U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Global Alliance for Clean Cookstoves – Clean Cooking Forum 2015

November 10-13, 2015

Elliott Levine

Technology Development Manager

Demonstration and Market Transformation Program

Bioenergy Technologies Office

Global Alliance for Clean Cookstoves: The United States' Commitment

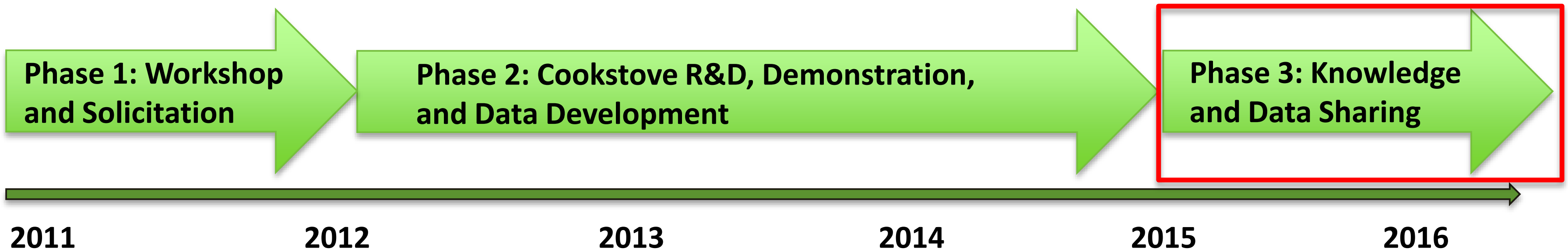
On September 21, 2010, Secretary of State Hillary Rodham Clinton announced the **Global Alliance for Clean Cookstoves**, a public-private partnership led by the United Nations Foundation, which focuses on creating a thriving global market for clean and efficient household solutions.

The U.S. Department of State, U.S. Environmental Protection Agency (EPA), U.S. Department of Energy, U.S. Department of Health and Human Services – Centers for Disease Control and National Institutes of Health, and the U.S. Agency for International Development (USAID), all of whom are founding partners of the Alliance, have forged an unprecedented government effort to mobilize financial resources, top- level U.S. experts, and research and development tools to help the Alliance achieve its target of '100 by 20,' which calls for 100 million homes to adopt clean and efficient stoves and fuels by 2020.

United States' Commitment – $50.82 million over the next five years

- **Department of State/U.S. Agency for International Aid and Development (USAID) – $9.02 million**
- **Environmental Protection Agency (EPA) – $6 million**
- **Department of Energy (DOE) – $10 million**
  - DOE will contribute $10 million over the next five years and conduct research aimed at addressing technical barriers to the development of low emission, high efficiency cookstoves through activities in areas such as combustion, heat transfer, and materials development.
- **Department of Health and Human Services (HHS)**
  - National Institutes of Health (NIH) –$24.7 million
  - Centers for Disease Control (CDC) – $1 million

Cookstove R&D Leading to Adoption



- **Phase 1: Workshop and Solicitation**
  - Determination of key barriers and technical R&D areas.
- **Phase 2: Cookstove R&D, Demonstration, and Data Development**
  - Nine currently funded projects that are contributing research, development, and tools that will lead to clean and efficient biomass cookstoves.
- **Phase 3: Knowledge and Data Sharing**
  - Promote technology transfer, commercialization and collaboration –facilitate adoption.
  - Dissemination of results, technologies, and lessons learned.
    - Organize an open, high-quality conference for the cookstove community to share knowledge of improvements in cookstove design, development, and use.
    - Assist with training in lab test protocols and use of necessary equipment.
    - Prototype testing and comparison of results.
    - Perform Life-cycle analyses emissions from alternative stove fuels over the entire supply chain.
    - Organize workshop on Stove Use Monitors (SUMs)—State Of The Art (SOTA) and key needs.
    - Identify other markets where new cookstove technology can be embedded-heating stoves.
  - Develop peer reviewed research and publications.

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Results From Cookstoves Workshop led Directly to Subsequent R&D Solicitation

- **DOE conducted Cookstoves workshop (January 2011)**
- **Key Findings from Workshop and Report (May 2011)**
  - At least 90% emissions reductions and 50% fuel savings are appropriate targets.
  - No single solution will adequately address the cookstove challenge.
  - Technical R&D should guide and be guided by field research and implementation programs.
  - The cost and performance tradeoffs associated with the use of processed versus unprocessed fuels should be explored.

DOE Solicitation and SBIR Opportunity Announced in 2012 (Phase 1)

- **Goal:** To increase the viability and deployment of renewable energy technologies through research, development, and tools that lead to clean and efficient biomass cookstoves.
  - Meet or surpass highest levels of stove performance (90% / 50% *)
  - Low-cost and affordable
  - Use the biomass fuels in indigenous areas
  - Durable and safe
- **Topic 1:** Development of innovative cookstove designs that allow users to burn wood or crop residues more efficiently and with less smoke than open fires and traditional stoves.
- **Topic 2:** Improved understanding of combustion physics, thereby enabling future developments in cookstove designs.
- **SBIR Topic:** Clean Biomass Cookstove Technologies

* Cut particulate emissions by 90% and reduce fuel use by 50%

Each Project Selected Offered Technical Improvements Leading to Performance Enhancement

Nine total projects – all are still in progress and are largely 3-year projects.

- **Five Competitively based projects from DOE solicitations:**
  - **Aprovecho (Oct 2013 – Sept 2015):** Development of high-performance Tier-4 biomass cookstoves.
  - **BioLite (Feb 2013 – Dec 2015):** Development of a clean burning and reliable "combustion core" using BioLite's advanced fan technology.
  - **Colorado State University (Feb 2013 – Jan 2016):** Development of a computational combustion model to assist in stove design.
  - **University of Washington (Sept 2013 – Sept 2016):** Development of a commercially viable, manufacturing ready, natural draft cookstove that will exceed ISO Tier-4 criteria.
  - **Research Triangle Institute (RTI) (Jan 2013 – Dec 2014):** Development of an affordable add-on device to enhance biomass cookstove performance.
- **Two National Laboratory Projects:**
  - **ORNL:** Combustor material durability.
  - **LBNL:** Developing advanced biomass research-grade cookstove.
- **Two Small Business Innovation Research (SBIR) Projects:**
  - **BioLite**: Commercialization of an ultra-clean fan stove that aims to cut toxic pollutant emissions by 90% and reduce fuel use by 50%.
  - **Berkeley Air Monitoring Group**: Platform for Integrated Cookstove Assessment (PICA) to monitor in-home impacts of household energy interventions

Characterizing the Projects

- **Developing low-cost, durable stoves that achieve stringent efficiency and emissions goals (advanced-stoves)**
  - Aprovecho
  - Biolite, LLC
  - LBNL
  - Research Triangle Institute
  - University of Washington
- **Understanding the engineering science for advanced stoves**
  - Colorado State University and ORNL
  - LBNL
- **Identifying stove designs to meet local cooking needs**
  - Aprovecho
  - LBNL
- **Identifying the nuances of successful stove dissemination and field performance**
  - Berkeley Air Monitoring Group
  - LBNL

DOE Funded Cookstove Project Benefits

- ❑ Development and testing new cookstove technologies
  - air manipulation, TEG, EGR, Other
- ❑ Development of parametrically variable research stove
- ❑ Development of combustion, heat transfer and computational fluid dynamics (CFD) models
- ❑ Studied improved hearth materials and material testing protocols
- ❑ Greater level of technical readiness
  - ❑ Technologies with a number of prototype iterations
  - ❑ Integrated stove development with user field testing
  - ❑ Greater emphasis of design for manufacturing
- ❑ Capacity building
  - ❑ Additional researchers working on these projects
  - ❑ Participation of post-doctorate, graduate, and undergraduate students
- ❑ Scholarly publications, paper, and a guide book
- ❑ Contributions to the ISO TC 285 process specifically for testing protocols
- ❑ Stakeholder engagement: Conducted research reviews with cookstove stakeholders-- DOE grantees, EPA, GACC and ETHOS to enable the exchanging of information

DOE Cookstove Grantee Achievements

Aprovecho Research Center

- Developed and field tested five working prototype biomass cookstoves
- Wrote a 174 page book detailing the technical approaches to manufacturing clean burning biomass cookstoves
- Published an article in EcoHealth titled "Results of Laboratory Testing of 15 Cookstove Designs in Accordance with the ISO/IWA Tiers of Performance."

Lawrence Berkeley National Lab

- Commissioned a world-class lab for rapid testing of stove emissions and efficiency; also for training
- Newly designed Berkeley Modular Stove produces only 90 mg/MJ_d even at high thermal power output of 5.3 kW
- Tested six own stove prototypes, and two external stoves in support of GACC's Round Robin effort
- Filed one invention disclosure with LBNL IP Office for stove flame manipulation
- Published four scientific articles on: testing protocols, stove-testing results, and field measurements of adoption
- Substantially contributed to ISO TC 285 process, specifically to WG2 on Lab Testing Protocols
- Trained 2 postdocs, 8 graduate students, and 3 undergraduates in biomass stove science and technology

Colorado State University

- Developed a new open source CFD code
- Developed a parametrically variable laboratory TLUD that enabled testing of over 30 different design configurations
- Performed over 100 tests with greater than 30 different configurations, enabling the development of a final conceptual prototype.
  - A market ready prototype is under development.
- Published "The Effects of Fuel Type and Stove Design on Emissions and Efficiency of Natural Draft Semi-Gasifier Biomass Cookstoves"

Oak Ridge National Lab

- Has validated a new method for evaluating new materials to help cookstove designers with future material selection.
- At least one material has been identified that offers promise for improved corrosion resistance over state-of-the-art cookstove materials at lower costs.
- At least 15 different materials combinations were tested and the results are being published in several peer-reviewed publications

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

DOE Cookstove Grantee Achievements Cont.

Research Triangle Institute

- Developed a working self-powered prototype add-on device for an Envirofit M-5000 cookstove that reduces PM emissions by 70%.
- Prototype enhanced M-5000 stove was tested both in the lab and in the field (India).
- Test results demonstrated a 70% reduction in PM emissions as compared to the standard M-5000 stove in both the lab and the field.
- CSU and Envirofit have filed a patent on the air injection method for the enhanced prototype stove.

University of Washington

- UW prototype rocket stove exceeds all Tier 4 ISO metrics (except low power consumption Tier 3.2)
- Rocket stove in final stages of production design to be manufactured in Kenya in 2016
  - 50 of these production stoves have been built for user research in Kenya, on durability testing, and pilot trials.
- Developed simple model to predict rocket stove efficiency (available on web December 2015)
- Three supported grad students and three publications nearing submission.
- Rocket stove intellectual property disclosure

BioLite

- Proof of concept in the lab achieved: > 80% particulate reduction vs. the 3-Stone fire and >50% reduction in fuel use from 3-Stone fire (50-70% Particulate reduction vs. Patsari baseline)
- Design for manufacturability and minimum cost yielded a less than $10 USD estimated cost of production per prototype
- 10 of 10 users decided to keep the prototypes at the end of the trial period.
- Air injection techniques and other lessons learned have been applied to the BioLite HomeStove and will be commercialized in Africa and India in 2016

Berkeley Air Monitoring Group

- Developed over 30 working prototypes of the PATS+ air quality monitor,
  - Measures PM, CO, temp, and humidity
- PATS+ prototypes are equipped with a sensor to determine if the instrument is being worn or not for personal exposure monitoring.
- Tested the PATS+ prototypes in the laboratory and field, including deployments in Laos, Cambodia, China, and India

What Else is Needed to Achieve Large Scale Impact?

- ❑ Sustained efforts are needed to fully understand new engineering science that makes stoves low-cost, and durable and added technology improvements to achieve stringent efficiency and emissions goals (50%/90% improvements respectively over the baseline).

- ❑ This new engineering science will need to be internalized by many dozens of stove designers to develop a variety of new stoves that meet a variety local cooking needs. So, substantial and sustained technology transfer efforts will need to continue.

- ❑ Sustained rigorous research is essential to understand the nuances of successful stoves dissemination and field-performance. Current top-down methods of stoves dissemination have very limited insights into what actually works, what doesn't, and why.

IWA – Tiers

- Please refer to Table 4.6 IWA Performance tiers, Water Boiling Test protocol for details, available at
- http://cleancookstoves.org/technology-and-fuels/testing/protocols.html

4.6 IWA Performance Tiers

The IWA Performance Metrics are grouped into tiers using the following table:

IWA VITA WBT Tiers	units	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4
High Power Thermal Efficiency	%	< 0.15	≥ 0.15	≥ 0.25	≥ 0.35	≥ 0.45
Low Power Specific Consumption	MJ/min/L	> 0.05	≤ 0.05	≤ 0.039	≤ 0.028	≤ 0.017
High Power CO	g/MJd	> 16	≤ 16	≤ 11	≤ 9	≤ 8
Low Power CO	g/min/L	> 0.2	≤ 0.2	≤ 0.13	≤ 0.1	≤ 0.09
High Power PM	mg/MJd	> 979	≤ 979	≤ 386	≤ 168	≤ 41
Low Power PM	mg/min/L	> 8	≤ 8	≤ 4	≤ 2	≤ 1
Indoor Emissions CO	g/min	> 0.97	≤ 0.97	≤ 0.62	≤ 0.49	≤ 0.42
Indoor Emissions PM	mg/min	> 40	≤ 40	≤ 17	≤ 8	≤ 2
Safety	Johnsons	< 45	≥ 45	≥ 75	≥ 88	≥ 95