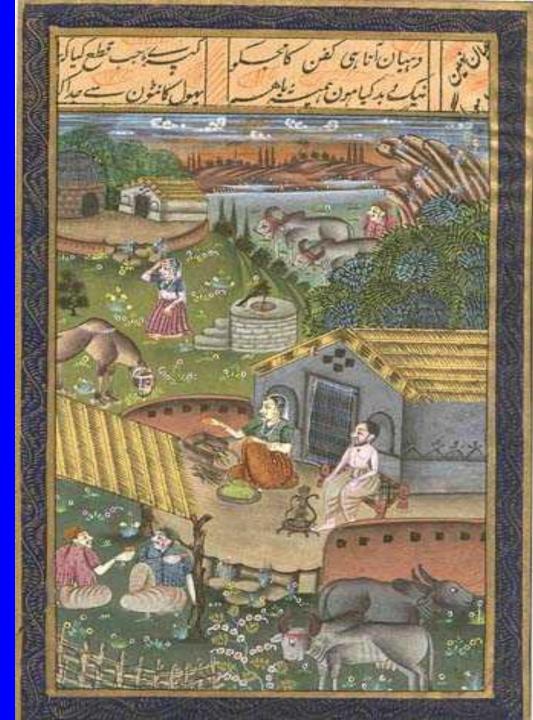
COOKFIRES, CLIMATE, AND HEALTH:

THE UNFINISHED AGENDA OF INCOMPLETE COMBUSTION

Kirk R. Smith Professor of Global Environmental Health University of California Berkeley

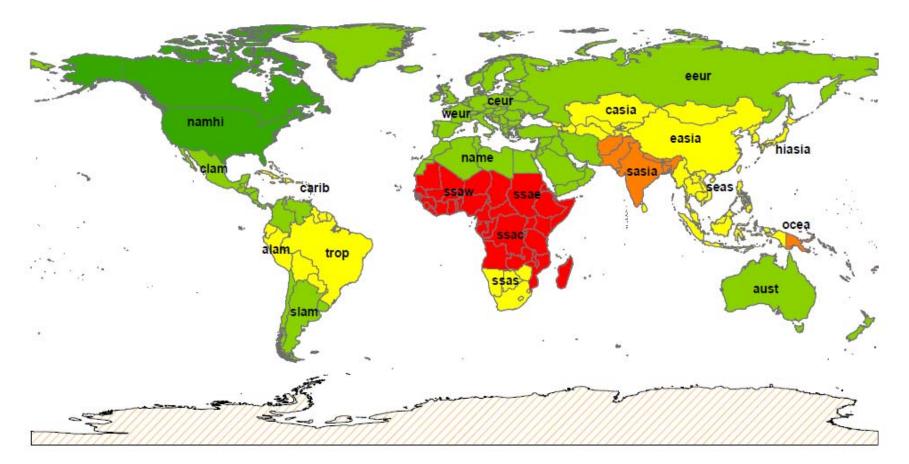
Indian Institute of Technology, Delhi March 28, 2011



Road Map

- Why a problem?
- What health effects are found?
- What are climate implications?
- What is India doing?
- What engineering is involved, besides designing new stoves?

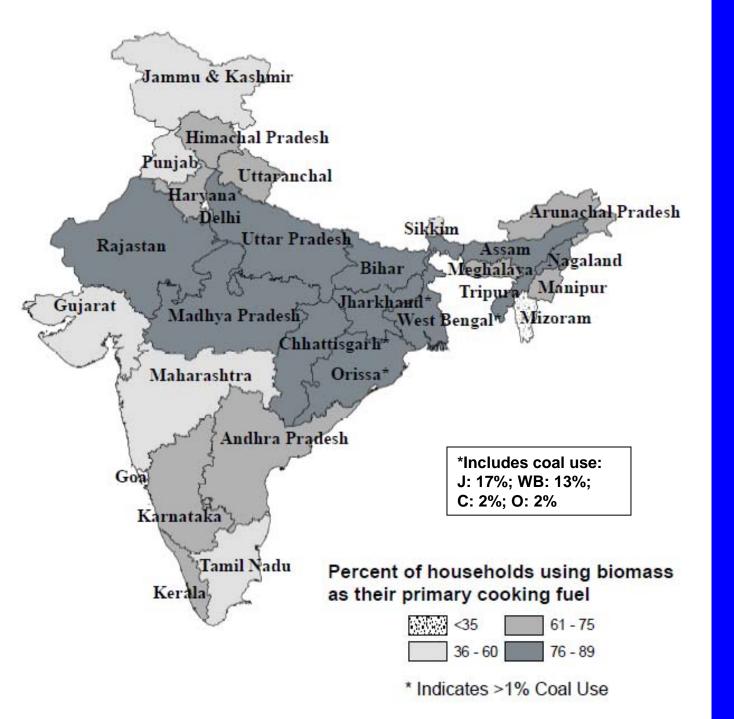
Households Using Solid Cooking Fuels



% of HH Exposed to HAP



For 2005, CRA-10 preliminary



India in 2005

Venkataraman et al. 2010

Woodsmoke is natural – how can it hurt you?

Or, since wood is mainly just carbon, hydrogen, and oxygen, doesn't it just change to CO_2 and H_2O when it is combined with oxygen (burned)?

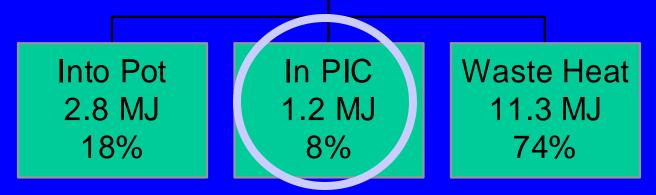


Reason: the combustion efficiency is far less than 100%

Energy flows in a well-operating traditional wood-fired Indian cooking stove

A Toxic Waste Factory!!

Typical biomass cookstoves convert 6-20% of the fuel carbon to toxic substances



PIC = products of incomplete combustion = CO, HC, C, etc.

Source: Smith, et al., 2000

Toxic Pollutants in Biomass Fuel Smoke from Simple (poor) Combustion

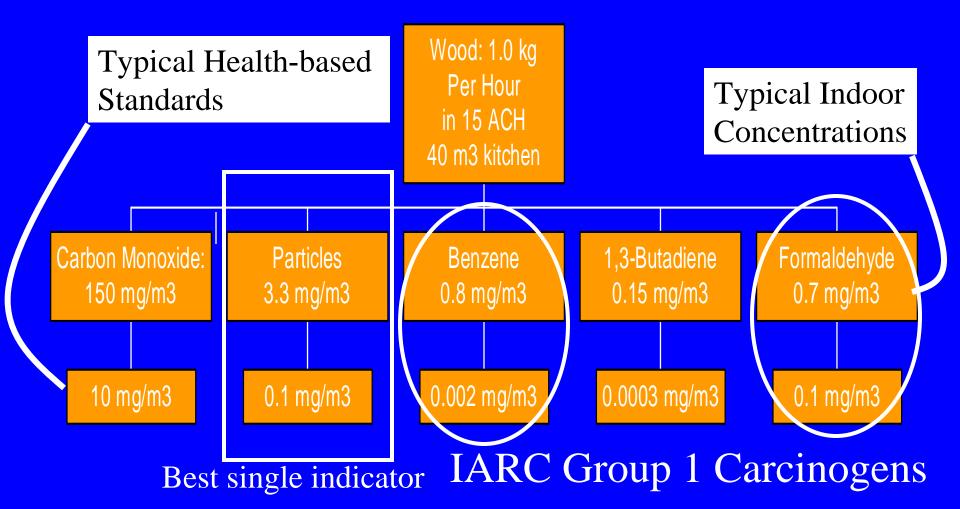
Organics known to be mutagens, immune system suppressants, severe irritants, inflammation agents, central nervous system depressants, cilia toxins, endocrine disrupters, or neurotoxins.

Several chemicals firmly established as human carcinogens.

Other toxic inorganic chemicals.

- 25+ alcohols and acids such as methanol
- 33+ phenols such as *catechol* & *cresol*
- Many quinones such as *hydroquinone*
- Semi-quinone-type and other radicals
- Chlorinated organics such as *methylene chloride* and *dioxin*

Health-Damaging Air Pollutants From Typical Woodfired Cookstove in India.



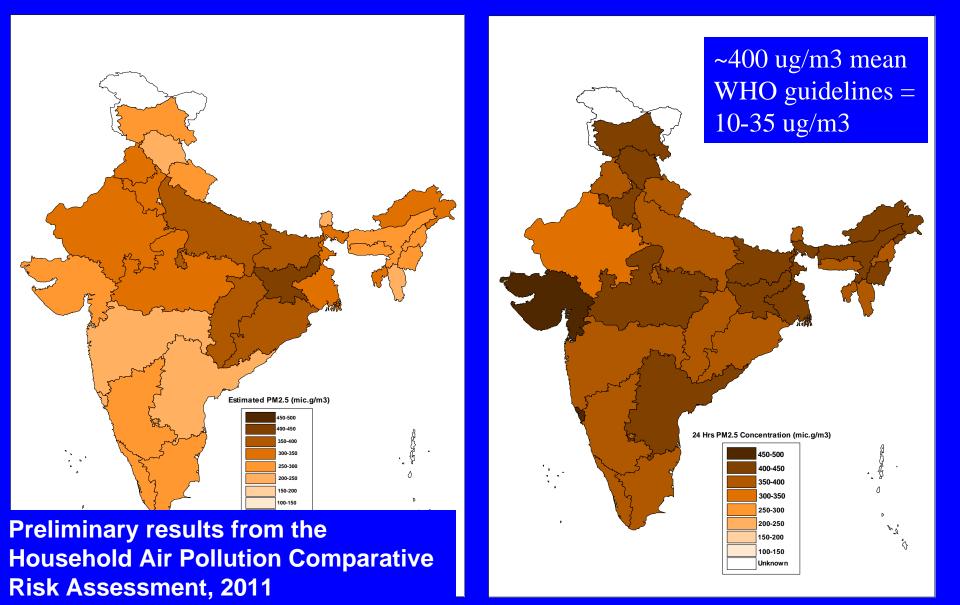
First person in human history to have her exposure measured doing the oldest task in human history

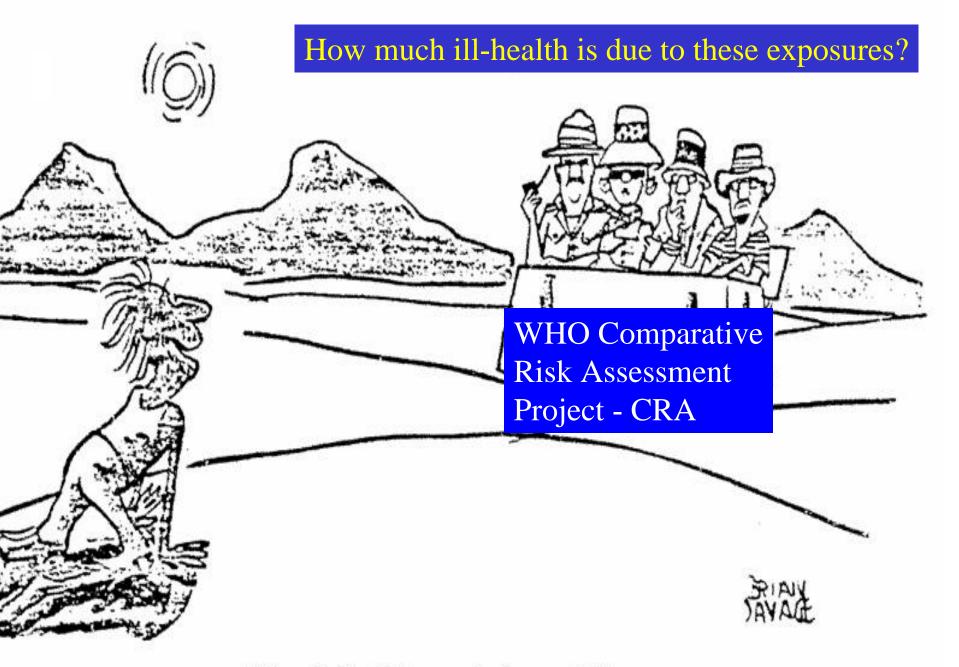
Emissions, yes, but what about exposures?

> Kheda District, Gujarat, 1981

Estimated PM2.5 indoors for <u>all</u> households

Estimated PM2.5 for <u>only</u> solid-fuel-using households





"Thank God! A panel of experts!"

Courtesy of Ross Anderson

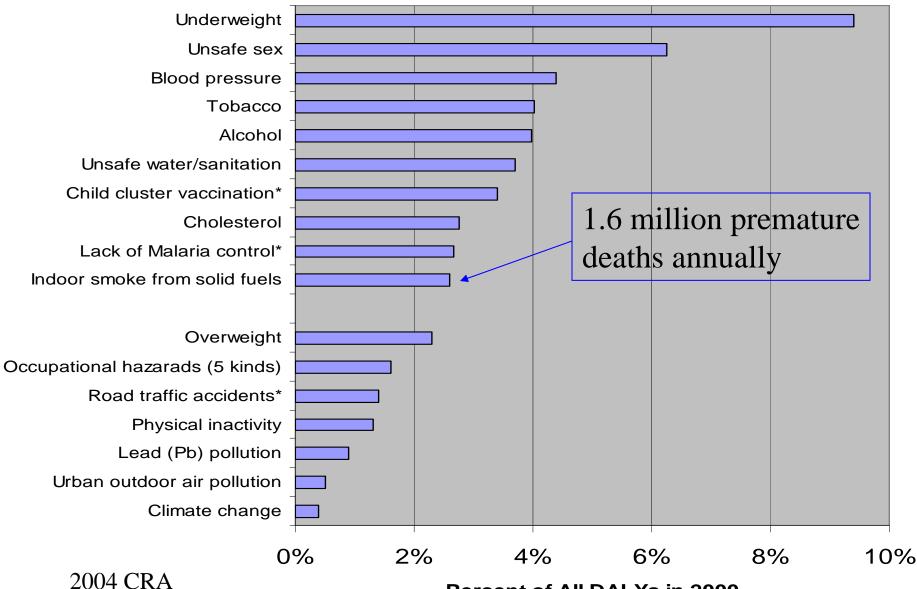
ALRI/ Pneumonia

Diseases for which we had epidemiological studies available around 2001 Chronic obstructive lung disease

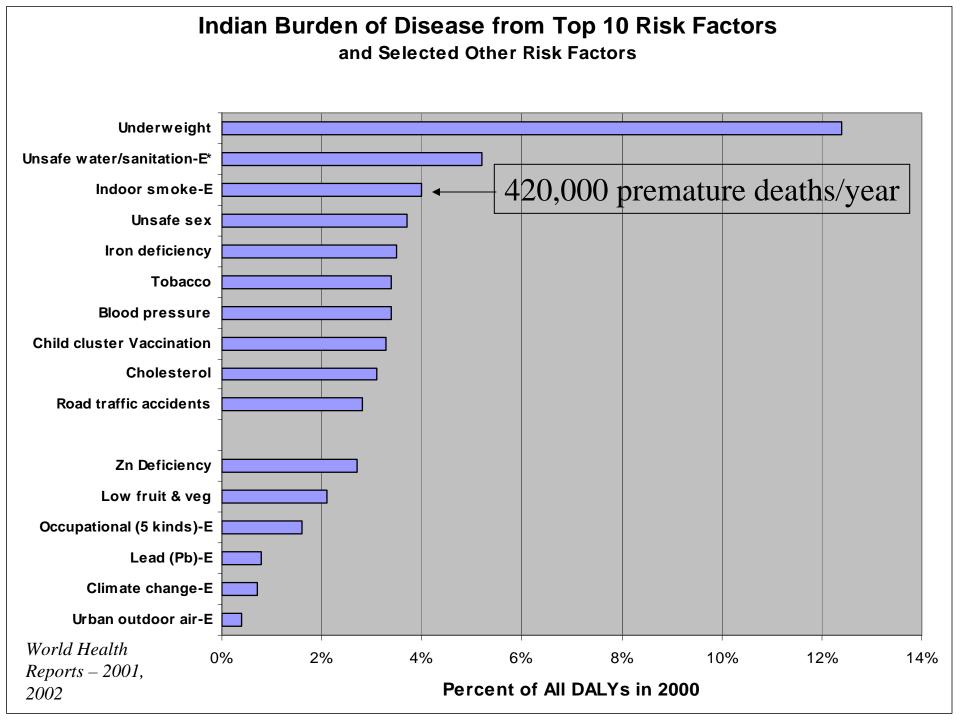
 Lung cancer from coal only

Three outcomes qualified with sufficient evidence to be included in the WHO CRA of 2004

Global Burden of Disease from Top 10 Risk Factors plus selected other risk factors



Percent of All DALYs in 2000



A	BCDEF	G	н		J	K		M	N	0	P Q	R S	Т	U	V	W	X
PODUIAtic	tion (thousands)	6224384.81	5	622741.70	817442.87	6633665.38	427071.29	166160.20	30443.11	26143.24	3131052.05	301091.79	589229.34	782028.21	646519.90	427846.34	181906.42
	2002: DALYs by age, sex and ca	encountry advances (and speed approximation when you															
NORL		Moe rer are	year acce		[
NORL	<u>-D</u>		1		/		Male				-					Female	
ode	Cause	Total	0-4	5-14	15-29	30-44		60-69	70-79	80+	Totai	0-4	5-14	15-29	30-44	Female 45-59	60-69
J000		The second second second	Contractor of States	the second second	the second s	1. 200 A. 10 A. 100000	Courses and				Second and the second se	Constant Constant	a la seconda esta de la composición de	These sectors are an and the sector of the			The America American
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J001	I. Communicable, maternal, perinatal	d 610319230	*****	20979812	29721889	36148775	16631072	5676094	2913759	849889		******	25248712	59740290	35979204	11499502	4476964
	and nutritional conditions	6100.00L		200100	2312100-	30140	100010	201000-	2010132	04000-	******		20270	20140	33010	1144444	*******
002	A. Infectious and parasitic diseases	350332571	87977510	12810197	25516201	33372707	14085712	3710016	1519252	315539	179307135	89749119	13534884	31549467	23070592	8616676	2658113
J003	1. Tuberculosis	34735908		782431		7335503	4868489	1832663	658401	90612	21905208	738745	821735	4163278	3822011	2041939	833205
J004	2. STDs excluding HIV	11347067	1521528	26245		660600	423721	103004	31641	7415	3854983	1726606	97221	4158088	1147558	260537	71612
1005	a. Syphilis	4200039		2292				99162	30394	6987	1970375	1265722	3432	521758	262487	107605	42492
006	b. Chlamydia	3571404		7209	241593	50929	1169	136	0	0	302234	1152	69338	2635460	439449	109658	14084
007	c. Gonorrhoea	3365 <mark>159</mark>	462945	10559	C020CA	201215	6664	719	91	2	1472160	447700	24323	989323	422675	6262	1616
008	d. Other STDs	2104											127	11546	22947	37012	13420
009	3. HIV/AIDS	844577	(CIO)		Burd	<u>aen</u>		NIGE	ase		aian	ase	1878957	17299389	13746555	2624463	230670
010	4. Diarrhoeal diseases	619661							abe		andie	000	754533	652616	545936	373258	201900
011	5 Childhood-cluster diseases	414795							Δ				1447659	172987	53966	19174	4837
012	a. Pertussis	12594	and		ompa	arai	IVA	RIG	$\langle A \rangle$	SSA	ssm	ent	50717	34	0		0
013	b. Poliomyelitis	1506	Cinc							200			8675	28237	16931	3822	615
014	c. Diphtheria	184											19365	523	386	572	29
015	d. Measles	214754											1269212	84741	29	30	0
016	e. Tetanus	7073											99690	59452		14737	4192
JO17	6. Meningitis*	61917											734345	341757	167759	110215	48775
JO18	7. Hepatitis B	21703											62506	173729	115391	110437	36630
1019	Hepatitis C	10036											24200	67867	53705	61307	30322
020	8. Malaria	464858											601958	689661	453207	280704	99111
021	5. Tropical-cluster diseases	122454		P.C	eing	eon		tol	un	dat	00		1203242	1297027	593336	496341	75537
022	a. Trypanosomiasis	15252						lery	<u>up</u>	Uat	eu		237244	149181	79329	46509	3694
J023	b. Chagas disease	6667											193	198737	51644	48058	15987
1024	c. Schistosomiasis	17017			for	ato	201	1 r		200			221149	232053	128589	58850	17056
JO25	d. Leishmaniasis	20898				RIE	201			Se			367279	246063	67203	30097	11647
J026	e. lymphatic filariasis	57774												405054		000000	45770
													349733	425651	206680	266630	15772
	f. Onchocerciasis	4842											27645	45343	59892	46198	11380
J028	10. Leprosy	1987											27645 23264	45343 16689	59892 15828	46198 9135	11380 4389
J028 J029	10. Leprosy 11. Dengue	1987 6155											27645 23264 215987	45343 16689 23174	59892 15828 10408	46198 9135 6396	11380 4389 2644
JO28 JO29 JO30	10. Leprosy 11. Dengue 12. Japanese encephalitis	1987 6155 709219		92418		70268		2292	1205	279	338116	160556	27645 23264 215987 131203	45343 16689 23174 41495	59892 15828 10408 26926	46198 9135 6396 7282	11380 4389 2644 2513
JO28 JO29 JO30 JO31	 Leprosy Dengue Japanese encephalitis Trachoma 	1987 6155 709219 2328780	1861	2594	32532	183952	201068	111206	53718	10162	597093	1973	27645 23264 215987 131203 7118	45343 16689 23174 41495 68754	59892 15828 10408 26926 517423	46198 9135 6396 7282 559520	11380 4389 2644 2513 344796
J028 J029 J030 J031 J032	10. Leprosy 11. Dengue 12. Japanese encephalitis 13. Trachoma 14. Intestinal nematode infection	1987 6155 709219 2328780 ns 2951341	1861 257716	2594 1196068	32532 14526	183952 7512	201068 8174	111206 4301	53718 1450	10162 492	597093 1490238	1973 273831	27645 23264 215987 131203 7118 1158847	45343 16689 23174 41495 68754 12068	59892 15828 10408 26926 517423 5192	46198 9135 6396 7282 559520 5921	11380 4389 2644 2513 344796 3469
J028 J029 J030 J031 J032 J033	10. Leprosy 11. Dengue 12. Japanese encephalitis 13. Trachoma 14. Intestinal nematode infection a. Ascariasis	1987 6155 709219 2328780 1s 2951341 1816942	1861 257716 157488	2594 1196068 751279	32532 14526 695	183952 7512 270	201068 8174 222	111206 4301 11	53718 1450 15	10162 492 40	597093 1490238 910021	1973 273831 171105	27645 23264 215987 131203 7118 1158847 735150	45343 16689 23174 41495 68754 12068 311	59892 15828 10408 26926 517423 5192 161	46198 9135 6396 7282 559520 5921 21	11380 4389 2644 2513 344796 3469 111
J028 J029 J030 J031 J032 J033 J034	10. Leprosy 11. Dengue 12. Japanese encephalitis 13. Trachoma 14. Intestinal nematode infection a. Ascariasis b. Trichuriasis	1987 6155 709219 2328780 ns 2951341 1816942 1006248	1861 257716 157488 8 82408	2594 1196068 751279 432805	32532 14526 695 1371	183952 7512 270 908	201068 8174 222 699	111206 4301 11 367	53718 1450 15 108	10162 492 40 27	597093 1490238 910021 518693	1973 273831 171105 74437	27645 23264 215987 131203 7118 1158847 735150 411117	45343 16689 23174 41495 68754 12068 311 823	59892 15828 10408 26926 517423 5192 161 388	46198 9135 6396 7282 559520 5921 21 433	11380 4389 2644 2513 344796 3469 111 238
J028 J029 J030 J031 J032 J033 J034 J035	10. Leprosy 11. Dengue 12. Japanese encephalitis 13. Trachoma 14. Intestinal nematode infection a. Ascanasis b. Trichuriasis c. Hookworm disease	1987 6155 709219 2328780 ns 2951341 1816942 1006248 58617	1861 257716 157488 8 82408 7 339	2594 1196068 751279 432805 3937	32532 14526 695 1371 11312	183952 7512 270 908 5396	201068 8174 222 699 5924	111206 4301 11 367 3091	53718 1450 15 108 1074	10162 492 40 27 262	597093 1490238 910021 518693 31336	1973 273831 171105 74437 0	27645 23264 215987 131203 7118 1158847 735150 411117 4583	45343 16689 23174 41495 68754 12068 311 823 9796	59892 15828 10408 26926 517423 5192 161 388 4212	46198 9135 6396 7282 559520 5921 21 433 4859	11380 4389 2644 2513 344796 3469 1111 238 2723
J028 J029 J030 J031 J032 J033 J034 J035 J036	10. Leprosy 11. Dengue 12. Japanese encephalitis 13. Trachoma 14. Intestinal nematode infection a. Ascanasis b. Trichuriasis c. Hookworm disease Other intestinal infections	1987 6155 2328780 1s 2951341 1816942 1006248 58617 69534	1861 257716 2 157488 3 82408 7 339 4 17481	2594 1196068 751279 432805 3937 8047	32532 14526 695 1371 11312 1148	183952 7512 270 908 5396 937	201068 8174 222 699 5924 1329	111206 4301 11 367 3091 831	53718 1450 15 108 1074 252	10162 492 40 27 262 163	597093 1490238 910021 518693 31336 30188	1973 273831 171105 74437 0 28290	27645 23264 215987 131203 7118 1158847 735150 411117 4583 7997	45343 16689 23174 41495 68754 12068 311 823 9796 1138	59892 15828 10408 26926 517423 5192 161 388 4212 432	46198 9135 6396 7282 559520 5921 21 433 4859 607	11380 4389 2644 2513 344796 3469 111 238 2723 397
U028 U029 U030 U031 U032 U033 U034 U035 U036 U037	10. Leprosy 11. Dengue 12. Japanese encephalitis 13. Trachoma 14. Intestinal nematode infection a. Ascariasis b. Trichuriasis c. Hookworm disease Other infectious diseases Other infectious diseases	1987 6155 709219 2328780 15 2351341 1816942 1006248 59617 69534 41445320	1861 257716 157488 82408 3339 17481 8567237	2594 1196068 751279 432805 3937 8047 2450753	32532 14526 695 1371 11312 1148 2311612	183952 7512 270 908 5396 937 2584703	201068 8174 222 6393 5924 1329 2021325	111206 4301 11 367 3091 831 757612	53718 1450 15 108 1074 252 461907	10162 492 40 27 262 163 118307	597093 1490238 910021 518693 31336 30188 19273457	1973 273831 171105 74437 0 28290 10586539	27645 23264 215987 131203 7118 1158847 735150 411117 4583 7397 4372108	45343 16689 23174 41495 68754 12068 311 823 9796 1138 2370886	59892 15828 10408 26926 517423 5192 161 388 4212 432 1795391	46198 9135 6396 7282 559520 5921 21 433 4859 607 1650048	11380 4389 2644 2513 344796 3469 111 238 2723 397 667703
U028 U029 U030 U031 U032 U033 U034 U035 U036 U037 U038	10. Leprosy 11. Dengue 12. Japanese encephalitis 13. Trachoma 14. Intestinal nematode infection a. Ascariasis b. Trichuriasis c. Hookworm disease Other intestinal infections Other infectious diseases B. Respiratory infections	1987 6155 709219 2328780 18 2951341 1816942 1006248 58617 69534 41445320 94603349	1861 257716 157488 82408 3339 17481 8567237 32429989	2594 1196068 751279 432805 3937 8047 2450753 6247258	32532 14526 695 1371 11312 1148 2311612 2411409	183952 7512 270 908 5396 937 2584703 1749936	201068 8174 222 6393 5924 1323 2021325 1847020	111206 4301 11 367 3091 831 757612 1735082	53718 1450 15 108 1074 252 461907 1261667	10162 492 40 27 262 163 118307 494366	597093 1490238 910021 518693 31336 30188 19273457 48176727	1973 273831 171105 74437 0 28290 10586539 30184256	27645 23264 215987 131203 7118 1158847 735150 411117 4583 7997 4372108 6903318	45343 16689 23174 41495 68754 12068 311 823 9796 1138 2370886 2987156	59892 15828 10408 26926 517423 5192 161 388 4212 432 1795391 1481589	46198 9135 6396 7282 559520 5921 21 433 4859 607 1650048 1357246	11380 4389 2644 2513 344796 3469 111 238 2723 397 667703 1460806
U028 U029 U030 U031 U032 U033 U034 U035 U036 U037 U038 U039	10. Leprosy 11. Dengue 12. Japanese encephalitis 13. Trachoma 14. Intestinal nematode infection a. Ascariasis b. Trichuniasis c. Hookworm disease Other infections Other infectious diseases B. Respiratory infections 1. Lower respiratory infections	1987 6155 709219 2328780 18 2951341 1816942 1006248 58617 69534 41445320 94603349 9137352	1861 257716 157488 82408 3339 17481 8567237 32429989 131836027	2594 1196068 751279 432805 3937 8047 2450753 6247258 5573644	32532 14526 695 1371 11312 1148 2311612 2411409 2310964	183952 7512 270 908 5396 937 2584703 1749936 1655193	201068 8174 222 699 5924 1329 2021325 1847020 1773743	111206 4301 11 367 3091 831 757612 1735082 1682121	53718 1450 15 108 1074 252 461907 1261667 1232996	10162 492 40 27 262 163 118307 494366 482877	597093 1490238 910021 518693 31336 30188 19273457 48176727 46547564	1973 273831 171105 74437 0 28290 10586539 30184256 29539590	27645 23264 215987 131203 7118 1158847 735150 411117 4583 7997 4372108 65903318 6167276	45343 16689 23174 41495 68754 12068 311 823 9796 1138 2370886 23870886 2387156 2918287	59892 15828 10408 26926 517423 5192 161 388 4212 432 1795381 1481589 1434738	46198 9135 6396 7282 559520 5921 21 433 4859 607 1850048 1357246 1329549	11380 4389 2644 2513 344796 3469 111 238 2723 397 667703 1460806 1425397
U027 U028 U029 U030 U031 U032 U033 U034 U035 U036 U037 U038 U039 U040	10. Leprosy 11. Dengue 12. Japanese encephalitis 13. Trachoma 14. Intestinal nematode infection a. Ascariasis b. Trichuriasis c. Hookworm disease Other infectious diseases Other infectious diseases F. Respiratory infections 1. Lower respiratory infections 2. Upper respiratory infections	1987 6155 709219 2328780 115 2328780 115 2328780 116942 1006248 56617 69534 41445320 94603349 91373521 1795292	1861 257716 157488 82408 339 17481 8567237 32429989 131836027 231836027 2458484	2594 1196068 751279 432805 3937 8047 2450753 6247258 5573644 84253	32532 14526 695 1371 11312 1148 2311612 2411409 2310964 86969	183952 7512 270 908 5396 937 2584703 1749936 1655193 82518	201068 8174 222 699 5924 1329 2021325 1847020 1773743 70655	111206 4301 11 367 3091 831 757612 1735082 1682121 51526	53718 1450 15 108 1074 252 461907 1261667 1232996 28370	10162 492 40 27 262 163 118307 494366 482877 11405	597093 1490238 910021 518693 31336 30188 19273457 48176727 46547564 874181	1973 273831 171105 74437 0 28290 10586539 30184256 29539590 513743	27645 23264 215987 131203 7118 1158847 735150 411117 4583 7997 4372108 63903318 6167276 201270	45343 16689 23174 41495 68754 12068 311 823 9796 1138 2370886 2387156 2918287 59304	59892 15828 10408 26926 517423 5192 161 388 4212 432 1795391 1481589 1434738 45228	46198 9135 6396 7282 559520 5921 21 433 4859 607 1650048 1357246 1329549 28339	11380 4389 2644 2513 344796 3469 111 238 2723 397 667703 1460806 1425397 34405
U028 U029 U030 U031 U032 U033 U034 U035 U036 U037 U038 U038 U039 U040 U041	10. Leprosy 11. Dengue 12. Japanese encephalitis 13. Trachoma 14. Intestinal nematode infection a. Ascanasis b. Trichuriasis c. Hookworm disease Other infectious diseases Other infectious diseases B. Respiratory infections 1. Lower respiratory infections 2. Upper respiratory infections 3. Otitis media	1987 6155 709219 2328780 1816942 1006248 59617 69534 41445320 94603349 91373521 1795292 1434536	1861 257716 2 157488 82408 339 17481 8567237 324298989 31836027 458484 1354777	2594 1196068 751279 432805 3937 8047 2450753 6247258 5573644 84253 589362	32532 14526 695 1371 11312 1148 2311612 2411409 2310964 86969 13476	183952 7512 270 908 5396 937 2584703 1749936 1655193 82518 12225	201068 8174 222 699 5924 1329 2021325 1847020 1773743 70655 2623	111206 4301 11 367 3091 831 757612 1735082 1682121	53718 1450 15 108 1074 252 461907 1261667 1232996 28370 300	10162 492 40 27 262 163 118307 494366 482877 11405 84	597093 1490238 910021 518693 31336 19273457 48176727 46547564 874181 754982	1973 273831 171105 74437 0 28290 10586539 30184256 29539590 513743 130923	27645 23264 215987 31203 7118 1158847 735150 411117 4583 7997 4372108 6903318 6167276 201270 534772	45343 16689 23174 41495 68754 12068 311 823 3796 1138 2370886 2987156 2918287 53304 9565	59892 15828 10408 26926 517423 5192 161 388 4212 432 1795381 1481589 1434738 45228 1622	46198 9135 6396 559520 5921 21 433 4859 607 1850048 1357246 1357246 32539 22539 1358	11380 4389 2644 2513 344796 3469 111 2388 2723 397 667703 1460806 1425397 34405 1004
U028 U029 U030 U031 U032 U033 U034 U035 U036 U037 U037 U038 U039 U040 U041 U042	10. Leprosy 11. Dengue 12. Japanese encephalitis 13. Trachoma 14. Intestinal nematode infection a. Ascariasis b. Trichuriasis c. Hookworm disease Other infectious diseases Other infectious diseases 1. Lower respiratory infections 1. Lower respiratory infections 3. Ottits media C. Maternal conditions	1987 6155 709219 2328780 18 2351341 1816942 1006248 58617 69534 41445320 94603349 91373521 1795292 1434536 33631593	1861 257716 157488 8 2408 8 339 17481 8567237 32429989 13836027 4 558484 4 135477 0	2594 1196068 751279 432805 3937 8047 2450753 6247258 5573644 84253 589362 0	32532 14526 695 1371 11312 1148 2311612 2411409 2310964 86969 86969 13476 0	183952 7512 270 908 5396 937 2584703 1749936 1655193 82518 12225 0	201068 8174 222 699 5924 1329 2021325 1847020 1773743 70655 2623 0	111206 4301 11 367 3091 831 757612 1735082 1682121 51526 1435 0	53718 1450 15 108 1074 252 461907 1261667 1232996 28370 300 0	10162 492 40 27 262 163 118307 494366 482877 11405 84 0	597093 1490238 910021 518693 31336 19273457 48176727 48176727 48547564 874181 754982 0	1973 273831 17105 74437 0 28290 10586539 30184256 29539590 513743 130923 50	27645 23264 215987 31203 7118 1158847 735150 411117 4583 7987 4372108 6903318 6167276 201270 534772 226832	45343 16689 23174 41495 68754 12068 311 823 9796 138 2370886 2987156 2918287 59304 9565 23053758	59892 15828 10408 26926 517423 5192 161 388 4212 432 1795391 1481589 1434738 45228 1622 9947305	46198 9135 6396 7282 559520 5921 21 433 4859 607 1650048 1357246 1329549 26339 1358 403615	11380 4389 2644 2513 344796 3469 2723 2723 2723 2667703 1460806 1425397 34405 14026397 34405 10004 19
U028 U029 U030 U031 U032 U033 U034 U035 U036 U037 U038 U039 U040 U041 U041 U042 U043	10. Leprosy 11. Dengue 12. Japanese encephalitis 13. Trachoma 14. Intestinal nematode infection a. Ascariasis b. Trichuriasis c. Hookworm disease Other intestinal infections Other infectious diseases B. Respiratory infections 1. Lower respiratory infections 2. Upper respiratory infections 3. Otitis media C. Maternal conditions 1. Maternal haemorrhage	1987 6155 709219 2328780 1816942 1006248 58617 69534 41445320 94603349 91373521 1795292 1434536 33631593 4437585	1861 257716 157488 82408 339 17481 8567237 31836027 31836027 458484 13437 13547 0 0 0 0 0 0 0 0 0	2594 1196068 751279 432805 3937 8047 2450753 6247258 5573644 84253 589362	32532 14526 695 1371 11312 1148 2311612 2411409 2310964 86969 86969 13476 0	183952 7512 270 908 5396 937 2584703 1749936 1655193 82518 12225 0 0	201068 8174 222 6399 5324 1329 2021325 1847020 1773743 70655 26253 0 0	111206 4301 11 367 3091 831 757612 1735082 1682121 51526 1435	53718 1450 15 108 1074 252 461907 1261667 1232996 28370 300 0 0	10162 492 40 27 262 163 118307 494366 482877 11405 84	597093 1490238 910021 518693 31336 19273457 48176727 46547564 874181 754982	1973 273831 17105 28290 10586539 30184256 29539590 513743 130923 50 50	27645 23264 215987 131203 7118 1158847 735150 41117 4583 7997 4372108 6903318 6167276 201270 534772 226832 226832 332	45343 16689 23174 41495 68754 12068 311 823 9796 1138 2370886 2987156 2982156 2918287 53304 9565 23053758 2359228	59892 15828 10408 26926 517423 5192 161 388 4212 432 1795391 1481589 1434738 45228 1622 9347305 1944088	46198 9135 6396 7282 559520 5921 433 4859 607 1650048 1357246 1329549 28339 1358 403615 133887	11380 4389 2644 2513 344796 3469 111 2388 2723 397 667703 1460806 1425397 34405 1004
U028 U029 U030 U031 U032 U033 U034 U035 U036 U037 U038 U039 U040 U041 U042 U042 U043 U044	10. Leprosy 11. Dengue 12. Japanese encephalitis 13. Trachoma 14. Intestinal nematode infection a. Ascanasis b. Trichuriasis c. Hookworm disease Other infectious diseases B. Respiratory infections 1. Lower respiratory infections 3. Otitis media C. Maternal conditions 1. Maternal haemorrhage 2. Maternal sepsis	1987 6155 709219 2328780 1816942 1006243 58617 69534 4144536 94603349 91373521 1795292 1434536 33631593 4437585 6903085	1861 257716 157488 82408 339 17481 8567237 32429989 31386027 456484 135477 0 5 0	2594 1196068 751279 432805 3937 8047 2450753 6247258 5573644 84253 589362 0	32532 14526 695 1371 11312 1148 2311612 2411409 2310964 86969 86969 13476 0 0	183952 7512 270 908 5396 937 2584703 1749936 1655193 82518 12225 0 0	201068 8174 222 6399 5324 1329 2021325 1847020 1773743 70655 26253 0 0	111206 4301 11 367 3091 831 757612 1735082 1682121 51526 1435 0	53718 1450 15 108 1074 252 461907 1261667 1232996 28370 300 0	10162 492 40 27 262 163 118307 494366 482877 11405 84 0	597093 1490238 910021 518683 31336 30188 19273457 48176727 48176727 48176727 48176727 48176727 48176726 874181 754982 0 0	1973 273831 17105 74437 0 28290 10586539 30184256 29553950 513743 130923 50 50 50	27645 23264 215987 131203 7118 1158847 730150 411117 4553 7997 4372108 690318 690318 6167276 201270 534772 226632 3322 3322	45343 16689 23174 41495 68754 12068 311 823 9796 1138 2370886 2987156 2982755 23053758 23053758 2355228 5204511	59892 15828 10408 26926 517423 5192 161 388 4212 432 1795391 1481589 1434738 45228 1622 9947305 1944088 1625431	46198 9135 6396 7282 559520 5921 433 4859 607 1650048 1329549 26339 1358 403615 133887 72999	11380 4389 2644 2513 344796 3469 2723 2723 2723 2667703 1460806 1425397 34405 14026397 34405 10004 19
U028 U029 U030 U031 U032 U033 U034 U035 U036 U037 U038 U039 U040 U041 U042 U044 U044 U044 U045	10. Leprosy 11. Dengue 12. Japanese encephalitis 13. Trachoma 14. Intestinal nematode infection a. Ascanasis b. Trichuriasis c. Hookworm disease Other infectious diseases Other infectious diseases 1. Lower respiratory infections 2. Upper respiratory infections 3. Otitis media C. Maternal conditions 1. Maternal haemorrhage 2. Maternal sepsis 3. Hypertensive disorders*	1987 6155 709219 2328780 1816942 1006248 58617 69534 41445320 94603349 91373521 1735232 434536 33631593 4437585 6903085 2162701	1861 257716 157488 82408 339 17481 08567237 32429889 3135477 458484 135477 0 5 0 5 0	2594 1196068 751279 432805 3937 8047 2450753 6247258 5573644 84253 589362 0 0	32532 14526 695 1371 11312 2311612 2411409 2310964 86969 13476 0 0 0 0 0	183952 7512 270 908 5396 937 2584703 174936 1855193 82518 12225 0 0 0 0 0	201063 8174 222 699 5924 1329 2021325 1847020 1773743 70655 2623 0 0 0	111206 4301 11 367 3091 831 757612 1682121 51526 1435 0 0	53718 1450 15 108 1074 2522 461907 12261667 1232996 28370 3000 0 0 0 0 0	10162 492 40 27 262 163 118307 494366 482877 11405 84 0 0	597093 1490238 910021 518693 31336 30188 19273457 48176727 46547564 874181 754982 0 0 0 0	1973 273831 171105 74437 0 28290 10586539 30184256 295539590 513743 130923 50 50 50 0 0	27645 23264 215987 131203 7118 1158847 735150 41117 4583 7997 4372108 6903318 6167276 201270 534772 226832 226832 332	45343 16689 23174 41495 68754 12068 311 8233 9796 1138 2370886 2987156 2918287 59304 9565 23053758 23053758 230524511 1398598	59892 15828 10408 26926 517423 5192 161 388 4212 432 1795391 1434738 45228 1622 9947305 1944088 1825431 722909	46198 9135 6396 559520 5921 21 433 4859 607 1650048 1329549 26339 1358 403615 133887 72399 40216	11380 4389 2644 2513 344796 3469 111 2383 2723 387 667703 460806 1450806 1450397 34405 1004 199 0
U028 U029 U030 U031 U032 U033 U034 U035 U036 U037 U038 U039 U040 U040 U041 U042 U043 U044 U043 U044 U045 U045 U046	10. Leprosy 11. Dengue 12. Japanese encephalitis 13. Trachoma 14. Intestinal nematode infection a. Ascanasis b. Trichuriasis c. Hookworm disease Other infectious diseases Other infectious diseases B. Respiratory infections 1. Lower respiratory infections 2. Upper respiratory infections 3. Otitis media C. Maternal conditions 1. Maternal haemorphage 2. Maternal sepsis 3. Hypertensive disorders* 4. Obstructed labour	1987 6155 709219 2328780 1816942 1006248 58617 94603349 91373521 1795292 1434536 33631593 4437855 6903085 2162701 3048231	1861 257716 157488 82408 339 17481 08567237 32429389 131836027 455484 135477 0 5 0 5 0 1 0	2594 1196068 751279 432805 3937 8047 2450753 6247258 5573644 84253 589362 0 0 0	32532 14526 695 1371 11312 241148 2311612 2411403 2310964 86969 13476 0 0 0	183952 7512 270 908 5396 937 2584703 174936 1855193 82518 12225 0 0 0 0 0	201063 8174 222 699 5924 1329 2021325 1847020 1773743 70655 2623 0 0 0	111206 4301 11 367 3091 831 757612 1735082 1682121 51526 1435 0 0 0 0	53718 1450 15 108 252 461907 1261667 1232996 28370 300 0 0 0	10162 492 40 27 262 163 118307 494366 482877 11405 84 0 0	597093 1490238 910021 518683 31336 30188 19273457 48176727 48176727 48176727 48176727 48176727 48176726 874181 754982 0 0	1973 273831 17105 74437 0 28290 10586539 30184256 29553950 513743 130923 50 50 50	27645 23264 215387 7118 1158847 735150 411117 4563 73937 4372108 6903318 667276 201270 534772 226832 332 344 9755 0	45343 16689 23174 41495 68754 12068 311 823 9796 138 2370886 2987156 2987156 2987156 23053758 2353228 5204511 1398598 2241561	59892 15828 10408 26926 517423 5192 161 388 4212 432 1795391 1481589 1434738 45228 1622 9947305 1944088 1625431 722309 794568	46198 9135 6396 7282 559520 5921 433 4859 607 1650048 1329549 26339 1358 403615 133887 72999	11380 4389 2644 2513 344796 3469 111 238 2723 3397 667703 1460806 1425397 34405 1004 19 0 0 0
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ALRI/ Pneumonia (meningitis)

Low birth weight

Stillbirth Cognitive Impairment

Birth defects? Asthma?

Burns, health and safety impacts of fuel gathering?

Diseases for which we have

epidemiological studies - 2010

Chronic obstructive lung disease

Interstitial lung disease Cancer (lung, NP, cervical, aero-digestive)

Blindness (cataracts, opacity)

Tuberculosis

Heart disease? Blood pressure ST-segment

Summary of Endpoints in New CRA for Household Air Pollution

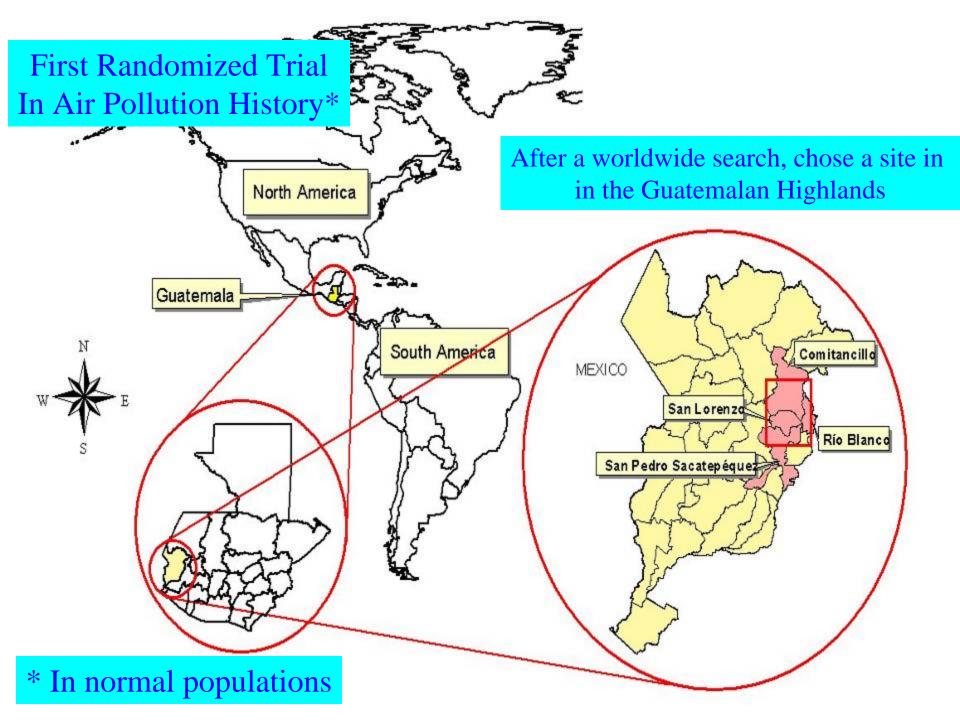
- New estimates for diseases in previous CRA
 - Pneumonia in children
 - COPD in adults (male and female)
 - Lung cancer in adults (male and female)
- Diseases now included
 - Low birth weight
 - Cataracts
 - Heart disease
- Still unclear not included
 - TB
 - Asthma
 - Other cancers

Story of Two Conferences

- Air pollution conference
 - High exposures to large vulnerable population
 - No more health effects work needed
- International health conference
 - Still doubt about causality
 - Need to know exact benefit to be expected
- Where are your randomized controlled trials?

History of an RCT

- ~1980: Early studies of health effects in Nepal and elsewhere
- 1981: First measurements of pollution levels in India
- 1984: International meeting to decide on needed research
 <u>Chose randomized control trial (RCT) of ALRI</u>
- 1986-89: Unfunded proposals to do RCT in Nepal
- 1990: WHO establishes committee to find best sites
- 1990-1992: Criteria established and site visits made
- 1992: Highland Guatemala chosen
- 1991-1999: Pilot studies to establish data needed for proposal
- 1996-1999: Unfunded proposals
- 2001: NIEHS funding secured
- 2002-2005: Fieldwork completed
- 2011: Main results published
- 25+ years from deciding to conduct RCT to results!



RESPIRE: (Randomized Exposure Study of Pollution Indoors and Respiratory Effects)



Traditional 3-stone open fire

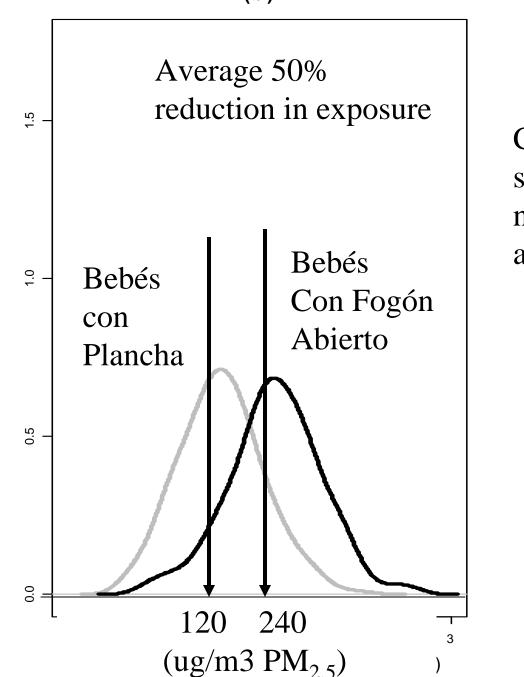
Chimney woodstove



Unpublished results from RESPIRE have been removed

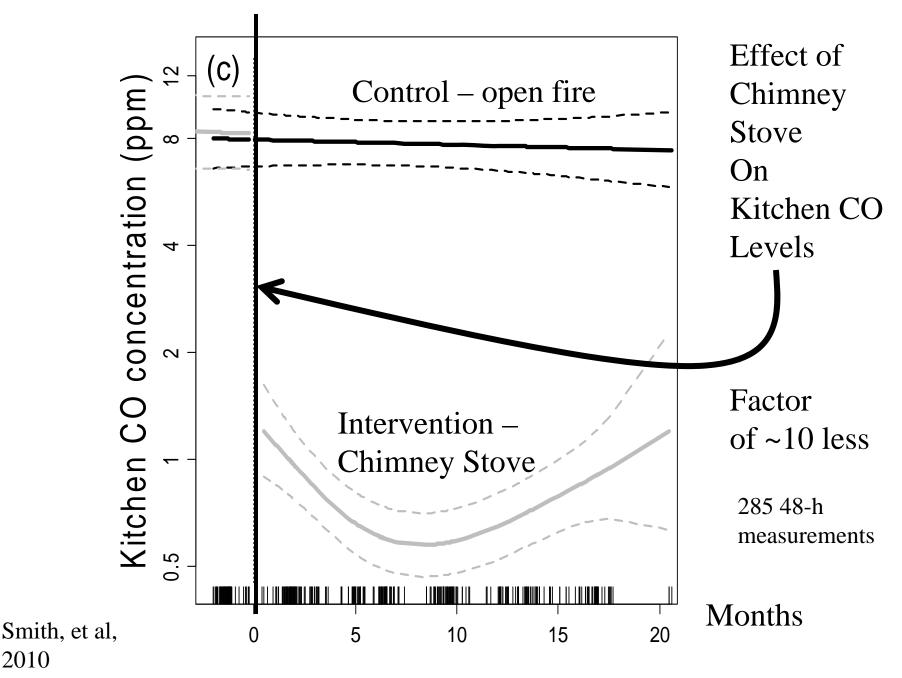
Watch the website below where they will be posted as soon as they are published.

http://ehs.sph.berkeley.edu/krsmith



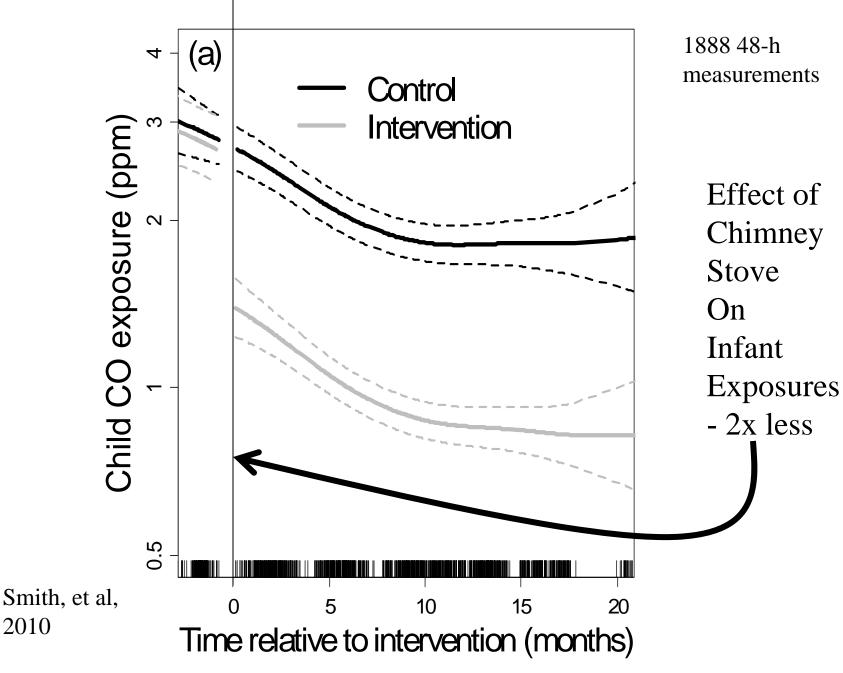
Chimney stove did not protect all children

Guatemala RCT: Kitchen Concentrations



2010

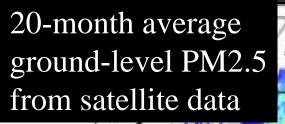
Infant Exposures



Effect of Plancha on PM2.5 Log Scale 1000 Open fire ~90% Reduction, sig. 100 Plancha 48-h ug/m3 10 1 Kitchen

Reasons that child personal exposures did not lower as much as kitchen levels:

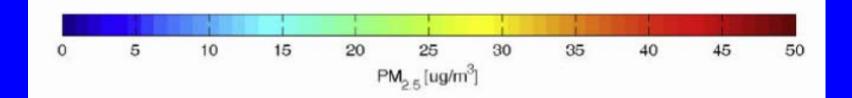
- --Time-activity: the kids do not spend their entire day in the kitchen
- --Household (or "neighborhood") pollution: a chimney does not reduce smoke, but just shifts it outside into the household environment, where the difference between intervention and control households was less
 --Other burning around house not different



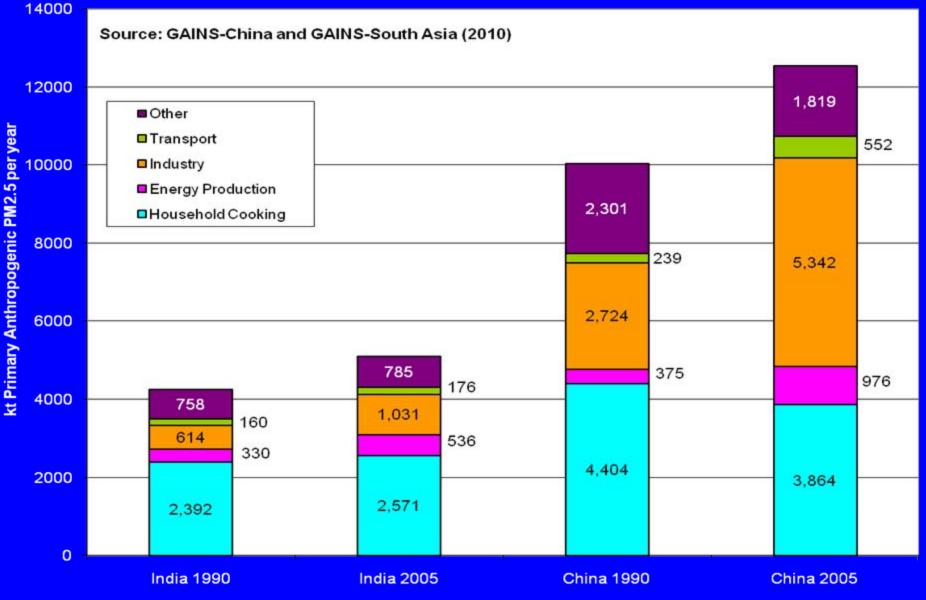
45

MODIS

Large areas of rural India and China have high ambient air pollution – much from household fuel

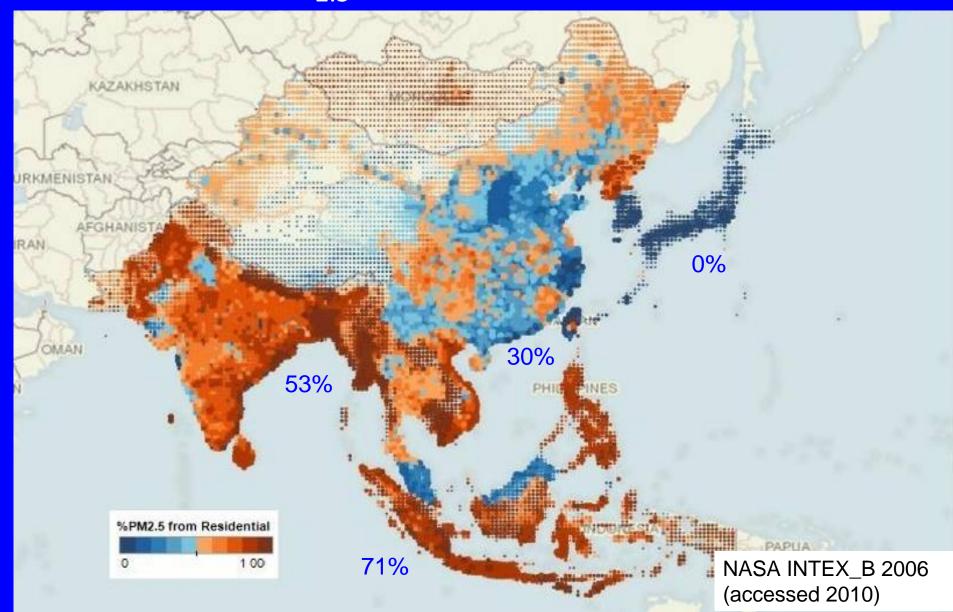


Sources of Primary PM_{2.5}: India and China

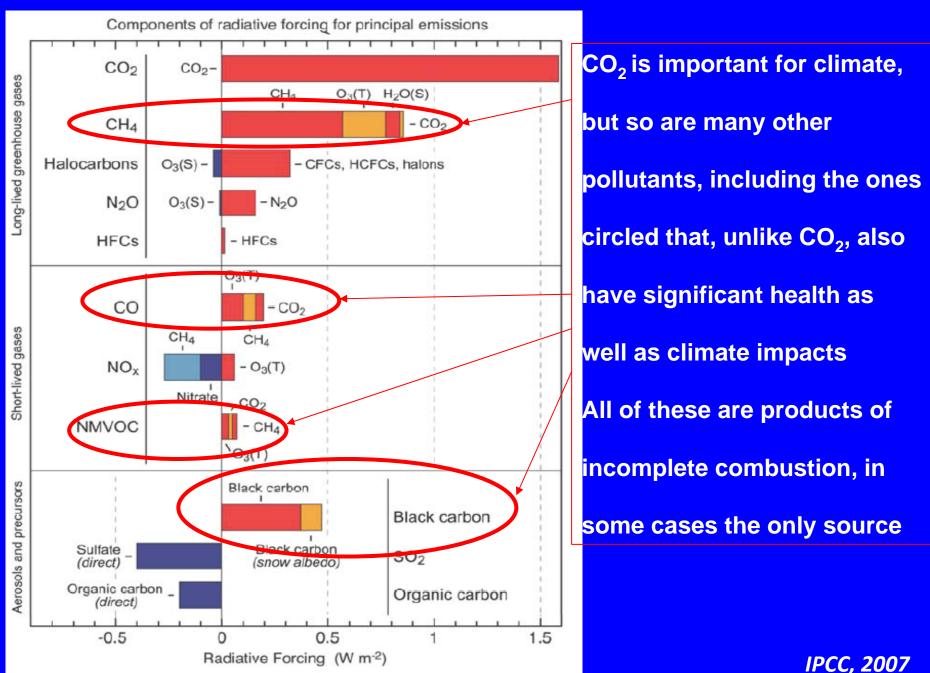


IIASA, 2010

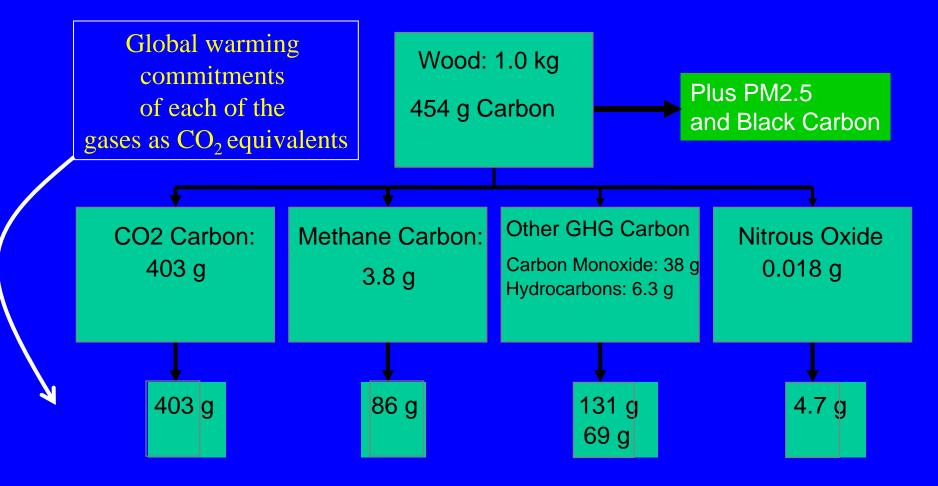
NASA INTEX_B Database Percent PM_{2.5} emissions from households



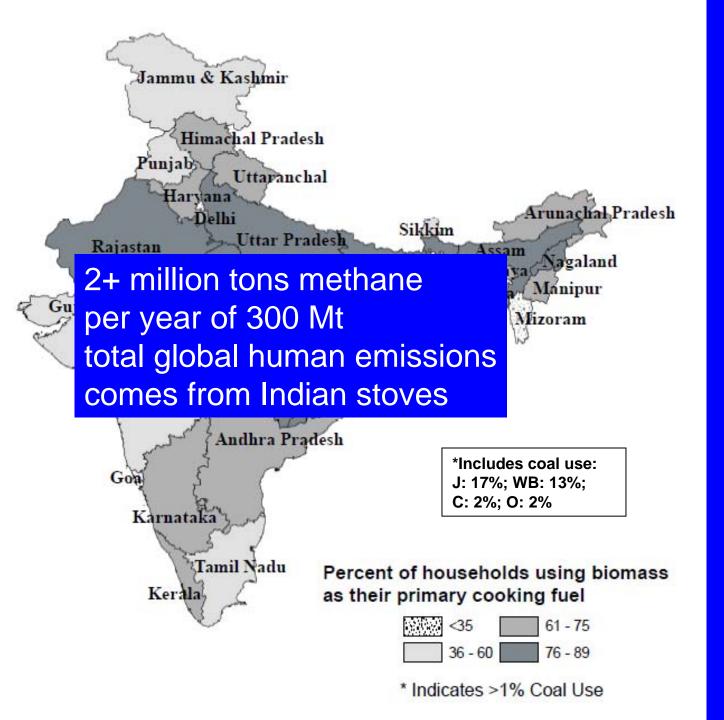
Global warming in 2005 due to all human emissions since 1750



Greenhouse warming commitment per meal for typical biomass-fired cookstove in China



Zhang, et al., 2000

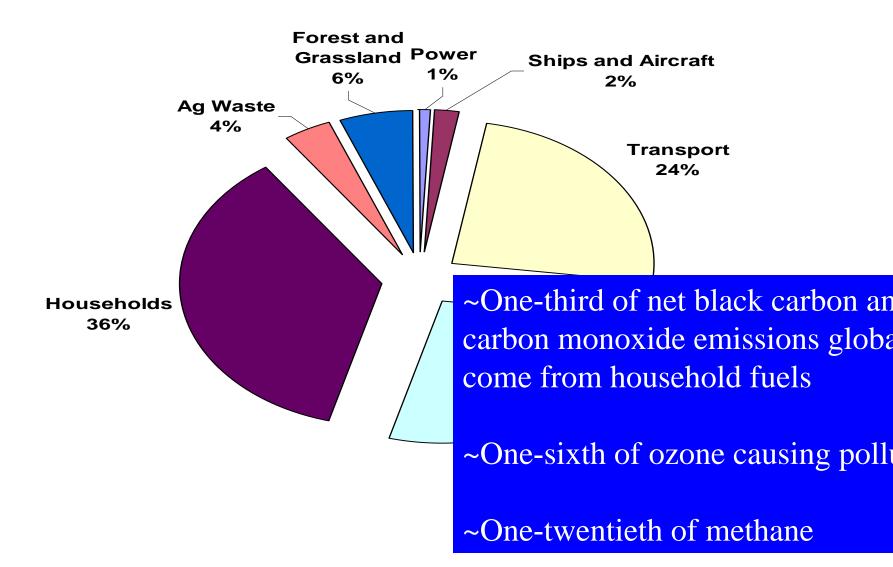


India in 2005

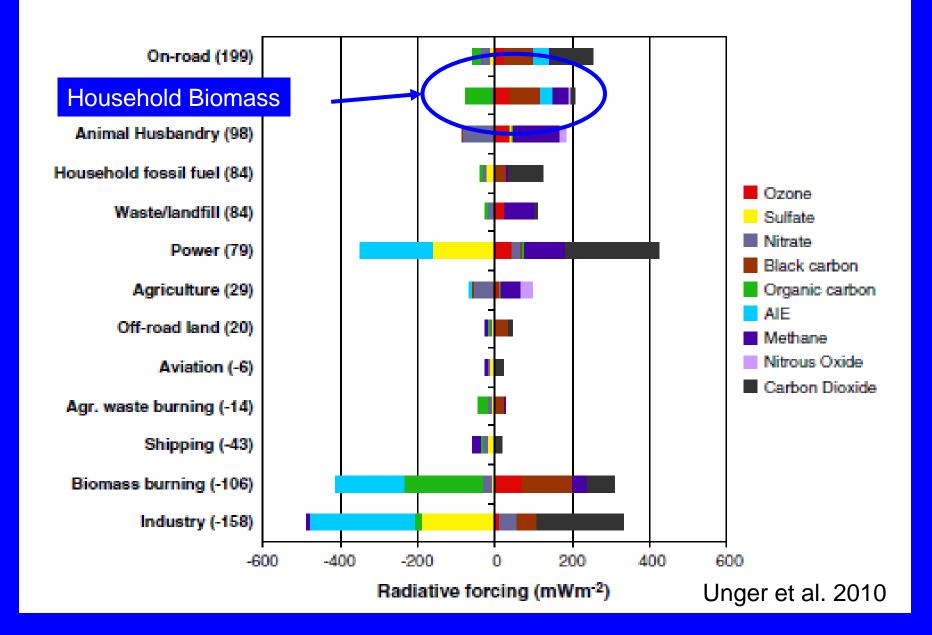
Venkataraman et al. 2010

Controllable Global Warming from Black Carbon Emissions

Net of OC, Forcings from IPCC, 2007: 0.25 W/m² Inventory from T Bond Database, V 7.1.1 Feb 2009



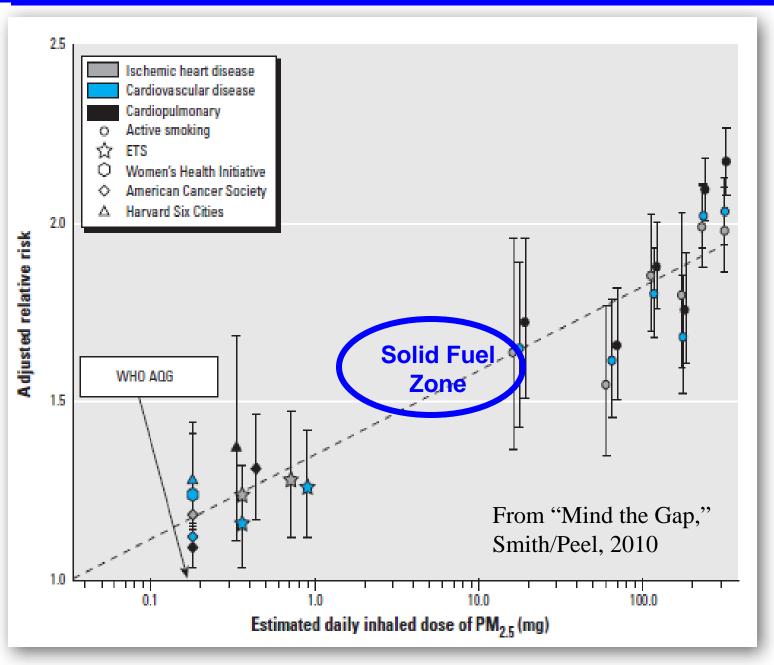
Climate Warming in 2020 Under Present Trends



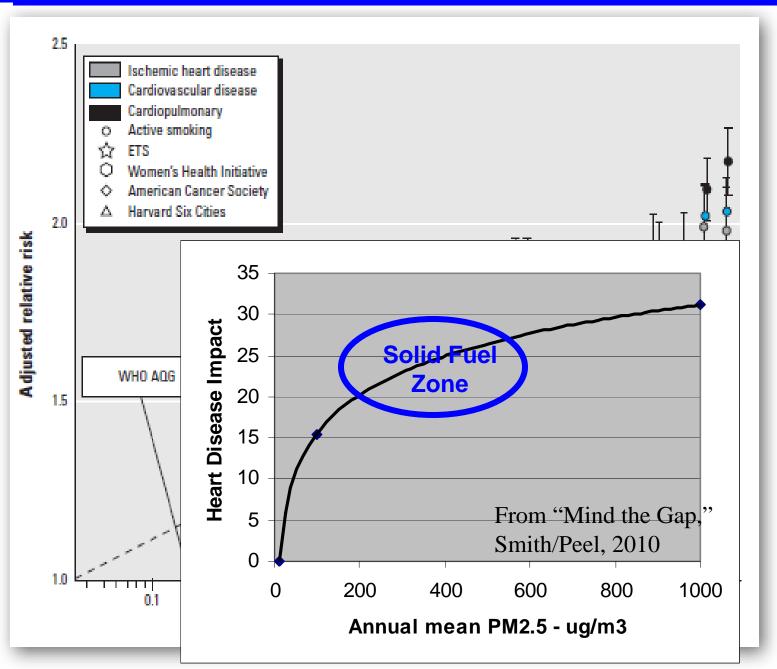
Household Fuels and Climate

- Climate impacts come from non-renewable wood, i.e., from net CO₂ emissions due to deforestation
- Poor combustion also leads to other emissions such as the relatively well-understood GHGs – methane and nitrous oxide – which are "Kyoto" GHGs
- In addition, a wide range of less well-understood shortlived GH-related emissions are emitted including
 - CO and black carbon warming agents
 - Ozone precursors warming But also cooling agents such as sulfates and organic carbon particles
- There are also indirect climate impacts of these pollutants including
 - Reducing carbon capture of forests by ozone damage
 - Darkening of snow/ice by black carbon

Heart Disease and Combustion Particle Doses



Heart Disease and Combustion Particle Doses



Indian National Biomass Cookstove Initiative (NCI)

- Saran Criterion: "Our aim is to achieve the quality of energy services from cookstoves [for all Indian households] comparable to that from other clean energy sources such as LPG." Dec 2, 2009
- Major innovations to be encouraged in technology, dissemination modes, and M&E – global innovation prizes and perhaps guaranteed sales – X Prize Foundation with MNRE and IITD
- Government backup of private sector in terms of testing, standards, benchmarks, smart subsidies, etc.
- Development of an "Indian Cooking Cycle" for testing
- Work on biomass processing and institutional stoves
- Role for public sector for reaching vulnerable groups

XPF/GOI/IITD Innovation Prize

- Global engage combustion engineering labs everywhere
- Perhaps not for stove *per se* stove is phenotype
- Perhaps for combustion unit with common dimensions that can be used locally to create stoves that fit local needs
- Very low emissions, very long lifetime, and reasonable cost – a serious challenge

Modes of Dissemination

Geographic

Support R&D Microfinance Marketing Protect IPR Subsidy to producer Subsidy to consumer

Commercial

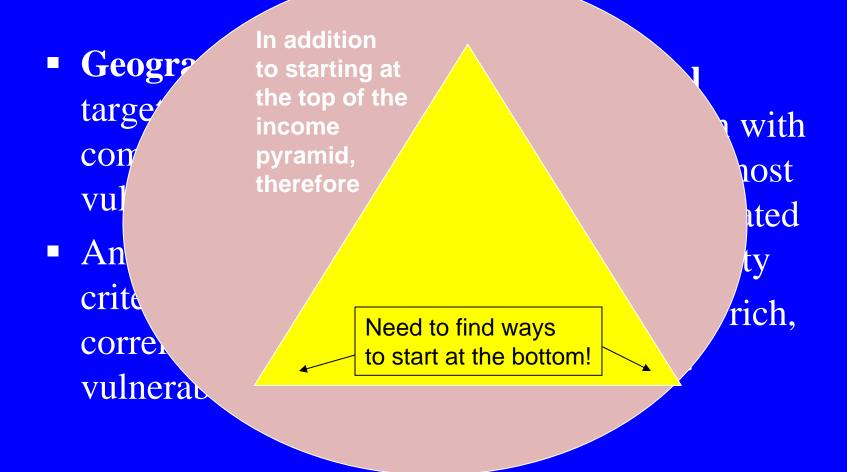
Areas of convenience Areas chosen politically Areas with deforestation Areas close to glaciers

> Refugees Disaster victims Other?

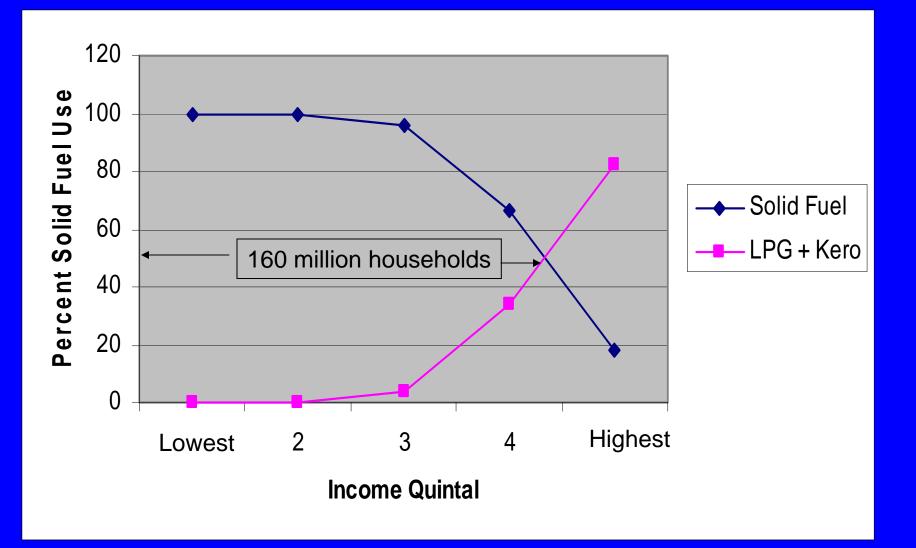
Why Vulnerability?

- Every house not the same for health impacts.
- Number of young children different
- Background disease rate different
- Interacting risk factors different, particularly poverty
- With limited resources, why not start with the most vulnerable first?

Alternative Approaches Do Not Target the Vulnerable



Distribution of Household Cooking Fuel by Income in India



NFHS, 2006

Rural Housing Program

Vulnerable populations in India now being reached by national programs

Women's Literacy Program Rajiv Gandhi Scheme – rural electrification

Antenatal Care System

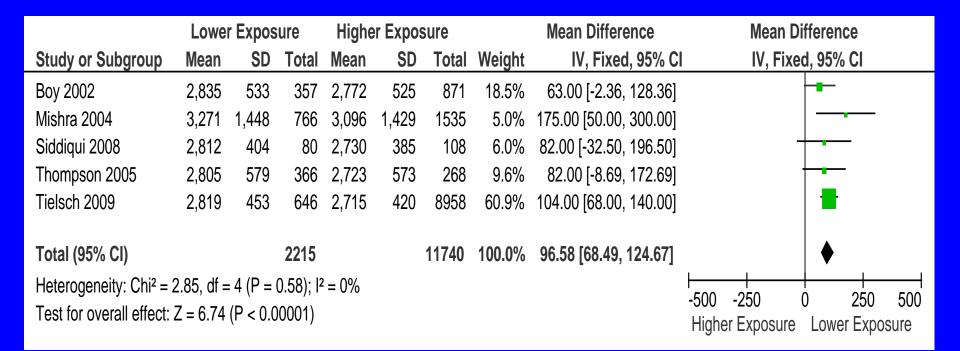
Antenatal Care System

- ANC centers run through public health system with village nurses and Asha workers
- Covered ~25% of all pregnancies in 2006 risen since
- Coverage varies nationally, but highest coverage in poorest groups (middle income and rich go to doctors)
- In the stove world, there could be no more vulnerable group than pregnant women attending a public antenatal clinic.
- Targets vulnerable group without raising issues of equity

The Newborn Stove (NBS) Program

- Pregnant women going to public pre-natal clinics are among the most vulnerable groups
- Already in the system and receiving iron/FA tablets, hygiene/nutrition education, etc.
- Potential for dealing with neo-natal mortality, which is refractory partly because of lack of viable interventions at that age
- Feasibility studies being planned in Haryana for informing major NBS Trial

Birth weight difference (low minus high exposure) – analysis of studies



All estimates: +96.6g (68.5, 124.7) Excluding self-reports +93.1g (64.6, 121.6)



SMALL, SMART, FAST, & CHEAP

monitoring devices for household energy & health



Alay Pillarisetti, lise Ruiz-Mercado, and Nick Lam on behalf of Prof. Kirk R. Smith's Research Group at University of California, Berkeley Visit ebs.seb.berkeley.ede/krswith for more information

STOVE USE MONITORS UTILIZATION

Time-of-use measuring devices allow more accurate estimations and objective definitions of usage patterns including cooking periods, meal times, and technology adoption rates.

Stove Use Monitors (SUMS) quantify utilization of cookstoves to improve estimates of personal exposure and environmental benefits related to household energy use. SUMS are based on commercially available, low-cost, small temperature loggers.



The stainless steel temperature sensors are the size of a coin and can record time, date, and temperature. Programming and downloading data can be easily performed in the field. They are easy to use, unobtrusive, waterproof and tamper-resistant. They come with algorithms and software to systematically assess stove use patterns.

Measurements of stove surface temperature can be used to test the effectiveness of behavioral interventions on stove use. Because they give precise, unbiased measures of a simple physical parameter, statistically reliable information is provided using smaller sample sizes than required for a household survey.

PARTICLE AND TEMP SENSOR CONCENTRATION

The ability to measure concentrations of small airborne particles is vital in understanding adverse health effects from combustion-derived air pollution. Available instrumentation to conduct such measurements is complex and expensive. Such devices are appropriate for developed countries and ambient air monitoring stations. However, their routine use in real-world household environments is expensive & cumbersome. Monitoring locations may also be remote, where security is questionable and electrical power not available,

limiting the applicability of conventional instruments. In an effort to fulfill the needs for small, smart, fast, and cheap particle monitors that could be

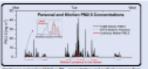
deployed easily in remote settings, a commercial smoke detector that uses optical scattering was identified and modified so that real-time signals could be logged continuously. This modified particle and temperature sensor is dubbed the UCB-PATS. Customized software handles data importing, graphing, and manipulation.



Device Software & Sample Output

Each device is controlled by polyness allowing assignment insuch, data downlos and manipulation, and experting of data time to tertian analysis. Review or with the continuum over a sectial and or viewe USE to Sectial converter.





Alle.

For more information, google "Kirk R Smith" • To acquire devices, visit berkeleyair.com

TIME-ACTIVITY MONITORING LOCATION

Measurement of exposure to pollutants is vital to the field of environmental health. The significance of a hazard depends on the amount of time a person is in contact with it. For instance, high indoor air pollution levels have been found in many homes globally. The risk of respiratory disease depends on the amount of time people spend in the presence of this pollution.

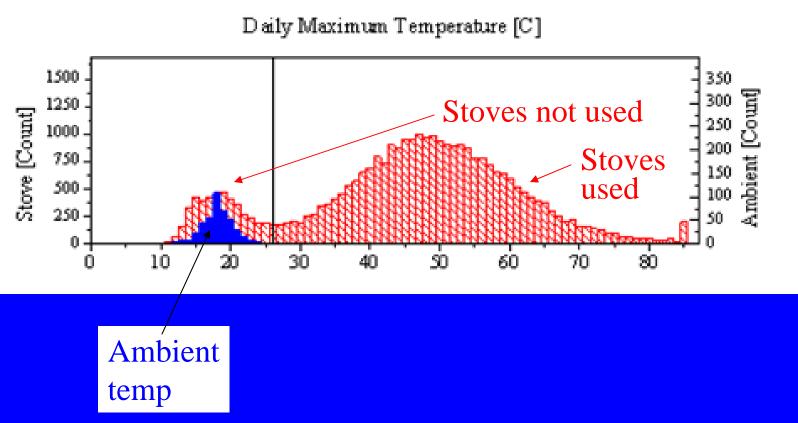
Time-Activity Monitoring System (TAMS) detects the presence or absence of individuals in an enclosed space. The system consists of one to five small ultrasound emitting devices worn on an individual's clothing. Each produces a distinct pattern that is emitted every few seconds. An ultrasound receiver is mounted on the wall of a room and detects the unique pattern from the device worn by an individual.

If the identifying signal pattern emitted from a particular locator

is received a certain number of times during a minute, that locator, and presumably the person wearing it, is recorded as being present in the room. Field trials show good results, with a 93% accuracy rate as measured against direct observation.

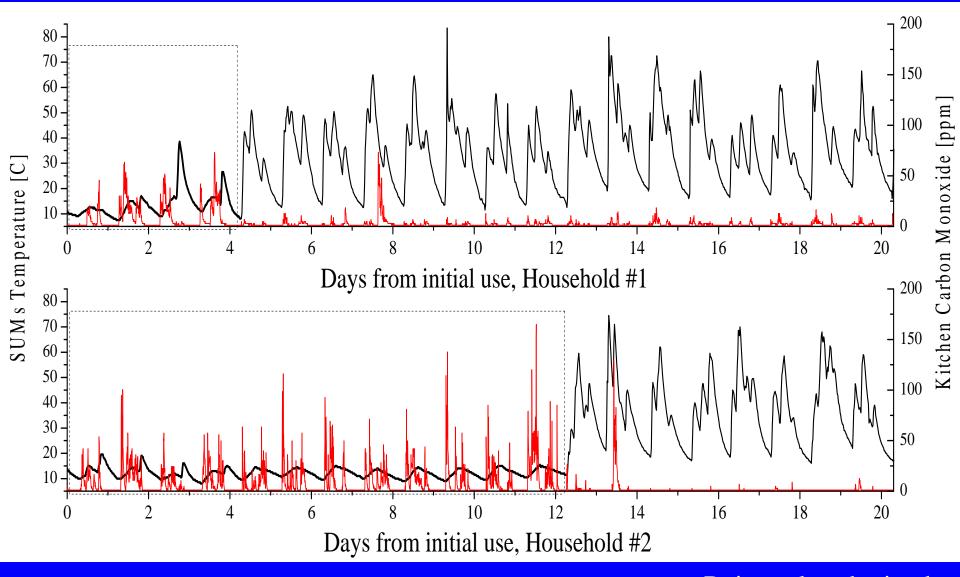


30,122 stove-days in 80 chimney stoves in the Guatemalan highlands

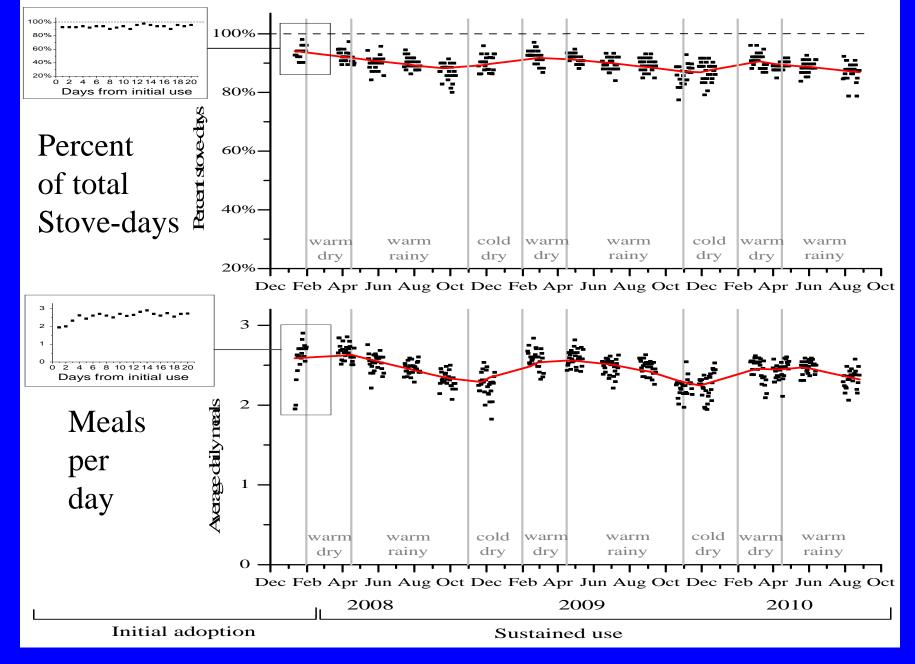


Ruiz et al, submitted

Stove Use Monitors (SUMs) in Action

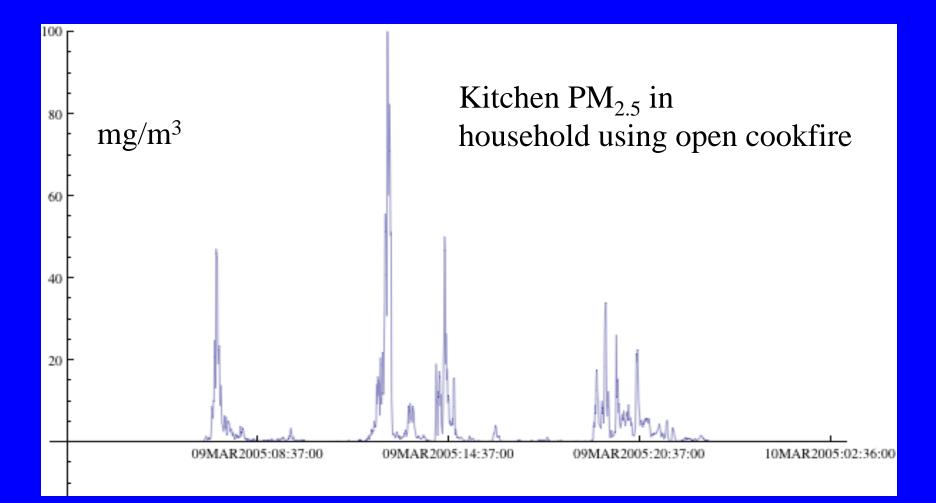


Ruiz et al., submitted



Ruiz et al., submitted

UCB Particle Monitor <u>How many hours should we measure to obtain</u> <u>good estimate of the long-term mean?</u>



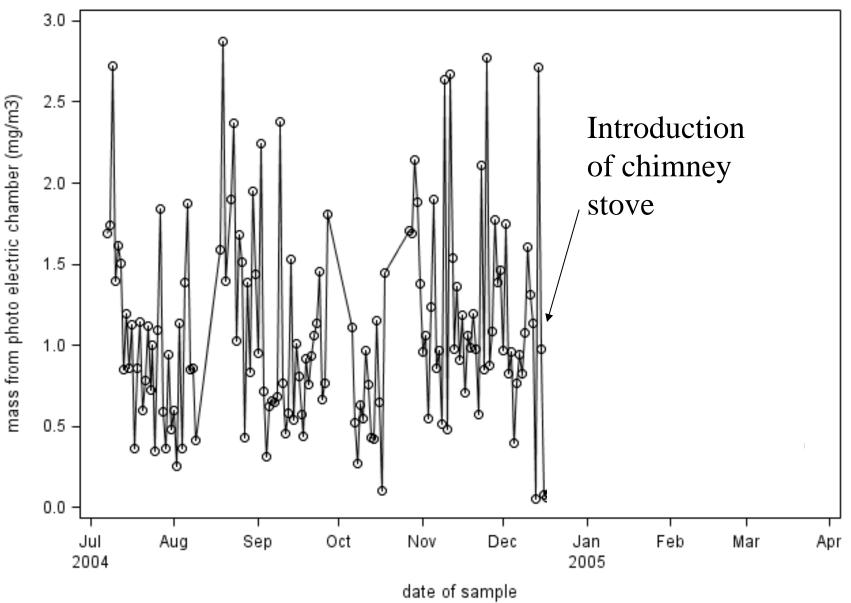
Inter-instrument Comparison: 30 UCB-PATS UCB Particle and Temperature Monitoring System (custom PM monitor using smoke alarm technology)

> Lopez Kitchen La Cienaga Plancha with chimney

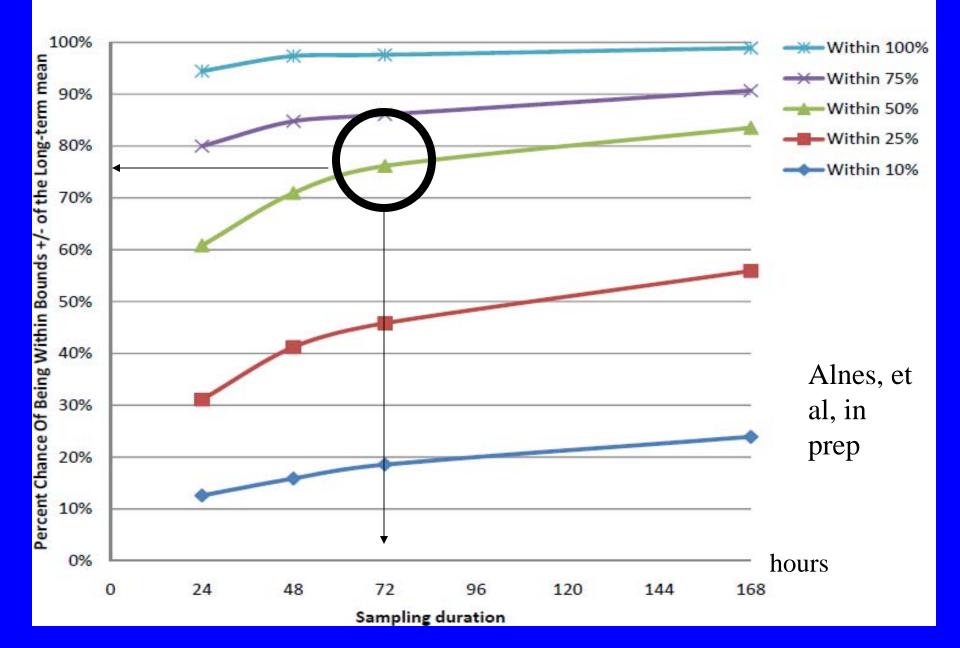
5 PM Sept 24 to 10 AM Sept 25, 2004.

Long-term Household Measurements

hhid=hh04041020



How Close to the True Mean With One Measurement?



Wood is the fuel that

- Heats you twice as is said?
 Once when you chop it and
 Once when you burn it
- Or four times?
 - The fever from respiratory infection and
 - Global warming
- Better combustion will get rid of the second pair

Many thanks

Publications and presentations available at my website: <u>http://ehs.sph.berkeley.edu/krsmith/</u>

Or just Google "Kirk R. Smith"