

QuickTime™ and a
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are needed to see this picture.



Science, Technology and Policy Options for Sustainable Energy in Africa

Dan Kammen

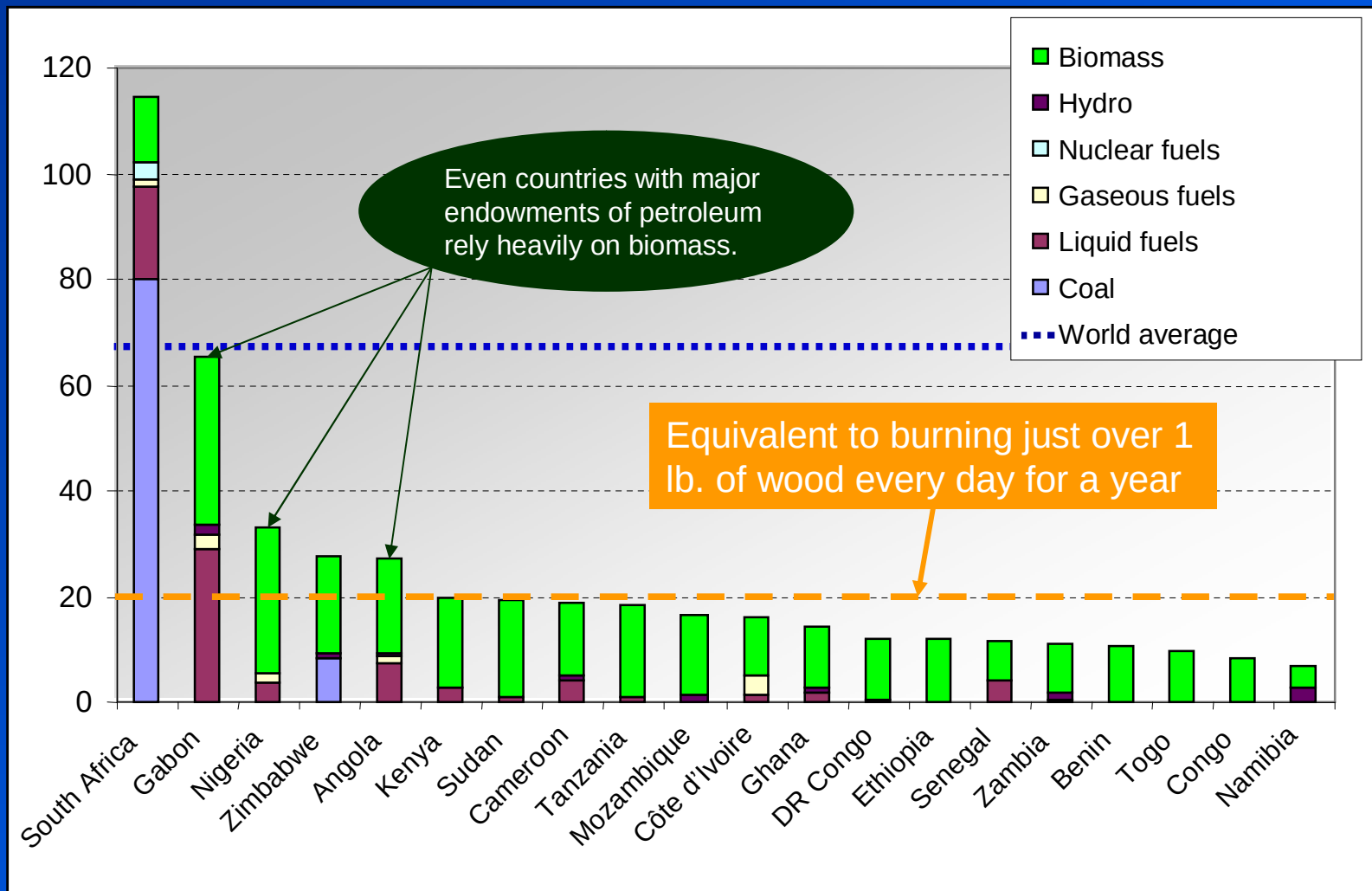
Energy and Resources Group & Goldman School of Policy
Department of Nuclear Engineering
Co-Director, Berkeley Institute of the Environment
University of California, Berkeley

2005 U. S. Frontiers of Engineering Symposium, September 22 - 24, 2005

Objectives & Overview

1. Explore energy access and impact across scales: from African households to nations & global impacts
2. Develop quantitative models of national/regional health and environmental impacts associated with energy provision
3. Develop science & engineering based policy approaches to support African economies and safeguard the environment
4. Explore Research & Development *linkages* to address energy needs in developed and developing nations

Annual per capita energy consumption by source (GJ per person - 1999)



Source: WRI: (2003). "EarthTrends: The Environmental Information Portal." 2003(January 15, 2003).
<http://earthtrends.wri.org/index.cfm>.



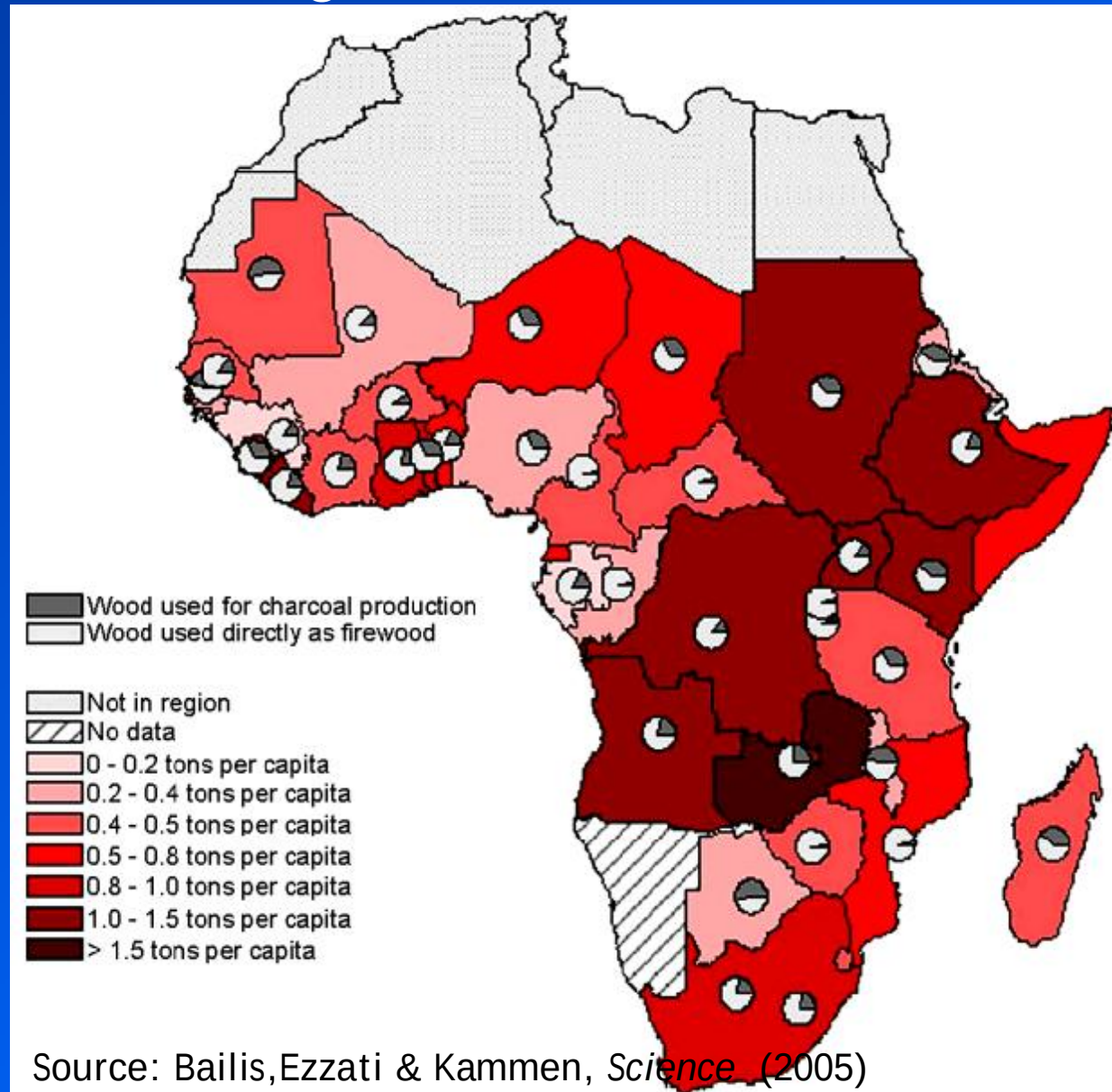
Sub-Saharan Africa's wood-energy consumption is the highest in the world

Primary production of biomass energy in 2000 (10^{18} Joules)

Sub Saharan Africa	10.2
China	8.9
India	8.4
Latin America	3.2

Source: IEA, 2003

Charcoal is *not* just an African issue



Dung Patty Preparation in India



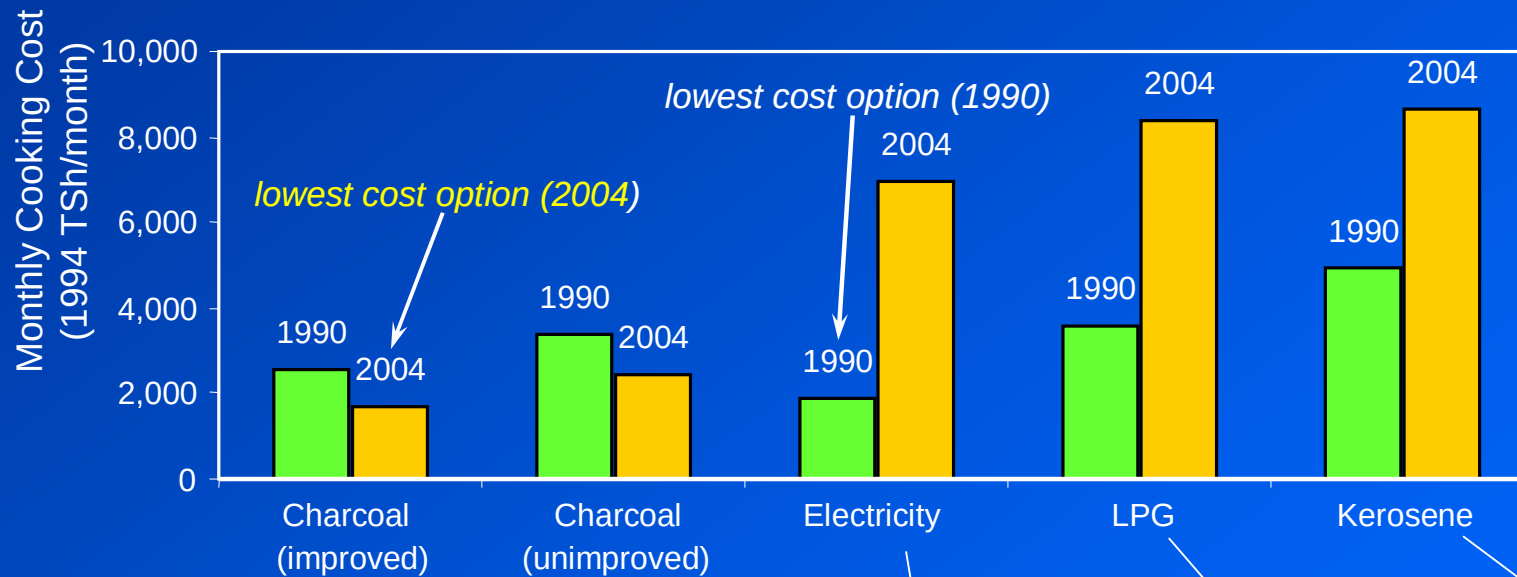
Energy Demand Links Rural and Urban Settlements

- 90% of residential energy in Sub-Saharan Africa is derived from biomass
- Charcoal, produced in rural areas, is used across socioeconomic strata in urban Africa (Hosier, 1987; Ribot, 1992)
- The African urban population is increasing 4-5% per year; the *fastest rate* of any region in the world



Rising energy prices have made charcoal the most economical cooking option

Monthly Cooking Cost: Dar es Salaam, Tanzania: 1990 and 2004



Data Source: Hosier, R.H. and W. Kipondya, *Urban household energy use in Tanzania*. Energy Policy, 1993. May: p. 454-473. (1990); R. Ghanadan, unpublished (2004)

Energetic Drivers of Charcoal Production:

Biomass → Charcoal (at low or *variable efficiency*)

- High calorific value
- Requires less attention to cook
- Emits less smoke
- More economical to transport
- Purchased in small (often daily) quantities

Preferred by urban consumers

- 82% of urban households use charcoal
- Avg. annual consumption ~150 kg/per person



Evidence of Land Conversion

Landsat images showing the expansion of mechanized farming in Narok



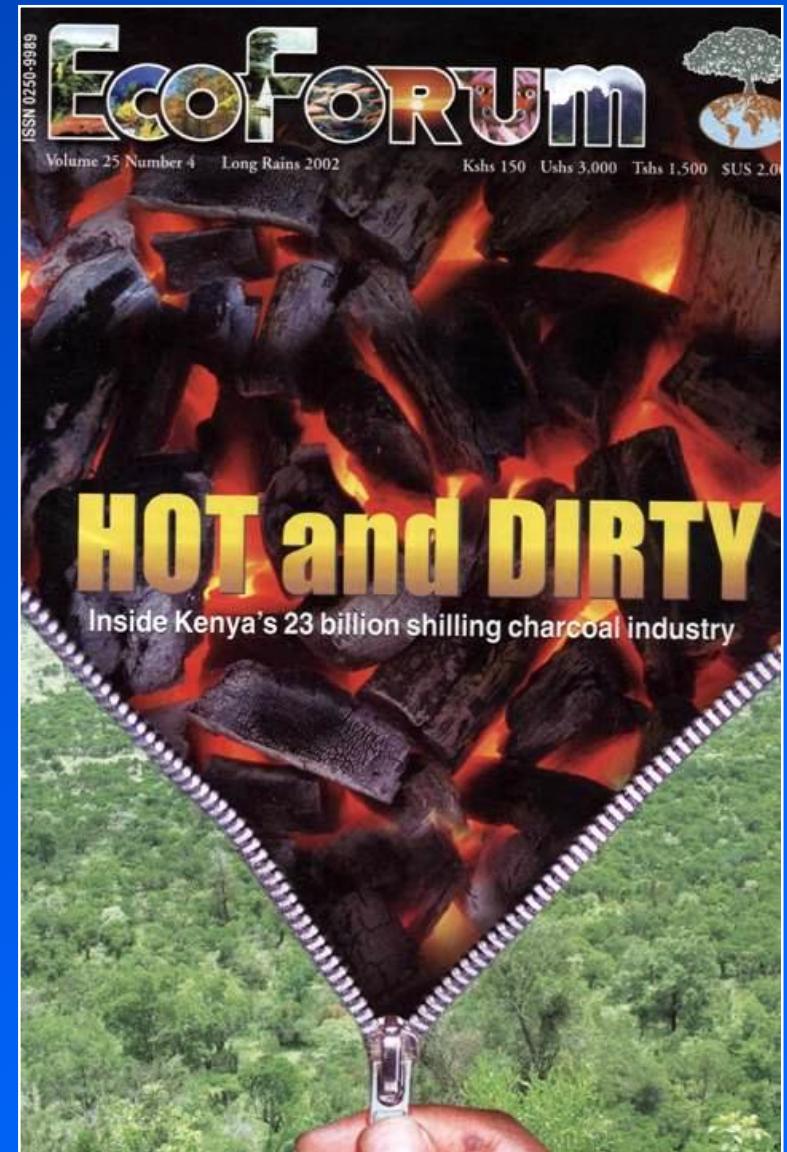
1995

From Serneels and Lambin (2004) http://www.geo.ucl.ac.be/Recherche/Teledetection/Projects/Serneels_Serengeti.html

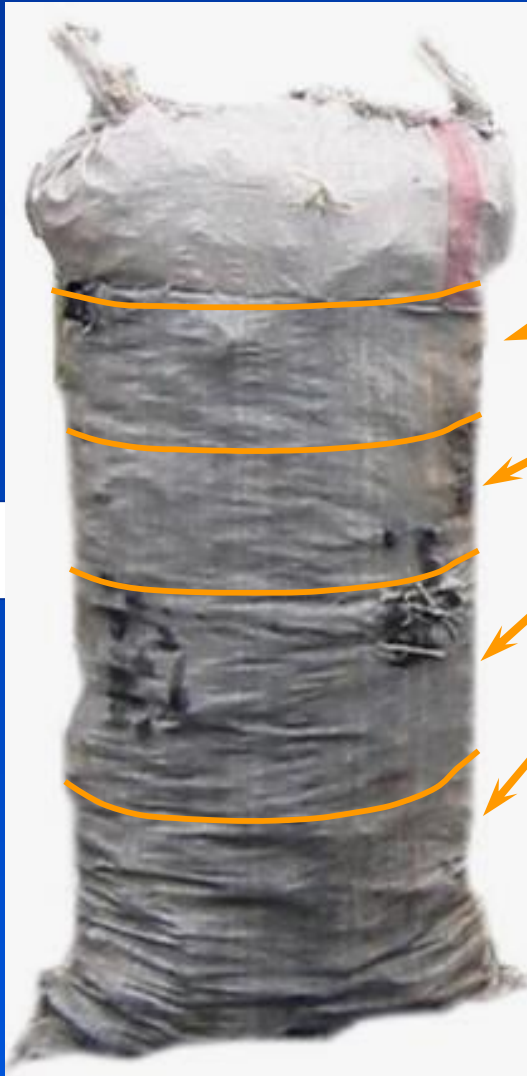
Charcoal Trade Now Under Scrutiny

Social-ecological Impacts:

- Over 200,000 people employed in Kenya
- ~ \$300 million in annual revenue (equivalent to tourism)
- Extensive but poorly characterized supply chains
- Ambiguous and inconsistent regulations
- Strong association with environmental degradation



Distribution of revenues of charcoal sold in Nairobi

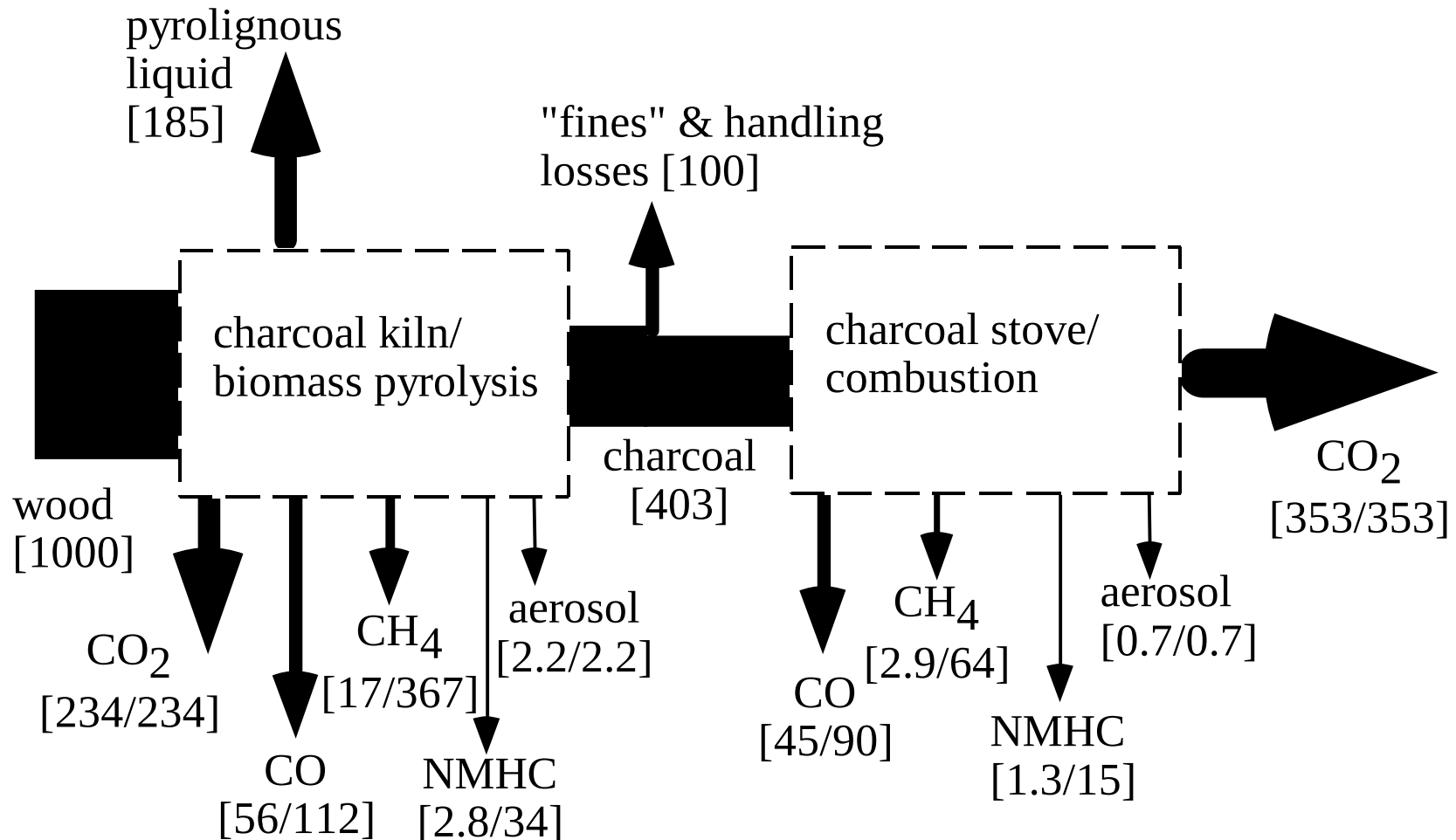


← Charcoal makers	17-20%
← Transporters	~15%
← Buyers	8-18%
← Police (bribes)	20-30%
← Others	27-30%
includes vendors, brokers, and local gov't	
← Government of Kenya	0%

No funding for R&D, enforcement of regulations, replacing harvested trees, or developing alternative feedstocks

(Bailis, 2005)

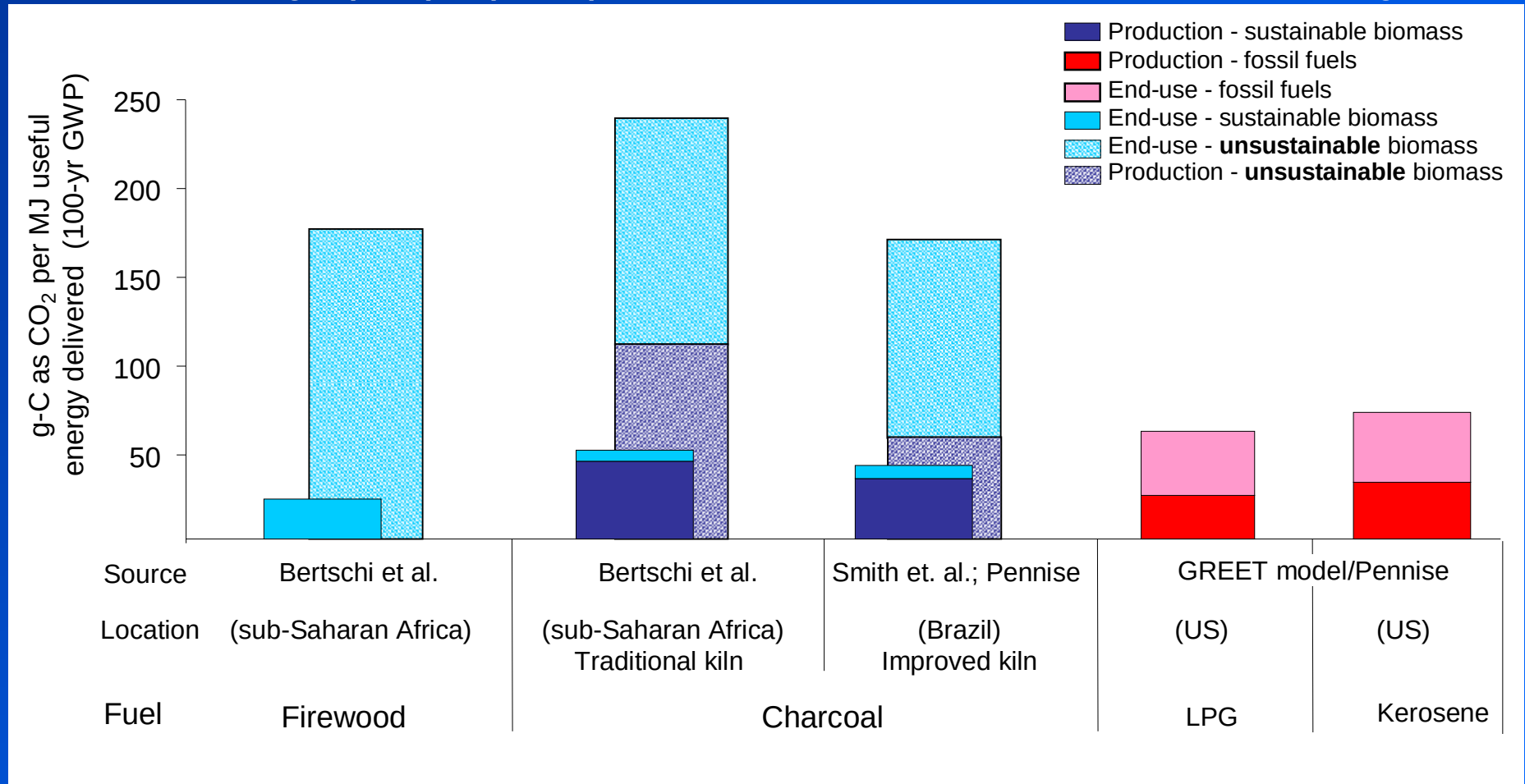
Carbon Emissions from Charcoal Production & Use



Carbon in grams is shown in brackets; followed by the global warming potential on a 100-year time horizon
Data from Smith and Thorneloe, 1992; Lacaux, *et al*, 1994. NMHC = Non methane hydrocarbons.

Atmospheric impacts of biofuels (100 life-cycle analysis: CO₂, CH₄, CO, ...)

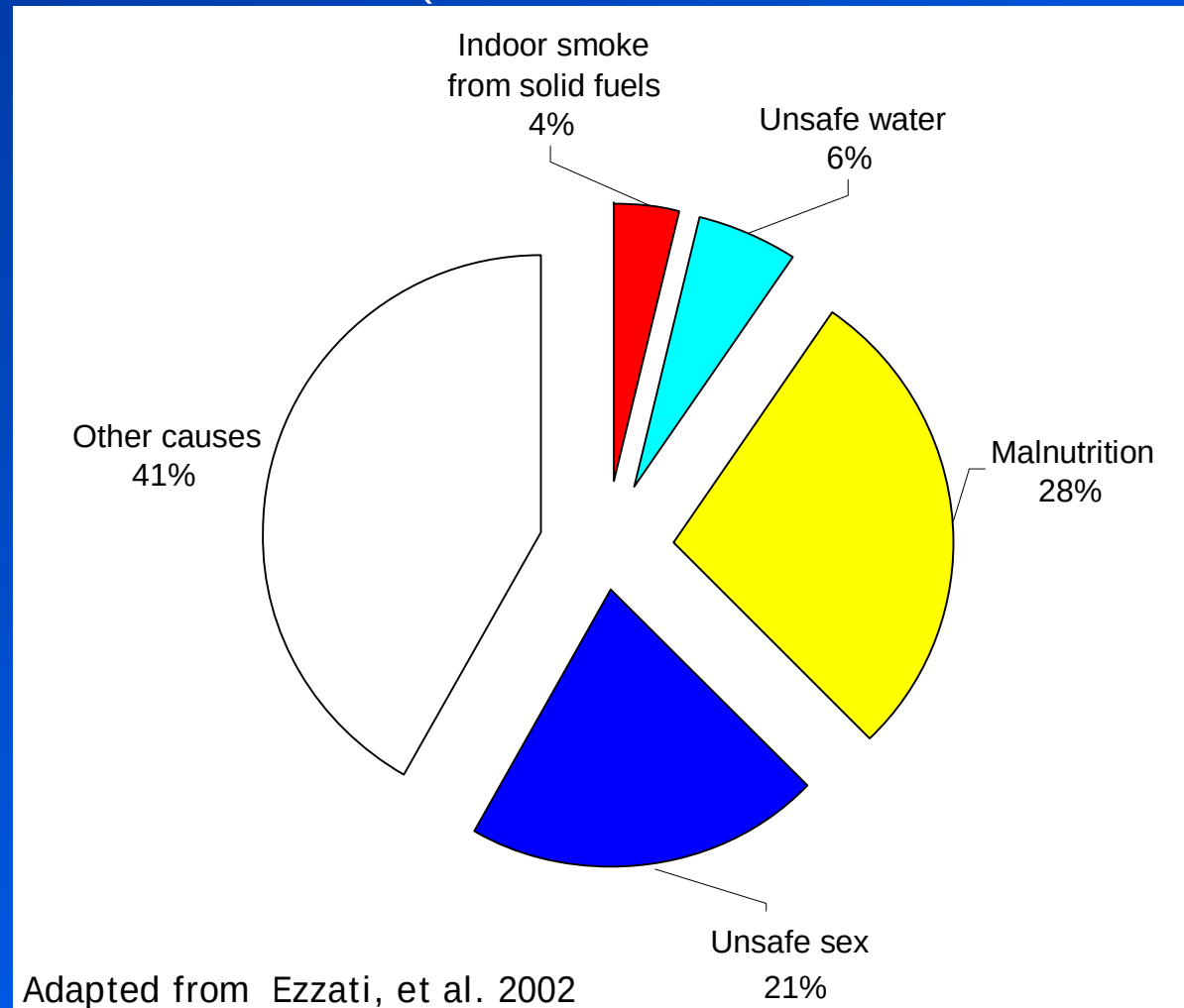
Global warming impact (GWI) from production and end-use of common household cooking fuels



Adapted from Bailis, Ezzati & Kammen, ES&T (2003)

Impact of Smoke from woodfuels: a leading risk factor for mortality in SSA

Sub-Saharan Africa (a total of ~10.4 million deaths in 2000)



Stove Science and Stove Services Laikipia, Kenya (1992 - 1998)

- Health examinations for all major diseases



- Detailed monitoring of both personal and ambient pollution



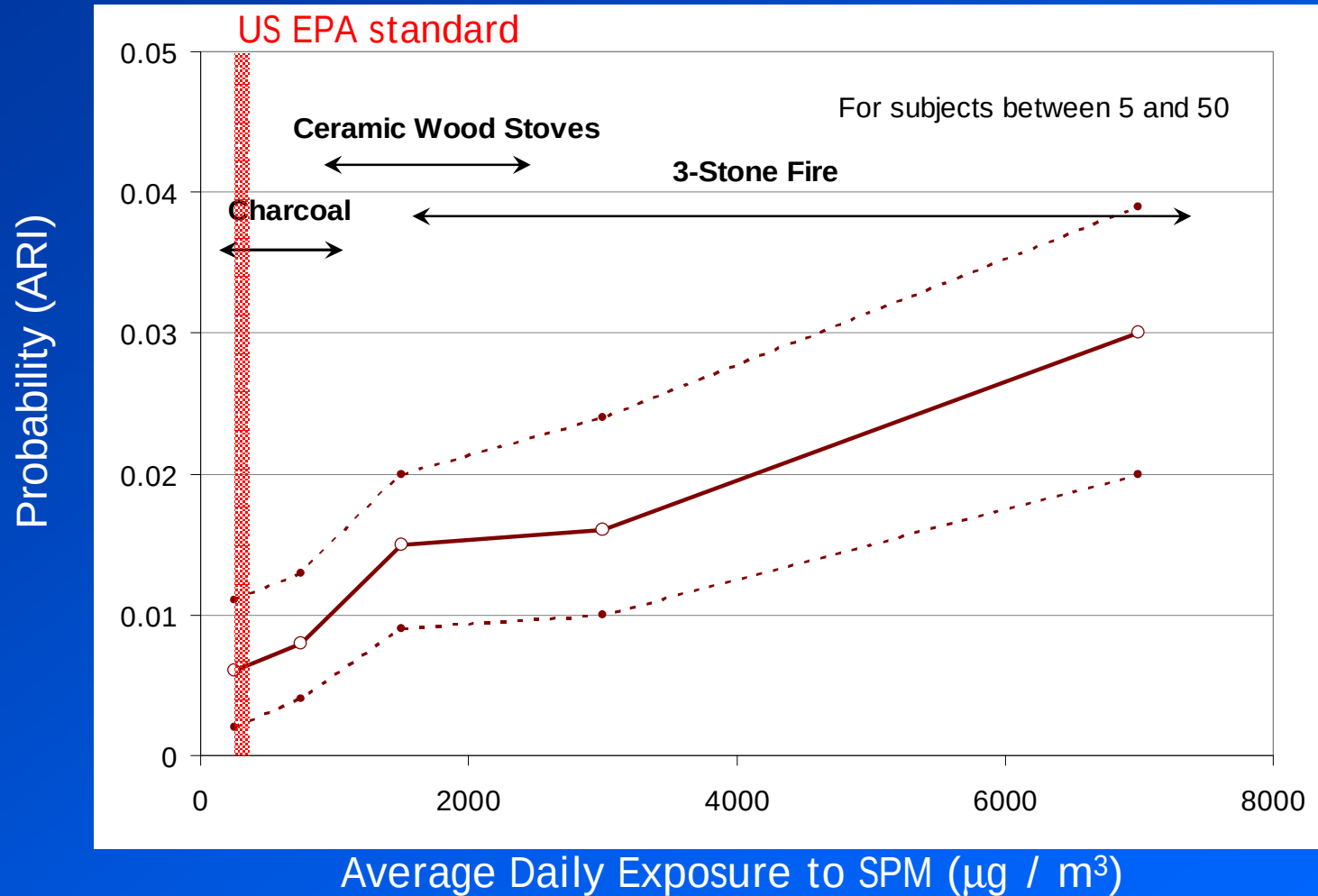
- Research and community testing of stoves



- Stove markets & local businesses



Exposure-Response Relationship for Acute Lower Respiratory Illness (ALRI)



Based on over 220 10+ hour continuous home monitoring sessions

Ezzati & Kammen, *The Lancet* (2001)

Global & Regional Impacts

Scenario	Primary cooking fuel	Change in GHG emissions relative to BAU (2000-2050)	Decrease in Mortality relative to BAU (2000-2030)
BAU	Fuelwood	--	--
BAU-S		-34%	No change
F	Fossil fuels	-10%	1.3 million
RF		-1%	3.7 million
RC-S	Charcoal	5%	2.8 million
C-S		37%	1.0 million
C		137%	1.0 million
RC		189%	2.8 million

S = sustainable (= 80% or more wood regrown)

R = rapid (~10 year) transitions

Cookstove Market Programs



The Chula: > 8 million in India

The Kenya Jiko: > 1 million

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4th QUARTER 2004

VOLUME 3 NUMBER 1



LPGas

AFRICA



Major Market Expansion

SEE PAGE 6

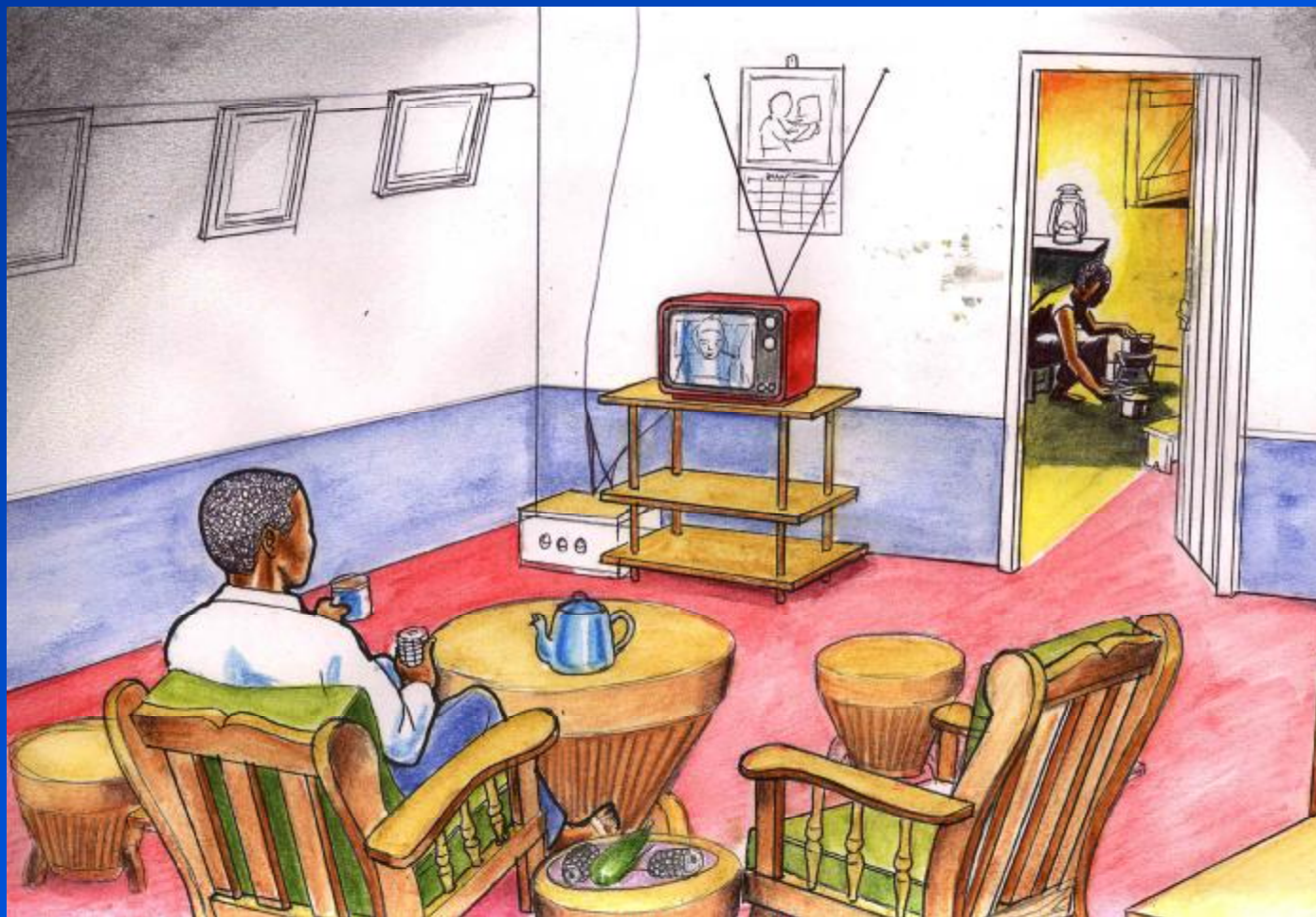
Sponsored by



Targeting urban
slums for “market
expansion”

QuickTime™ and a
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Energy Awareness Calendars: Produced for the East African market



“Mr. and Mrs. Kanogo need to talk about household energy”

Household Allocation of Solar Electricity

- Lighting
- Television
- Radio
- Cellular Phone Charging



Chinese *Great Wall* DC TV (\$US 50)



Solar Advertising in Kenya

FANTASTIC
CHEAPEST
 cost per watt **XMAS**
OFFER

14 Watt Solar Panel

The 14 Watt Solar Panel from Sollatek is ideal for small home solar systems, to provide cheap power for lighting, radios and television.

- Metal frame for easy mounting and security
- More than 10 year expected life span
- 5 year warranty

Sollatek Solar

Available from:

Nairobi:
 Solagen Ltd - Tom Mboya Street
 M-Kays - Tom Mboya Street
 Domestic World - Tom Mboya Street
 Tuki Electronics - Lidihi Avenue
 Nigul - Lidihi Avenue
 Bhat Electronics - Lidihi Avenue

Embu:
 Gandhi Brother - Kenyatta Highway

Kitale:
 San Electricals - Ogiaga Odanga Road

Nyeri:
 Teni General Trading - Kimathi Way
 Ladies Tailoring House - Kimathi Way

Morogoro:
 Mulumadi Moti - Moi Avenue
 American Solar Technology - Moi Avenue

Nakuru:
 Solagen - Moi Road
 N.P.I. - Kenyatta Avenue
 M.D. Vaid - Kenyatta Avenue

Kenya:
 Kenia Motor Spares - Garage Road

Kitui:
 A.M. Tailor - Main Road

MOMBASA: P.O. BOX 8381, TEL: 011 311715 / 312223, FAX: 312889
 NAIROBI: THE MALL, WESTLANDS, TEL: 02 442009, FAX: 444182
 KAMPALA: 76 KAMPALA (BOMBO) ROAD, TEL/FAX: 041 214390

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 H1VOLTGUARD 1,995/= • AC/DC Colour Television 14" 17,500/= •
 AC/DC VCR 8,100/= • World Space receiver 4,985/=

Solagen

Tom Mboya Street (Opp. Meridian HTL) Tel: 251630/1, FAX: 251652
 The Mall (basement), Westlands Tel: 441160/1, FAX: 444182
 Luthuli Avenue (Opp HTL, Cema) Tel: 315538 P O BOX 45678 Nairobi
 Email: info@solagen.com web: www.solagen.com

NAKURU: Moi Road (Opp. KP&L) Tel: 41338 **ELDORET:** Ogiaga Odanga Rd. Tel: 22556
EMBU: Kenyatta Highway Tel: 0722 808896 0722 820085
MERU: Moi Avenue (Opp. Kobil) Tel: 20366 **KISUMU:** OPENING SOON

A Solar panel that will operate Colour TV & Video
11,500/-

The latest monocrystalline panel.
 * Guarantee-20 years, life-span-30 years!!
 * From the most reputable solar firm in Kenya.

With our solar panel you will never miss Bold & Beautiful or your favourite TV show.

KENITAL
 Energy for the Future

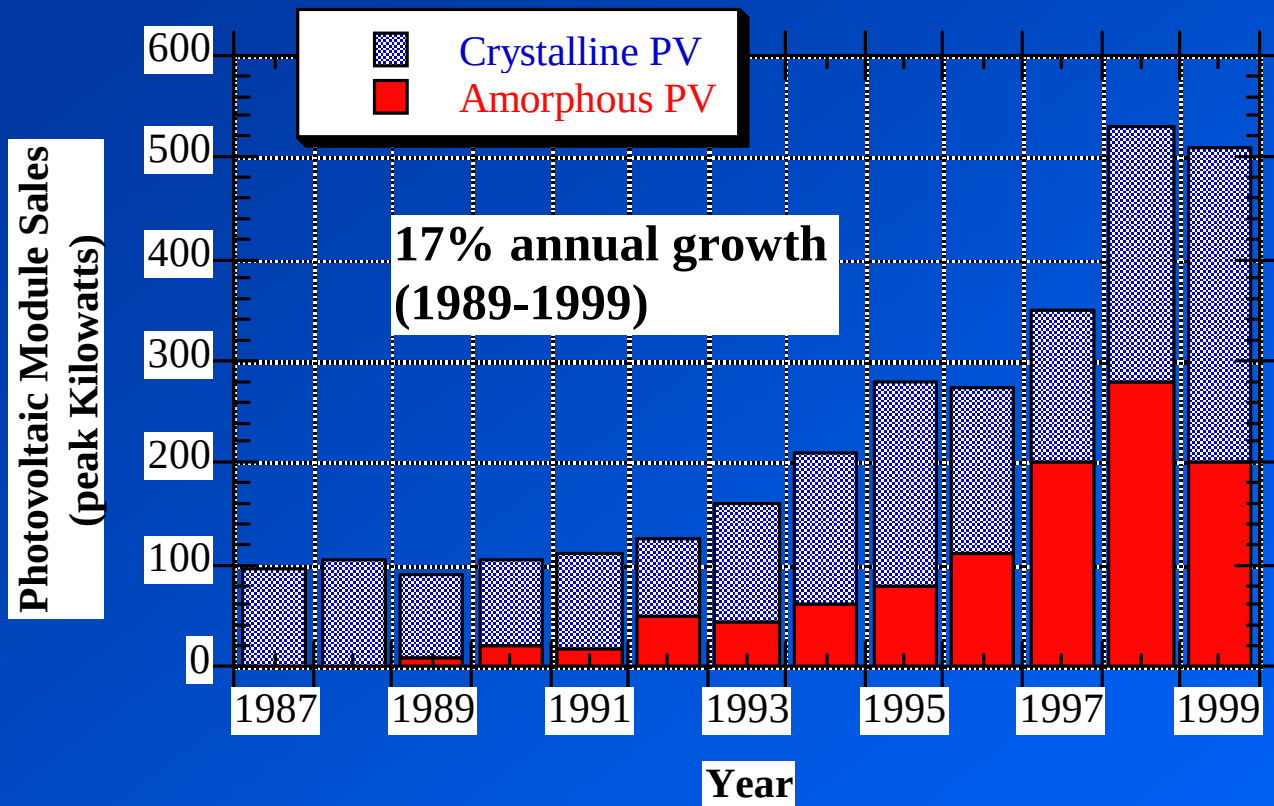
Smart power solutions
 P. O. Box 19764, Nairobi - 00202, Ngong Road
 (Mimosa Bus Stop). Tel/Fax:- 715960 / 714551-4
 Mobiles: 0722820560, 0733641574
 Email: info@kenital.com www.kenital.com

70 Shillings (Ksh)/dollar: 12,435 Ksh = \$170

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Kenya Solar Market Growth

(largest developing nation market per/capita)



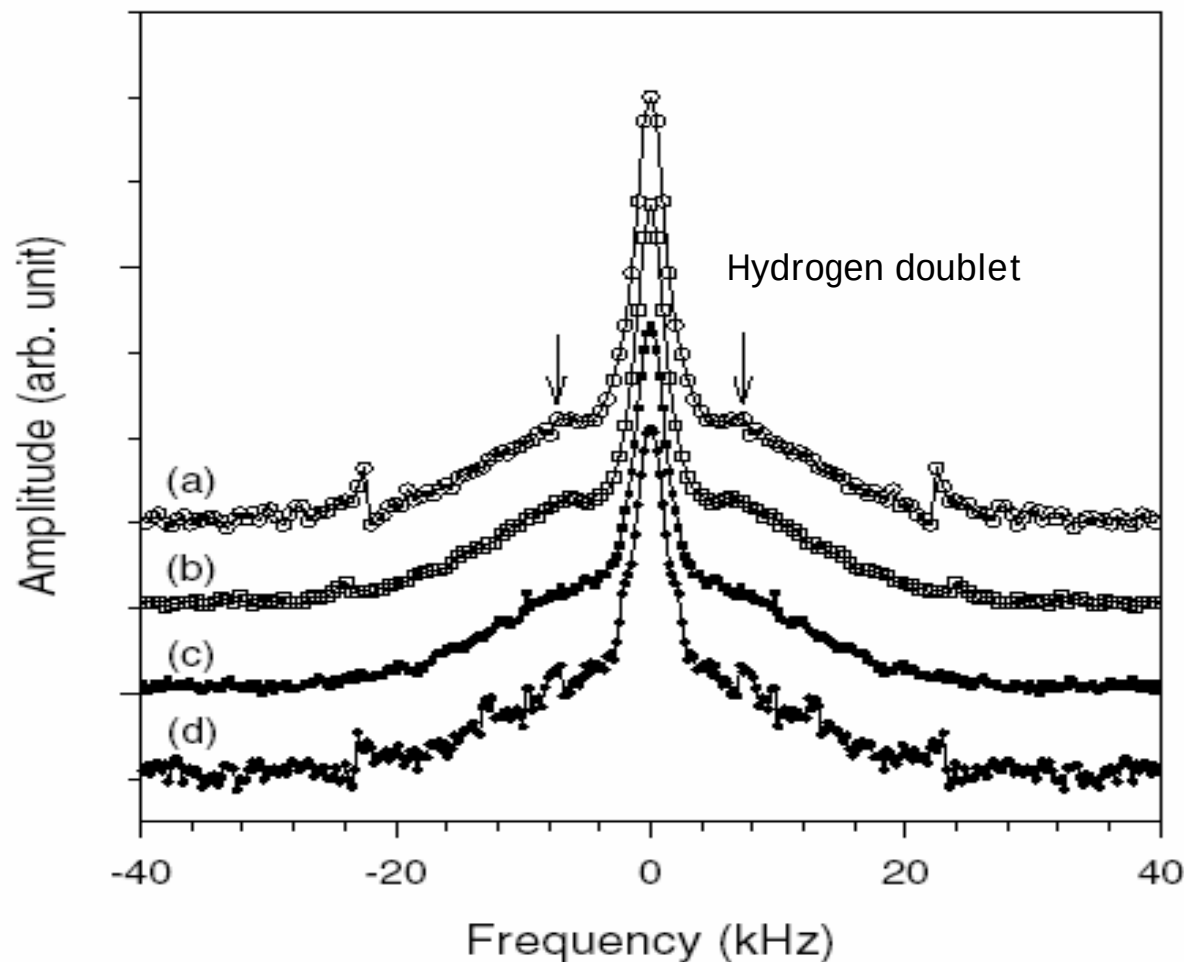
14 W aSi panel

Duke, Richard. D, Jacobson, Arne, and Daniel M. Kammen (2002) "Product quality in the Kenyan solar home industry", *Energy Policy*, 30 (6), 477-499

U. of Nairobi Test Site



Staebler Wronski Degradation for a New NAPS aSi PV Module

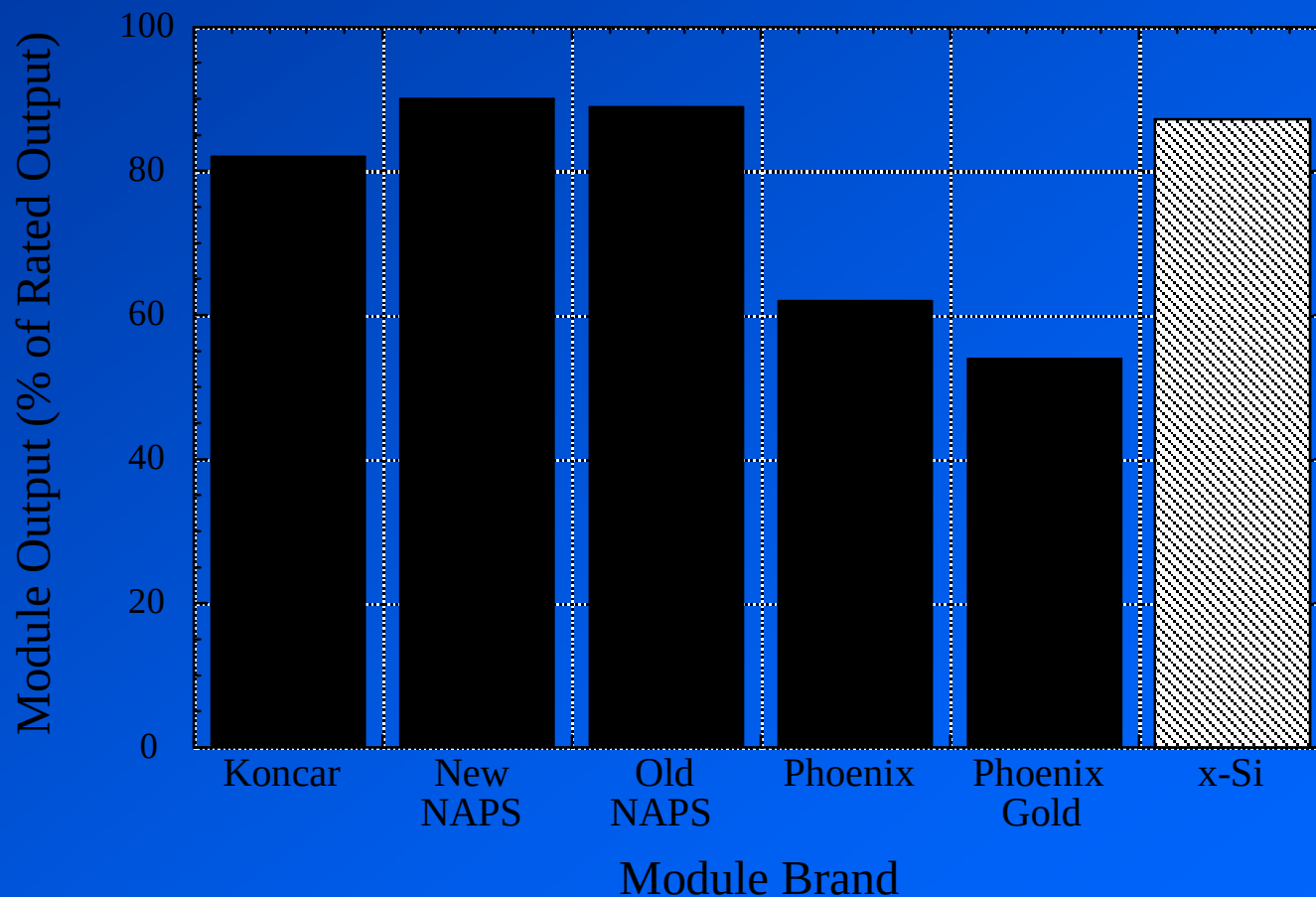


Su, et al,
Phys. Rev. Letters
(2002)

Stimulated echo spectra of aSi:H after light soaking intervals



Results of Market Study: > 150 systems surveyed in the field





We sell

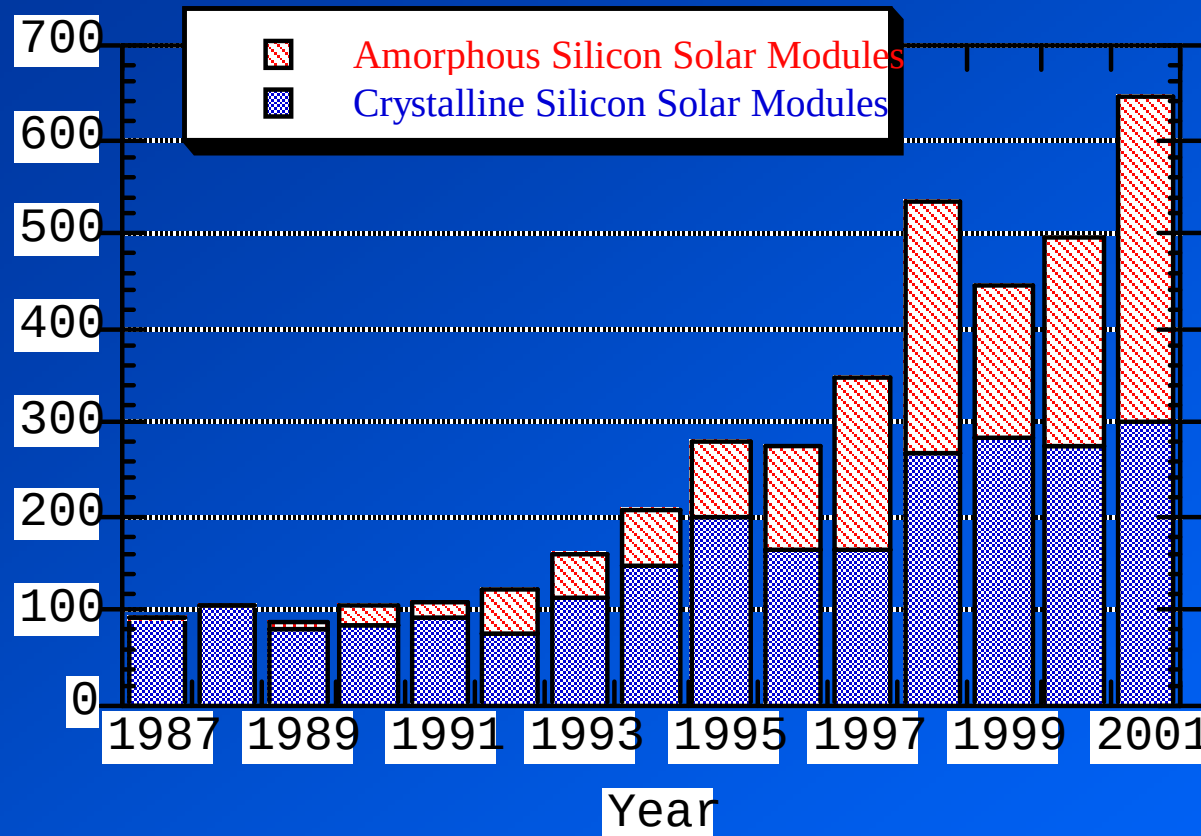
SOLAR PANELS

Made by Free Energy Europe, France

Best tested in Kenya, 1999-2000

Kenya Solar Market Growth

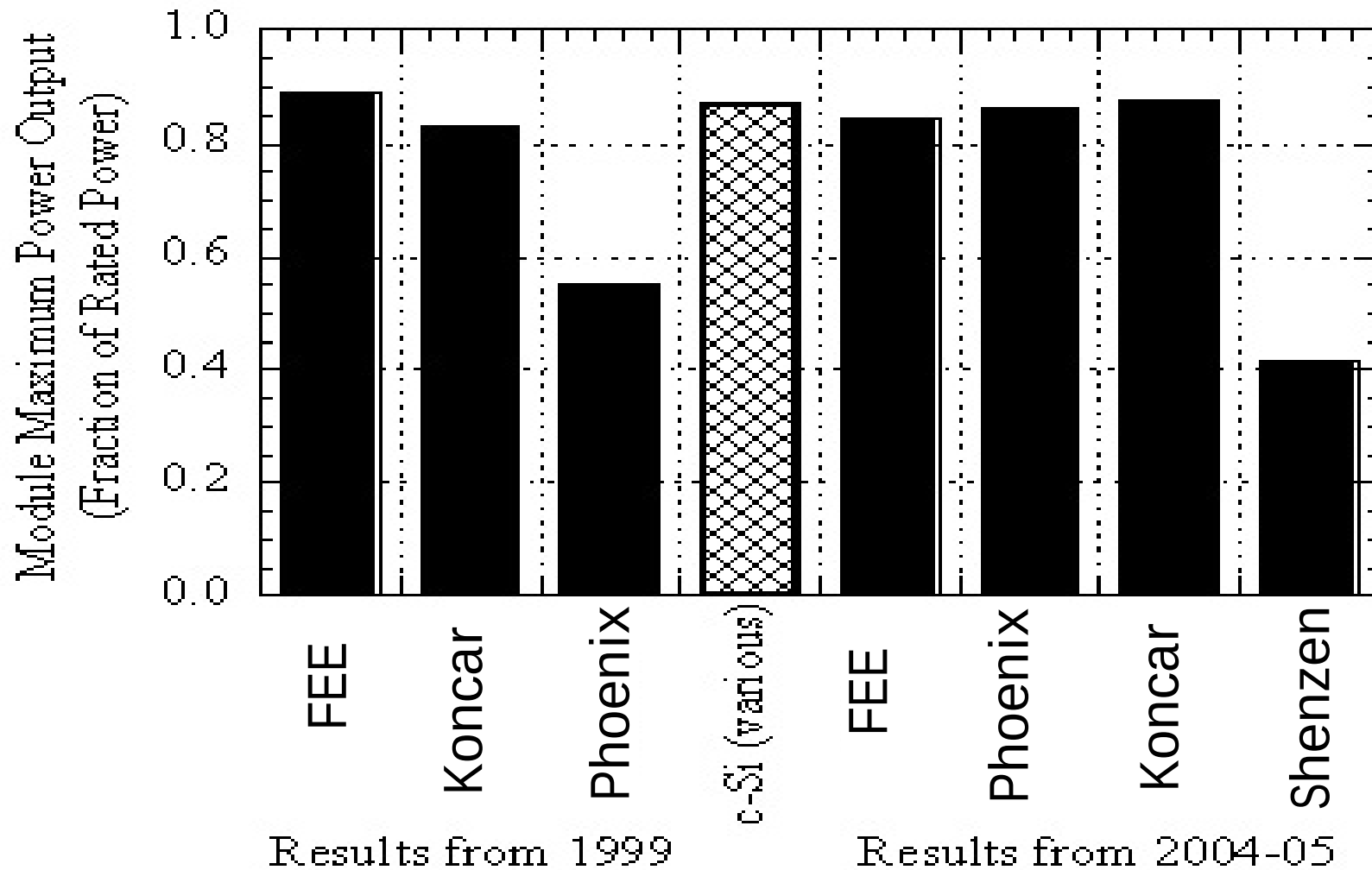
(largest LDC market per/capita)



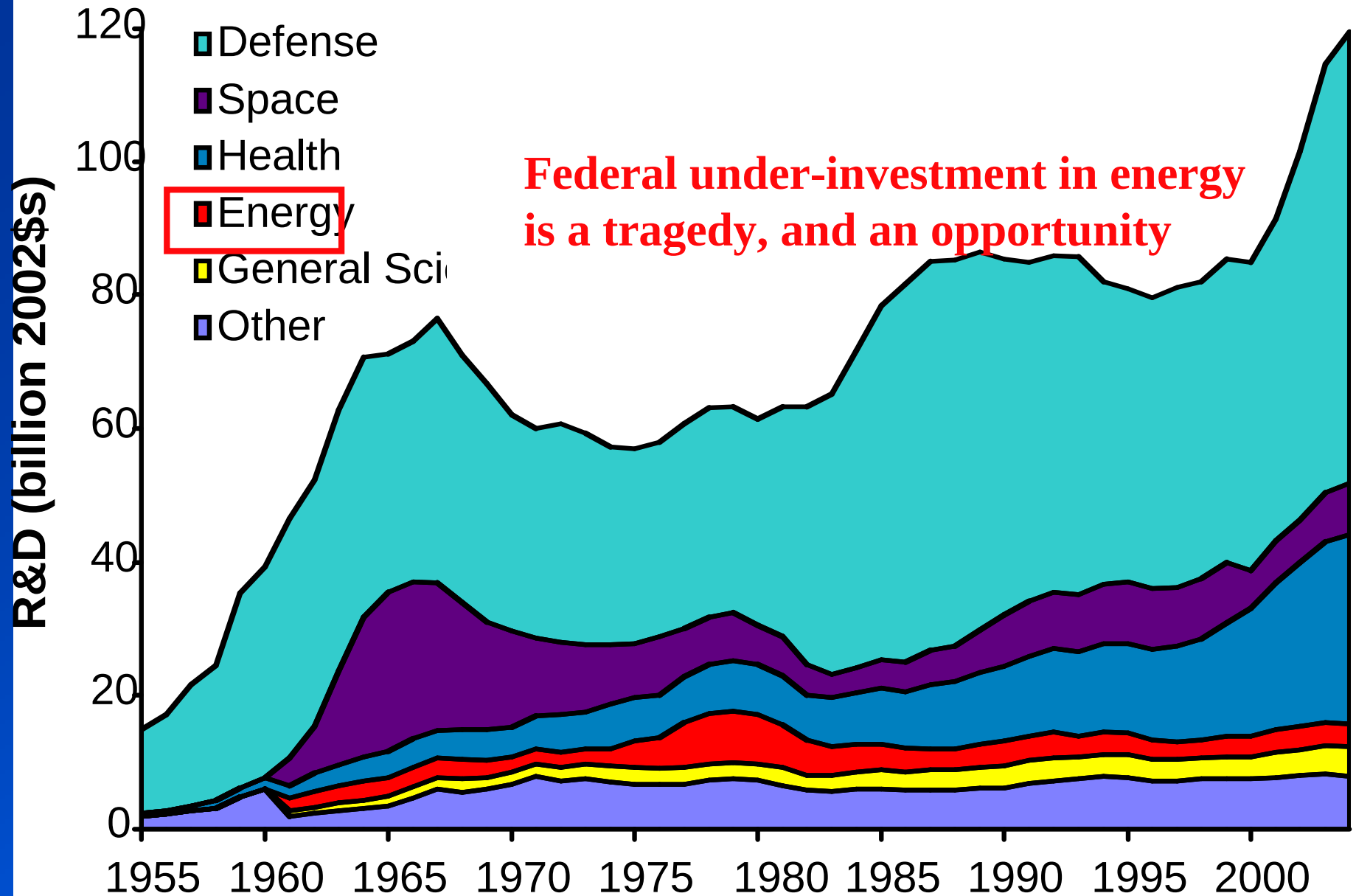
14 W aSi panel

- SHS market grew out of donor aid market in 1980s
- Infrastructure & capacity building support key for sustained growth

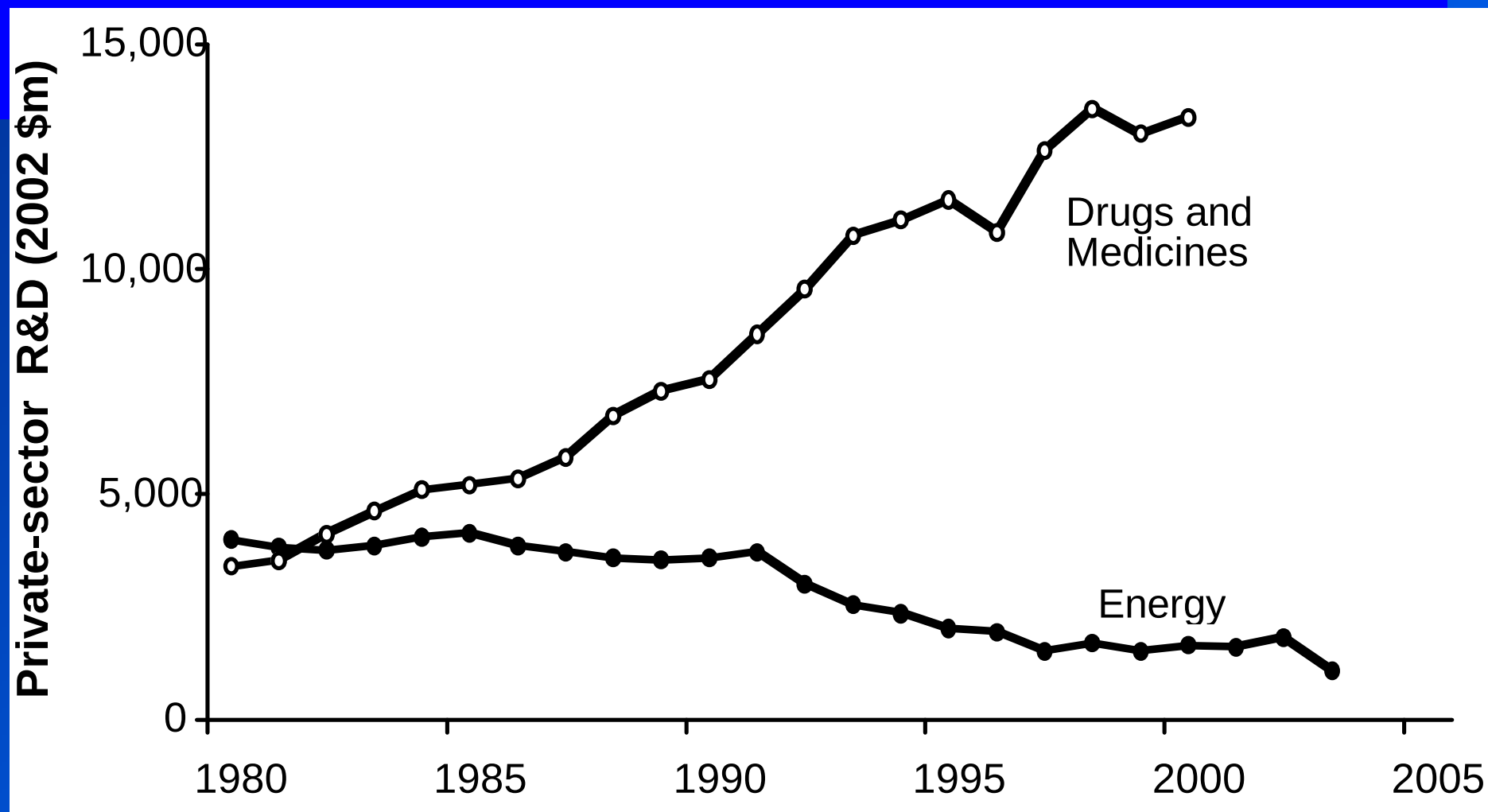
A New 'Bad Actor' Has Entered the Market



Federal R&D Investments, 1955 - 2004

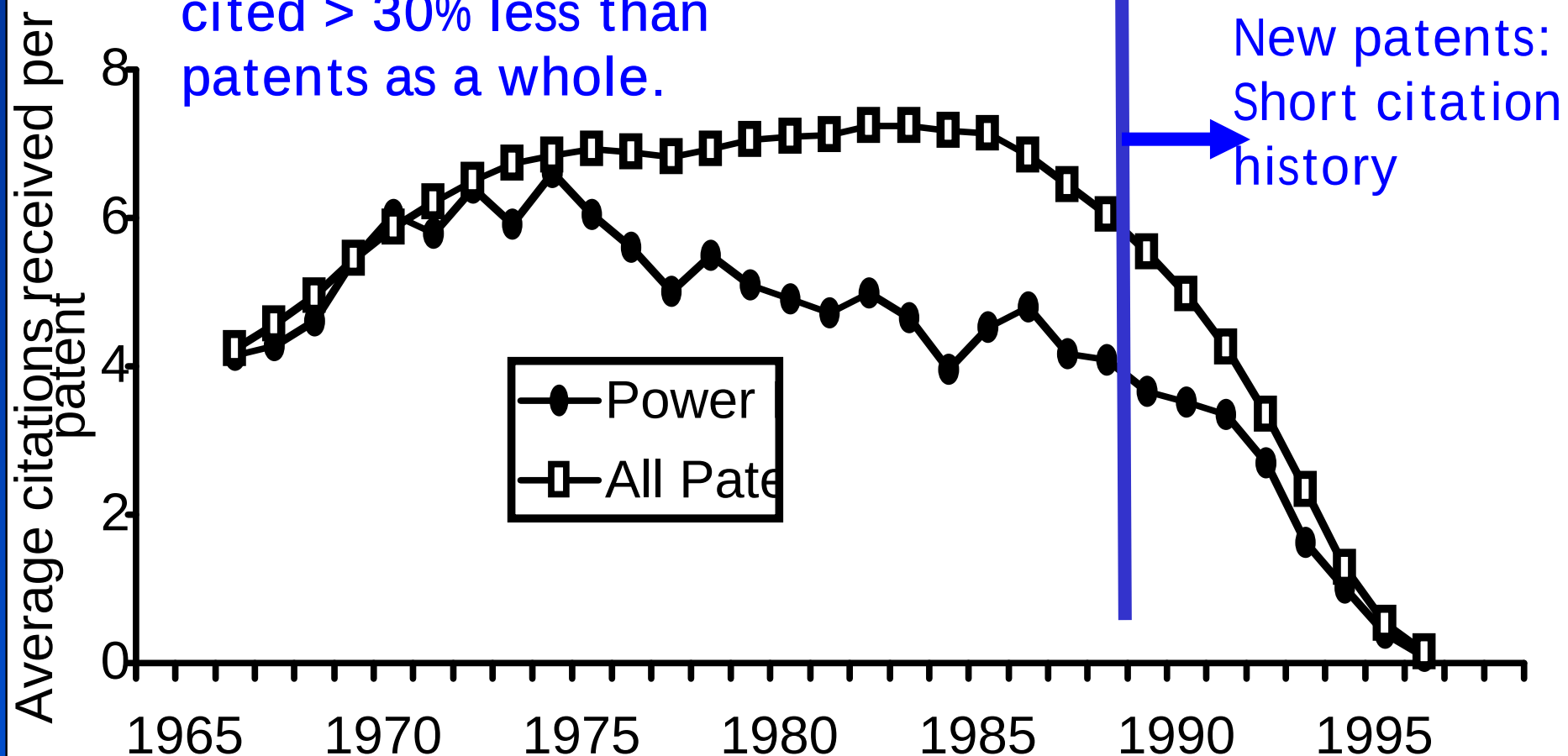


Private Sector R&D Investment in Health and Energy



Citations Received "Energy Sector"

1975 - 1990: Energy patents
cited > 30% less than
patents as a whole.



Life Magazine, 1962



Science helps build a new India

Oxen working the fields . . . the eternal river Ganges . . . jeweled elephants on parade. Today these symbols of ancient India exist side by side with a new sight—modern industry. India has developed bold new plans to build its economy and bring the promise of a bright future to its more than 400,000,000 people. ▶ But India needs the technical knowledge of the western world. For example, working with Indian engineers and technicians, Union Carbide recently made available its vast scientific resources to help build a major chemicals and plastics plant near Bombay. ▶ Throughout the free world, Union Carbide has been actively engaged in building plants for the manufacture of chemicals, plastics, carbons, gases, and metals. The people of Union Carbide welcome the opportunity to use their knowledge and skills in partnership with the citizens of so many great countries.

A HAND IN THINGS TO COME

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WRITE for booklet B-5, "The Exciting Universe of Union Carbide," which tells how research in the fields of carbons, chemicals, gases, metals, plastics and nuclear energy keeps bringing new wonders into your life.

Union Carbide Corporation, 270 Park Avenue, New York 17, N. Y.



Opportunities & Directions

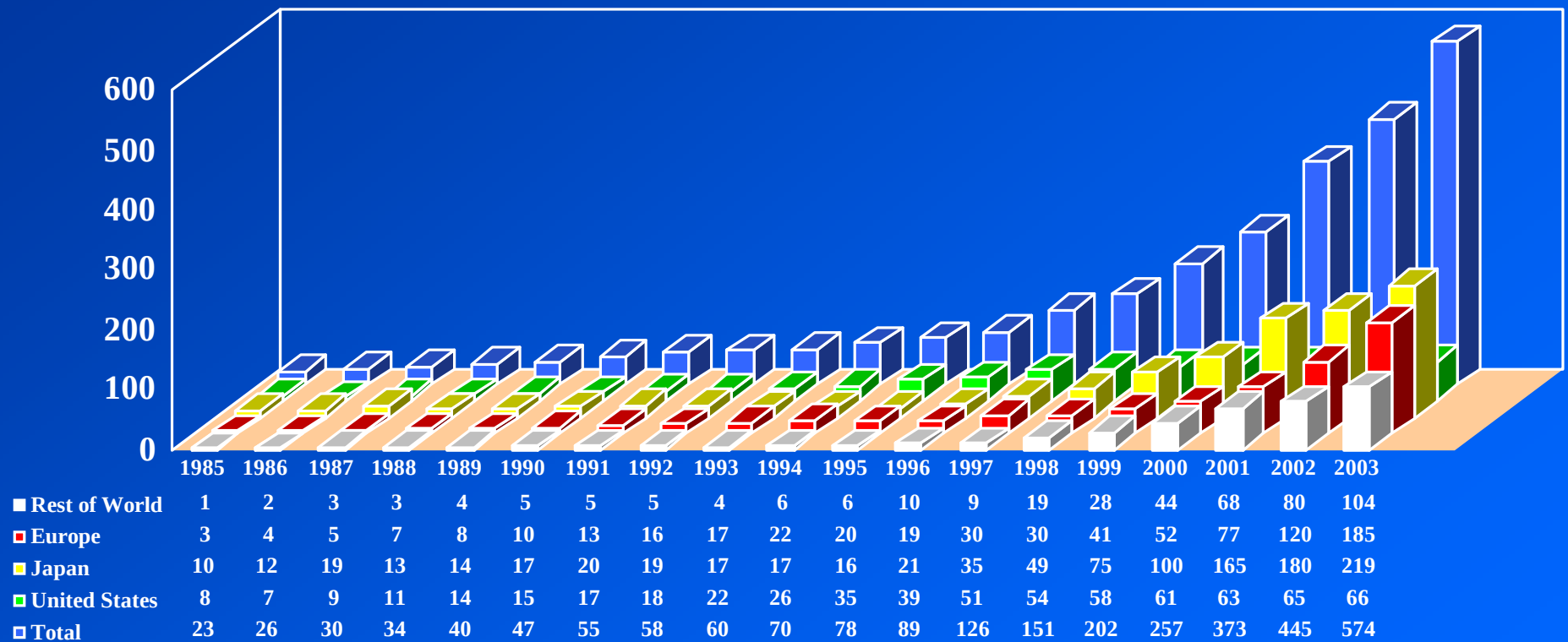
Low-cost opportunities exist to improve local environments and health, *and* build clean energy economies.

- Biomass combustion & gassification
- Solar & wind energy systems across application scales
- Local *smart* mini-grids

Energy challenges link developed and developing nations, and we won't discover or act on these issues without making this area a priority

World PV Module Shipments (Megawatts)

(25% annual growth for 10+ years)

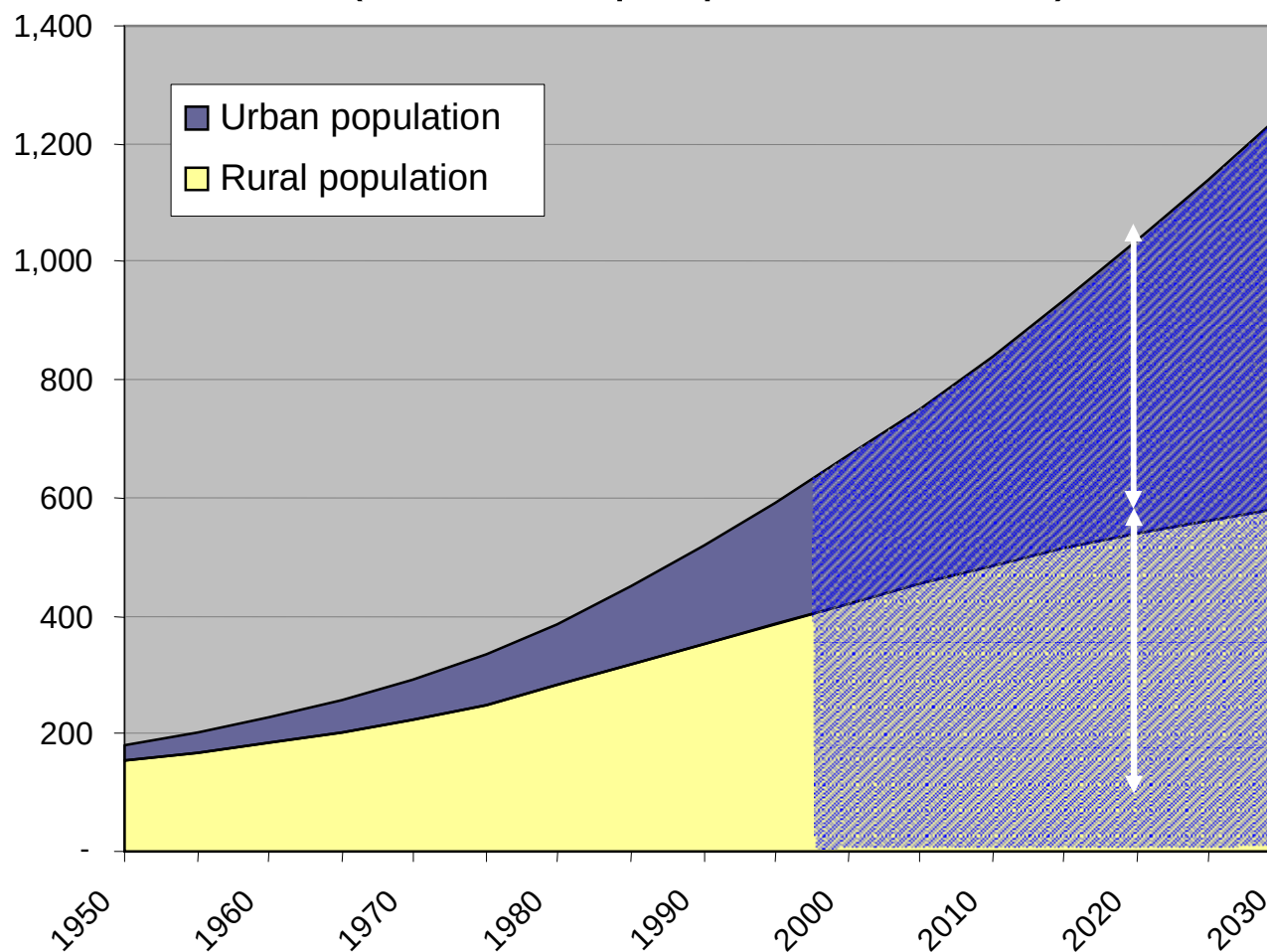


2003 Annual growth: 34%; 50% in 2004 (to 1200 MW)

Today: global PV production is equivalent (MW) to one large fossil-fuel power plant/year

Sub-Saharan Africa's population

Rural and Urban Population in sub-Saharan Africa
(millions of people: 1950-2030)



Source: Population Division, Dept. of Economic and Social Affairs, United Nations

Solar Energy for Many Applications

Moscone Center: 675,000 W



Kammen home: 2400 W



Key finding: Investment in solar energy research and deployment pays dividends for *many* applications and for businesses *across scales*.

Kenyan PV market:
Average system: 18W



Energy Calendar & Industry Workshops:

Extension Efforts



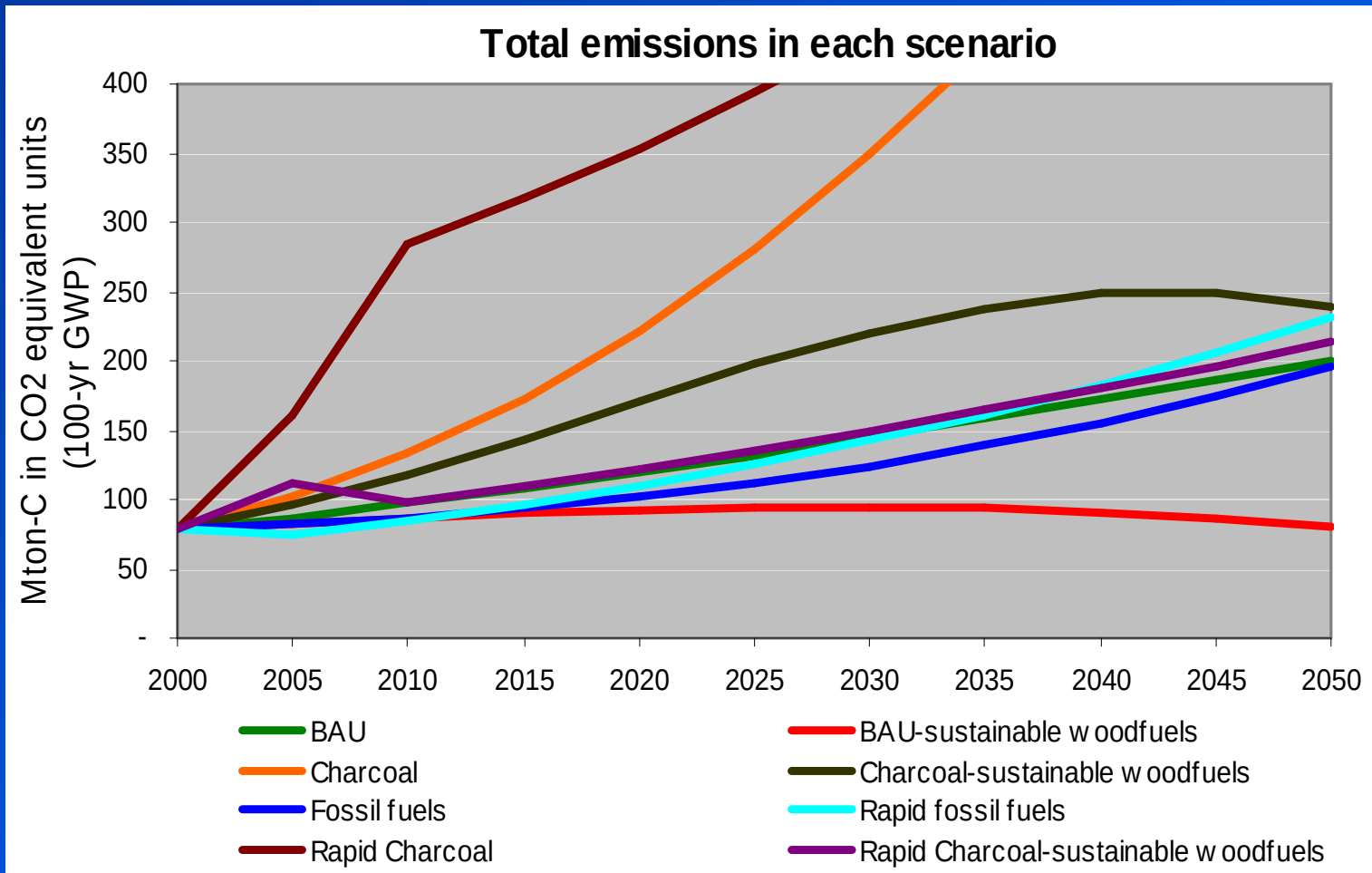
English: "Do not buy a solar panel or battery without official written information from the manufacturer and a guarantee. Keep the guarantee and receipts for your solar panel and battery in a safe place - you may need them to return the equipment later if there is a problem!"

Swahili: "Usinunue sola au be tri ambazo hazina cheti cha urekebisha au tarifa rasmi kutoka kwa watengenezaji wa bidhaa hizo. Weka hiyo karatasi vizuri kwa sababu zitaku saidia ku rudisha vifaa vikileta shida baadaye."

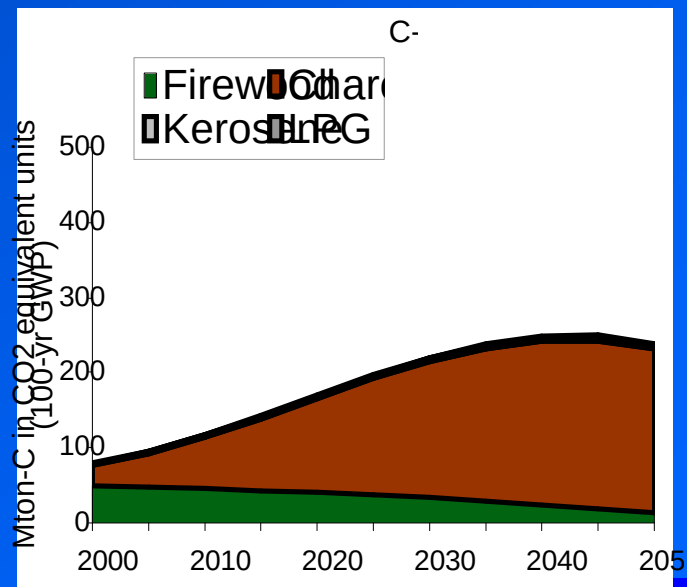
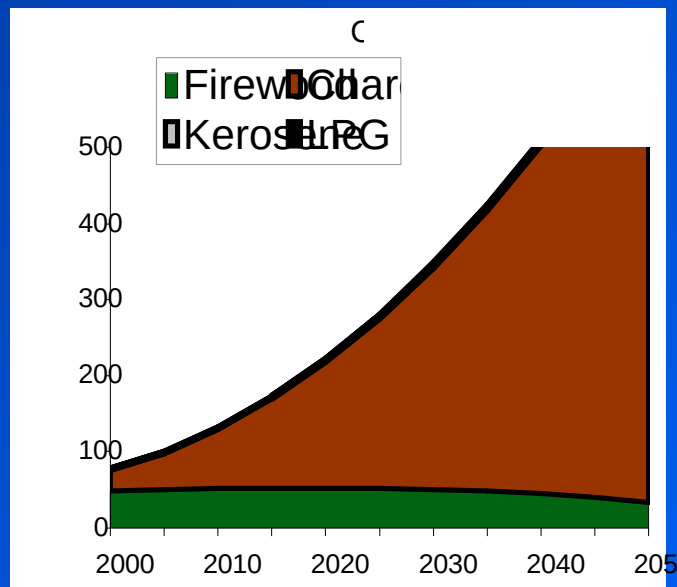
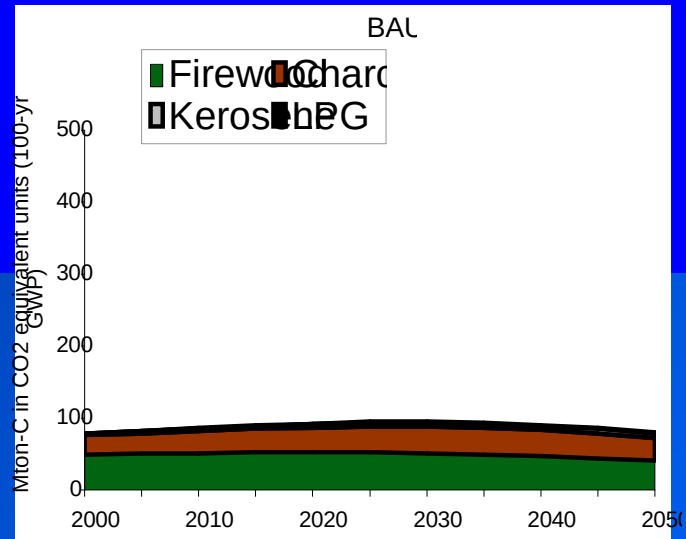
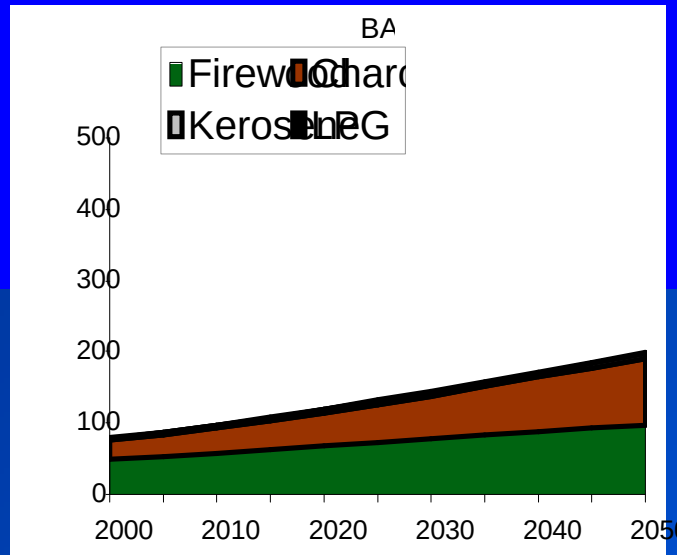
Regional Analysis of Energy Futures in Africa

Scenario	Household fuel choice pattern	Woodfuel harvest and charcoal production	Definitions
Group 1: Business as usual scenarios			
Business-as-usual (BAU)	Little change from current patterns in rural and urban areas	Unsustainable	The proportion of people in rural and urban areas using each fuel remains unchanged from the baseline year. 20% of trees removed for charcoal and 80% for wood regenerate.
Sustainable BAU (BAU-S)		Fully sustainable by 2050	Increase in the proportion of trees harvested sustainably as well as in the use of improved (high-efficiency) charcoal kilns. By 2050, tree regeneration reaches 80% for charcoal harvesting and 100% for firewood harvesting.
Group 2: Charcoal intensive scenarios			
Charcoal (C)	Large shift from wood to charcoal with minimal use of fossil fuels	Unsustainable	Linear transition from wood to charcoal in both urban and rural areas In 2050 approximately 80% of urban households and 40% of rural households are using charcoal (61% of the total population).
Sustainable charcoal (C-S)		Fully sustainable by 2050	By 2050, tree regeneration reaches 80% for charcoal production and 100% for firewood harvest; <u>all</u> charcoal efficiently produced.
Rapid charcoal (RC)		Unsustainable	Firewood users decreases by 40% in rural areas and by 100% in urban areas In 2010, (52% of the total population). By 2050, the fraction of the population using charcoal increases to 64%.
Rapid sustainable charcoal (RC-S)		Fully sustainable by 2010	Tree regeneration reaches 80% for charcoal production and 100% for firewood harvest; 100% of charcoal production in high-efficiency kilns.
Group 3: Fossil fuel intensive scenarios			
Fossil-fuel (F)	Large shift from wood and charcoal to petroleum-based fossil fuels	Unsustainable	Firewood and charcoal users switch gradually to LPG/kerosene. Fossil fuel use = 54% in 2050.
Rapid fossil-fuel (RF)		Unsustainable	RF follows a similar pattern as scenario F, but at an accelerated pace.. Fossil fuel use = 63% in 2050.

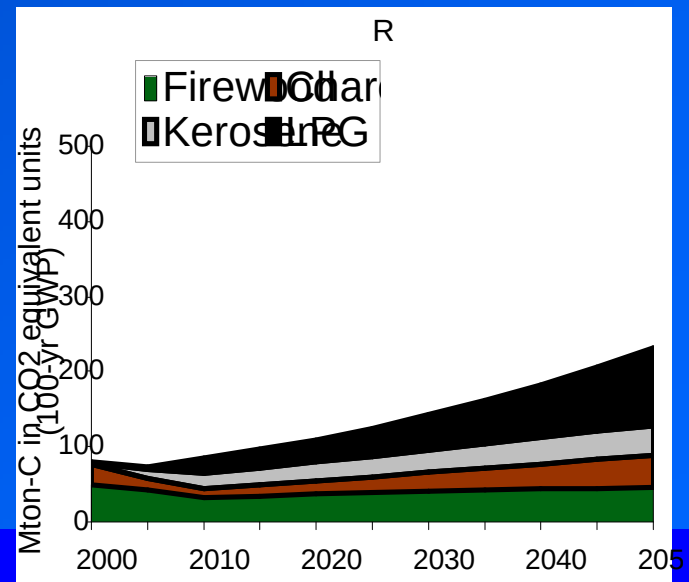
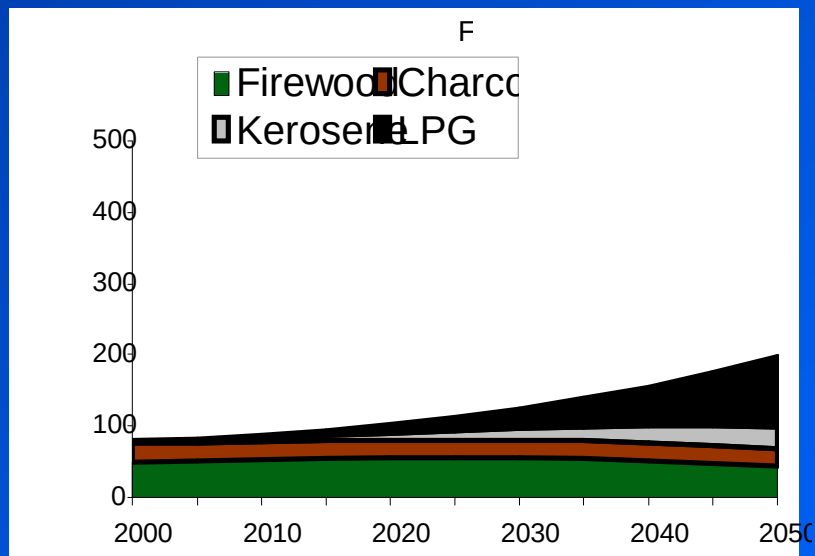
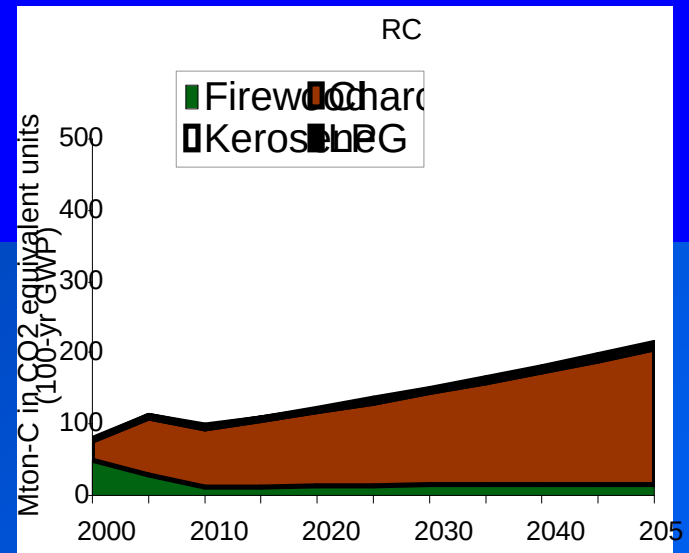
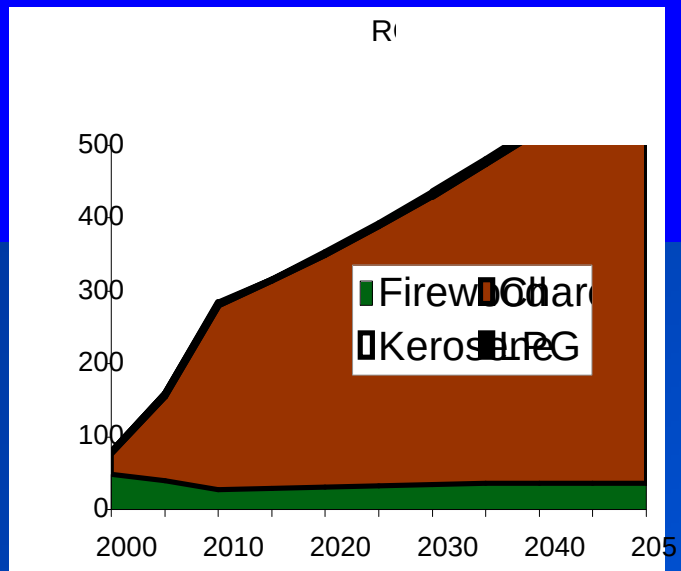
Results of GHG emissions



African Residential GHG Emissions



African Residential GHG Emissions



Africa is Undergoing Dramatic Power Sector Reforms (privatization)

Region	No. of Countries
Africa & Middle East	17
Western Europe	17
Central & Eastern Europe	12
Asia & Australia	14
South America	7
North America	3
Total	70

Source: Bacon, R.W. and J. Besant-Jones, *Global Electric Power Reform, Privatization and Liberalization of the Electric Power Industry in Developing Countries*. Annual Review of Energy and the Environment, 2001. 26: p. 331-359.



Co-Conspirators

Students:

Biomass Energy:

Rob Bailis (ERG ® Yale FES)

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Solar Energy:

Arne Jacobson (HSU/SERC)

Rebecca Ghanadan (ERG)

Charles Kirubi (ERG/Kenyatta)

Energy R&D:

Greg Nemet (ERG)

Carla Peterman (ERG)

UNIVERSITY OF CALIFORNIA
BERKELEY

REPORT OF THE
RENEWABLE AND APPROPRIATE ENERGY
LABORATORY

**Putting Renewables to Work:
How Many Jobs Can the
Clean Energy Industry
Generate?**

by

**Daniel M. Kammen
Kamal Kapadia
Matthias Fripp**

of the
Energy and Resources Group &
the Goldman School of Public Policy

APRIL 13, 2004



Finding:

Investments in
energy
efficiency and
renewables
creates **3 - 5
*times*** more jobs
than similar
investments in
fossil fuel
energy systems

**Report
available**

at: **<http://socrates.berkeley.edu/~rael/papers.html>**

Narok District feeds Urban Energy Demand (R. Bailis)

Narok Case Study

25% of Nairobi's charcoal is produced in Narok, but only became major source in the past 5 years

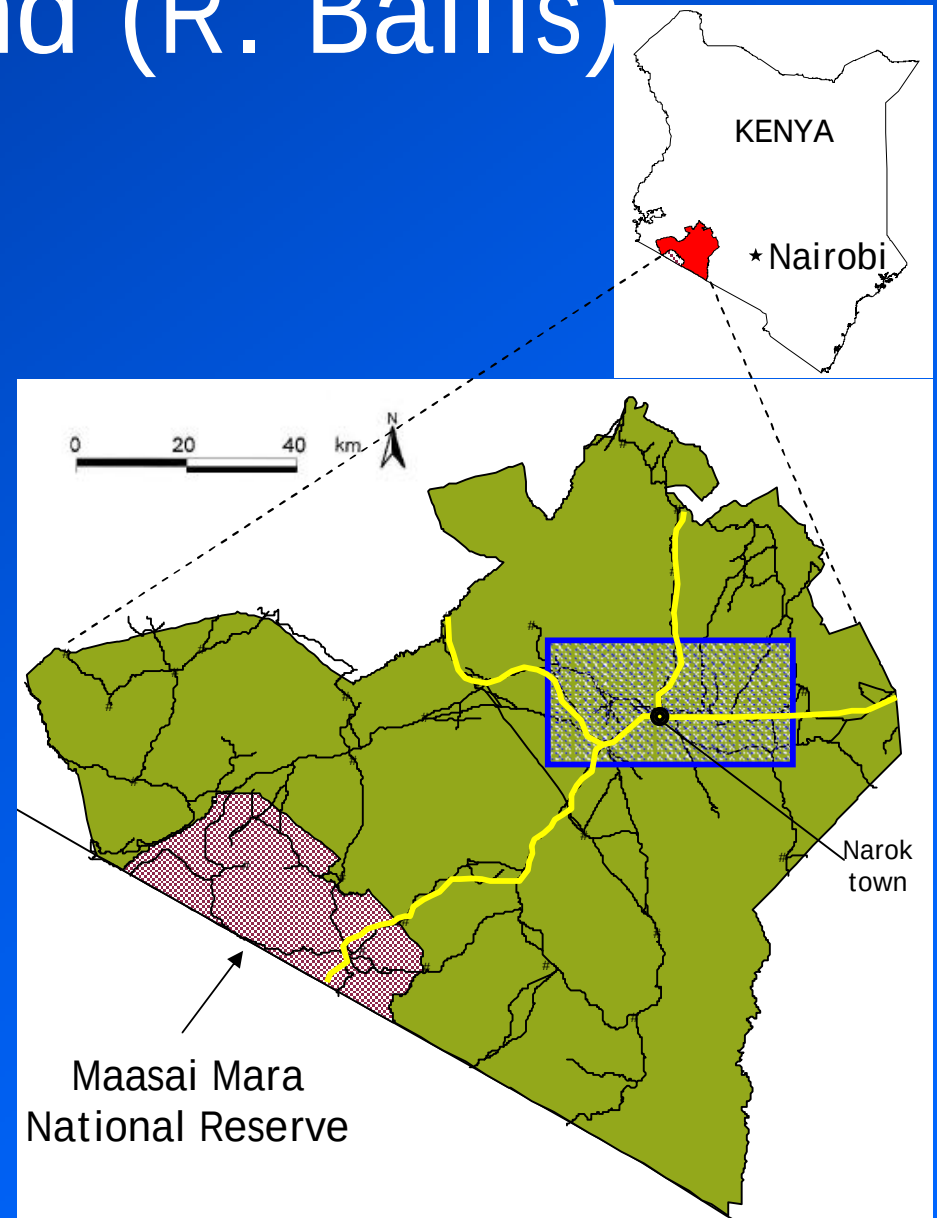
1963 -1990s

Land tenure in Narok evolved from group tenure to freehold tenure

Shift in economic focus from mostly pastoral to commercial grain and subsistence cultivation

1999-2005

Charcoal makers arrive in district *en masse*. Facilitate LUC by lowering the cost of clearing land.





Project or Program Costs/DALY

(DALY - disability adjusted life year)

Hospital care (respiratory illnesses)	\$300 - 1,000/DALY
Vehicle improvement programs	\$100 - 250/DALY
Anti-smoking campaigns	\$35- 75/DALY (African settings)
Immunizations	\$5 - 25/DALY

Stove programs

- Improved biomass stoves: \$5 - 25 per DALY
- Addition of chimneys: \$? per DALY
- Use of kerosene and LPG: \$150-200 per DALY

GHG Management (***not the primary motivation in Africa***)

- Sustainable forestry has tremendous benefits and low costs (~ \$5/ t Carbon)
- Improved stove (& charcoal kiln) programs also at very low cost

Summing up regional impacts

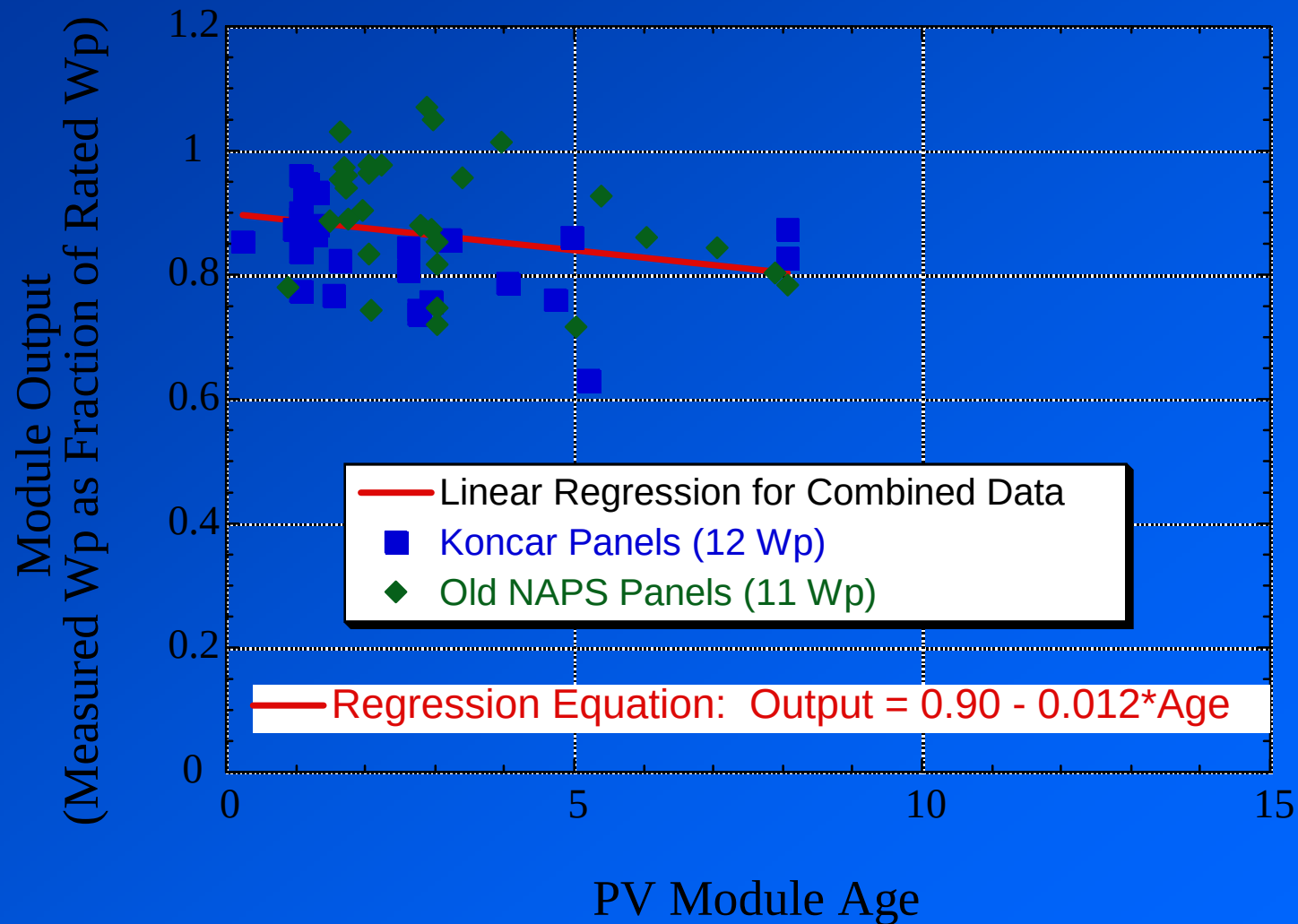
Mortality: ~ 10 million deaths from LRI and COPD

- Gradual transition to charcoal or fossil fuels **avoids 1 - 1.3 million deaths**
- Rapid transition to charcoal or fossil fuels **avoids 2.8 - 3.7 million deaths**

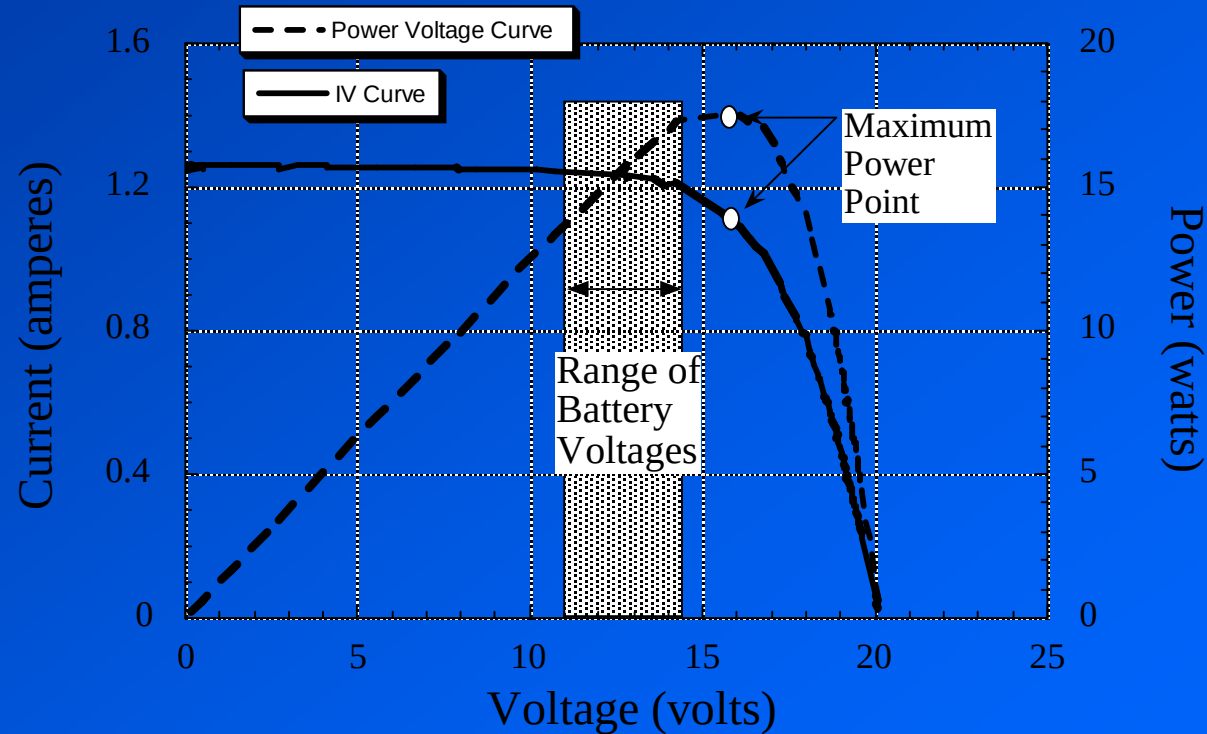
GHGs: ~ 6.7 GtC (CO₂ equivalent units using 100-yr GWP)

- Pace of transition not as important
- Transition to fossil fuels **decrease emissions 1 - 10 %**
- Transition to charcoal with current production practices **increases emissions 140 - 190 %**
- Charcoal transition with **sustainable harvesting and improved production only increases emissions by 5 - 36 %**

aSi PV Module Output vs. Age (years)



Photovoltaic IV Curve Basics



Solar Panels.

What you should know before you buy

MONOCRYSTALLINE SOLAR PANELS are the oldest in the market and they are the industry standard since the 1960's. To date they have the best record for efficiency, life span and technology. Their life span is over 25 years, guarantee 12 years.

AMORPHOUS SOLAR PANELS are much lower quality than monocrystalline

- Are the newest and least tried technology in the market.
- They are also the cheapest and mostly sold in developing countries where there are no standards.
- They lose 25% efficiency within the first three months, due to the cheap manufacturing process.
- There is no international recognised standard for amorphous. Failure rate is very high within the first 2 years. International solar experts have discredited the amorphous panels as they rarely maintain the nominal output.
- Lifespan is very short and unlikely to last more than 4 years maximum, hence need of continuous replacement. Guarantee is between 2 and 5 years but you still need to understand what it means and how it is applied.

14 Watts Amorphous Kshs. 4,990
(3-4 years lifespan)

Kenital 15 Watts Monocrystalline Kshs. 8,000
(25 years lifespan)

Before you buy a solar panel think whether it is not worth paying few shillings more for a kenital monocrystalline solar panel (guaranteed 12 years with 25 years lifespan) and upgrade your system when you can afford or else pay a little less for a amorphous panel which you must replace every 3-4 years.

H 15 Watts	Kshs. 6,000	H 45 Watts	Kshs. 18,000
H 20 Watts	Kshs. 8,500	H 50 Watts	Kshs. 21,500
H 25 Watts	Kshs. 10,500	H 60 Watts	Kshs. 25,000
H 30 Watts	Kshs. 12,000	H 80 Watts	Kshs. 32,000
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SOLAR PANEL SCANDAL!!



- 14 WATT LABEL
- ONLY 8.1 WATTS..!
- ONLY 1 YEAR WARRANTY
- MADE IN CHINA

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BEWARE OF THE
SILVER FRAME



- 14 WATT LABEL
- OVER 17 WATTS
- 10 YEAR WARRANTY
- MADE IN U.K. BY ICP SOLAR

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LOOK FOR THE
GOLD FRAME

Tests carried out at Loughborough University in U.K. have shown that 14 watt panels made in China only give out half the power they should do !! They are therefore actually only 8 watt panels and should cost not more than Kshs 2000/= each. They can be identified by their **silver frames**.

This scandal has been reported to the Kenya Bureau of Standards. The detailed test results can be viewed at any Sollatek Solar Distributor, Sollatek Service Centre or www.sollatek.co.ke

LOOK FOR THE PANEL WITH THE GOLD FRAME MADE IN U.K. BY ICP SOLAR AND SOLD EXCLUSIVELY BY SOLLATEK IN E. AFRICA TO BE GUARANTEED GOOD VALUE FOR YOUR MONEY.

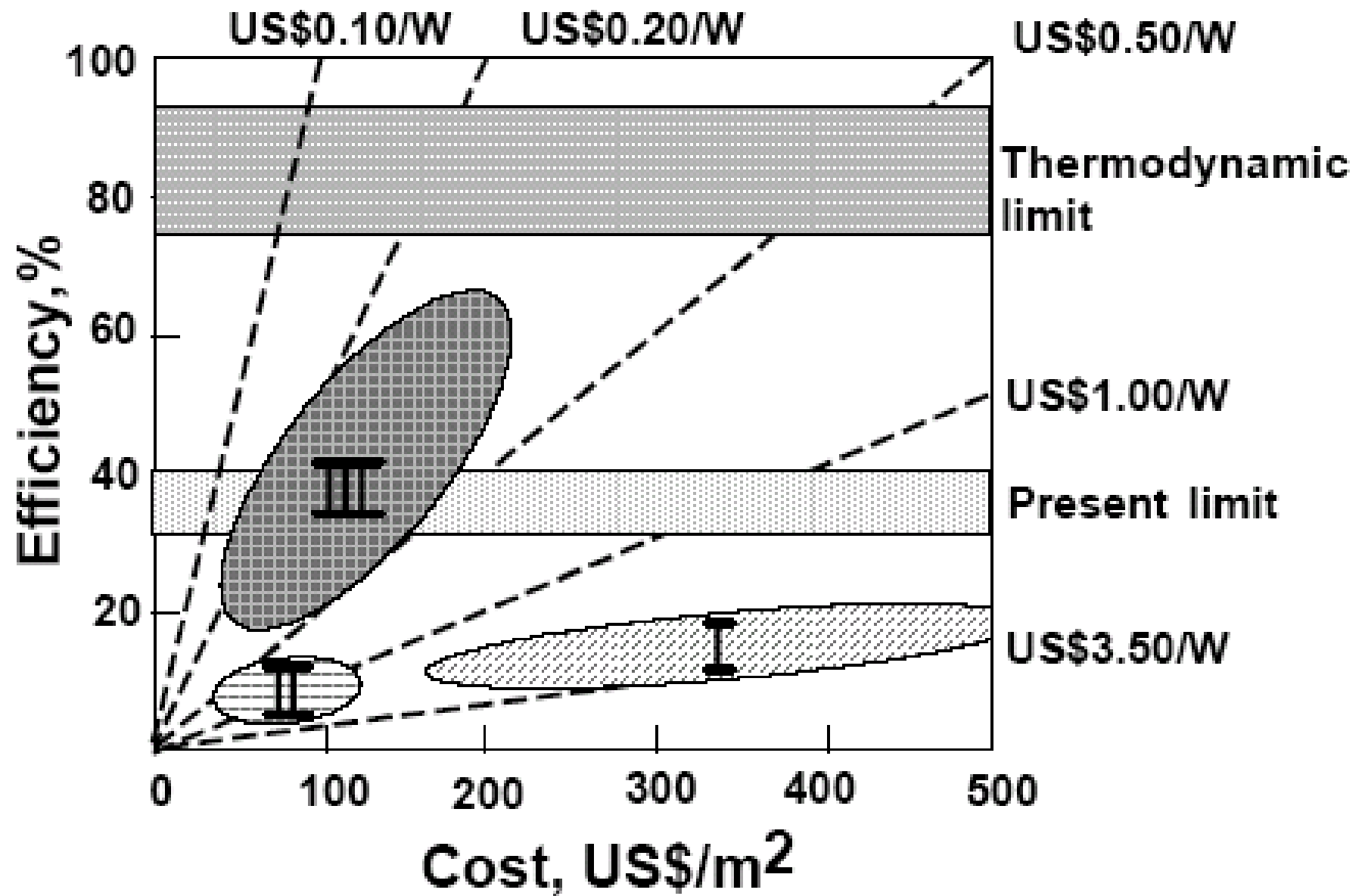
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