Second Girish Sant Memorial Lecture

# Innovating Technologies for the Poorest Two Billion

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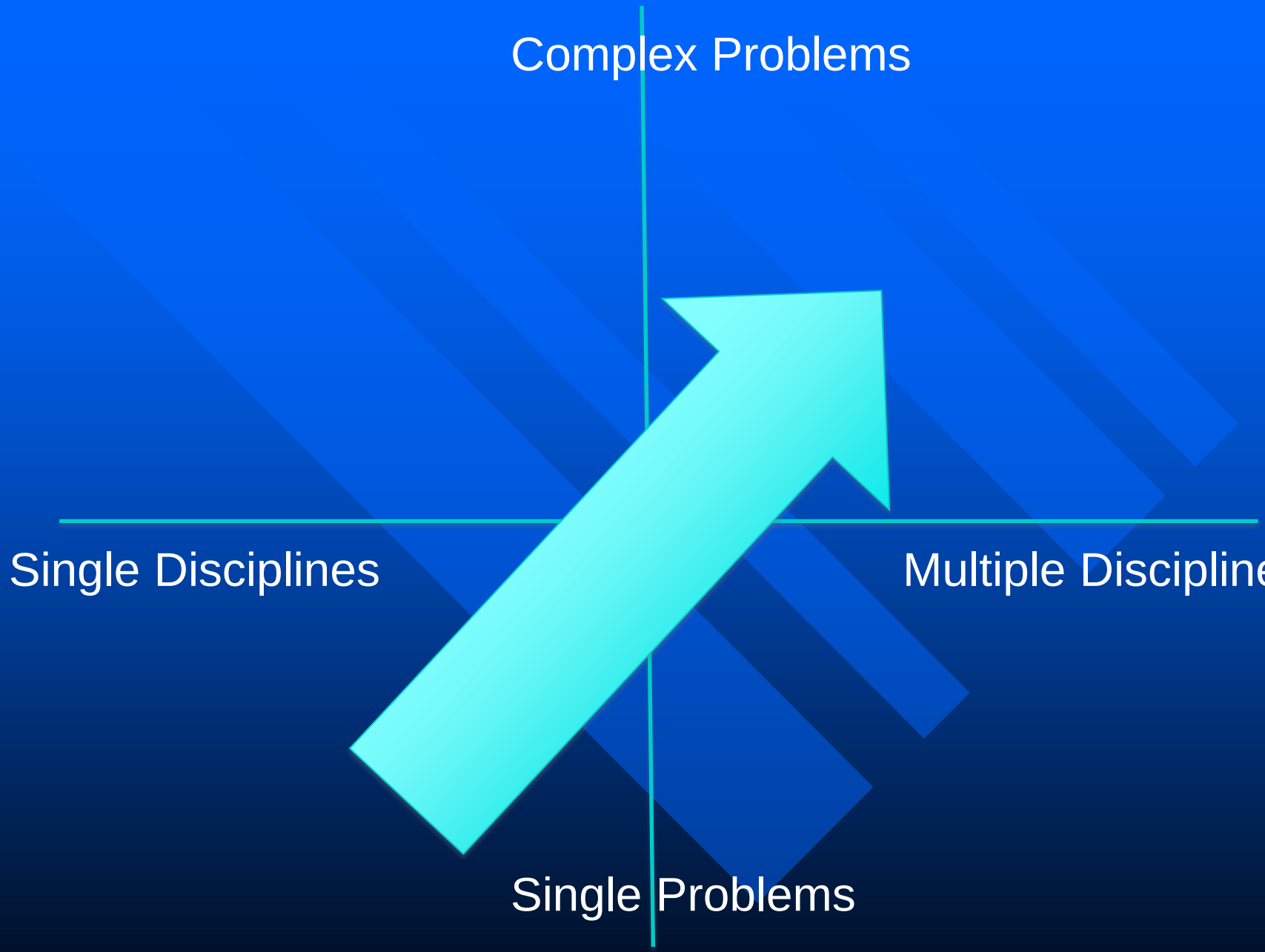
Pune

First of all, a caveat: the title of the talk says: Innovating Technologies…

In the literature, innovating is about adapting an invention to market conditions and scale-up

In this space (for the bottom 2B), we need both inventing and innovating, with a sense of urgency, all wrapped together

Time is limited. So, I'll give a summary of my approach and "lessons learned," then briefly illustrate with an example, leaving time for discussion


Complex Problems
Single Disciplines
Multiple Disciplines
Single Problems

# Approach:

A low-cost high-impact innovation must be:

1. Technically effective
2. Robust
3. Affordable
4. Culturally acceptable
5. Fit a scalable business model

# My 6 take-home lessons about technical solutions to hard real-world problems

1. For sustained great work, love what you do, and don't be embarrassed of working really hard – every day
2. Have fun inventing – it is a mental game, it is playful
3. Learn everything about the subject relentlessly with passion and diligence – inform your innovations with deep and broad understanding
4. Know your weaknesses, and team up with brilliant energetic people with strengths that compensate
5. Aim to fail quickly, inexpensively, and often -- rather than getting locked onto a bad pathway, or fearful of trying anything at all
6. Above all, be an optimist – about yourself and the world!

An illustrative example–with an engineering science handle, but addressing a much broader serious problem

# With grateful acknowledgment for support from:








**And numerous individual donors, advisors, and the sweat and dedicated efforts of many volunteers (over the years, total now >50)**

# Reducing hunger, rape, and violence against women and girls in Darfur

Berkeley-Darfur Stove

# the Darfur Conflict

- The conflict started in 2003
- About 400,000 Darfuri were killed
- 2.7 million (mostly women and children) were driven into crowded IDP camps

# Darfur IDP Camp

**Otash Camp** *photo by Ashok Gadgil Nov 2005*

# Plight of Darfur Women

Women and girls routinely risk rape and mutilation when they must leave the camps for gathering fuelwood. Large zone of denudation surrounds the camps. Average trip duration: >7 hours.

**Outside Kalma Camp**

*photo by Ashok Gadgil Nov 2005*

# End of a long and risky trek.
# Evening in Otash Camp

*photo by Ashok Gadgil Nov 2005*

# Cookstoves

It was exciting for me to discover that almost all women cooked on three-stone fires!

Three stone fires are 5-7% efficient!

So, here was a weak spot in the causation-chain leading to rape, hunger, hardship and humiliation!

Darfur three-stone fire

# Earlier stoves effort in Darfur

A major British NGO initiated a program to teach IDPs to hand-build fuel efficient stoves (“FES”) from local materials -- adopted by also many other NGOs,

The “FES” is built from sieved local clay, donkey dung, and water -- all kneaded together

Each stove takes 3 days to build – since it has to be air-dried after it is put together

The cost of materials per stove is approx. US$2,

The NGO claims a 50 -60% reduction in fuelwood use and a large reduction in harmful smoke exposure. Neither claim is supported by data.

# The fate of mud FES Cookstoves

Only a small percentage of IDP families have the “FES”.

We observed only few “FES” actually in use in IDP camps: (1) used in addition to a 3-stone fire, even though it fit no pot in the household, (2) never used since it “did not work”, (3) used for storage, and (4) used as a *bambur* (cooking stool).

# Get the facts yourself if no one has collected them

- In Nov.-Dec. 2005, I led a team to Darfur camps, to collect data and test four stoves
- None of the stoves were satisfactory
- Each family then used about US$1 worth of fuelwood daily (fuelwood was traded because some women sold part of their rations to buy fuelwood).

# Side by side testing of stoves in Kalma camp, Darfur

# Berkeley grad students testing stove-design, Spring 2006

# Collaborate to add missing expertise

In Summer 2006, we worked with Engineers without Borders -- San Francisco Professional Chapter

www.ewb-sfp.org

They brought substantial experience in manufacturing, redesign for production, metal working, tools, quality control of production process

# Collaborate to add missing capacity

By summer 2009, we built an alliance with Oxfam America, who had boots on the ground in Darfur relief, and also with their Sudanese partner, Sustainable Action Group (SAG).

After much searching, in 2008 we identified a small industrial partner near Mumbai to build knock-down-kits of stoves on industrial scale. We looked for reliability, competitive cost, quality, and knowledge and passion.

# Supply Chain: how to deliver stoves in a risky war-torn region in Africa

We then successfully set up a complex supply chain:

(1) make Ikea-style flat-kits in India,

(2) get them shipped to SAG in Darfur,

(3) assemble stoves in a workshop that we set up in Darfur, and finally

(4) distribute stoves to women in Darfur camps after training them.

# The Berkeley-Darfur Stove “V14”

“Poka-Yoke” kit design to eliminate assembly errors

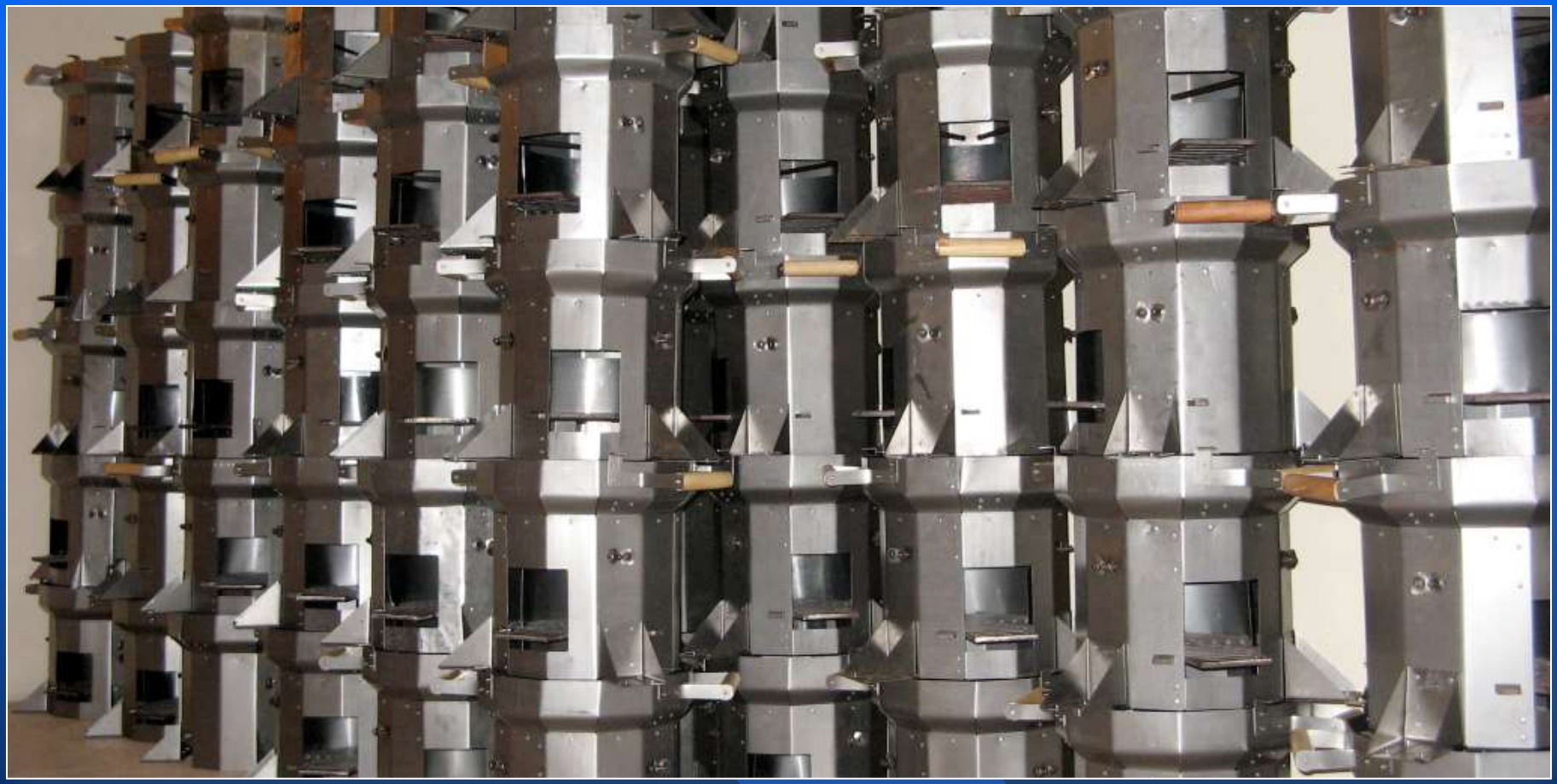
Successive learning from Darfur women cooks has improved design until a stable “V14” design has emerged

# Berkeley-Darfur Stove “V14” assembly shop El Fasher, Darfur

In October 2009 we built 1000 stoves in single month!

Output capacity of assembly shop is a stove every 5 minutes, or 2000 stoves per month single-shift!

# 2010



**Stack of Berkeley-Darfur Stoves in the assembly shop.**

# 2011: Stoves waiting for distribution at a camp

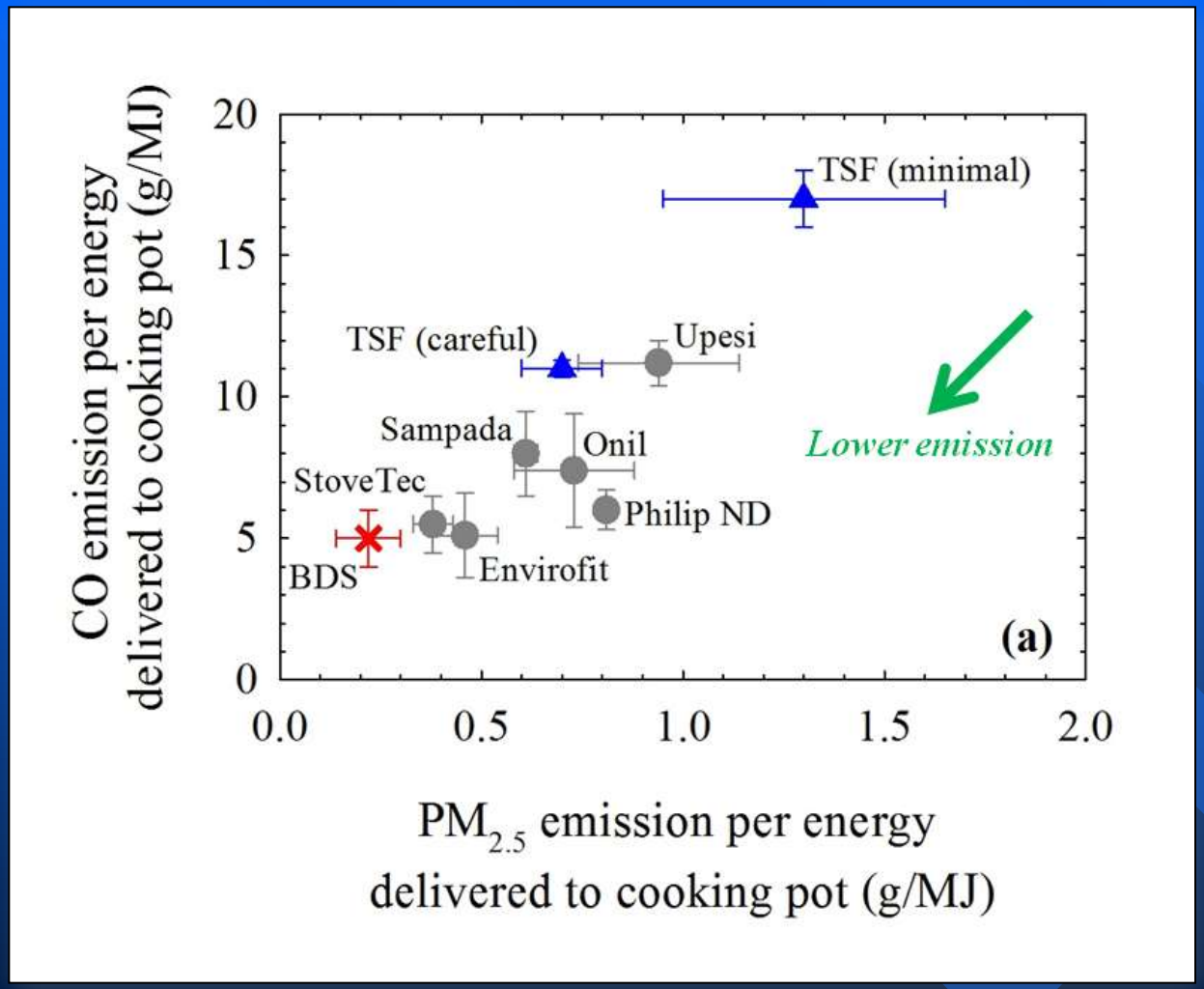
Cost: $20 per stove (includes delivery and training)

# Testing for Efficiency and Emissions – 2013 setup


Instruments measure emissions at 1 Hz frequency, for particle sizes from 5 nm to 5000 nm, and also CO2, CO, and O2, as well as 0.1 g accuracy on the weighing scale holding the stove

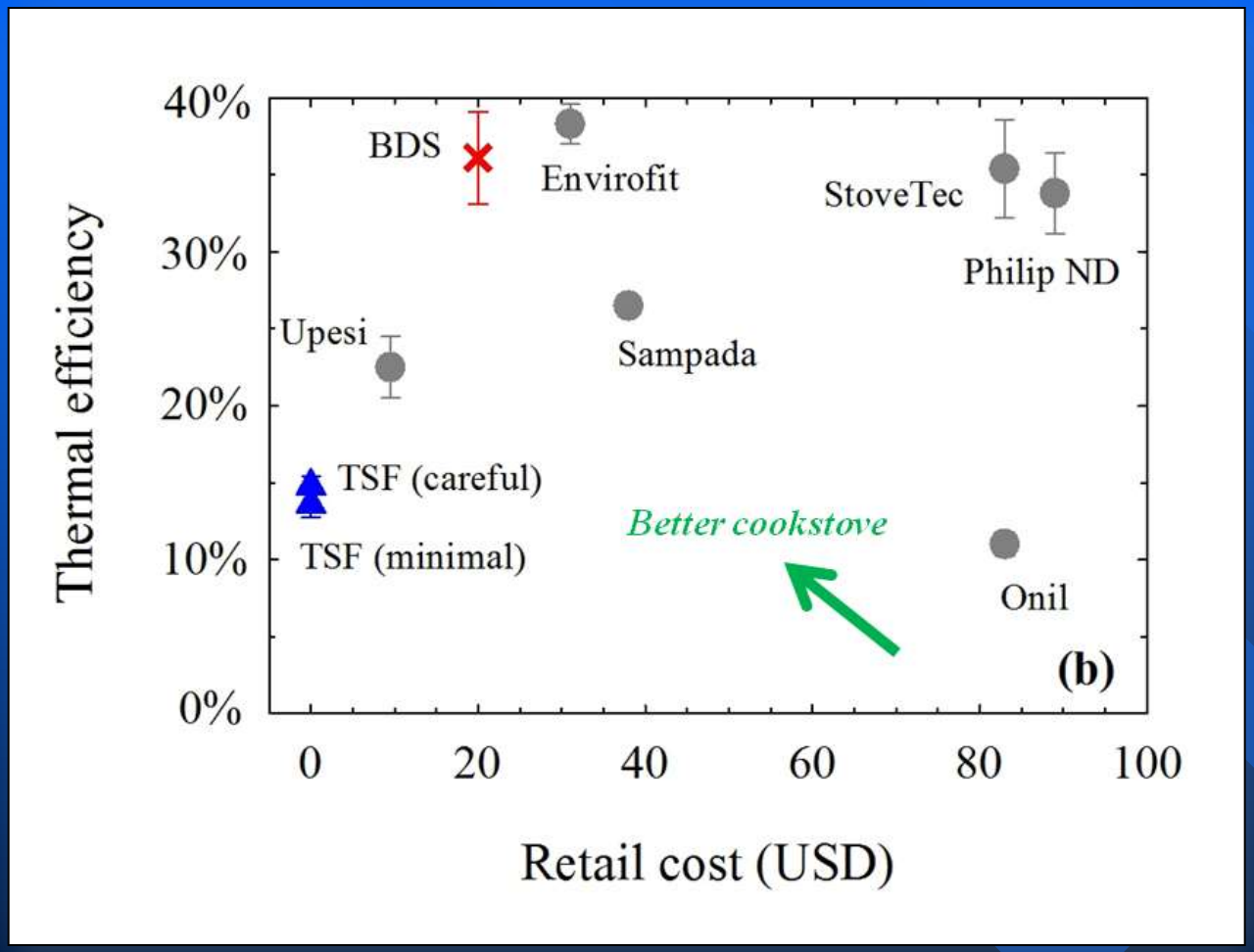
"A metric of effectiveness of work is to count how many experiments could you do in 24 hours."
-- Edison

# Comparison of Berkeley-Darfur Stove with other stoves in the same category. Part 1




*Stove emissions data from from Jim Jetter et al., ES&T, V46, pp 10827–10834, (2012).*

# Comparison of Berkeley-Darfur Stove with other stoves in the same category. Part 2




***Stove efficiency data from from Jim Jetter et al., ES&T, V46, pp 10827−10834, (2012). Stove price data collected in 2012 by Dr. Carl Wang, LBNL.***

# Monitoring for Impact: Field Survey Results from 2010

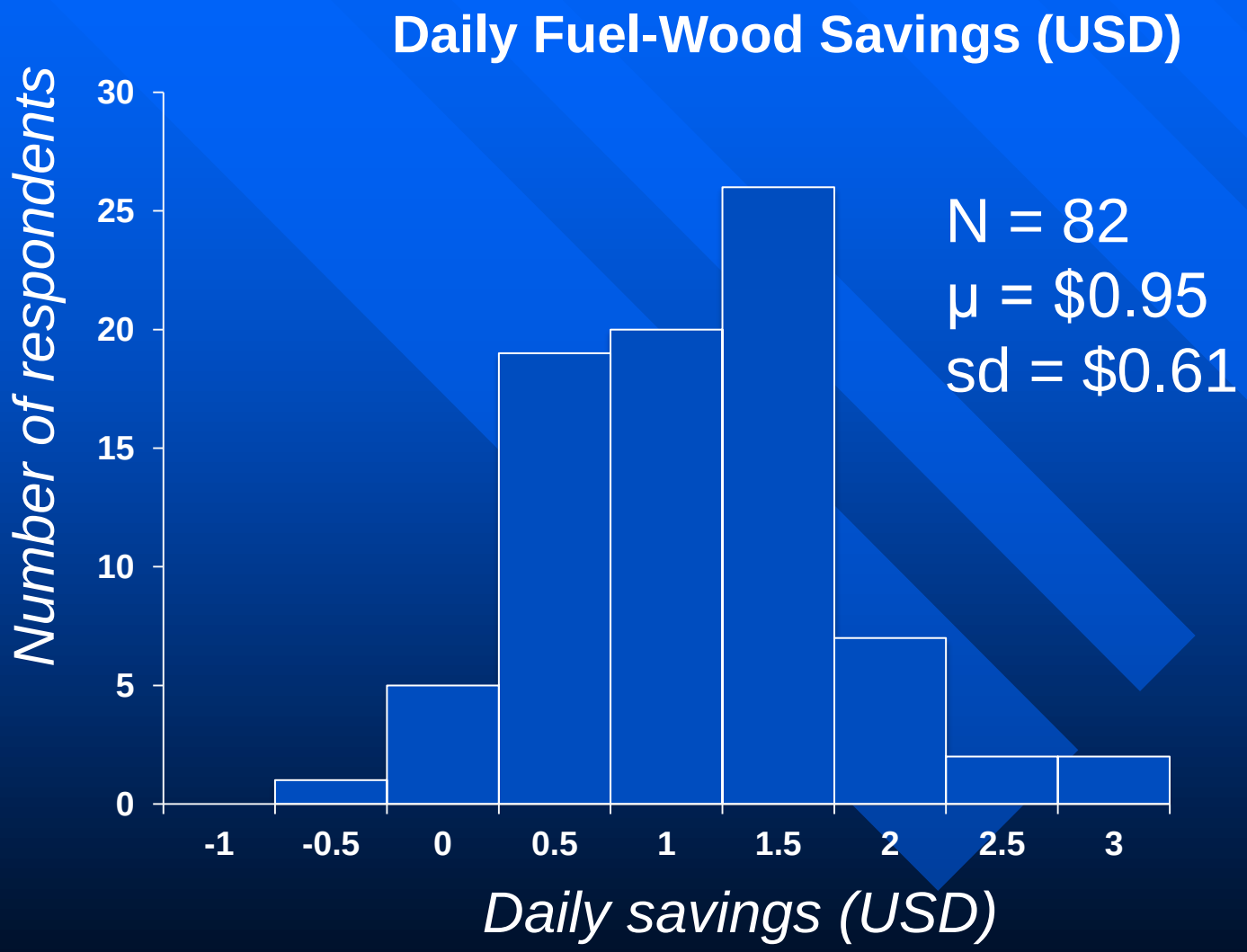
2010 third-party survey of fuelwood spending of ~80 households:

Users reduced spending on fuelwood (in North Darfur camps) from ~33% of household budget to ~15%

Per the survey data, each stove puts $345/year in the pocket of the woman using the stove – worth $1730 over the stove-life of 5 years

Photo by Michael Helms

# 2010 Impact-Survey
# Zam Zam Camp, North Darfur




*Baseline: Jan.2010, Follow-up: July 2010*

# January 2013: A sea of stoves!

El Haj Adam in a sea of stoves
outside El Fasher assembly workshop

In early 2012, the assembly rate of the workshop was about 80 stoves per day.

By Jan. 2013, the assembly rate had grown to 175 stoves per day!!

# Physics-based sensor survey of BDS recipients in Darfur, Aug. 2013

Stove Use Monitor (SUM) and its housing

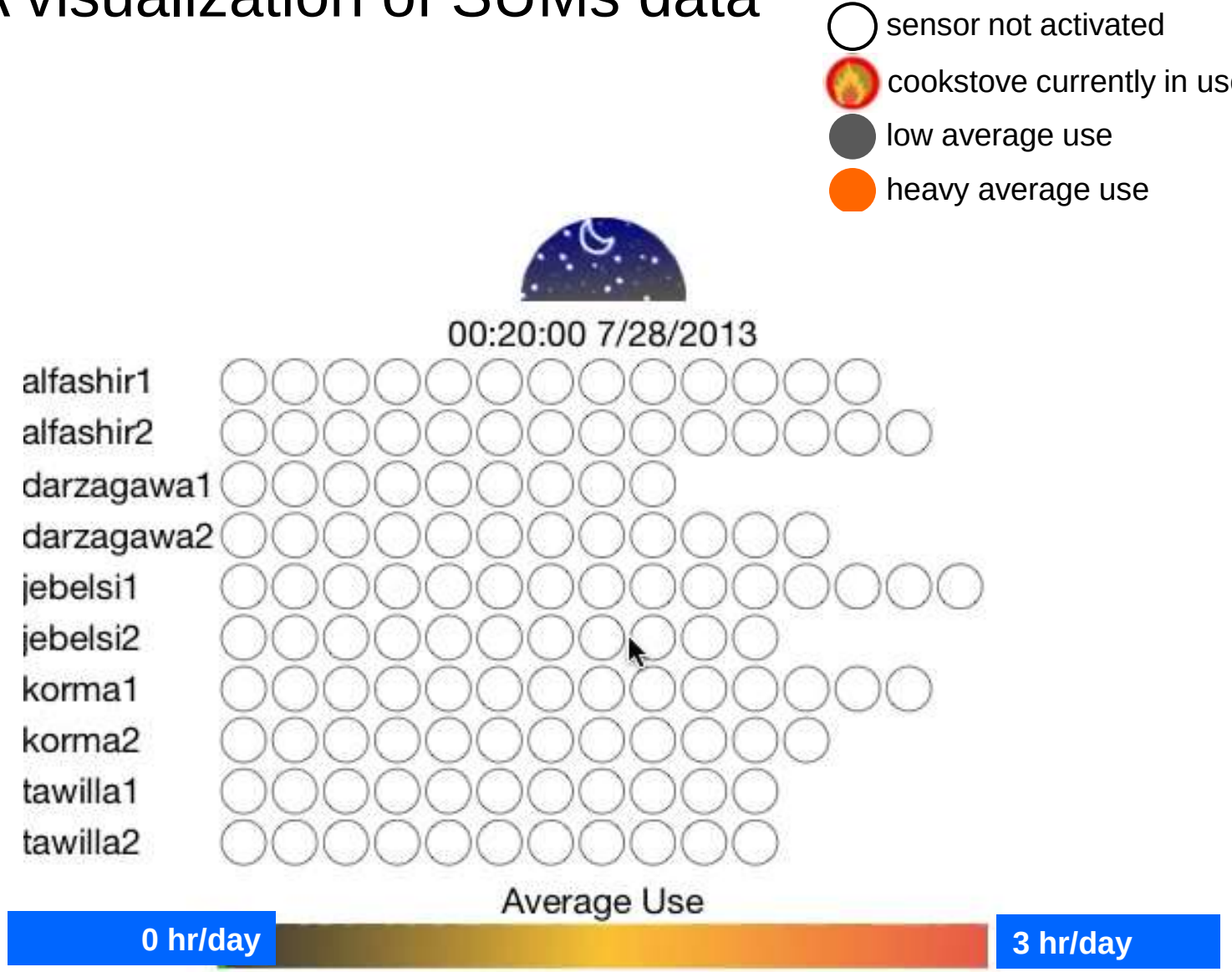
Stack of BDS stoves with two SUMs installed on each stove near its bottom exterior

Are the IPD recipients actually using the stoves?

How intensely and how many times a day?

What can we learn from “real” data, rather than a social survey?

# A visualization of SUMs data



# 35,000 stoves, worth $60M , by Jan. 2014

So far, built and distributed 35,000 stoves
Helping >200,000 women and their dependents

Since each $20 stove saves $1730, the stoves distributed so far are worth $ 60 million to the recipients (over 5 years of stoves life)

10,000 more stoves planned for 2014, worth an additional >$17 million to the IDPs

# Non-profit project website

www.PotentialEnergy.org

# Projects Website:

GadgilLab.berkeley.edu

# Recap: Ashok's 6 take-home lessons about solving hard real-world problems

1. For sustained great work, love what you do, and don't be embarrassed of working really hard – every day

2. Have fun inventing – it is a mental game, it is playful

3. Learn everything about the subject relentlessly with passion and diligence – inform your innovations with deep and broad understanding

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# Relevant Lessons-learnt for policy makers

1. Technology Development takes time – so be watchful but be patient

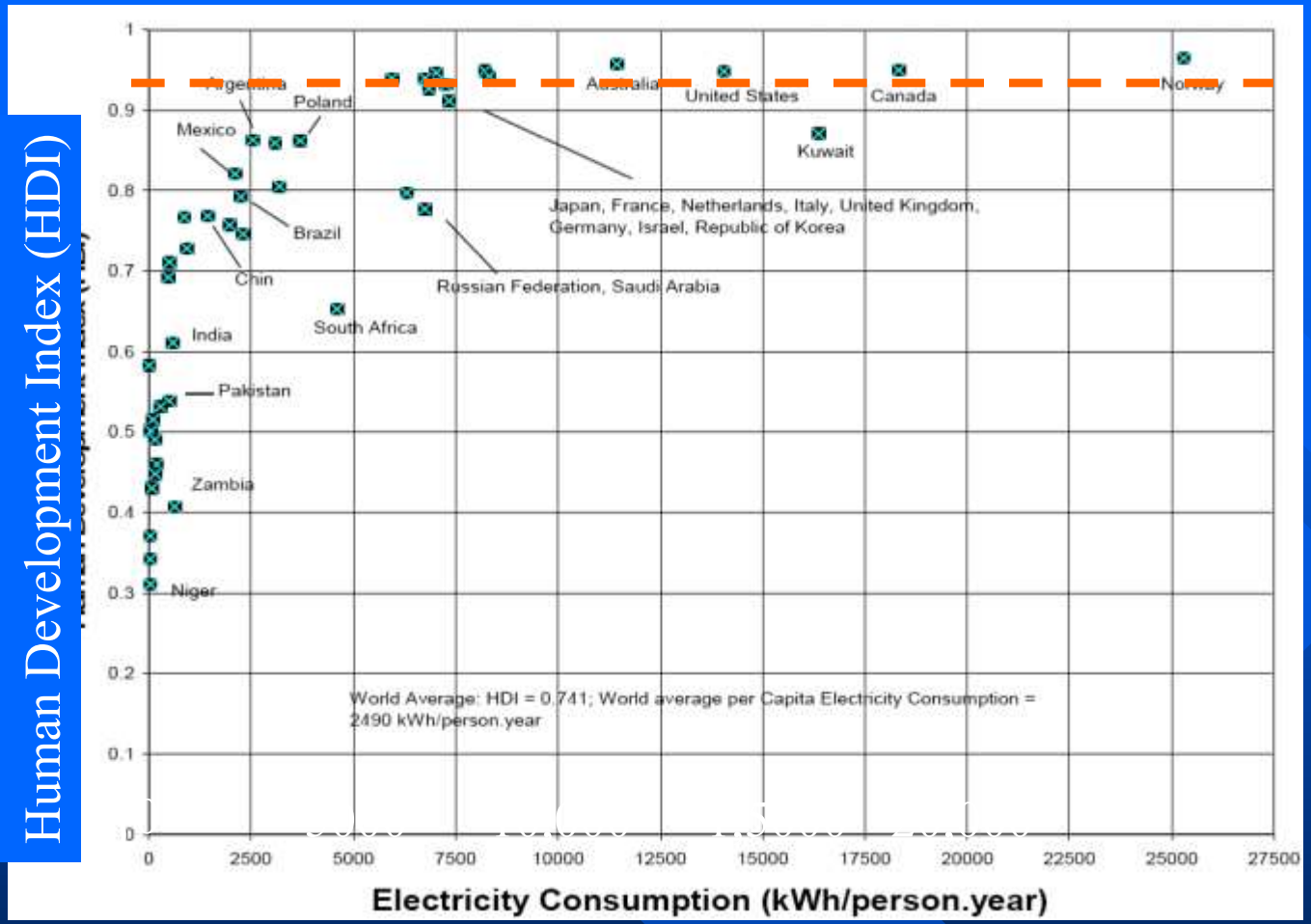
2. Insist on third-party measurements of field impacts – double check everything

3. Implement incentives for engineers and scientists to address hard and important societal problems with tech. handles

4. Know your weaknesses – hire savvy technical people on your side too

5. Do not punish for failing quickly, inexpensively, and often – invest in the teams, rather than a particular technical solution

# Human Development Index vs. Electricity consumption




**There is relentless pressure from the bottom towards a better life**