# Providing Clean Fuel for the Developing World: Hydrogen Stove Technology to Mitigate Indoor Air Pollution

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## Introduction

*Acute lower-respiratory infections (ALRI's) are the #1 cause of death in children under five.[1]*

3 billion of the world's poorest rely on biomass-fueled stoves (left)

3.8 million people die annually from exposure to household air pollutants

50% of pneumonia deaths in children under five linked to indoor air pollution

*From World Health Organization, 2018*

Our Bass Connections team began by researching the current trends and history of biomass as a fuel source for cooking, focusing specifically on India. We gained an understanding of the cultural motivations for using biomass, indoor air pollution problems resulting from burning biomass, restrictions in accessibility to cleaner resources, and the implications of government incentives to convert to other cooking fuels. From here, we devised an idea for an alternative fuel source that would eliminate the need for a supply chain, be renewable, and provide fuel for cooking and heating at a lower cost than using electricity from an electrochemical battery.

## Project Goals

**Generate** hydrogen locally with an alkaline water electrolyzer

**Combust** hydrogen gas safely as a cooking fuel with a hydrogen stove

**Compress** hydrogen gas in an ultra-high pressure vessel system

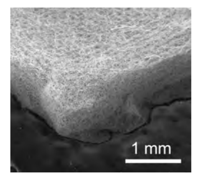
**Conduct** case study in India to examine cultural context of target population

## Hydrogen Generation

**Purpose:** Generate $H_2$ locally with an Alkaline Water Electrolyzer for use with hydrogen cook stove

**Target:** Generate current densities high enough to produce 40 L of hydrogen (i.e. 10 hrs of cooking time)

**Alkaline Water Electrolyzer System Set-Up:**



2 porous Ni microfiber electrodes

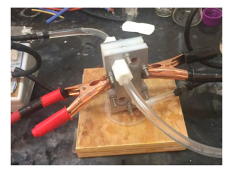
+

Gas impermeable PES membrane

+

Electrolyte (30% wt. KOH)

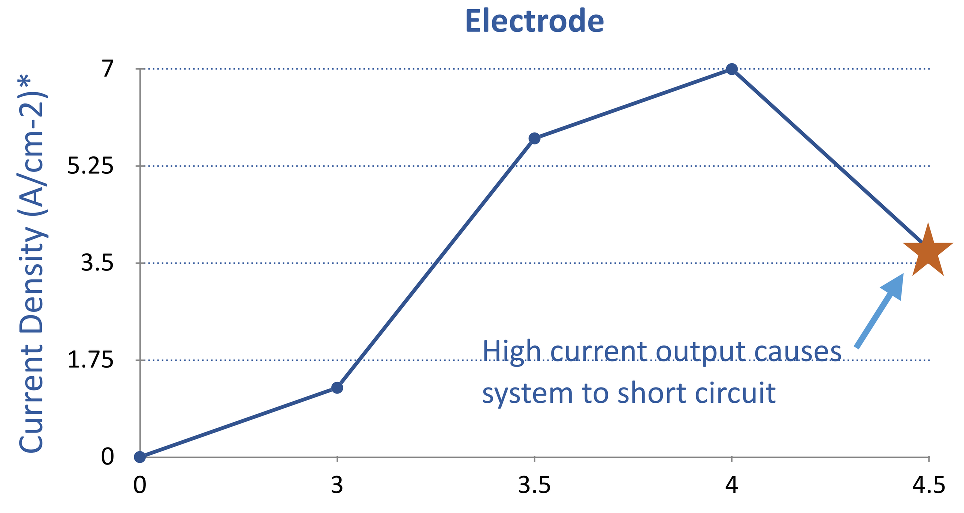
+



Power Supply

**Result:**

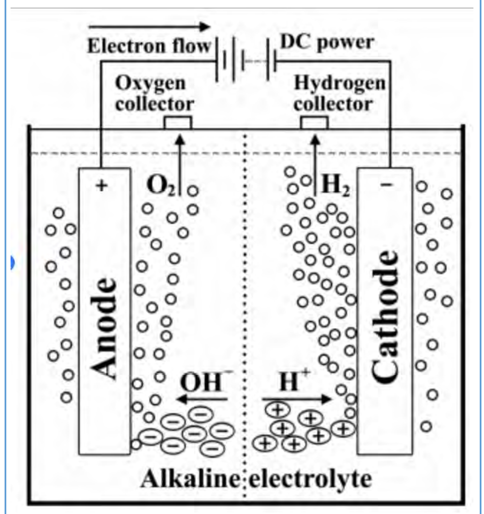
Sustained Operation of 2 x2 cm Ni Microfiber Electrode




*Current density measures $H_2$ production

**Electrolysis Reaction**

$$2H_2O \longrightarrow 2H_2 + O_2$$




Basic Scheme of a Water Electrolysis System[3]

## Hydrogen Compression

**Purpose:**

Hydrogen is the least dense gas, therefore it must be compressed to ultra-high pressures to maximize its energy density.

**Target Pressure:** 300 bar

**Pressure Vessel Set-Up:**

Sealed interior chamber contains water and 2.5 mL balloon filled with gas + Additional water is pumped into the vessel to increase the pressure of the interior chamber

Interior of ultra-high pressure vessel with balloon attachment fitting

**Result:**

1 L of air @1 bar (~1 atm) → Compression → 3 mL of air at 300 bar (~296 atm)

## Combustion

**Purpose:**

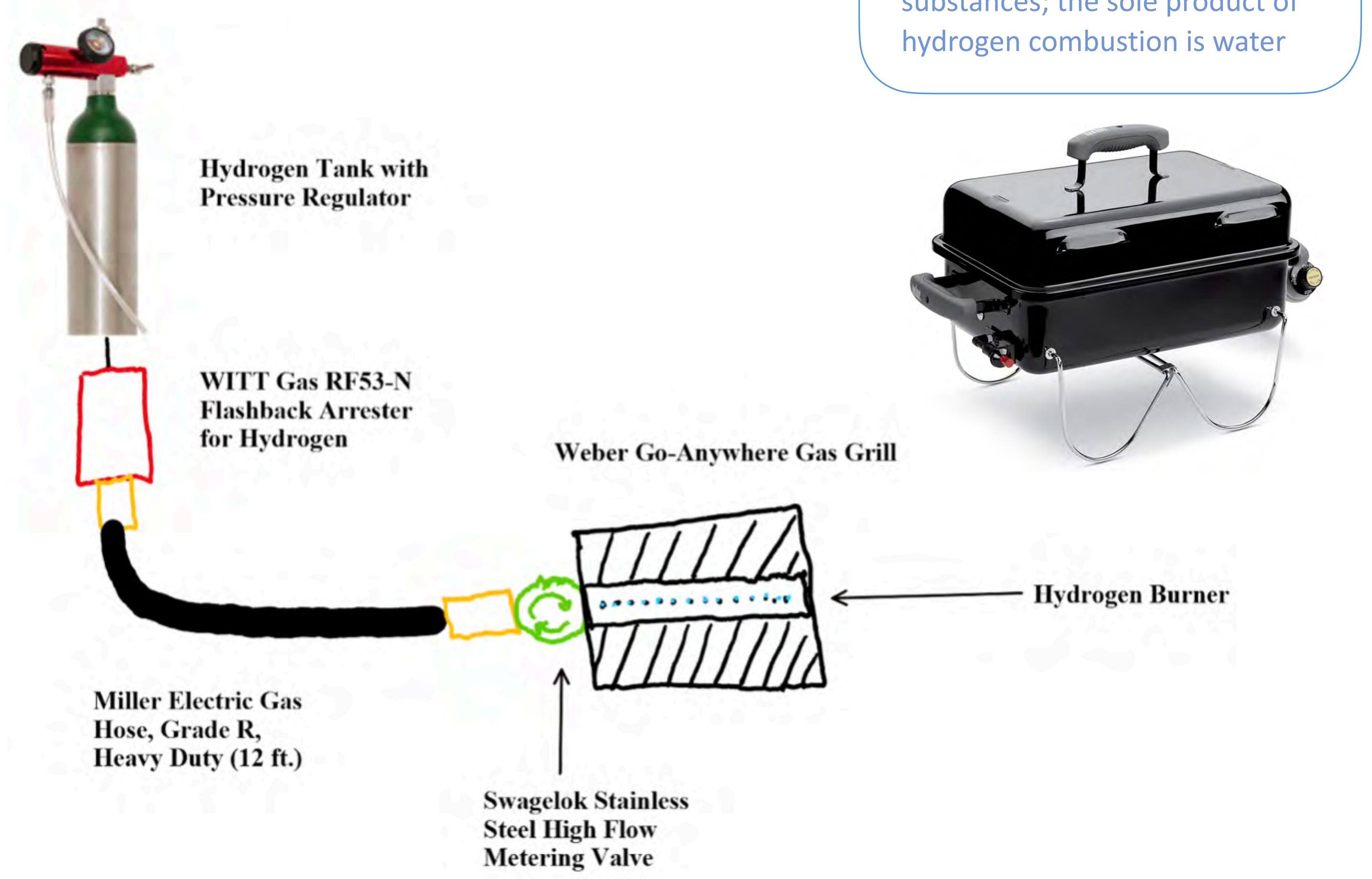
Construct a safe, efficient hydrogen stove that can utilize 40 L of $H_2$ at 300 bar for 10 hours of cooking.

**Combustion Reaction**

$$2H_2 + O_2 \xrightarrow{\Delta} 2H_2O$$

Ideally, hydrogen combustion in air does not generate harmful substances; the sole product of hydrogen combustion is water

**Hydrogen Stove System Set-Up:**




A Weber 1141001 Go-Anywhere [Propane] Gas Grill (right) was modified to combust hydrogen with the assistance of the Duke Physics Instrument Shop and Dr. Walter Pyle, director of research at H-Ion Solar Inc.

**Additional Modifications:**

- Aluminum griddle top
- Variable-area flowmeter

**Safety & Efficiency:**

- Tightly sealed connectivities and flashback arrestor to maximize safety
- Burner crafted from stainless steel to minimize NOx formation
- Variable-area flowmeter permits for efficiency testing in the future

**Result:**

The team tested the modified grill under a fume hood, successfully cooking a patty.

## Implementation

Developing a clean cookstove solution is one challenge, but implementing it requires a whole new set of considerations. While working on building the cookstove, we simultaneously researched policy implications of a clean cookstove intervention.

**The most critical findings were:**

- **Cost** is the **largest barrier** to cookstove adoption
- **Women and children** are disproportionately impacted by pollutants from traditional cookstoves
- Households in which **women** have **less bargaining power** are **less likely to adopt** novel cookstove solutions
- Consumer cookstove **preferences vary significantly** from each individual household. Thus, consumer preference should guide cookstove design

### Independent Duke Engage Project: Piloting Improved Cookstoves In India

As a continuation of this project, we worked with an NGO in Gujarat, India to help them pilot their improved cookstoves. The purpose of this was to fully understand what it takes to implement a cookstove intervention and understand the workings of a village and the numerous actors necessary for an intervention to be a success. This project was later cancelled due to the COVID-19 crisis. **However, the framework of the plan once arriving in India was:**

- Phase 1: Familiarization with the NGO and the scope of their work. Finalizing which employees will aid in this project specifically.
- Phase 2: Immersion in the community to understand consumers' daily lives and preferences
- Phase 3: Creating awareness and developing interest in the community through demonstrations, flyers, door-to-door discussion, etc.
- Phase 4: Developing the pilot program through working with community members, NGO employees, and local actors (especially cookstove manufacturers).

## Summary of Progress

**Generation**

- Produced and scaled AWE electrolyzer
- Optimized required power input and electrolyte flow rate to maximize current density

**Compression**

- Compressed air in ultra-high pressure liquid vessel as proof-of-concept
- Identified compressor specifications to accommodate system volume goals

**Combustion**

- Constructed $H_2$ stove from commercial grill
- Modified cooking surface to accommodate Indian cuisines
- Conducted multiple leak checks to verify and improve safety of apparatus

**Next Steps**

- Seamlessly integrating these three components
- Scale electrolyzer and compression unit to serve an entire village
- Cost analysis
- Field-test the efficacy of the unified system in a village in India
- Refine system components as needed
- Distribute cookstoves on a household basis

*Technology alone is not enough to address global problems. In light of this, an exhaustive literature review of the social, economic, and theoretical requirements and obstacles associated with our project has been written.*

**References**

1. Household Air Pollution and Health. https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health (accessed Nov 6, 2019).
2. Wiley, B. J., Burning Hydrogen to Prevent Pneumonia. Duke University: 2019; p 2.
3. Hydrogen production by alkaline water electrolysis - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Basic-scheme-of-a-water-electrolysis-system_fig3_262617097 [accessed 6 Nov, 2019]

Acknowledgements

*Sincere gratitude to Dr. Benjamin Wiley, Dr. Nico Hotz, Feichen Yang, Dr. Marc Jeuland, Dr. Walter Pyle and the Bass Connections Research Program for your mentorship, dedication, and support.*