution, supported for 5 years.

To account for the differential timing of costs, a commonly used discount rate of 3% is applied to all costs and benefits occurring after 2014. As an important robustness check, we also examine results at 0% and 5% discount rates. We find that our overall conclusions are not sensitive over the range of discount rates. The net present value (NPV) can then be calculated using the following formula:

$$NPV_{costs} = \sum_{t}^{T} \frac{costs}{(1+r)^t}$$

where $\sum(t, T)$ is the sum of all costs at time periods from t = 0 to the end of the intervention T = 10 years, and r is the discount rate.

### 2.2. Technology adoption quantification

A data set collected by the implementer to meet the United Nations Clean Development Mechanism requirements for carbon credit issuance, a primary form of revenue to support the program, was used to quantify initial uptake and adoption values for cookstoves and water filters. In a recent study, the determinants of water filter and cookstove adoption in

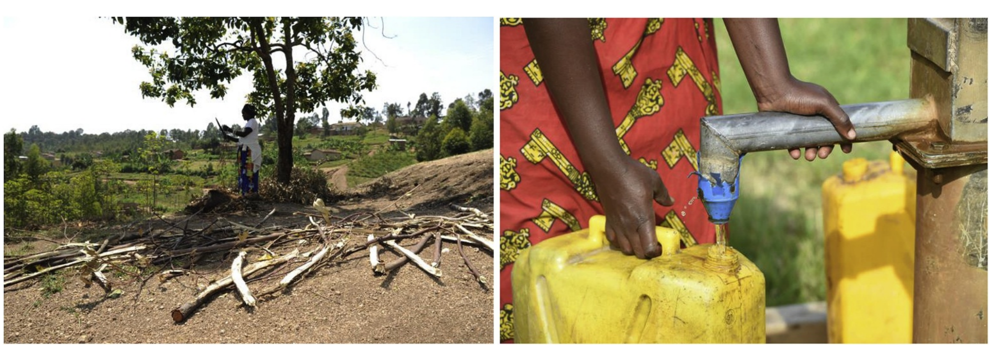

**Fig. 1.** Woodfuel and water collection practices in Rwanda.