Innovating Technologies for the Poorest Two Billion

Ashok Gadgil

Civil and Env. Engineering, UC Berkeley, and

Lawrence Berkeley National Laboratory

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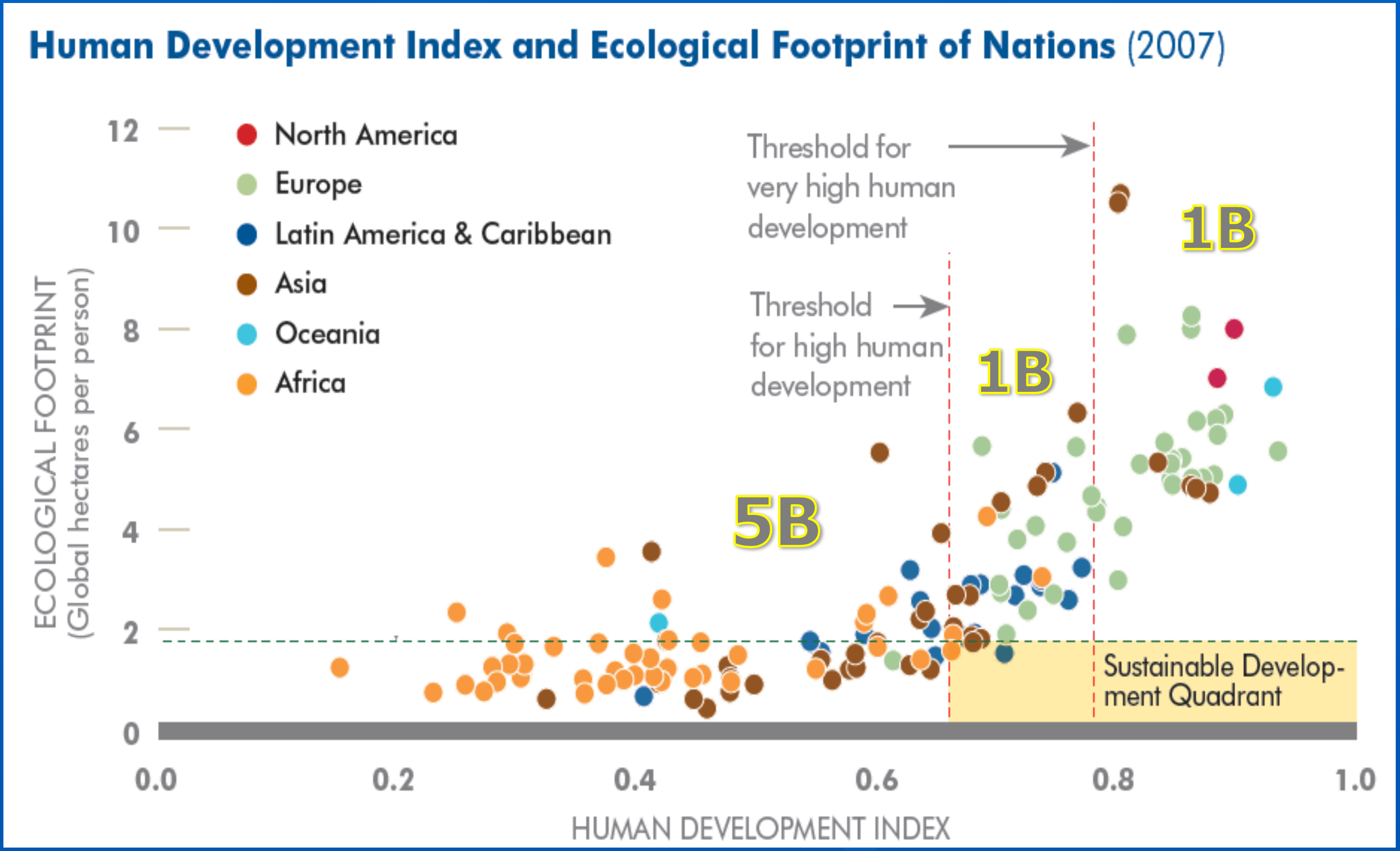
First of all, a caveat: the title of the talk says: Innovating Technologies…

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

I’ll first give the key summary,
then briefly illustrate with two examples

Inexorable pressure in Emerging Countries for Development pushing boundaries of what is sustainable for the planet

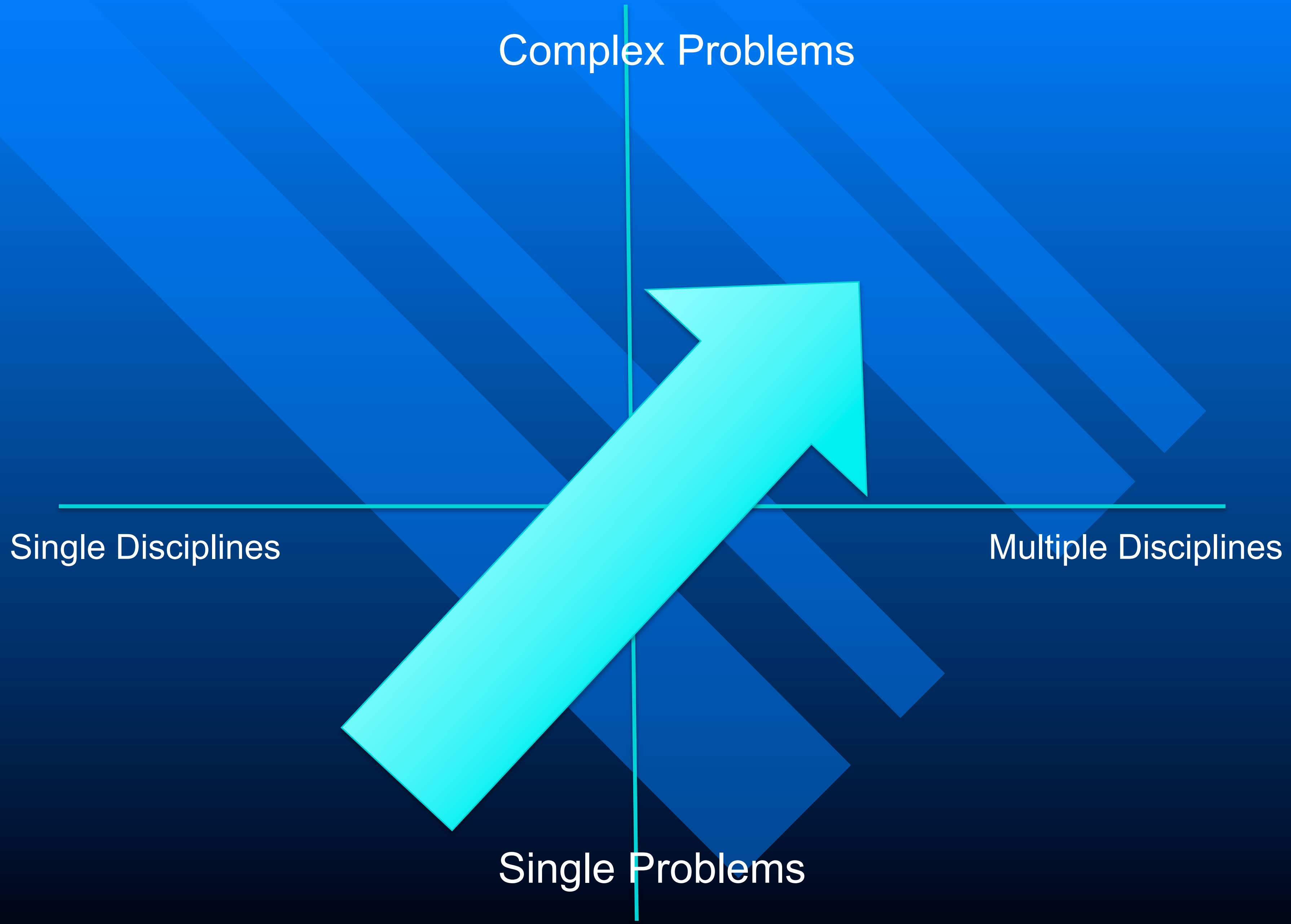


Motivation:

Anthropogenic Climate Change and its consequences constitute the single biggest threat to modern society

Even the best actions, if limited to the first world, will be overwhelmed by the rapidly rising emissions from the high-carbon path to development from the rest of humankind (6B people)

A low-carbon development path is needed for the developing world


Complex Problems
Single Disciplines
Multiple Disciplines
Single Problems

Top level summary

A low-cost high-impact innovation must be:

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

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
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!

Two illustrative inventions – each with an engineering science handle, but addressing a much broader serious problem

With grateful acknowledgment for support from:

BERKELEY LAB

SUSTAINABLE PRODUCTS
+ SOLUTIONS PROGRAM
CENTER FOR RESPONSIBLE BUSINESS

THE UNIVERSITY OF CALIFORNIA BERKELEY
LET THERE BE LIGHT
1868

JEWISH COMMUNITY Teen FOUNDATIONS

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

P3 award competition
people prosperity planet
a student design competition for sustainability

BLUM CENTER FOR DEVELOPING ECONOMIES

NCIIA

Rudd Family Foundation
BIG IDEAS @BERKELEY

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

USAID
UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

And numerous individual donors, advisors, and the sweat and dedicated efforts of many volunteers (over the years, total now >100)

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

- I got excited to learn that the women cook 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

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 students testing stove-design Spring 2006

Collaborate to add the missing expertise

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

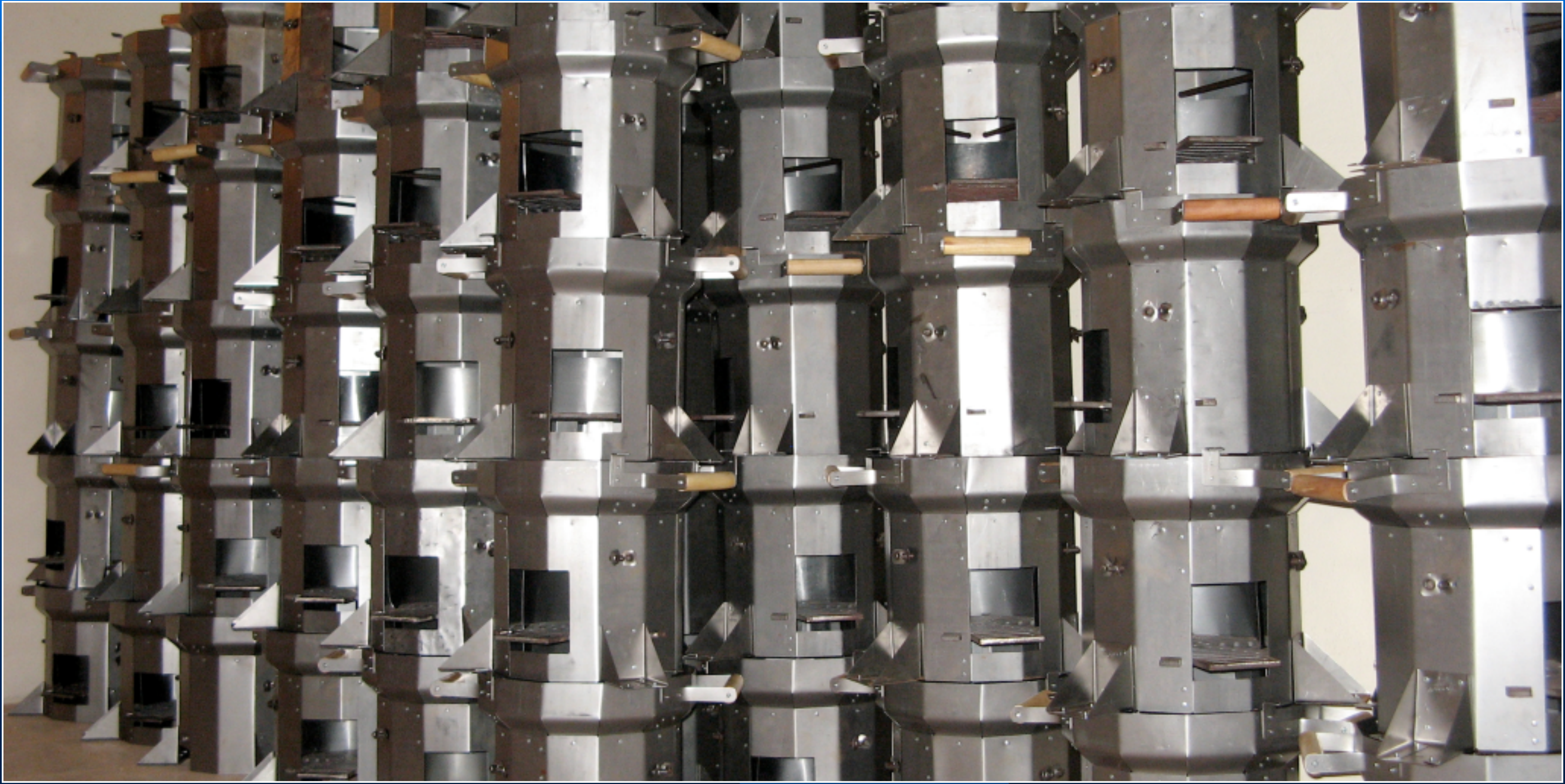
www.ewb-sfp.org

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

Berkeley-Darfur Stove "V14" assembly shop El Fasher, Darfur

- In October 2009 we built 1000 stoves! Output capacity of assembly shop is a stove every 5 minutes, or 2000 stoves per month single-shift!

2010

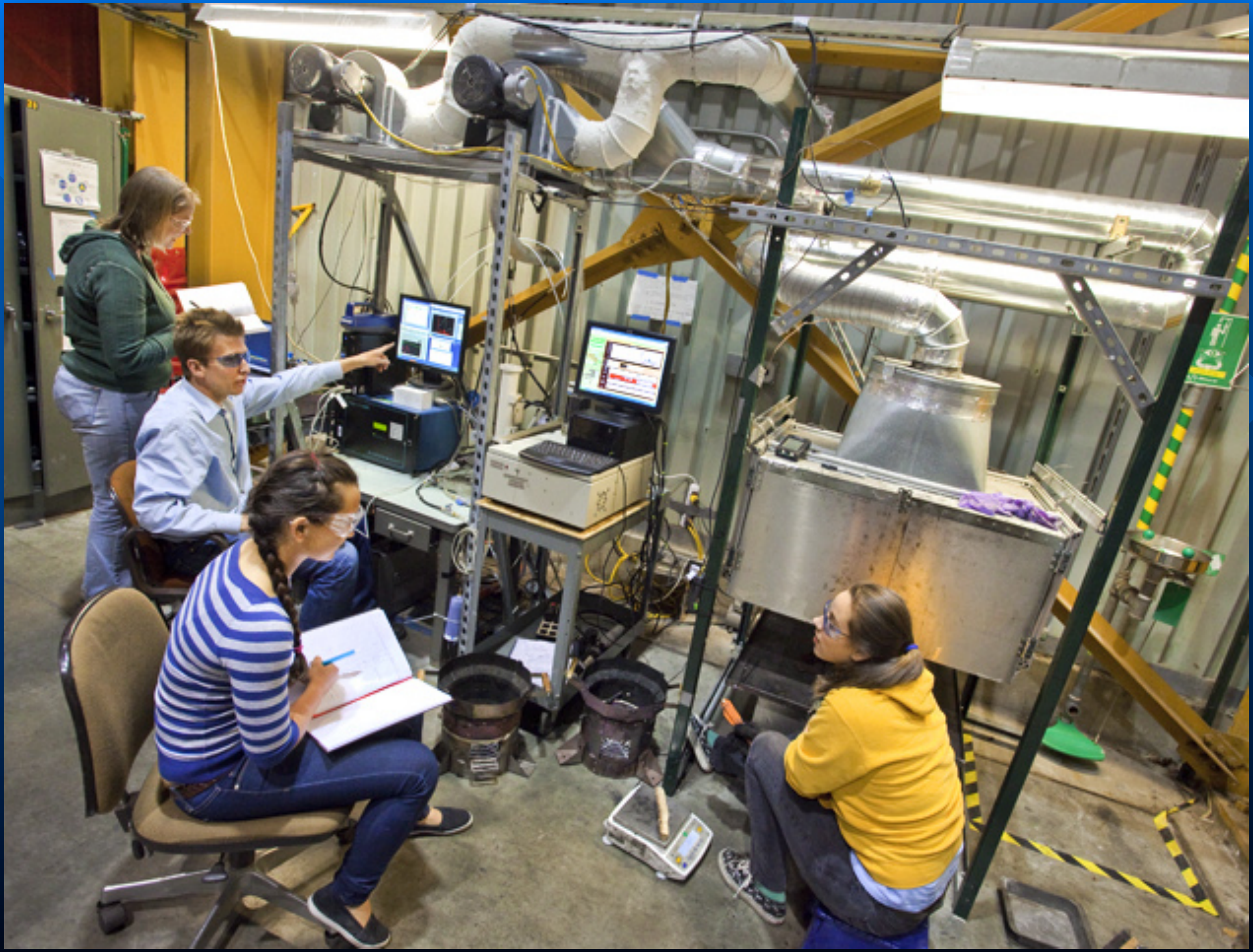


Stack of Berkeley-Darfur Stoves in the assembly shop.

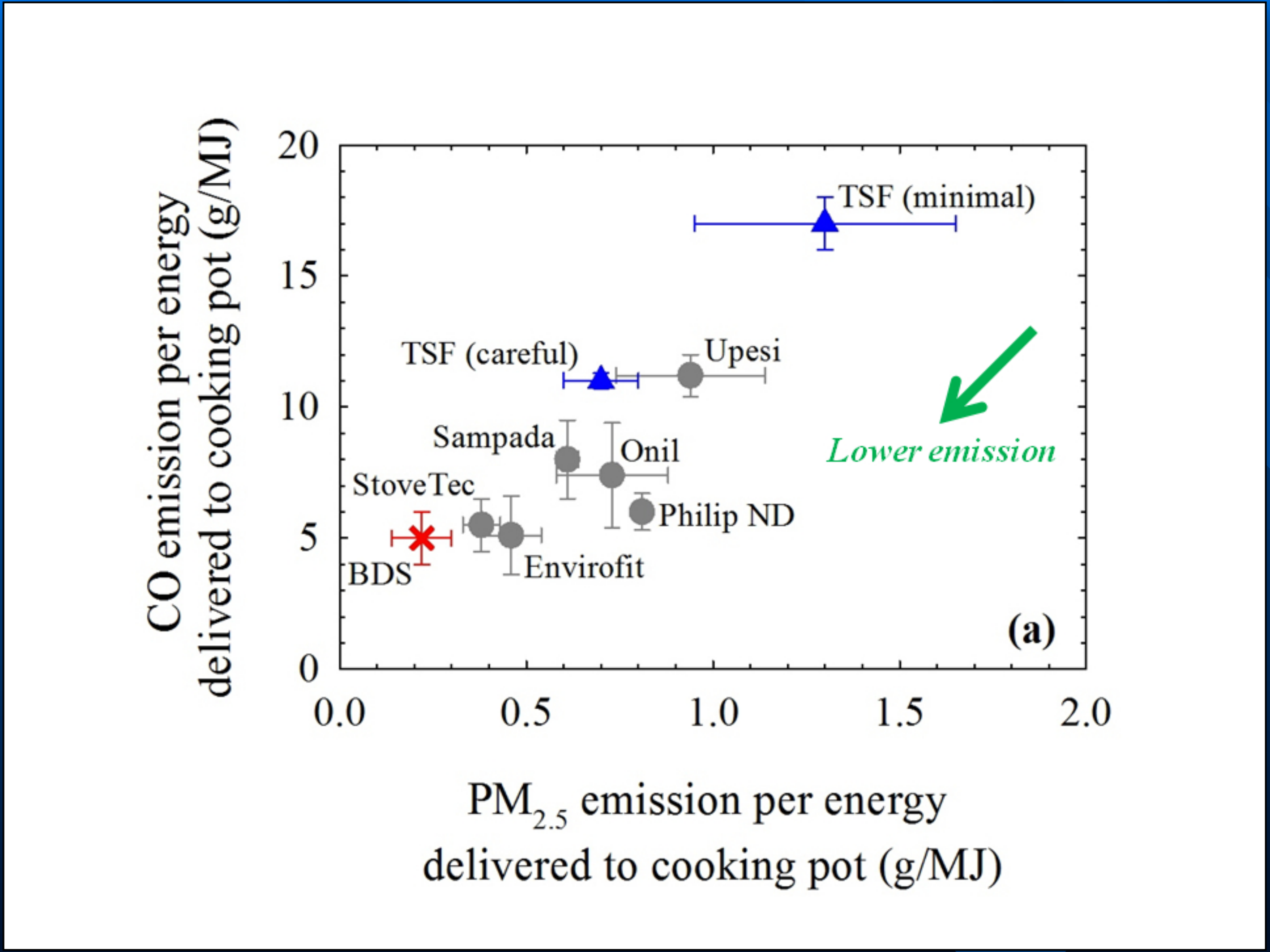
2011: Stoves waiting for distribution at a camp

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

Testing for Efficiency and Emissions

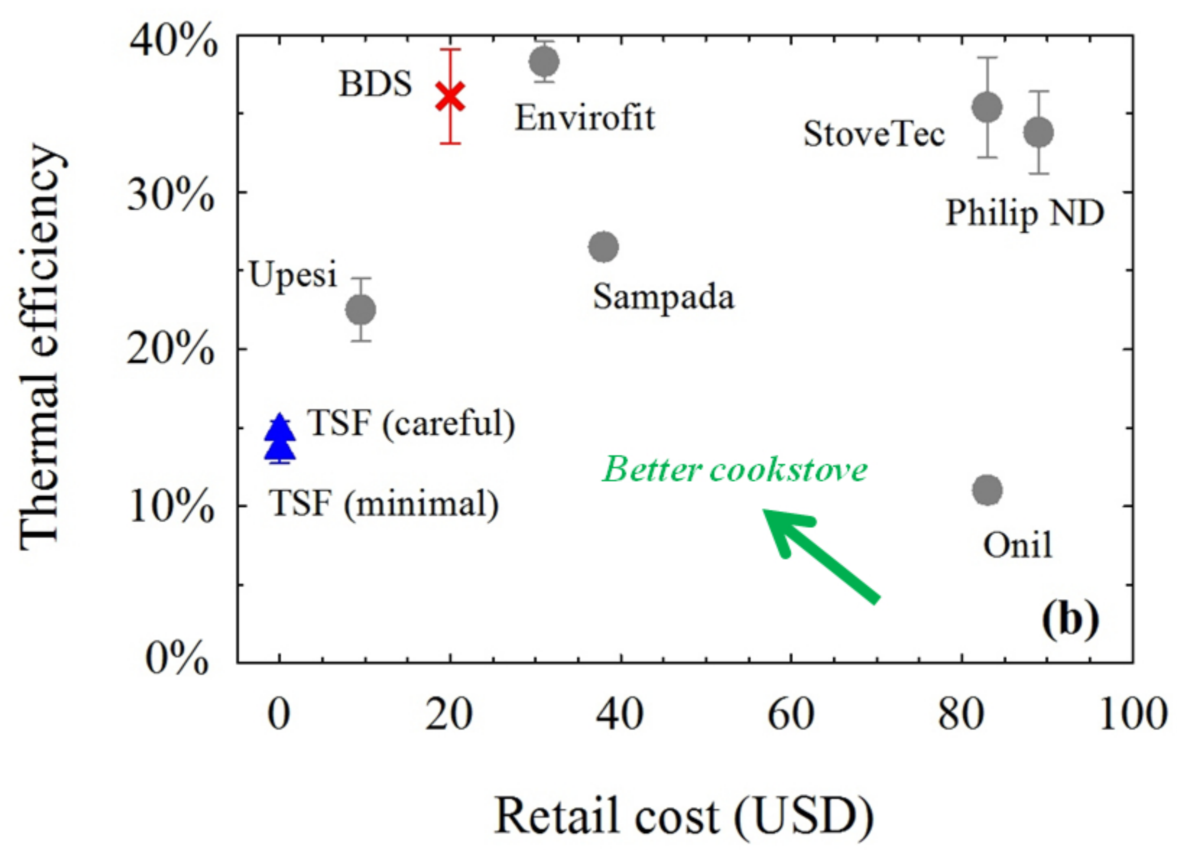


Comparison of Berkeley-Darfur Stove with other stoves in the same category. Part 1



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.

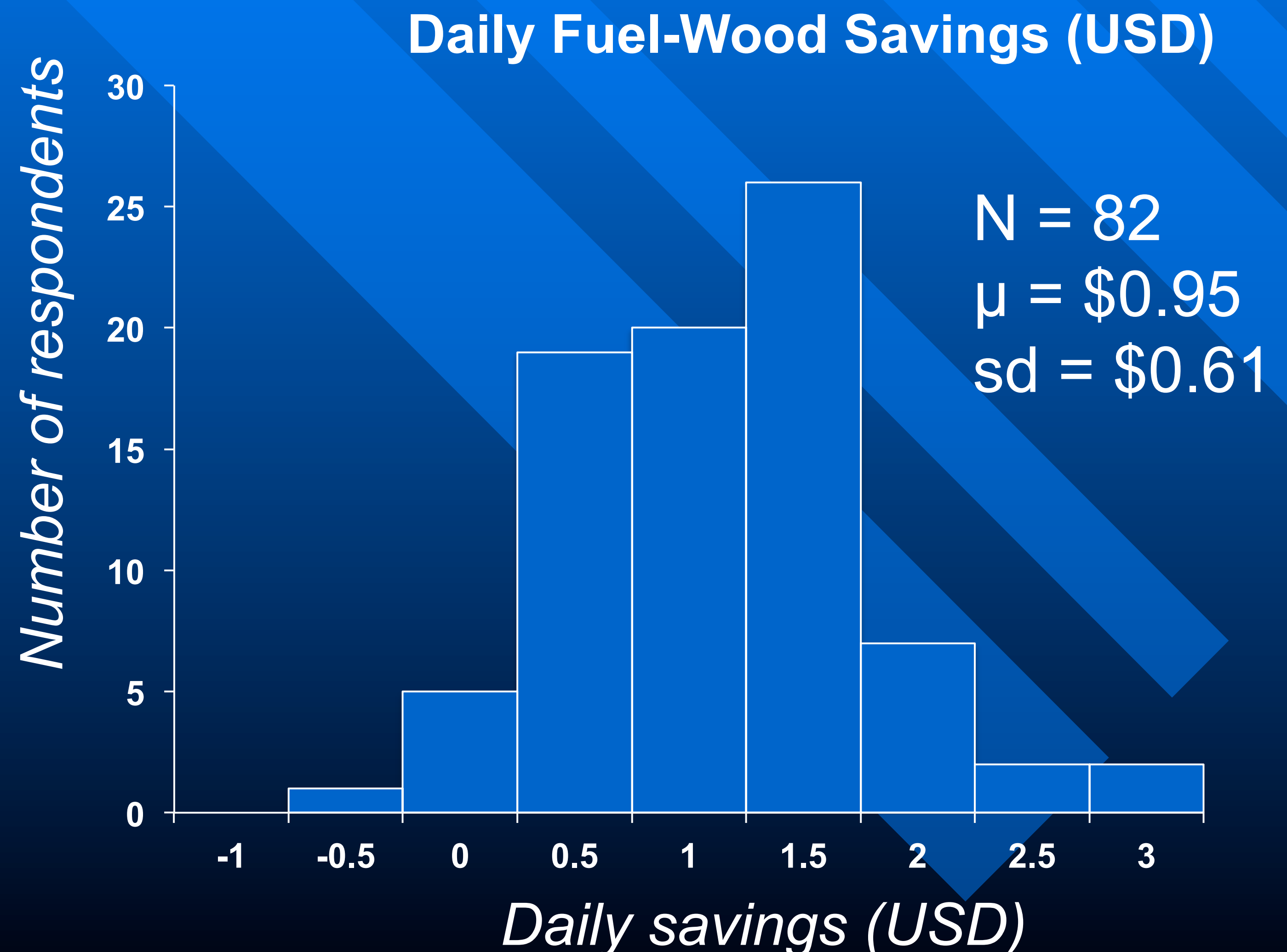
Monitoring for Impact: Field Survey Results from 2010

2010 survey of ~80 households showed that users reduced spending on fuelwood (in North Darfur camps) from ~33% of household budget to ~15%

Per the survey data, each $20 stove put $345/year in the pocket of the woman using the stove – worth $1725 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

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!!

As of April 2013

So far, built and distributed 27,400 stoves
Helping >160,000 women and their dependents

Since each $20 stove saves $1725, the stoves distributed so far are worth $ 47 million to the recipients over 5 years

10,000 additional stoves planned for 2013, worth $17.25 million to their recipients

Non-profit project website

www.PotentialEnergy.org

Example 2: Electro-Chemical Arsenic Remediation

Dealing with the largest mass poisoning in the history of mankind

Arsenic in drinking water in Bangladesh and vicinity

Massive switch to tube-wells accomplished in Bangladesh 1970-2000

>10 million tubewells in Bangladesh

several million more in West Bengal

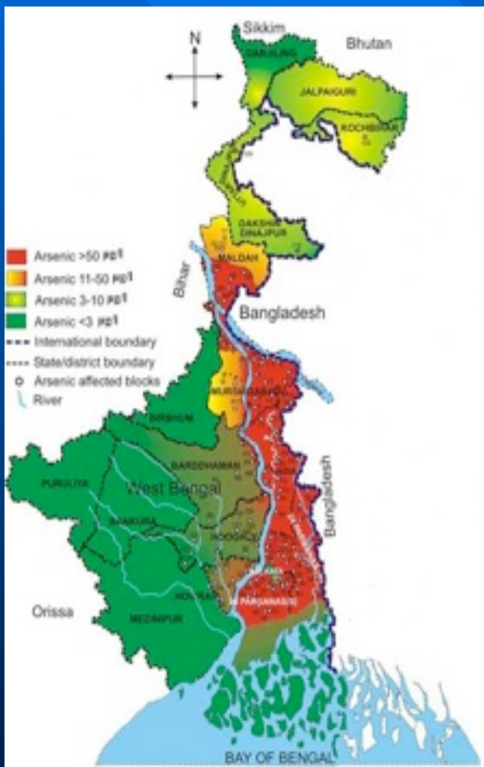
Arsenic is now reported in many locations in North India

This led to the largest mass poisoning in human history!

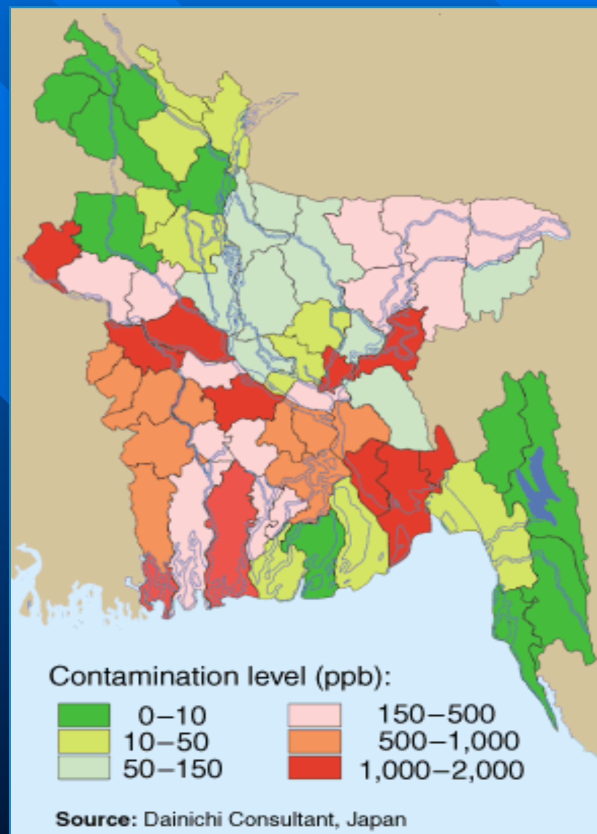
>70 million being poisoned in Bangladesh

One estimate is 20% of adult deaths are now from arsenic*

Only the dark-green areas in maps have safe groundwater



West Bengal, India



Bangladesh

Arsenic is so toxic that WHO MCL is 10 ppb

Bangladesh water has levels up to 2000 ppb!!

* Argos et al, Lancet 2010; **376**: pp252-258

ARSENICOSIS

Lower IQ for children, neuropathy, hand lesions, gangrene, amputation, cancers, cardio-vascular diseases, death

Why this grave problem remains unsolved

For a good summary of socio-economic barriers to address this problem see:

Johnston, Hanchett, and Khan, *The socio-economics of arsenic removal*, Nature Geoscience, **3**, 2-3, January 2010.

A successful technology innovation must also plan to overcome these socio-economic barriers

Why is this problem hard to solve?

- Ongoing maintenance incentives
- Field performance assurance (costly to test for 10 ppb Arsenic)
- Arsenic-laden waste disposal
- Low ability / willingness to pay enough ($ and time) for available options
- Both As-III / As-V in water (As-III harder to remove)
- Very low safe limit (WHO MCL is 10 ppb)
- Competing ions in groundwater















>90% of these failed in 6 months*!

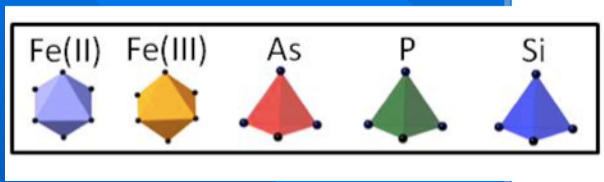
*Ph.D. Thesis, Abhijit Das, Jadavpur University, 2012

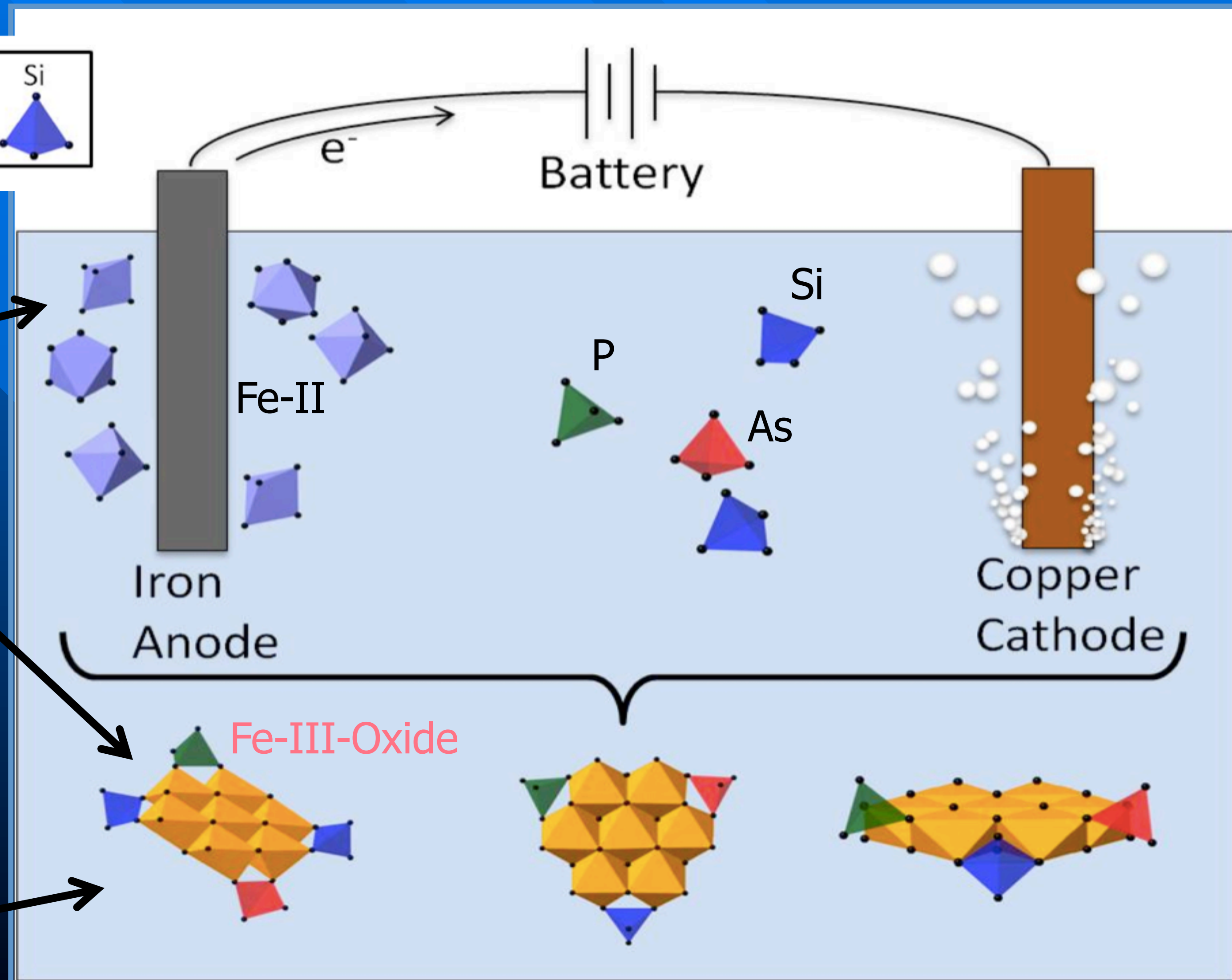
Need: a Sustainable Technology *System*
= *Effective, Robust, and Affordable*




How does ECAR work?

ECAR = ElectroChemical Arsenic Remediation

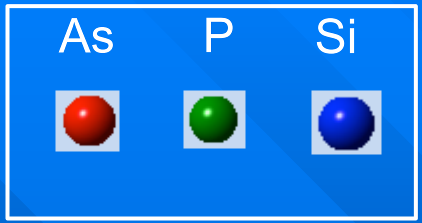




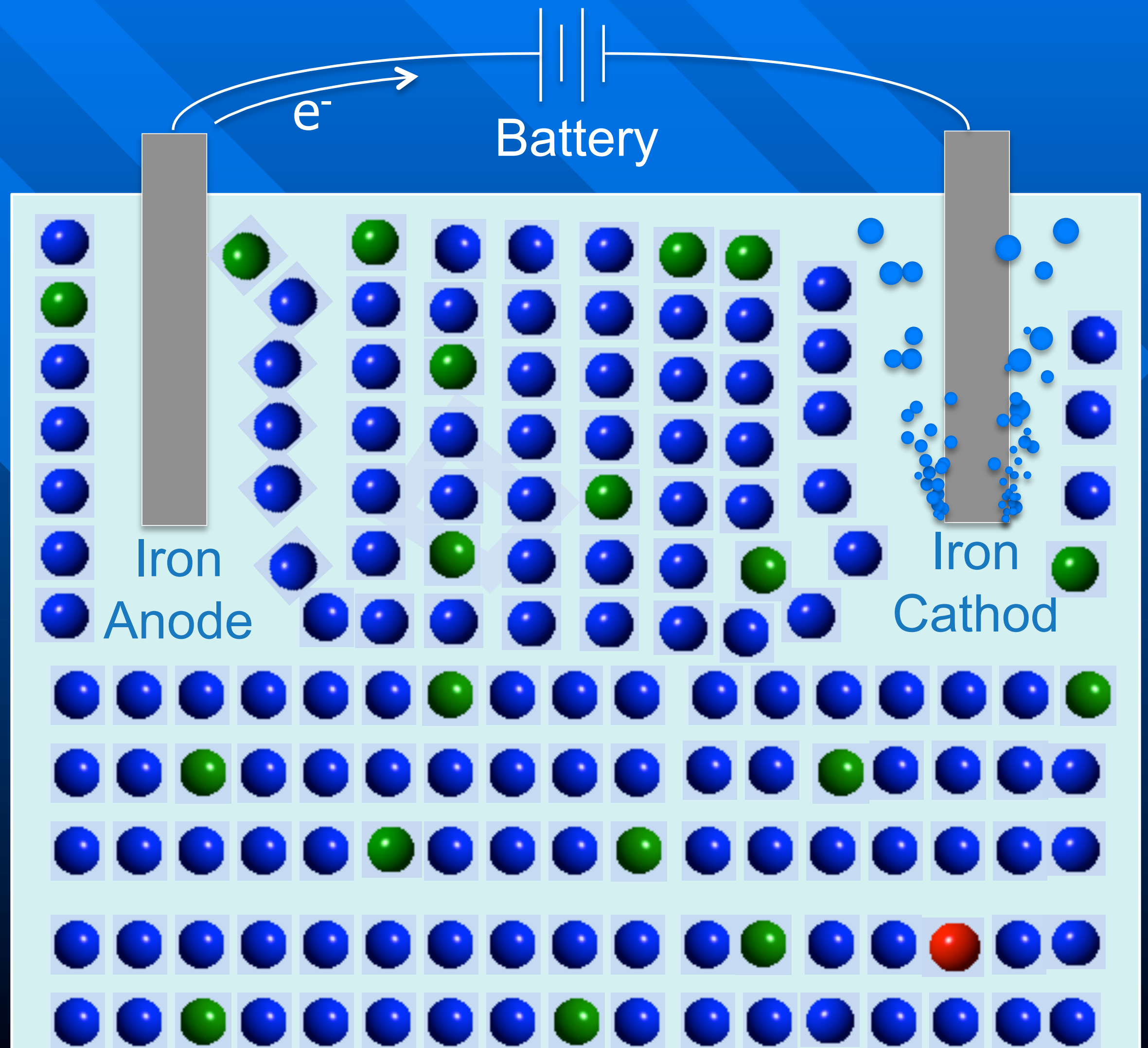
Fe-II dissolves, becomes Fe-III and precipitates as Fe-III-Oxides (i.e. rust)

P, Si, As sorb to Fe-III-Oxides

Competing (harmless) ions greatly outnumber Arsenic ions



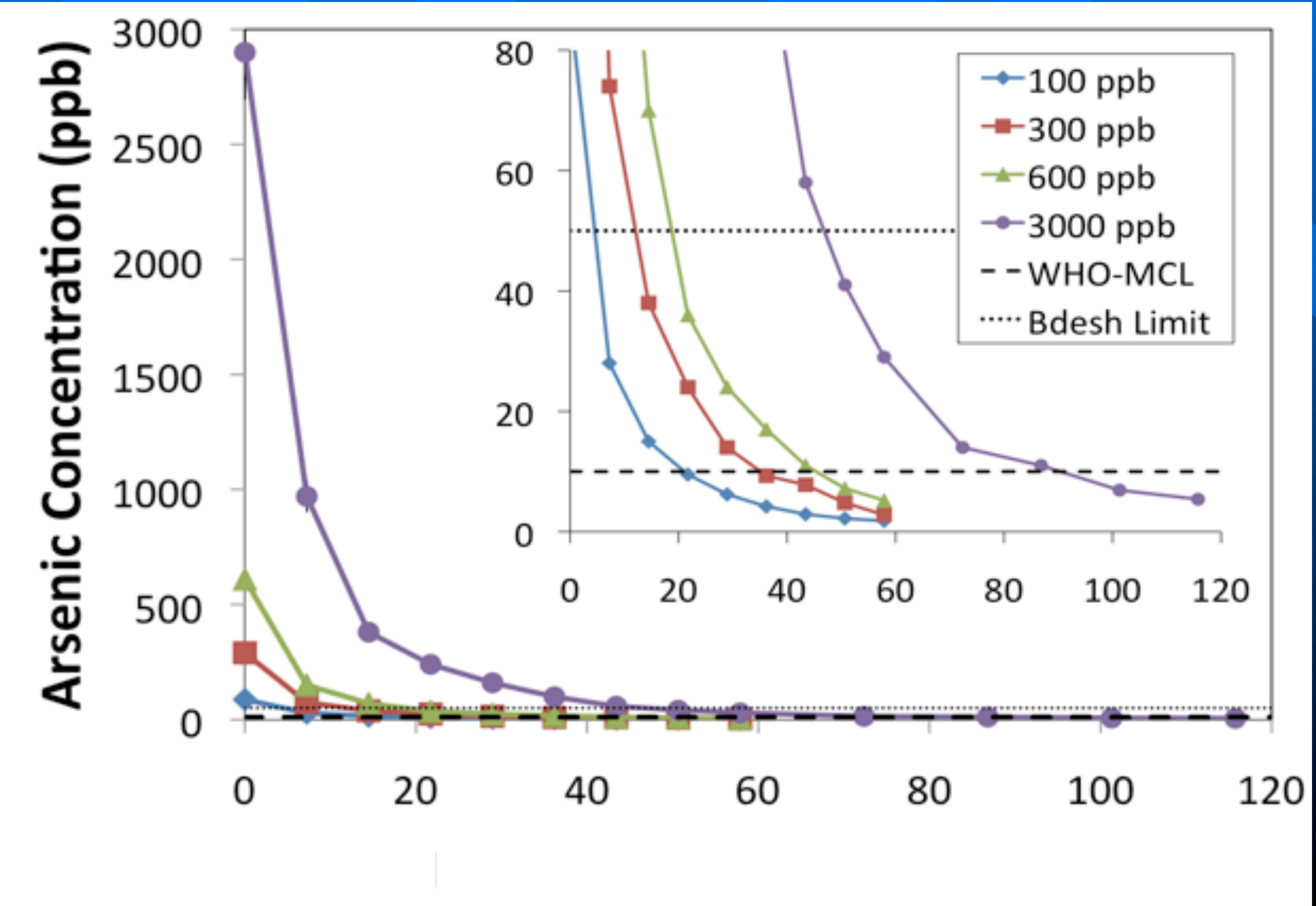
As: 300 µg/L
P: 3 mg/L
Si: 30 mg/L



Initial ideas were tested at LBNL and then work moved to Davis Hall on Campus

Arsenic Removal
in Synthetic (Lab) Groundwater

50% AsIII
50% AsV

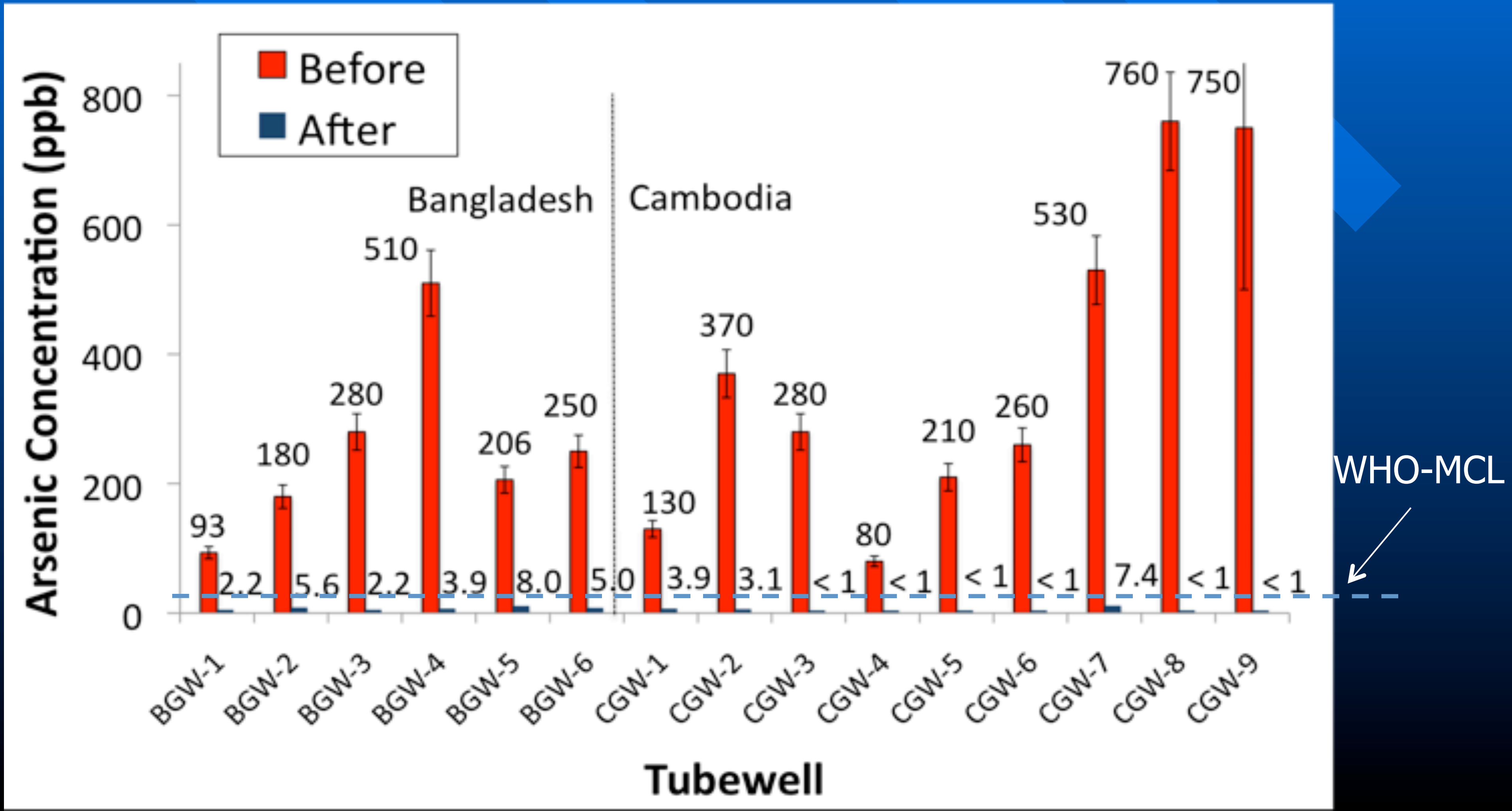


Will it work with real groundwater from the field?

Arsenic Removal

In real groundwater- Bangladesh and Cambodia

(But only with small-volume samples)



ECAR ADVANTAGES

Highly effective in real groundwater even with intermittent power supply

- consistently delivers < 5 ppb arsenic and < 0.3 ppm iron

Locally affordable

- consumables + utility + capital (@5% over 10 yrs) = 5 paise/L

No regeneration, No hazardous materials, No imported adsorbent

Simple supply chain ➔ ordinary steel plate, non-ferric alum

Minimal sludge (~250 grams/m^3), passes TCLP, and is well stabilized in concrete

Recent Science Results

- *Removing arsenic from synthetic groundwater with iron electrocoagulation: An Fe and As k-edge EXAFS study,* van Genuchten, Addy, Pena, and Gadgil. **Environmental Science and Technology**, 46(2):986–994, 2012.
- *Modeling As(III) oxidation and removal with iron electrocoagulation in groundwater,* Li, van Genuchten, Addy, Yao, Gao, and Gadgil. **Environmental Science and Technology**, 46(21):12038–12045, 2012.
- *Addressing arsenic poisoning in South Asia,* Gadgil, Roy, Addy, Das, Miller, Dutta, and Deb-Sarkar. **Solutions**, 3(5):40–45, September-October 2012.
- *Arsenic removal from groundwater using iron electrocoagulation: effect of charge dosage rate,* Amrose, Gadgil, Srinivasan, Kowolik, Muller, Huang, and Kostecki. **Journal of Environmental Science and Health, Part A**, *in Press*, 2013.

Low Capital + Operating Cost

~ 0.1 US Cent per Liter

So, can profitably sell Arsenic-safe water for 1 US Cent per L; i.e., a dime per 10 L (~ 5 rupees / 10 L)

Affordable + Financially viable ⇔ Sustainable and scalable

Possible Scale-up Model: WaterHealth International

Andhra Pradesh, India

Community Scale
- 2¢ for 10 Liters (in India, 2007)

Affordable + Financially viable ⇔ Sustainable

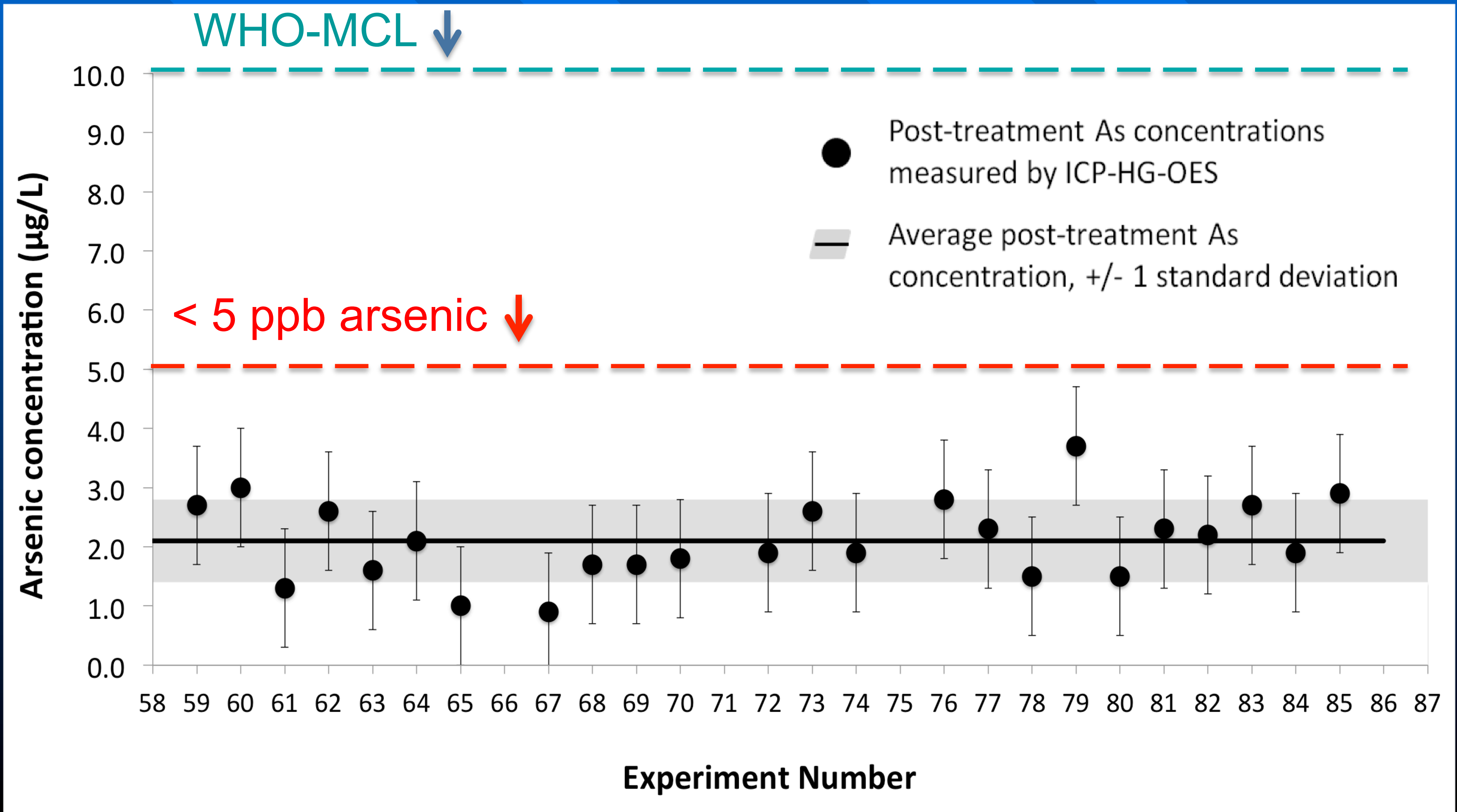
600L Prototype

Settling Tank

Dosing Tank

ECAR consistently delivered < 5 ppb As in field

January 2013 results, Dhopdhopi High School (Initial Arsenic **246 ± 20 µg/L**)



Projects Website:

GadgilLab.berkeley.edu

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

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

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Questions?


DISCUSSION

Two past projects not discussed in this talk

CFL introduction in low income customers in poor countries. Now in 100 million homes. Annual savings ~$5B

http://www.myindiapictures.com/cfl-bulb-protections-in-india-funny/

“UVWaterworks” to affordably disinfect drinking water in poor communities in poor countries.

People served daily >5M

Diarrheal deaths annually avoided ~1000