Technology Perspectives on Clean Energy R&D Needs of Emerging Economies

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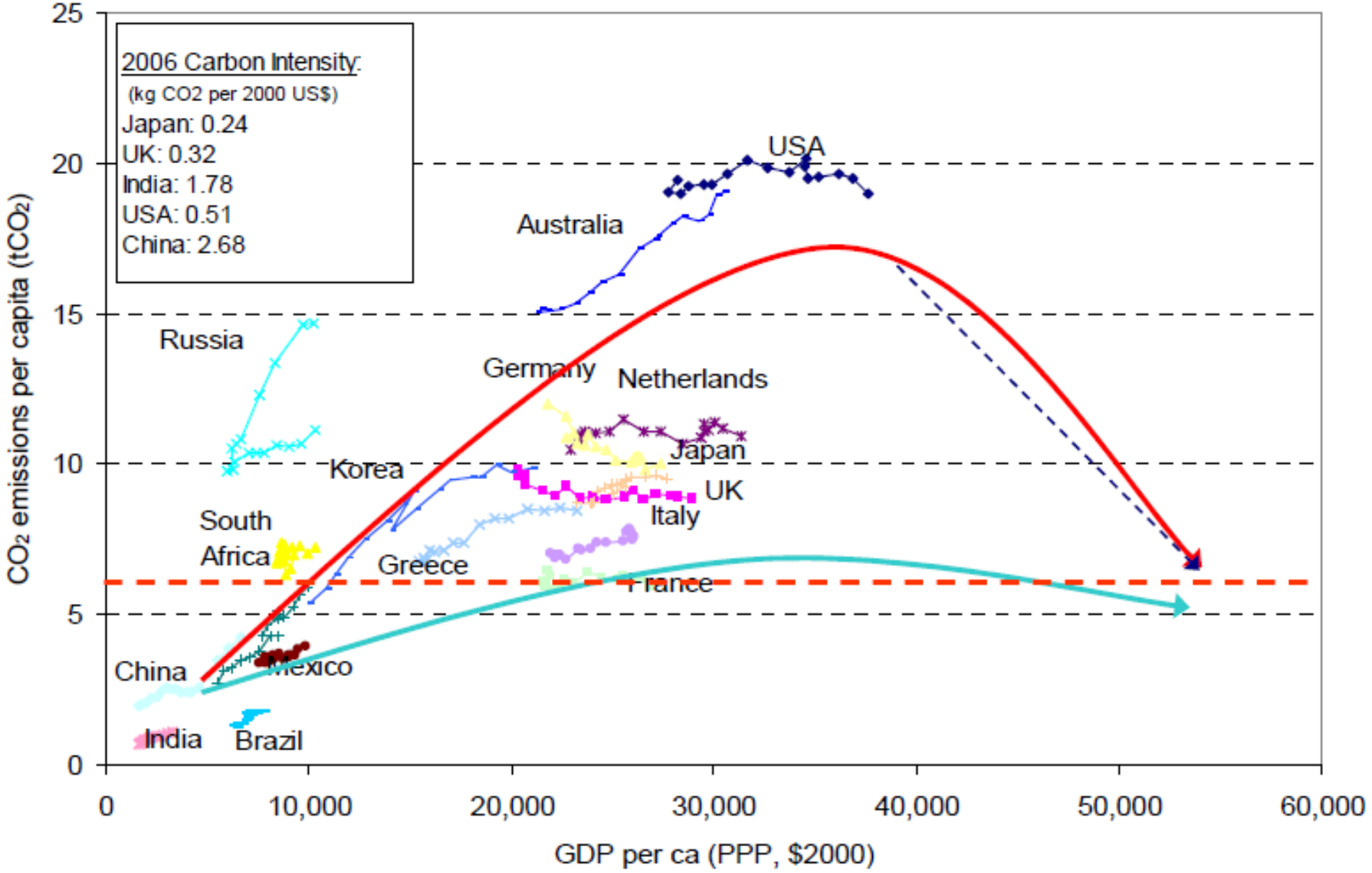
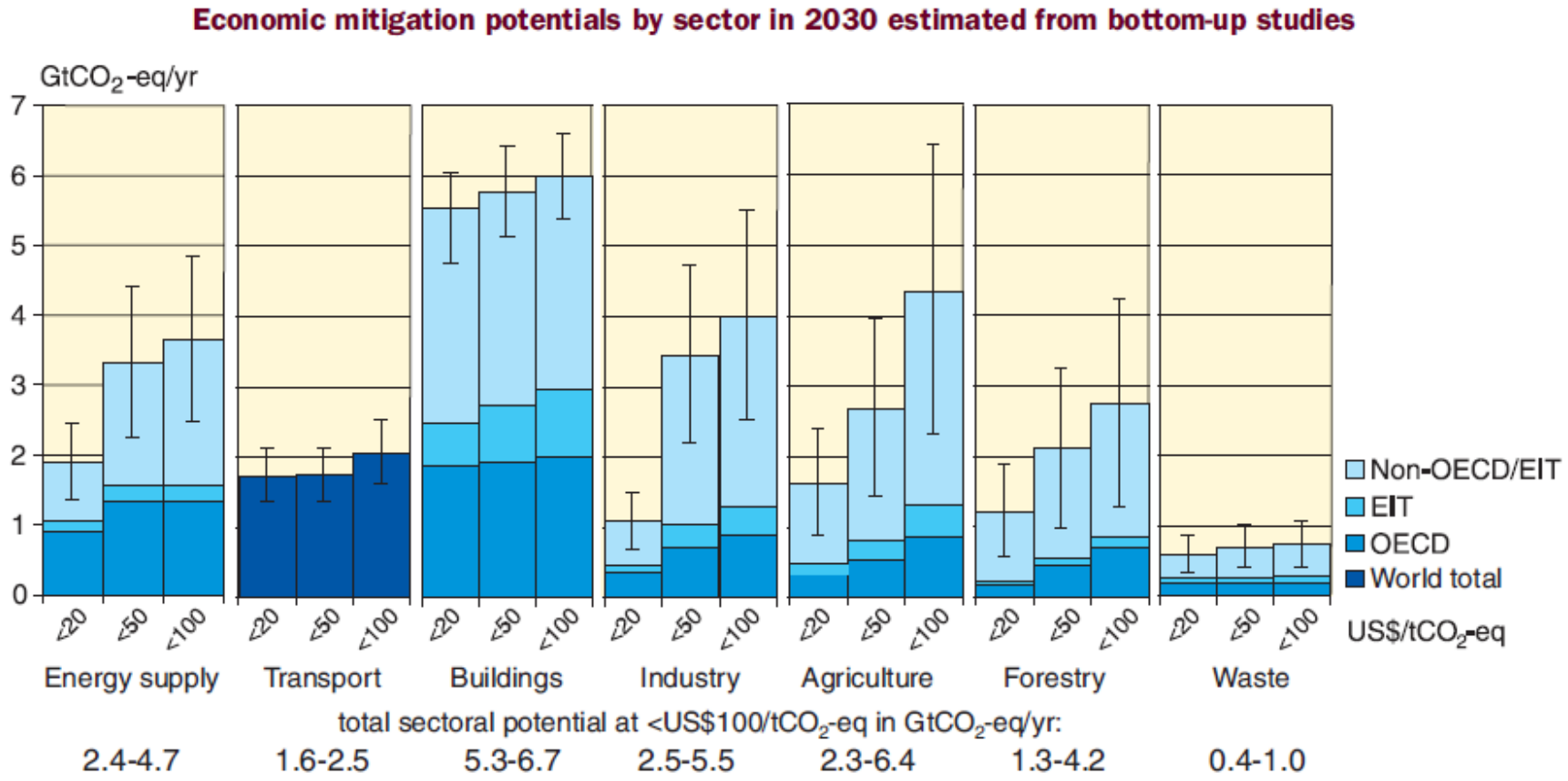
CO_2 Emissions of Selected Countries



All Sectors and Regions have the Potential to Contribute



Source: IPCC 2007

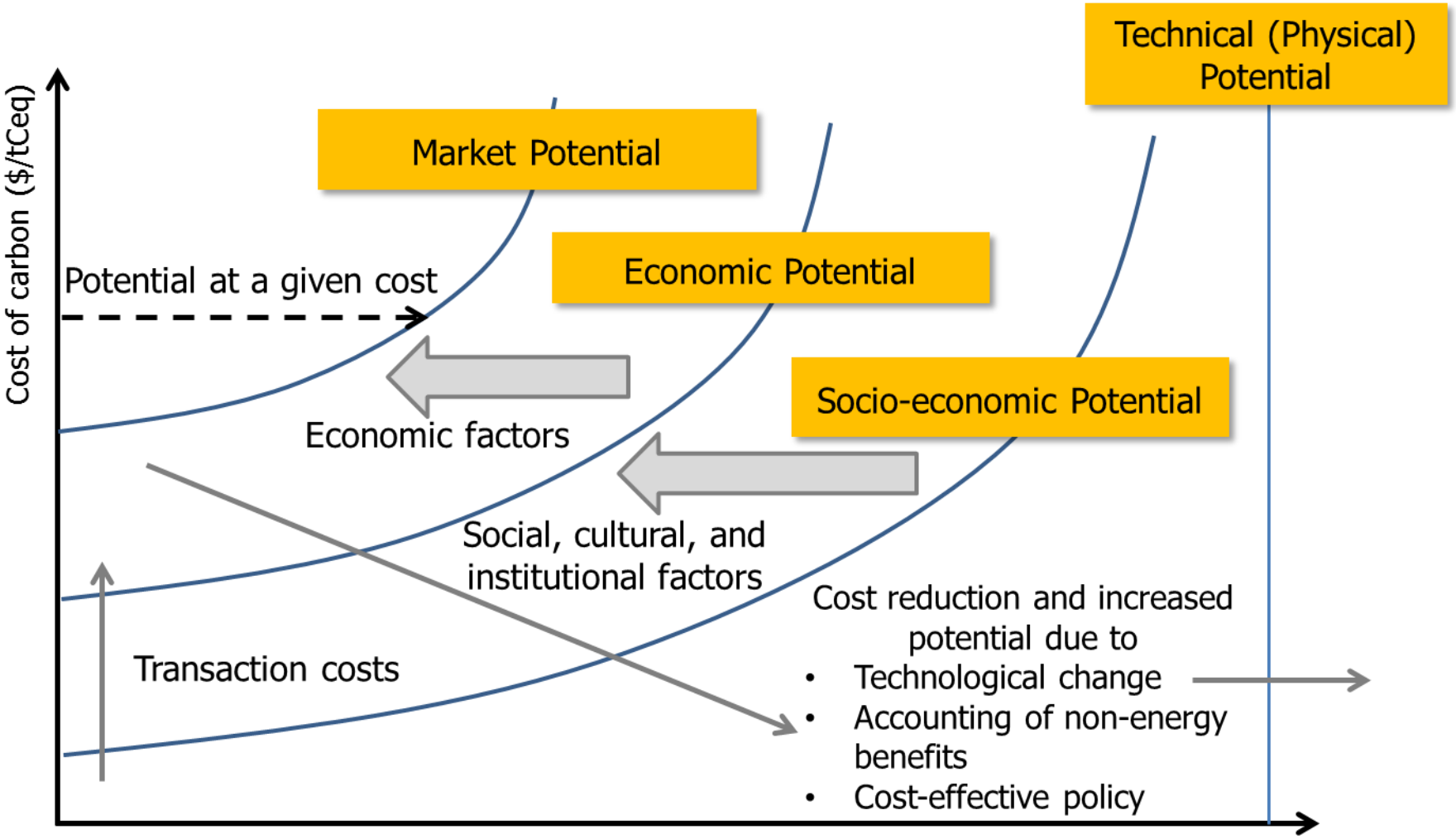
Note:

- Sectoral estimates are for 2005-2030 and are based on bottom-up studies
- Estimates do not explicitly include non-technical options, such as lifestyle changes.

Multiple Country Examples

1. Energy Efficiency in Appliances
2. Energy Efficiency in Industries
3. Affordable, Clean, Quality-assured Off-Grid Lighting
4. Affordable Safe Drinking Water
5. Fuel-efficient Cook Stoves
6. Affordable Solution to Water Poisoning

Penetration of Mitigation Technologies



Source: Sathaye and Phadke (2010)

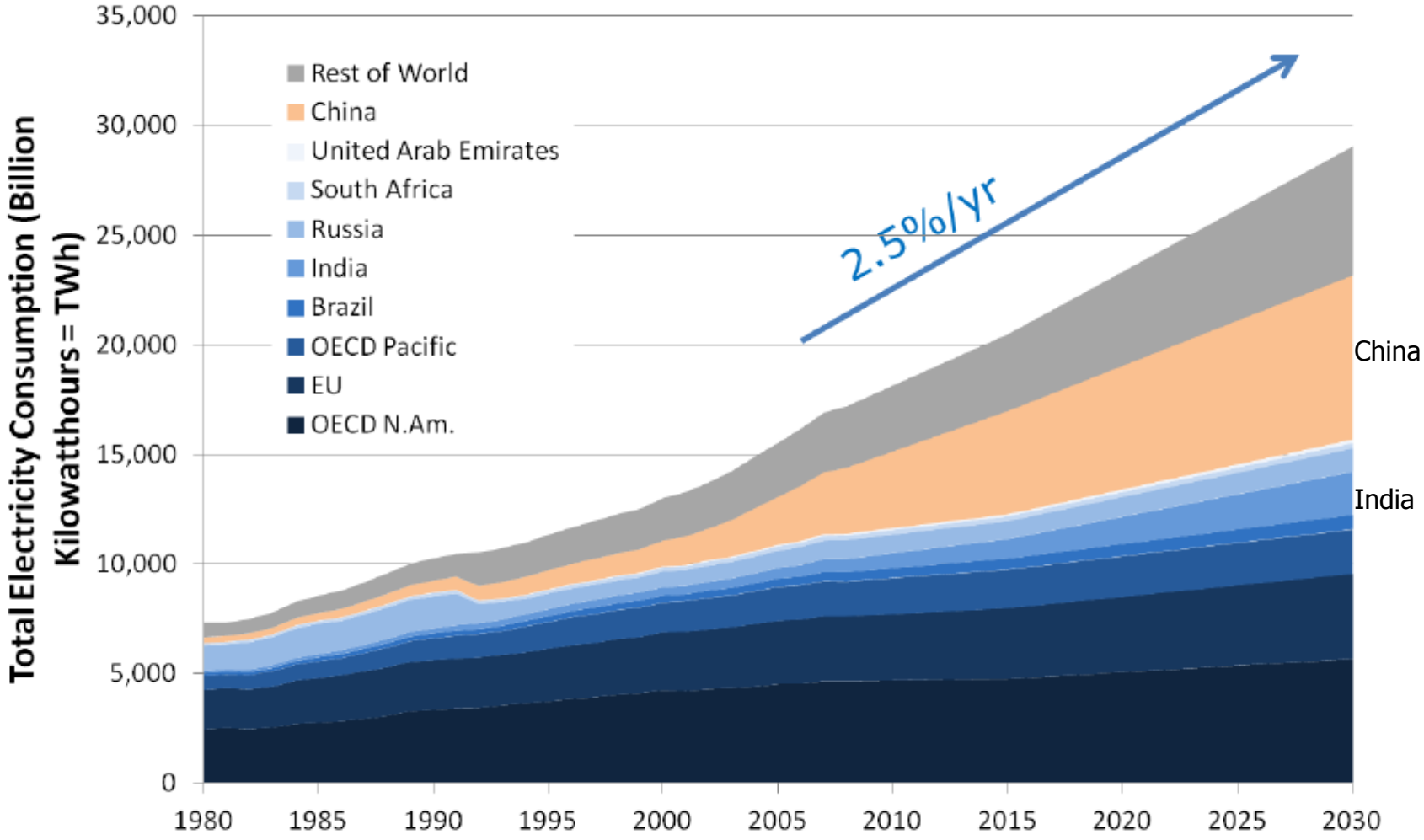
To be useful, effective and scalable for emerging economies, technology innovation must share the following characteristics

Characteristics	
Affordable	• To the poorest • To consumers and suppliers
Technically Effective	• Efficient • Quality assured • Easy to maintain
Robust, Reliable	• Relevant to operating environment
Culturally Appropriate	• Adjustable
Widely Applicable	• Applicable across region • Practical to manufacture
Cost Effective	• Low incremental cost (to manufacturers or consumers) of conserved energy

1 Energy Efficiency in Appliances: Super-efficient Appliance Deployment (SEAD)

Global Electricity Demand

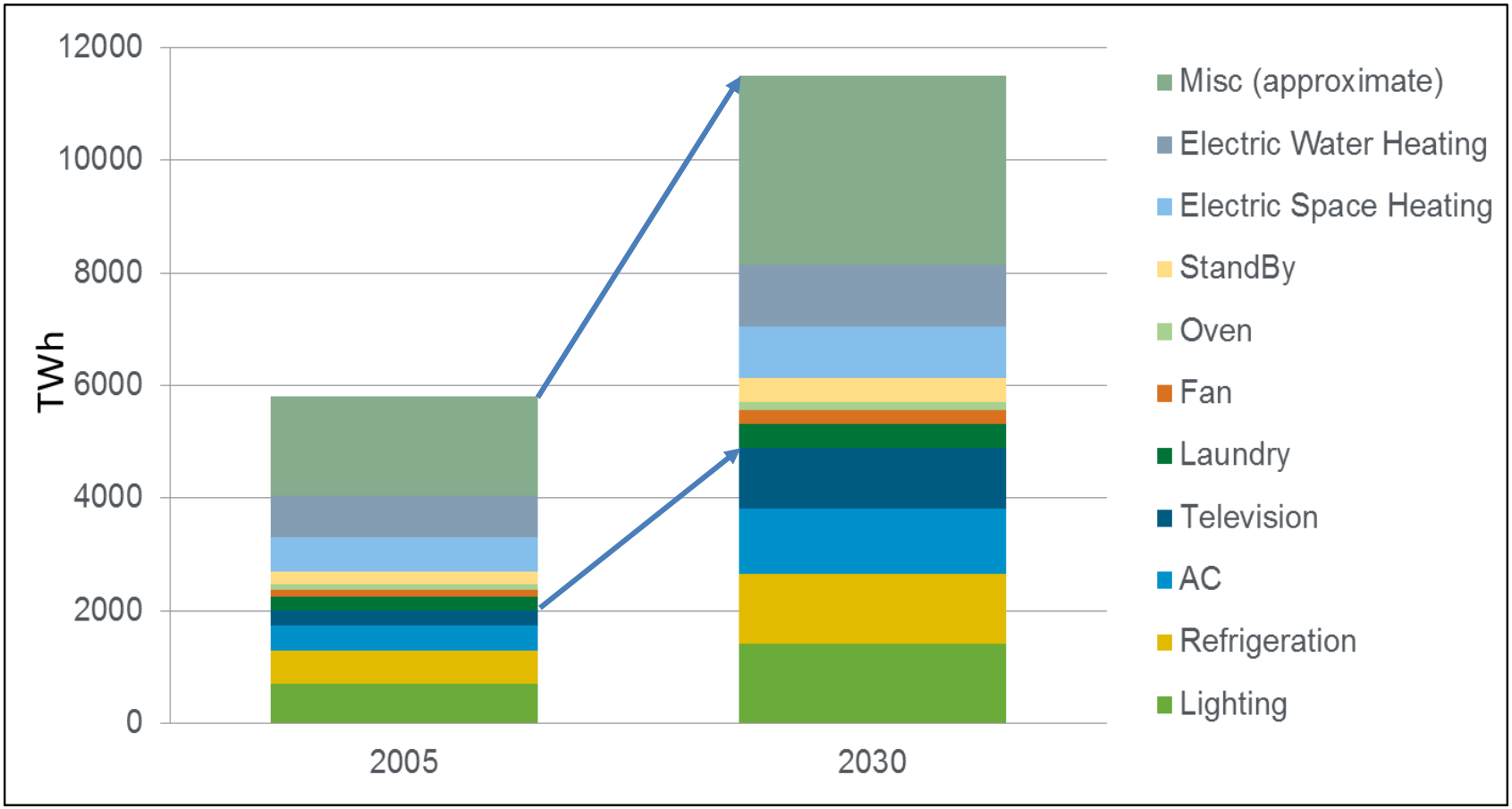
- Rapidly growing global electricity demand is led by emerging economies.
- About half of this electricity consumption is from appliances and equipment.



Source: EIA Int'l Energy Statistics, IEA World Energy Outlook 2009 (Pre-read for Public-Private Roundtable at CEM-3)

Electricity Consumption in Appliances

- Four appliance categories are expected to continue to constitute about 40% of residential consumption.

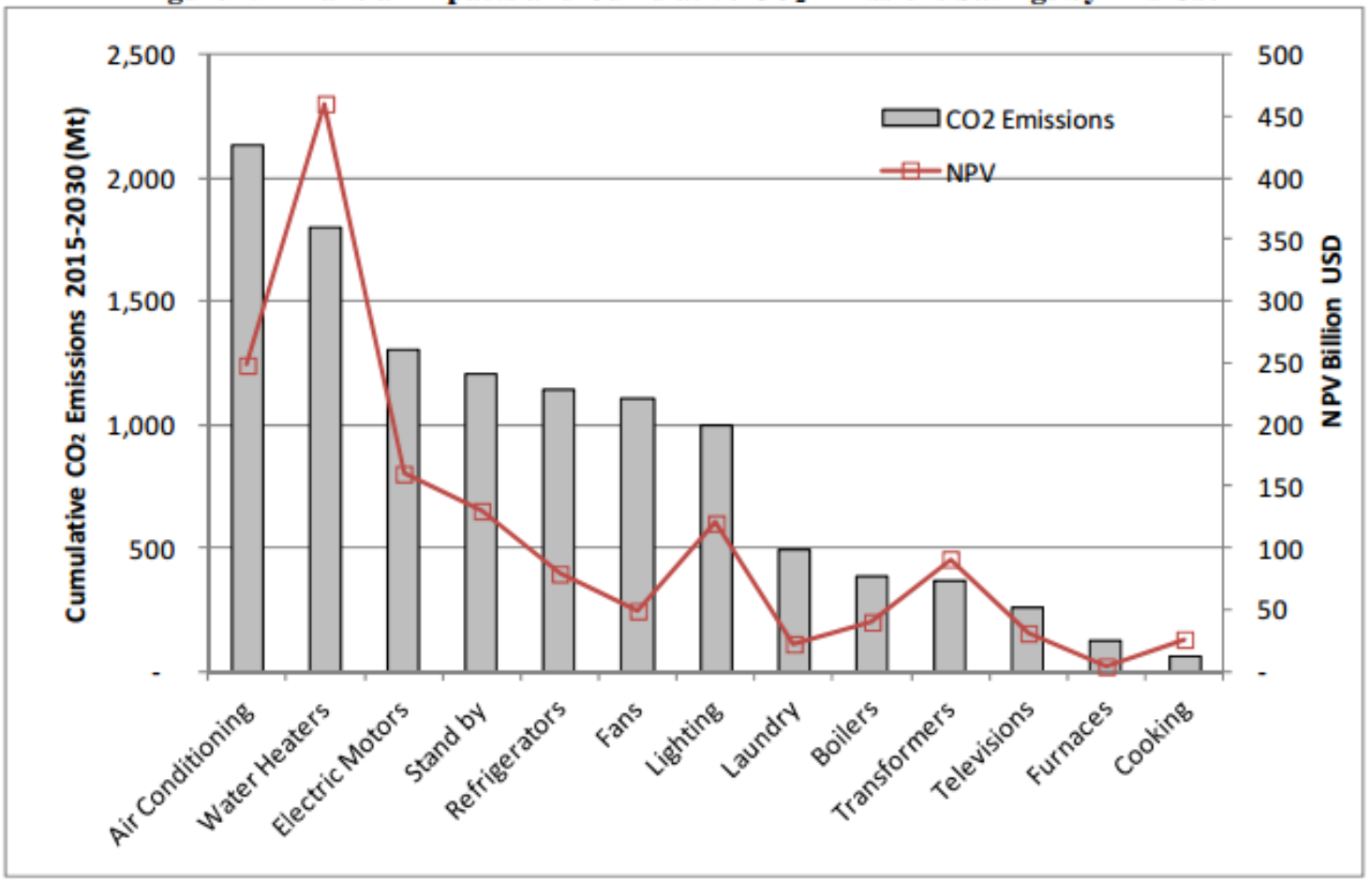


Source: LBNL, May 2010 (* Results for SEAD participating economies)

Impacts of Cost-Effective Technologies

- More investment in efficient appliances and equipment would be cost-effective and would reduce GHG emissions.

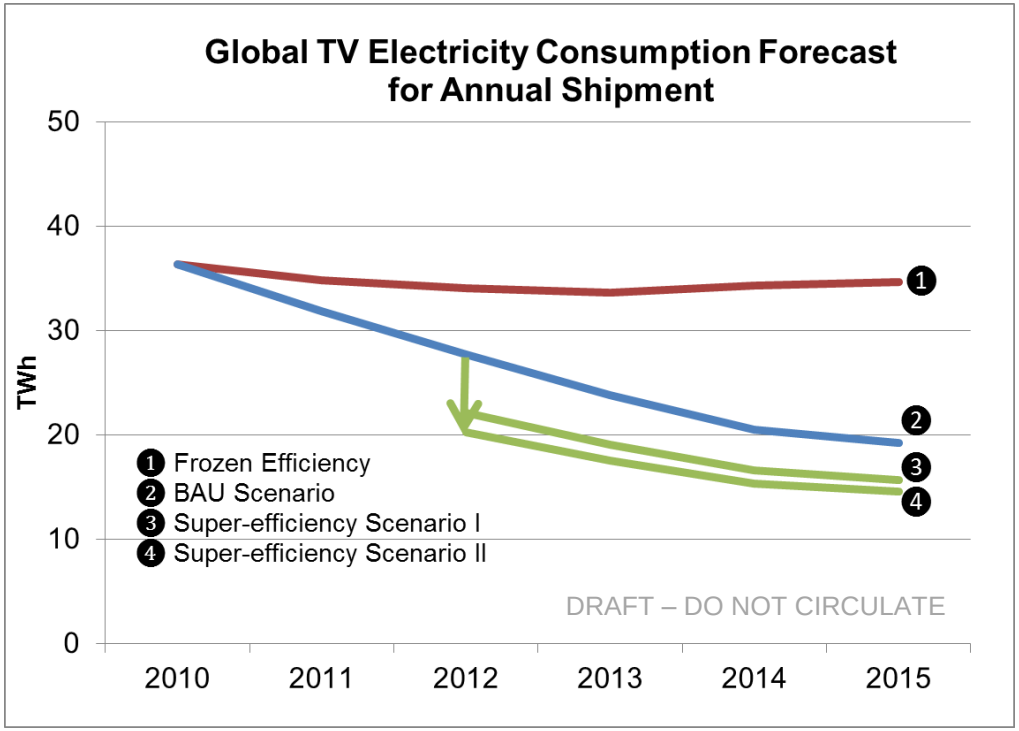
Figure 2. Financial Impacts and Cumulative CO_2 Emissions Savings by End Use



Source: Letschert et al. 2012, Estimate of Cost-Effective Potential for Minimum Efficiency Performance Standards in 13 Major World Economies, LBNL.

Rapid Improvement in TV Efficiency

- There are only limited regional differences and global similarity in TV screen (i.e., LCDs) and LCD backlight technology. Beyond the on-going TV market transition towards LED backlit LCD TVs, TV consumption within the technology can be further reduced by 20-40% cost effectively.



Source: Park et al. 2012, LBNL (forthcoming)

Components		Improvement Options	
Backlight Unit	Backlight Source	• CCFL to LED transition	❷
		• High LED efficacy	❷
	Optical films	• Optimized combination of films • Multi-function film	❷
		• Reflective polarizer (e.g., DBEF[a])	❸
LCD Panel		• Improvement in panel transmittance by optimizing pixel design, functional layers, e.g., polarizer, color filter, and data line	❷
Power management		• Brightness control (local dimming) by image signals	❸
		• Brightness control based on ambient light condition	❹

CCE vs. Room AC Efficiency -- SEAD

- If all the efficiency improvement options shown in the table below are employed, then the higher efficiency Room AC would save an estimated 60-72% of energy compared to the base case model.
- In addition to these traditional options, options to save energy exist such as occupancy sensors, and demand response measures such as "smart ACs" linked to the "smart Grid", which could further reduce energy consumption by 20-30%.

Option	Description	% improvement from base case
Efficient Heat Exchangers	high efficiency micro channel heat exchangers, larger sized heat exchangers	9.1-28.6%
Efficient Compressors	two-stage rotary compressors, high efficiency scroll compressors with DC motors	6.5-18.7%
Inverter/Variable Speed	AC, AC/DC or DC inverter driven compressors	20-24.8%
Expansion Valve	Thermo and electrostatic expansion valves	5-8.8%
Crankcase Heating	Reduced crankcase heating power and duration	9.8-10.7%
Standby load	Reduced standby loads	2.20%
Total/cumulative		~60.4%-71.7%

Source: LBNL/Navigant (under review)

Refrigerators for Emerging Economies

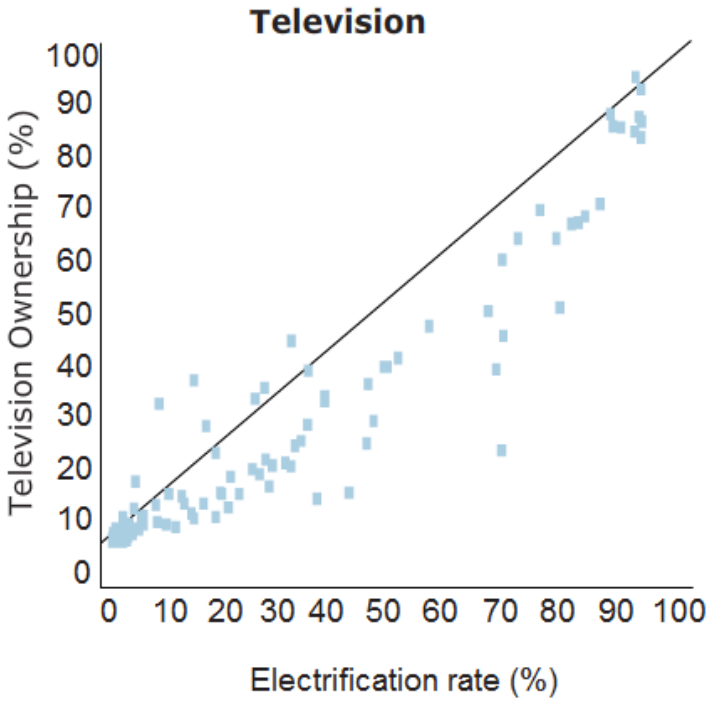
- Refrigerators are among the appliances most frequently targeted by efficiency standards and policies, but cost-effective improvement potential for emerging economies is still significant.

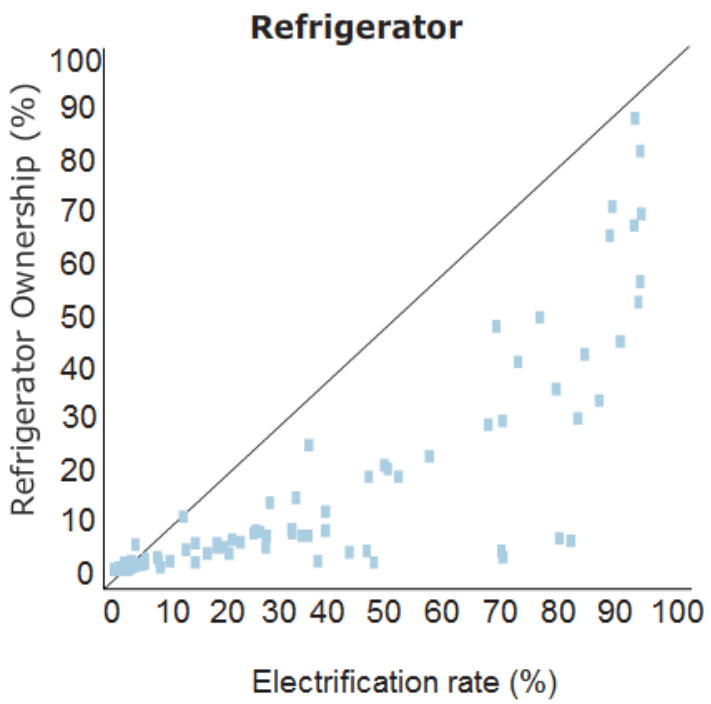
Country	Baseline UEC (kWh/yr)	Baseline Price (USD)	Target UEC (kWh/yr)	Target Price (USD)	CCE (USD/kWh)	% improvement from baseline UEC
AUS	700	1,300	430	1,700	0.16	39%
BRA	360	390	220	510	0.11	39%
CAN	560	390	460	710	0.07	18%
CHN	550	320	290	440	0.05	26%
EU	240	830	200	920	0.22	17%
IND	470	N/A*	330	29	0.03	30%
IDN	470	N/A*	330	29	0.03	30%
JAP	370	1,400	320	1,500	0.23	14%
KOR	690	510	440	700	0.07	36%
MEX	370	500	310	510	0.03	16%
RUS	540	320	No CCE below tariff			-
ZAF	540	320	160	540	0.08	70%
USA	560	630	460	710	0.07	18%

Source: Letschert et al. 2012, Estimate of Cost-Effective Potential for Minimum Efficiency Performance Standards in 13 Major World Economies, LBNL.
* Target prices are based on incremental costs; baseline prices not available.

Electrification and Appliance Ownership

- Electrification is one of necessary conditions for TV and refrigerator ownership.
- Growing number of rural electrification projects is likely to lead penetration of key appliances into off-grid rural areas in emerging economies.

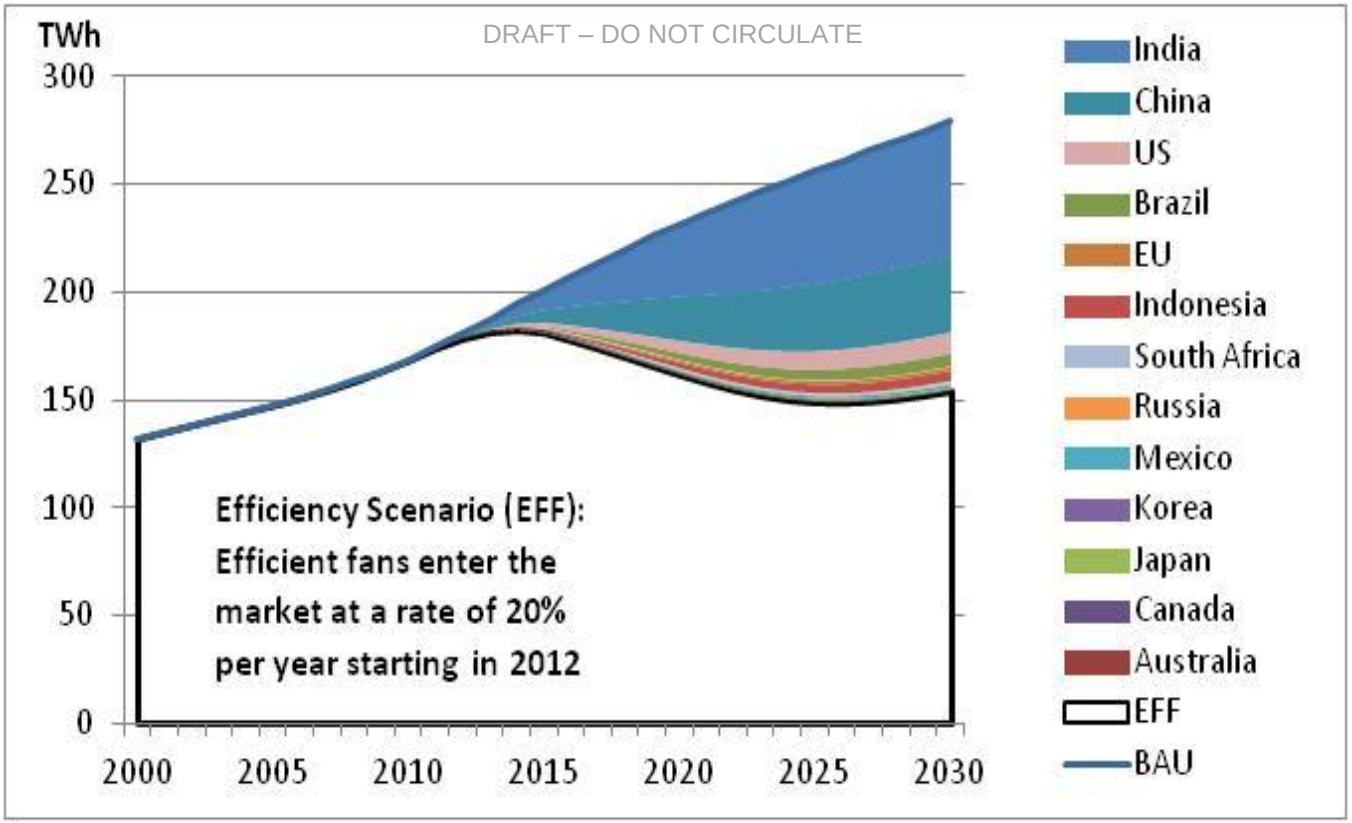




Source: The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits, World Bank (2008)

Ceiling Fans for Emerging Economies

- **China and India** represent more than half of worldwide energy consumption by ceiling fans (total 156 TWh) in 2012.
- Improved AC induction motors, efficient blades and brushless DC motors can reduce power consumption in a cost effective manner.



Source: LBNL (under review)

Ceiling Fans for India: Case Study

- **Super-efficient Equipment Program (SEEP) was initiated in India in 2010 by Bureau of Energy Efficiency (BEE).**
- **Ceiling fans, refrigerators, air conditioners and TVs were accepted candidates.**
- **Fans were chosen as primary technology to initiate a DSM program that would provide discount funds to manufacturers.**
- **Now supported by World Bank, BEE and regulatory commissions.**
- **Current Considerations:**
  - **Discounts to manufacturers → opposed by government**
  - **Include a "micro" pilot where mechanism can be used to pass on the rebates directly to consumers**
  - **No less than 3 to 4 important government ministries' approval steps are pending**

2

Energy Efficiency in Industries – US EPA, China, India

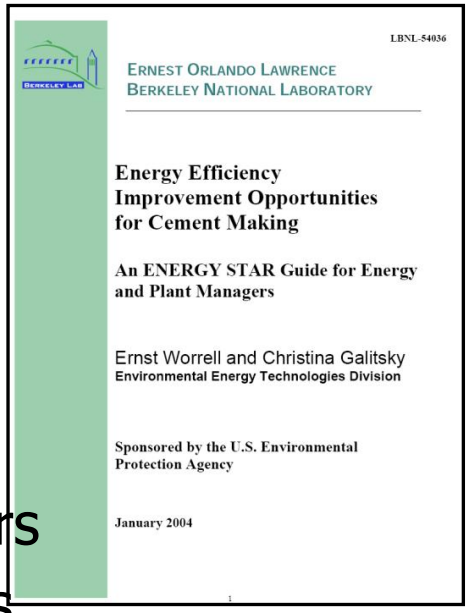
ENERGY STAR Program

- ENERGY STAR is a symbol for energy efficiency and a way to protect the environment
- ENERGY STAR began expansion in 2000 to include voluntary partnerships between industries and government
- Over 500 industrial partners

- ✓ For Industry, ENERGY STAR steps include:
  - company committing to improve energy performance
  - benchmarking and tracking energy use
  - developing and implementing a plan to improve energy performance
  - educating staff and public on partnership
- ✓ ENERGY STAR provides tools and recognition
  - Energy Guides
  - Energy Performance Indicators (EPI)
  - Program Development

What is an Energy Guide?

- Compilation of proven, energy-efficient practices in the U.S. and internationally for a single industry
  - Data collected on the industry structure as a whole (major industry segments [like wet and dry cement kilns] energy use, production and economic trends)
  - Data collected for each efficiency measure: savings, costs, payback period and examples
- Data gathered from many sources:
  - Literature review (100s of sources used from journals, energy organizations, case studies, websites)
  - Vendor information (publishable and/or verifiable only)
  - Company supplied information
- Created <u>for</u> corporate energy and plant managers
- Reviewed <u>by</u> industrial professionals and experts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ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

Energy Efficiency Improvement Opportunities for Cement Making

An ENERGY STAR Guide for Energy and Plant Managers

Ernst Worrell and Christina Galitsky
Environmental Energy Technologies Division

Sponsored by the U.S. Environmental Protection Agency

January 2004

Energy Efficiency Opportunities

No Capital Cost	Short Payback	Capital Projects
Preventative maintenance	Energy & Process Controls: - Kiln - Raw material - Finish Grinding	Efficient Grinding Mills
Seal Replacement (kiln)	High-efficiency Classifier	Roller Mill
Shell heat loss reduction	Improve Combustion System	Grate Cooler
Optimization of compressed air systems	Indirect Firing	Low-Pressure Drop Preheaters
Low-Carbon Fuels	Optimize Grate Cooler	Multi-Stage Preheaters
Intergrinding Limestone	High efficiency Motors	Precalciner
Reduced fineness cement	Adjustable Speed Drive	
Increased Alkali Content	Blended Cement	
	Slags in Clinkermaking	

Energy Efficient Technology Example

Precalciner Kiln

- The U.S. has a very high share of the inefficient wet process kiln
- Precalciner kiln is an efficient kiln with preheating of raw materials and pre-calcining limestone at low temperature
- Precalciner kiln reduces energy consumption to 3.2 GJ/t, saving 40% compared to wet process kiln
- Standard technology for new kilns
- Benefits include:
  - reduced NOx emissions,
  - reduced water use,
  - increased productivity,
  - increase use of refuse derived fuels
- Retrofit cost estimate of $75/t
- O&M savings $1/t

Energy Efficient Technologies in Key Industries

- Cost-effective energy-efficient technologies are available in energy-intensive industries.

Sector	Examples of Cost-Effective Technology Options
Iron and Steel	Sinter plant heat recovery, Coal moisture control in coke plants, Coke dry quenching, Recovery of blast furnace gas, Automated monitoring and targeting system, Energy monitoring and management system, Improved process control, etc.
Cement	Kiln shell heat loss reduction (Improved refractories) , Energy management and process control systems in clinker making, Optimize heat recovery/upgrade clinker cooler, High-Efficiency classifiers for finish grinding, Replacement of cement mill vent fan with high efficiency fan, etc.
Pulp and Paper	Continuous digester modifications, Lime kiln modifications, Chlorine dioxide preheating, Air system optimization, Sludge recovery and utilization, Vacuum system optimization, Adjustable-speed drives, etc.
Aluminum	Strong soda heat exchanger circuit modification, Pump optimization, Replacement of existing rotary kiln with statutory calciner, Furnace optimization, Optimizing lighting, Voltage optimization, Replace reciprocating compressors with screw compressor, Replacement of new Transformer, etc.
Ammonia	Lighting improvement, Installation of variable speed drives for cooling tower fans of ammonia and power plant, Replacement of traditional tube lights with true tube lights & lamps, Fan optimization, etc.

Source: Karali et al. 2012, LBNL (under review)

Energy Intensive Industries for Emerging Economies

- **India:** Five major industries (Iron and Steel, Cement, Ammonia, Aluminum and Pulp and Paper) accounted for 63% of total final energy use in industry in 2005.

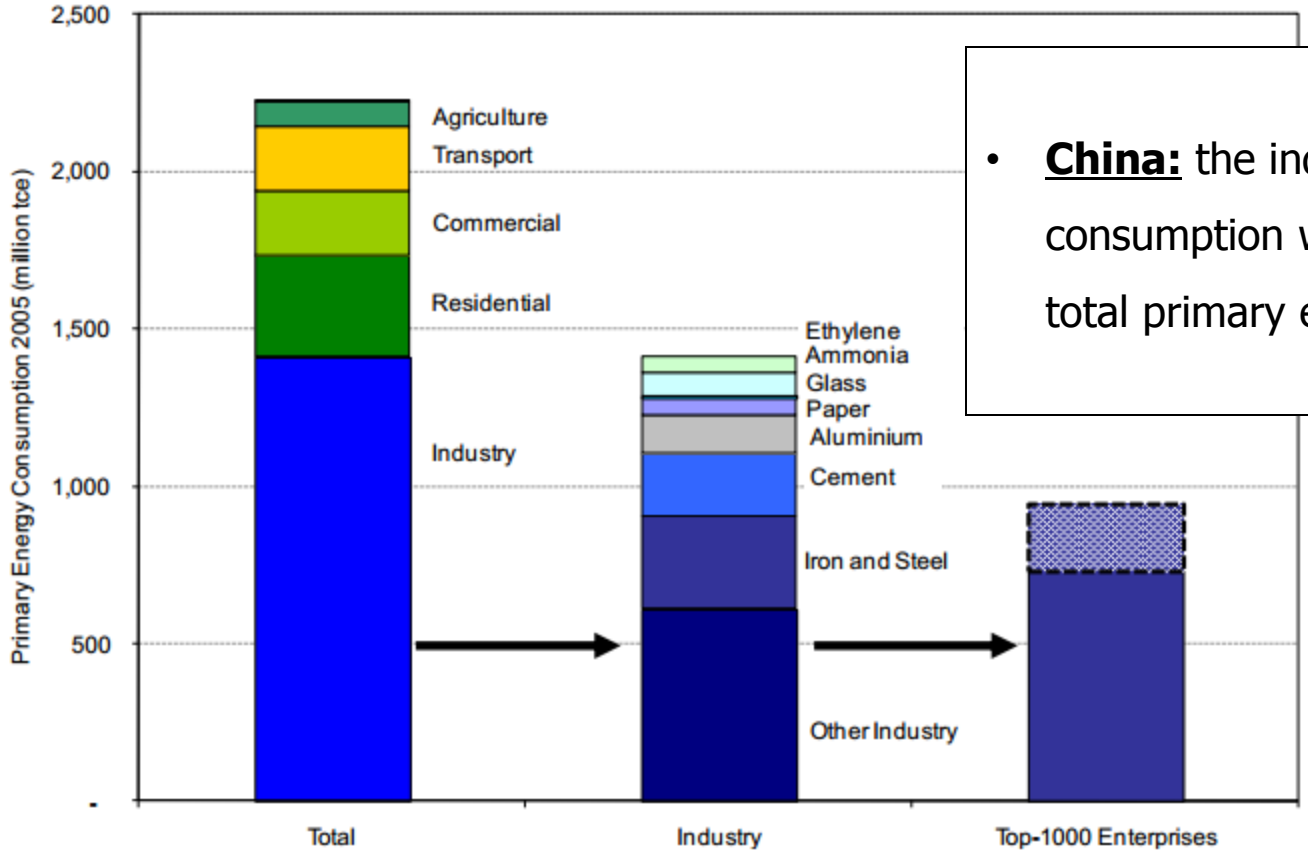


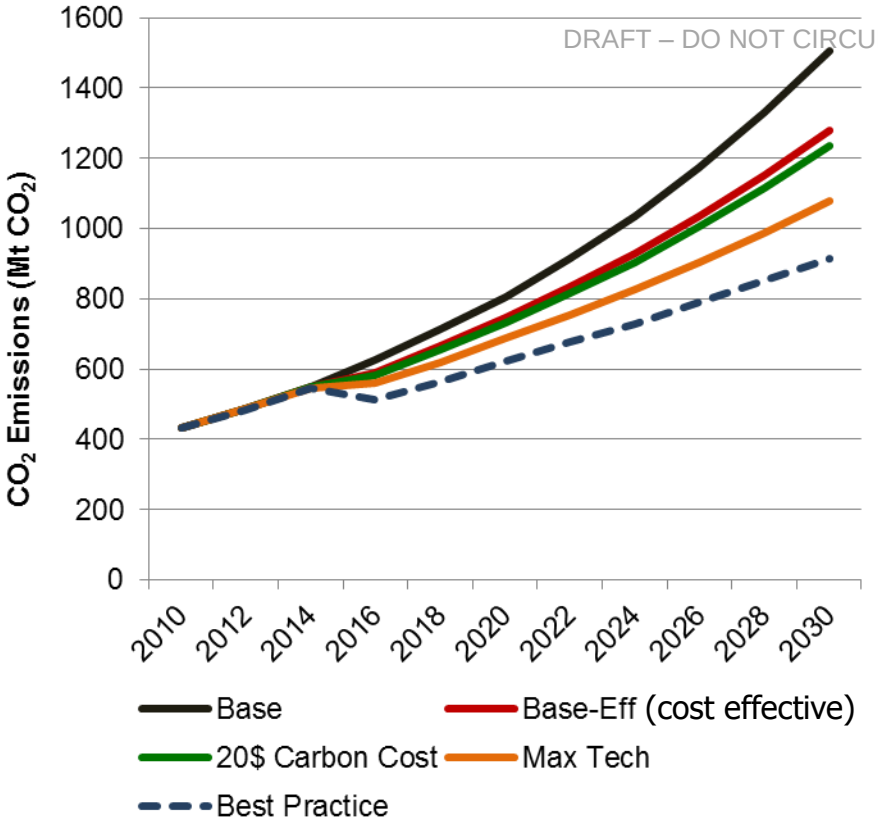
Figure 2. Energy Consumption of China, China's Industrial Sector, and the Top-1000 Energy-Consuming Enterprises, 2005

- **China:** the industrial sector energy consumption was 64% of China's total primary energy consumption.

Source: Price et al. 2010, LBNL

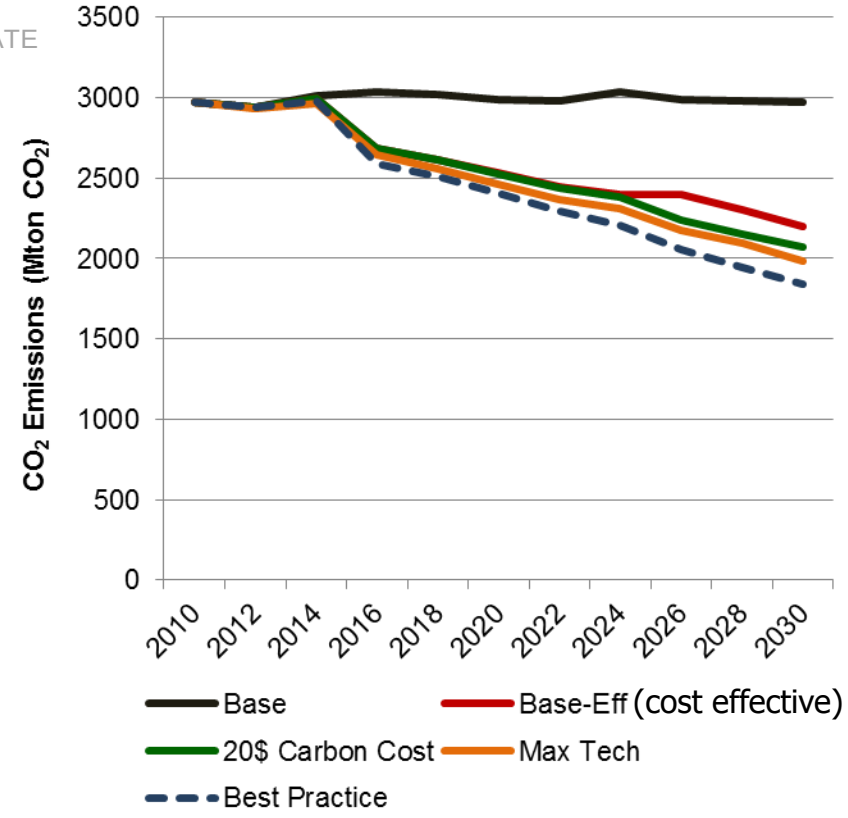
Emissions Reduction Potential in Key Industries

Total CO_2 Emissions of India's Key Industries: *aluminum, cement, iron and steel, pulp and paper, and ammonia*



Source: Karali et al. 2012, LBNL (under review)

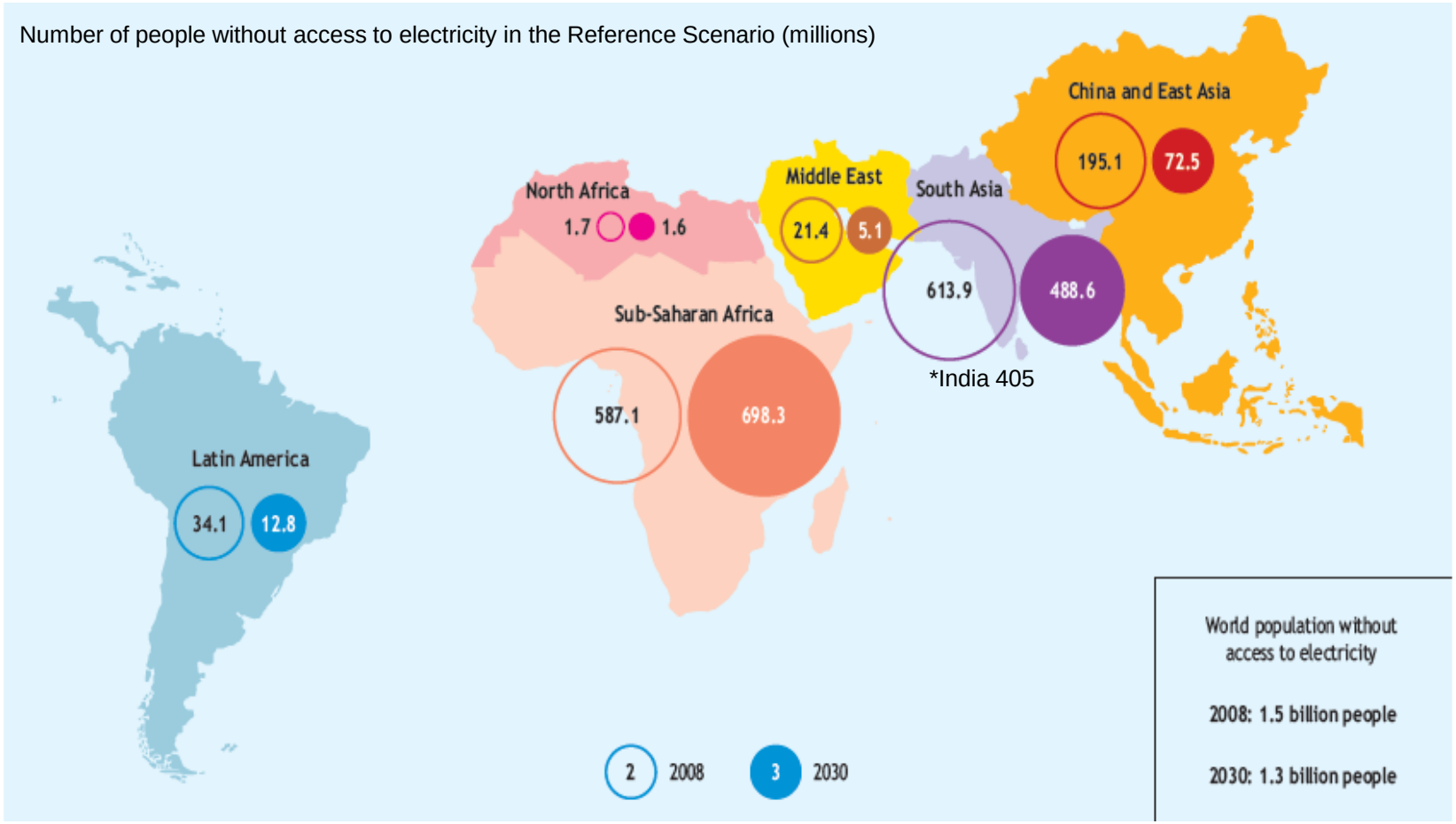
Total CO_2 Emissions of China's Key Industries: *aluminum, cement, iron and steel, pulp and paper, ammonia, ethylene, and glass*



3 Affordable, Clean, Quality-assured Off-Grid Lighting

Electricity Access

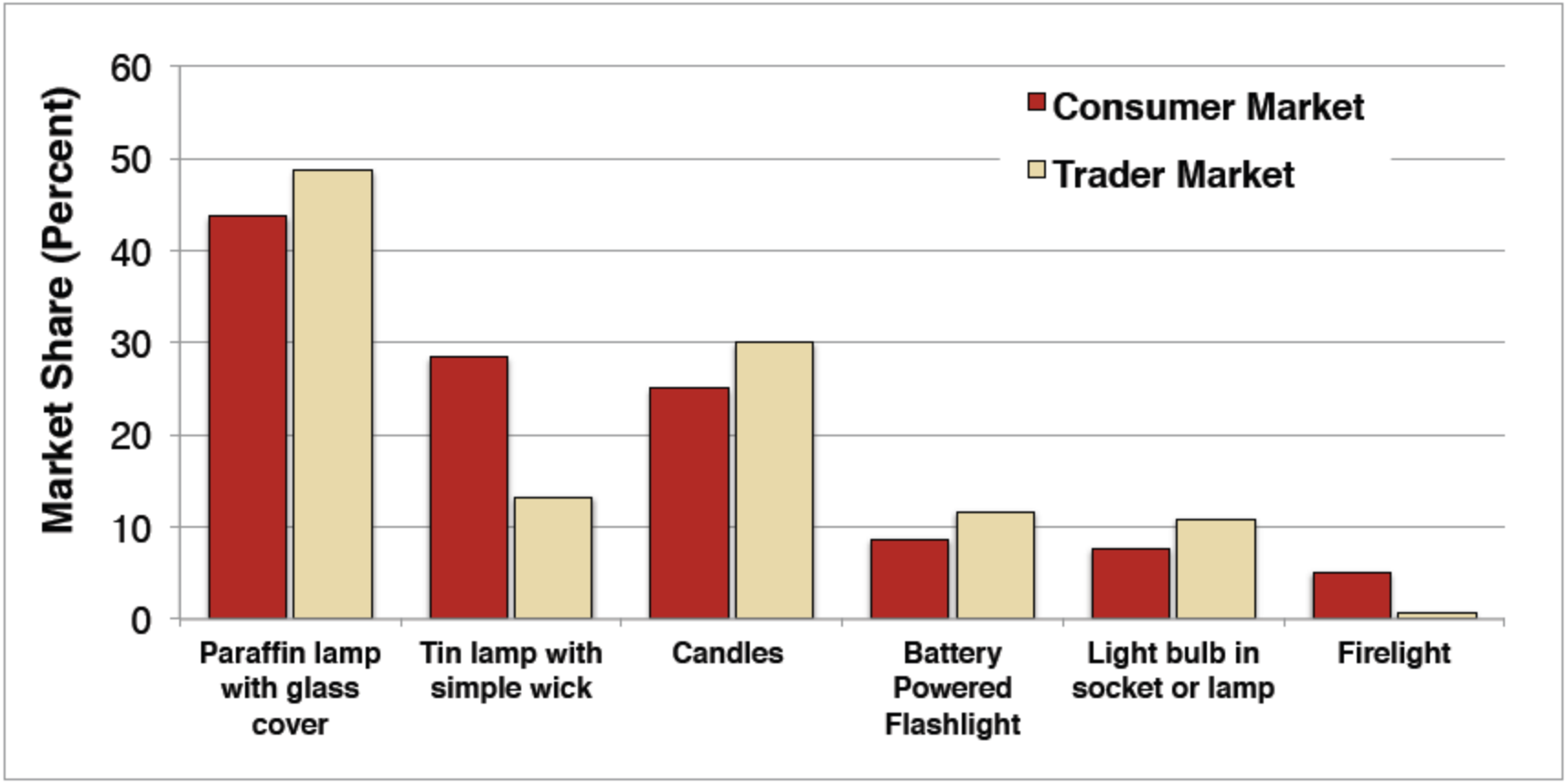
- Roughly 22% of the world's population - 1.5 billion people, 260 million households - still does not have access to electricity. Most of these people are located in sub-Saharan Africa and South Asia.



Source:IEA World Energy Outlook (2009)

Off-grid Lighting in Africa

- Based on survey results, more than half of households in Sub-Saharan Africa use paraffin and kerosene for cooking as well as lighting.



Graph 5. Types of lighting devices used, average across countries, consumers and traders (%).

Source: The Off-grid Lighting Market in Sub-Saharan Africa: Market Research Synthesis Report, Lighting Africa (2011)
* Results for Ethiopia, Ghana, Kenya, Tanzania, Zambia

Desirable Characteristics of Lighting Device for Off-grid Regions

Characteristics	Details
Affordability	The average optimum prices for general consumers are: rechargeable lantern (US$7), rechargeable torch (US$4), and rechargeable task light US$6.
Recharging methods	Solar recharging is well received across all countries due to the lack of operating costs.
Adequate light intensity	Lighting devices in a household are used for several activities, or in places.
Multi-purpose/ Portability	People have only 1 or 2 lighting devices, but more places to light.
Long battery life	Most people need to use lighting products for a minimum of 4-5 hours per day.
Ease of use and maintenance	User guides, user education or demonstrations on how to use the products are recommended.
Safety	e.g. no possibility of burning users or starting a fire.
Security	For products that are recharged using solar panels, the respondents avoid putting devices outside their house unattended due to the risk of theft.

Source: The Off-grid Lighting Market in Sub-Saharan Africa: Market Research Synthesis Report, Lighting Africa (2011)

Solar and Energy Access Program (SLED)

- A global market transformation initiative with an initial focus on replacing dirty, fossil fuel-based light sources such as kerosene lanterns with solar-powered, lighting emitting diode (LED) lights.
- Builds on a joint initiative led by IFC and World Bank, known as ***Lighting Africa***.
- Affiliated with the ***Global Lighting and Energy Access Partnership (Global LEAP)*** which was launched by 10 partner organizations at CEM 3 in 2012.
  - ✓ Cumulative sales of quality-assured off-grid lighting products have exceeded 500,000 units, benefitting an estimated 2.5 million people.
  - ✓ In 2011, IFC began preparations to launch *Lighting India* and conducted initial market research to inform the development of future activities in other Asian countries.
  - ✓ The product quality assurance program has tested more than 60 products using a standardized set of test methods, and it is currently testing other products under these standards.

Source: http://www.cleanenergyministerial.org/our_work/energy_access/index.html

4 Affordable Safe Drinking Water

Challenge and Opportunity

Photo by WHO/Richard Carr

Aasma and her mother at
ICDDRB Cholera Hospital, Dhaka, Dec. 2009

- **1.2 billion people lack access to safe (uncontaminated) drinking water, causing 2M deaths from waterborne disease (mostly of children below 5)**

UV Disinfection is extremely efficient!

- UV-Energy dose to the water is measured in milli-watt-seconds/sq. cm. of water surface. We need to deliver 40 mW-sec/sq. cm, to all water parcels

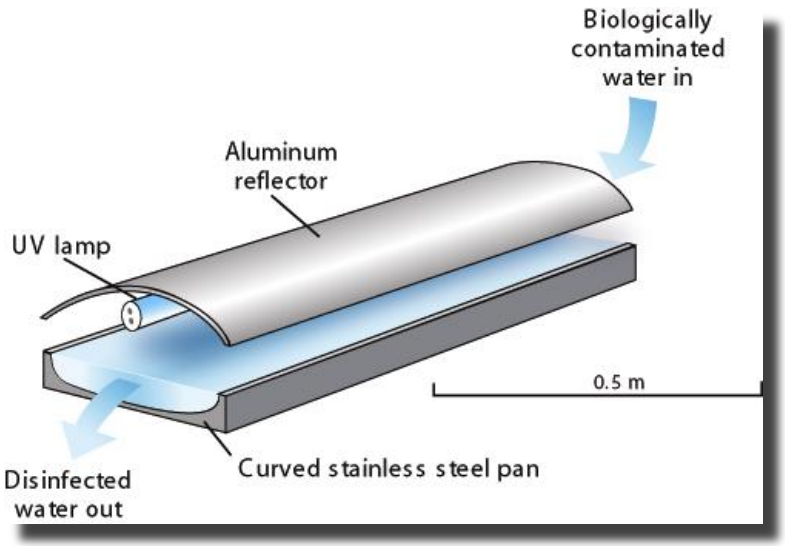
- UV lamp output is measured in watts. Say a 36-watt UV lamp produces about 15 watts of UV light (the rest comes out as heat)

- This light shines on ~1000 sq. cm. of water surface for ~10 seconds, so ~ 150 mW-sec/sq.cm. (Actual number is >120 mW-sec/sq.cm.)

- Even at this high dose, we use 6000 times less *primary* energy than that needed to disinfection by boiling on biomass cookstove

UV Disinfection

UV Waterworks



- **UV disinfection is extremely efficient.**
- **Even at >120mW-sec/sq.cm., we use 6000 times less primary energy than that needed for disinfection by boiling on biomass cook stove**

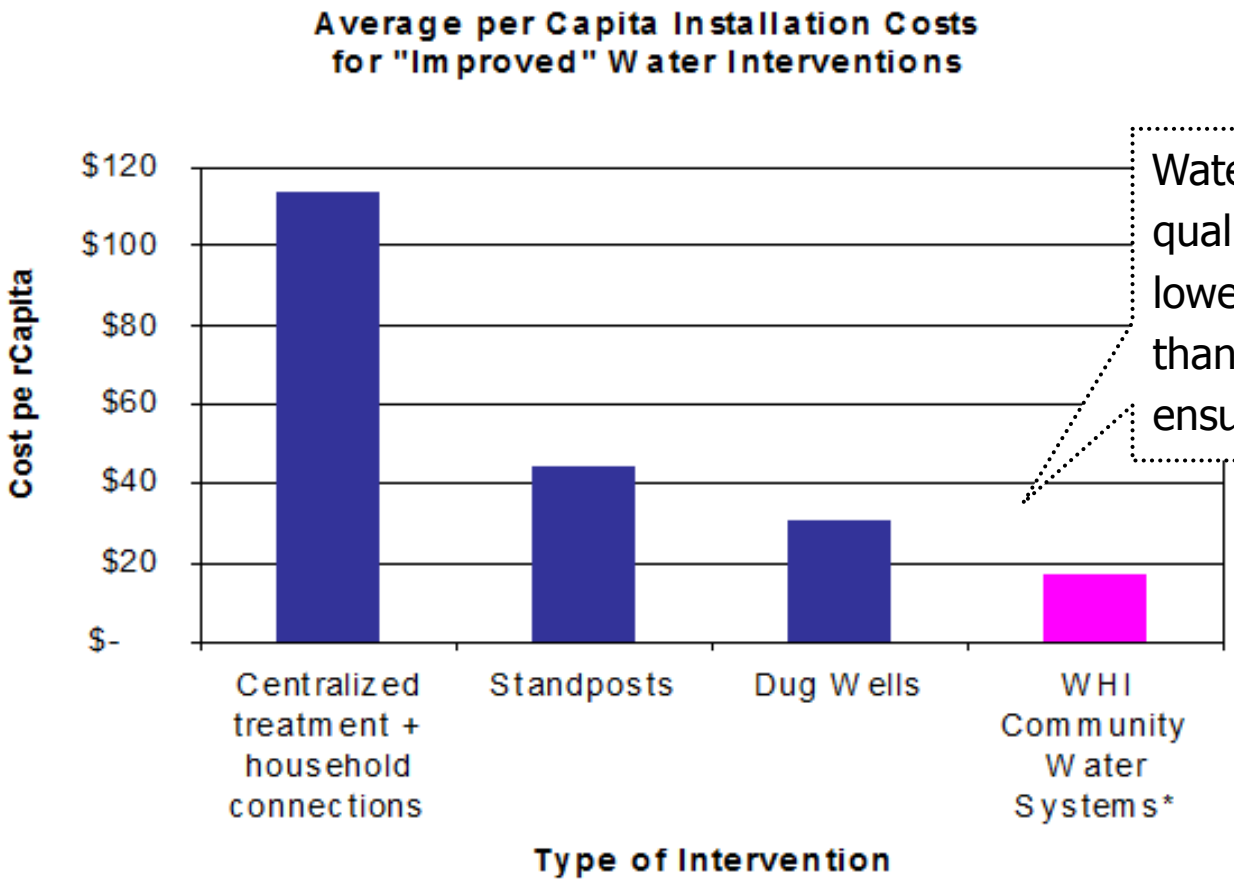
Length	= 28 in.
Width	= 15 in.
Height	= 11 in.
Weight	= 15 lb.

Water Disinfectors for Developing Countries

Design Criteria

- Meet/exceed WHO and US EPA criteria for disinfection
- Energy efficient: 60 watts disinfects 1 ton/h
- Low cost: 4 cents disinfects a ton of water
- Reliable, Mature components
- Can treat unpressurized water
- Rapid throughput: 12 seconds
- Low maintenance: once every three months
- No overdose risk
- Fail-safe

WHI's Investment Cost advantage vs. Other Treatment Options



WaterHealth produces WHO-quality potable water at a lower capital cost per person than other interventions while ensuring safety

Source: WHO/UNICEF Global Water Supply and Sanitation Assessment 2000 Report

* Based on WaterHealth International (WHI) Community System/Structure @ $50,000 serving 3,000 people with 10-20 Liters/person/day

A long way to go, but cracked a hard problem!

Service capacity of WaterHealth Centers by year-end:

2005 -->	~10,000
2006 -->	~300,000
2007 -->	~600,000
2008 -->	~1,000,000
2009 ->	~2,000,000
2011->	~5,000,000

Estimated statistical lives saved > 1000 per year in 2011

- And this is no longer charity, and can go to scale on its own!
- For most customers, this is the first time in their lives that they can access affordable safe drinking water!

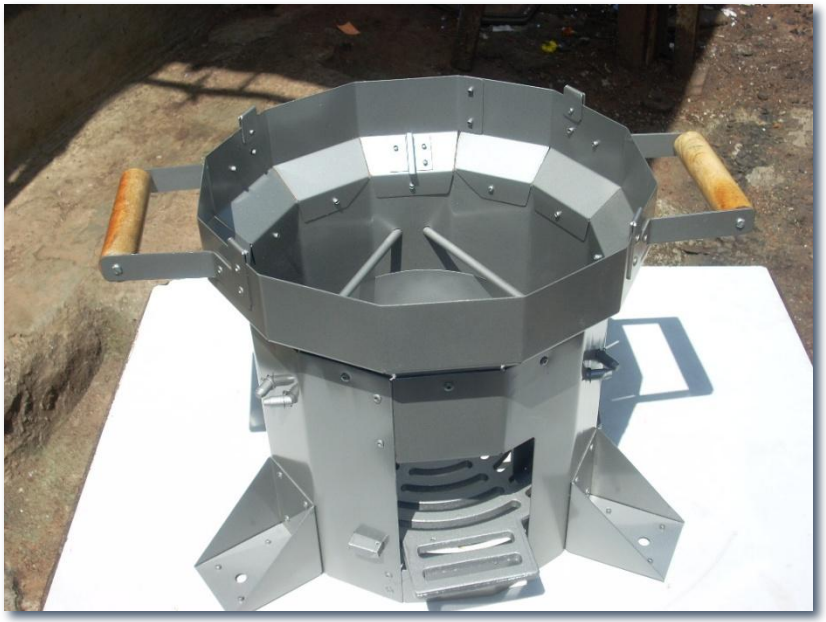
5 Fuel-efficient Cook Stoves

Challenge and Opportunity

- More than 2 billion people cook on solid fuels, mostly with stoves of very low efficiency.
- Families use about $1 US worth of fuel (wood) daily.
    - Almost all cooking takes place on simple three-stone fires or home-made mud stoves of low efficiency.

Photo by Mark Jacobs

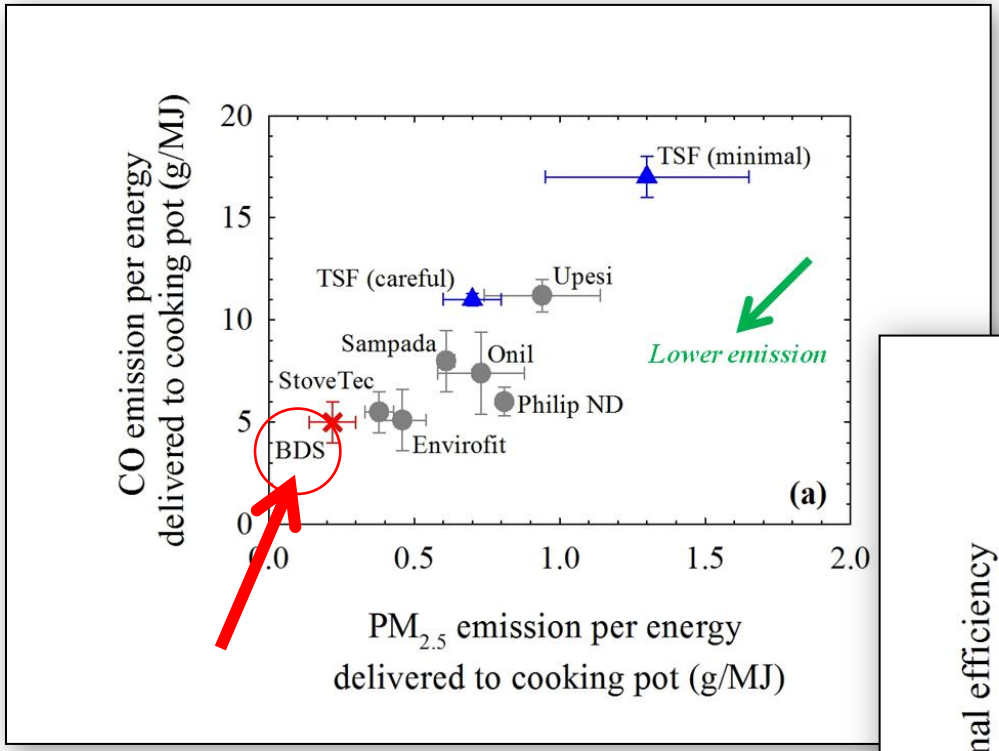
Berkeley-Darfur Stove (BDS)

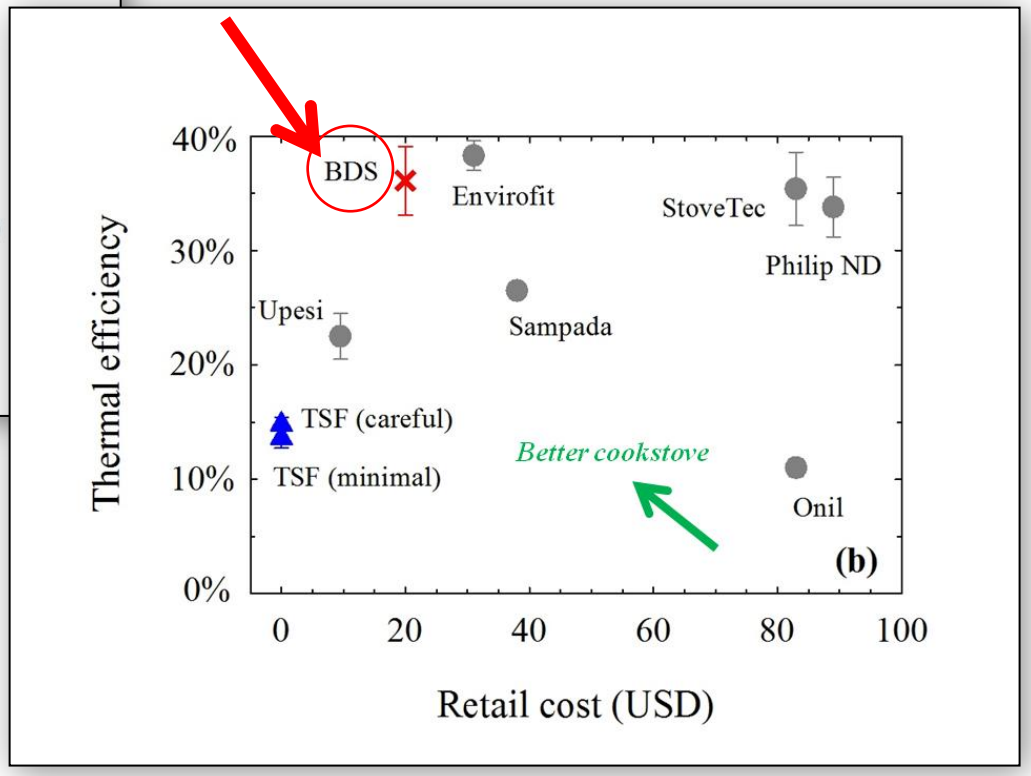


Version 14 or "V14" of Berkeley-Darfur Stove

- **BDS costs $20, saves $330/year fuelwood costs, and least 5 years.**
- **Each BDS offsets ~2.0 tonnes of CO_2e per year**

Lower Emissions and Energy Efficient





Data from Jim Jetter et al., "EPA's Laboratory Test Results for Household Cook Stoves", Partnership for Clean Indoor Air (PCIA) Webinar, June 2011.

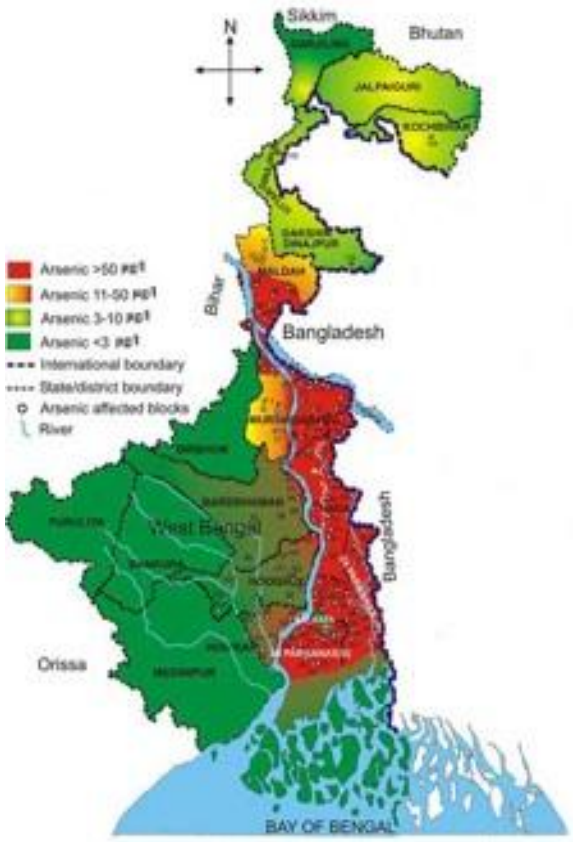
6 Affordable Solution to Water Poisoning

Challenge and Opportunity

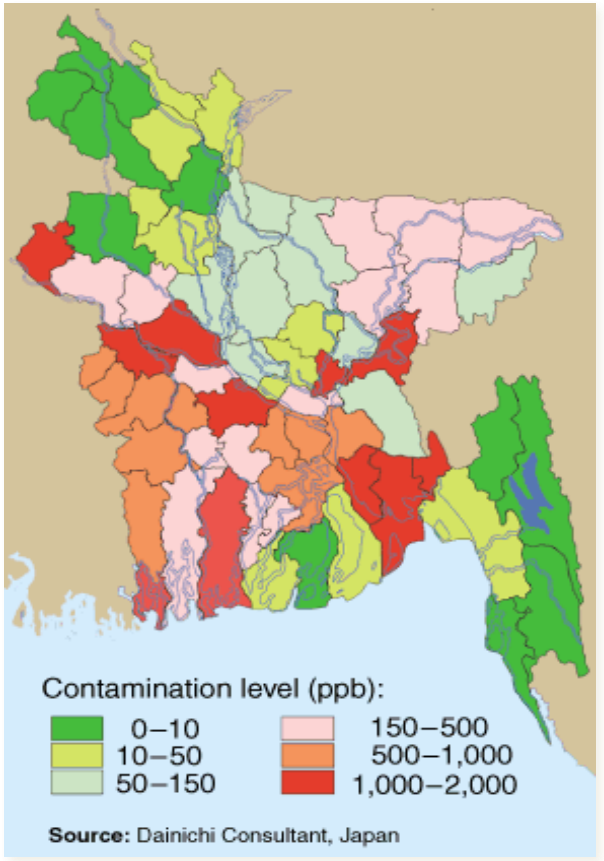
- Arsenic in drinking water : 70+ countries, 137 M people (as of 2007)
- The region worst affected : Bangladesh and vicinity

  >10M tube-wells in Bangladesh; more in West Bengal

  > 70M being poisoned in Bangladesh



West Bengal, India



Bangladesh

ARSENOCOSIS

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

Modular ECAR device with 10 ti
mes higher throughput

500 L / hour

Estimated selling price of water
0.4 cents / L

Current (Oct 2012) Status:

Successful first field tests of ECAR 100L device in deep rural West Bengal Dec 2010, and 2011

Preliminary results show excellent performance, at about 5-times cheaper cost than the next-cheapest alternative for removing arsenic

Modular ECAR device with 10 times higher through put, designed in Berkeley, built in Mumbai, and test ed successfully in summer 2012 in Kolkata

GOVERNMENTS, PRIVATE SECTOR AND NGOs HAVE IMPORTANT ROLES TO PLAY IN TECHNOLOGY R&D, BUT NOT AS LARGE AND EXCLUSIVE ONES AS EACH DESIRES

Thank you

Jayant Sathaye
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