Energy, Technology and Development Challenges for Innovation Policy: What matters most?

Bill Clark

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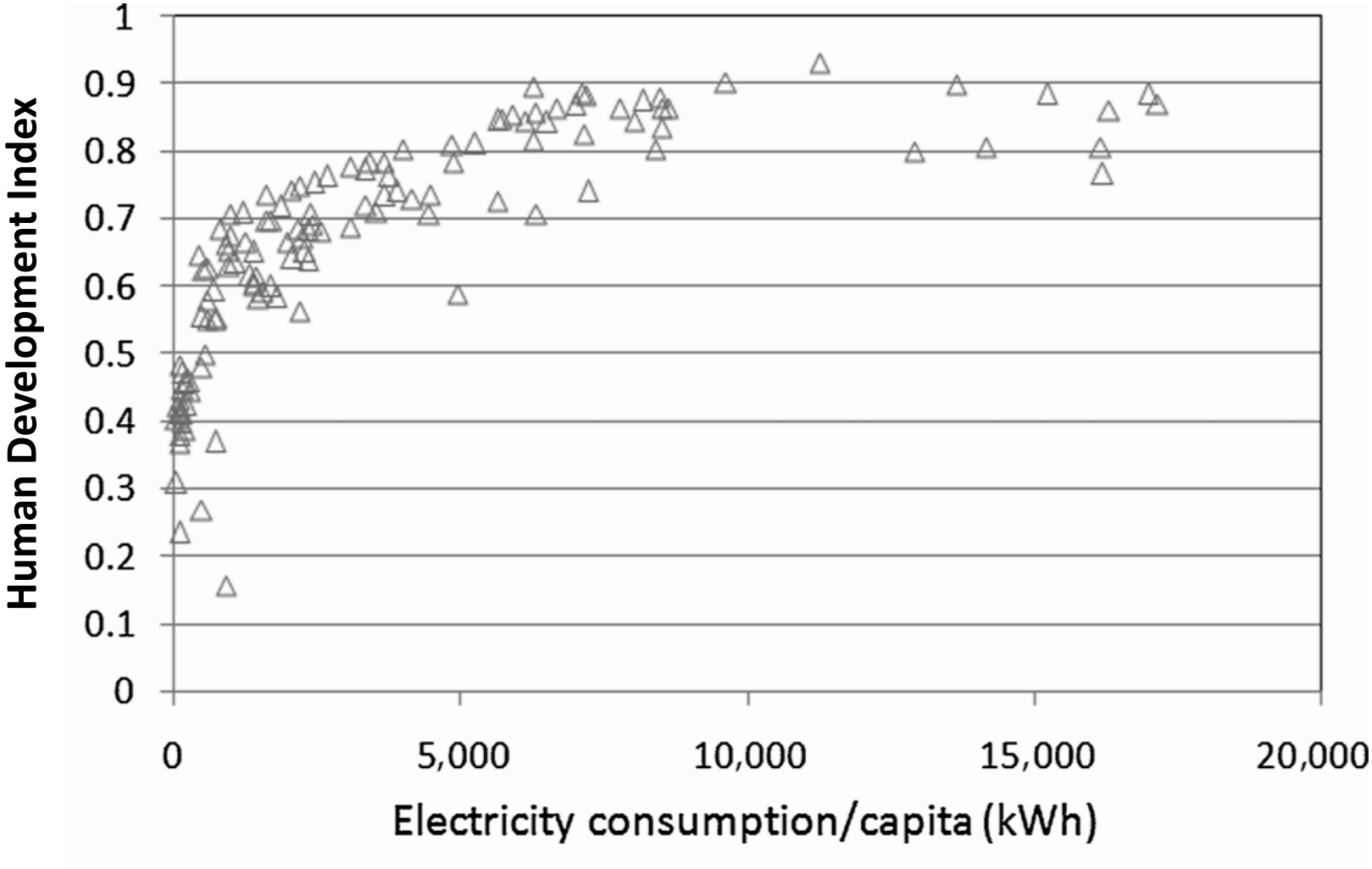
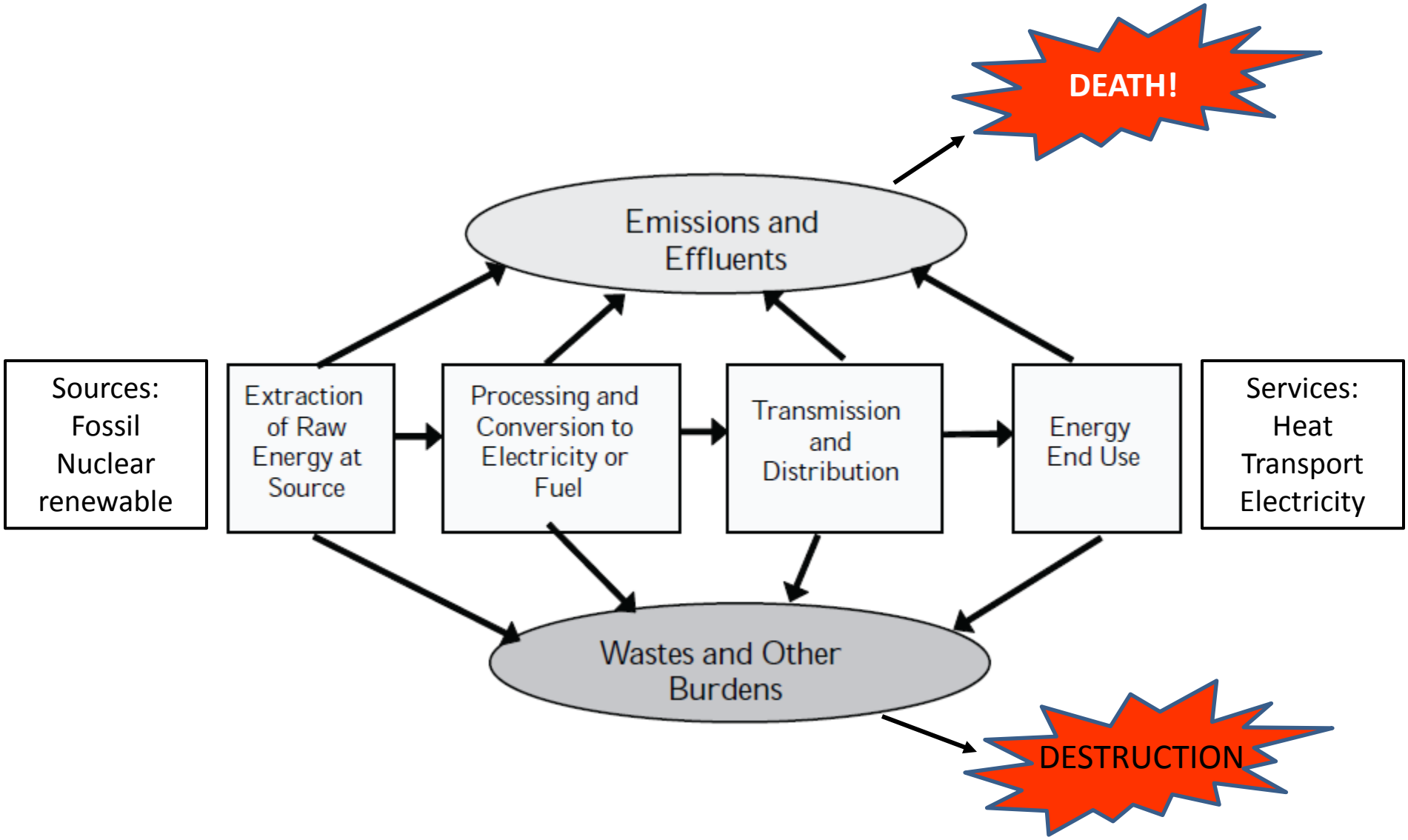
Well-being and Energy Use



(Data from 2010)

(Chikkatur et al., 2011, AnnRev Envir Res)

Energy Use and the Environment



The Challenge?

Knowing where to hit it: Goals for Energy Policy?

- Goals?
- Sustainable Development, mid-1980s:
  - "meets the needs of the present without compromising the ability of future generations to meet their own needs."
  - World Commission Environment & Development
- Sustainable development, now:
  - "non-decreasing *intergenerational well-being"*
  - Measured as "inclusive" or "true" social worth of society's productive assets
  - World Bank, UNEP, Sarkozy Report, Arrow et al., etc.

Sustainable Development

$$W \equiv f(C_i, K, I)$$

- W is 'human well-being'
  - Aggregated intra- and inter-generationally
- C_i are 'capital asset' stocks from which flow services (including energy services…)
  - C_m is 'manufactured capital' (factories, homes, roads)
  - C_h is 'human capital' (health, education, population)
  - C_n is 'natural capital' (land, natl resources, climate, etc)
- K, I, are 'knowledge and institutions' (aka TFP)
- f is a forecasting model of $W_{aggregated}$, given $(C_i,K,I)_{now}$
  - JUST like a policy analysis gives us a present value of BAU,
  - …prior to assessing marginal impact of a policy change (eg. tax C)
- Sustainability question is whether W is non-decreasing
  - "without compromising ability of future generations to meet their needs"

Sustainable development:

$W = f(C_i, K, I)$

Capital Stock Estimates for China, 1995 – 2000

(per capita in 2000 US$; author's calc from Arrow et al. 2012)

	Natural capital	Human capital	Manuf. capital	TOTAL Capital
1995 capital stock	$3,200	$1,717,900	$3,100	$1,724,200

- Human capital (health) dominates, but dependent on VHL
- Natural capital ~ Manufactured capital
  - Least developed are 3-5X; OECD is ~1/3

Sustainable development:

$W = f(C_i, K, I)$

Capital Stock Estimates for China, 1995 – 2000

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	Natural capital	Human capital	Manuf. capital	TOTAL Capital
1995 capital stock	$3,200	$1,717,900	$3,100	$1,724,200
Change 1995-2000	-$400	$9,400	$2,000	$11,000
Growth rate/ yr	-2.6%	+0.1%	+10.8%	+0.1%

Per capita annual growth rates: C_T (0.1%) + K,I [TFP] (2.7%) = W (2.8%)

•Innovation matters!

•C_h results from losses to pollution, gains to other public health

•Natural capital vanishing (-50% in 25 years)

How Energy Development affects Sustainability

- Manufactured capital
  - Corrosion of building materials, monuments, electronics**
  - Inundation of coastal areas due to climate change *
- Natural capital
  - Natural resource depletion ***
  - Crop, forest, biodiversity damage **
  - Nutrient cycle disruptions (eg. eutrophication) *
- Human capital (via health**, not education)
  - Respiratory, cardiovascular disease,
  - Cancers and neurological disorders
  - Heat stress / dehydration
  - Workplace accidents

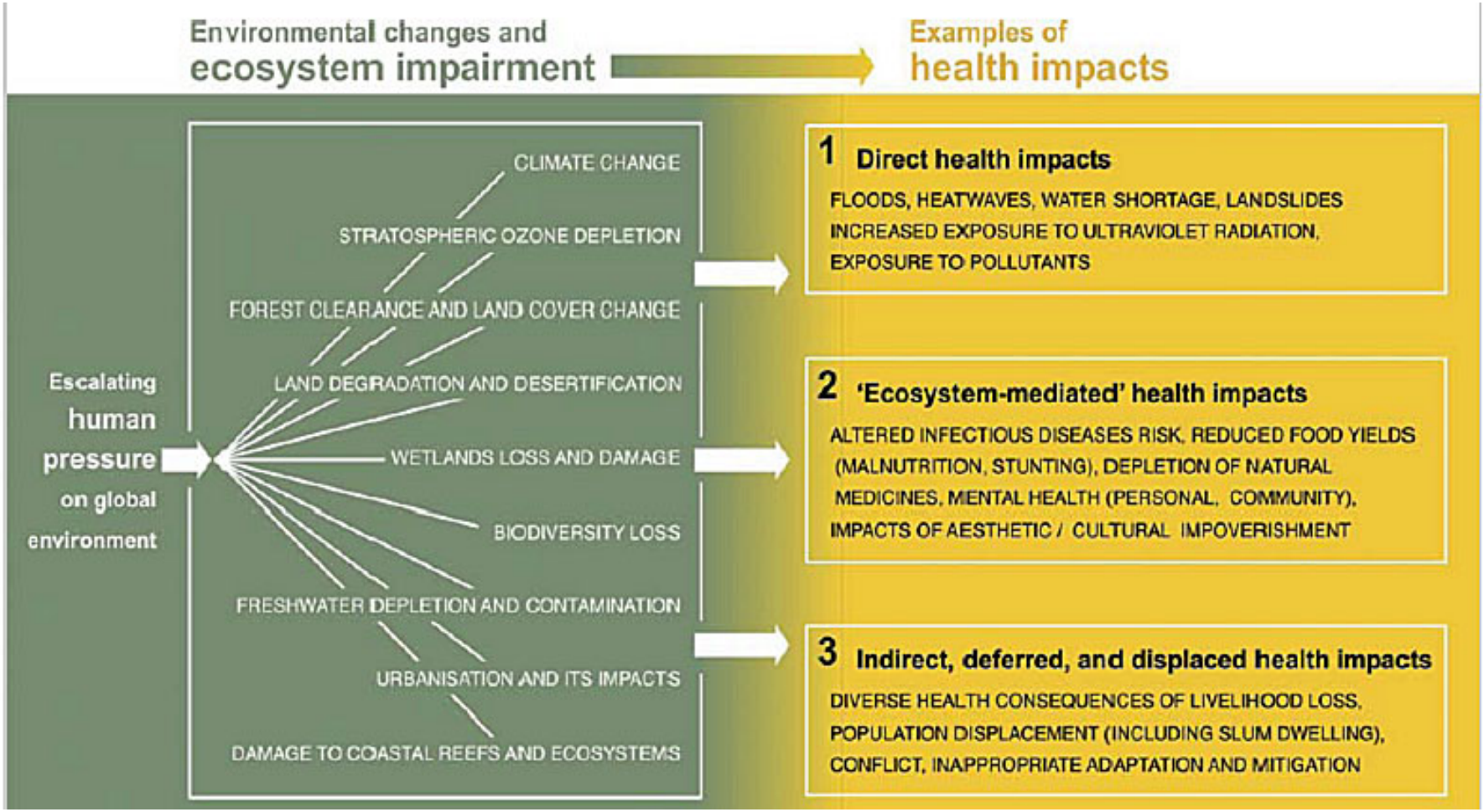
*(How well studied: *** a lot … * a little)*

(OECD, 2012)

Energy's impacts presently captured in Well-being accounts

- Climate impacts across all** [at \$50/ton C_{eq}]
- Manufactured capital
  - Corrosion of building materials, monuments, electronics
  - Inundation of coastal areas due to climate change**
- Natural capital
  - Natural resource depletion*
  - Crop*, forest*, biodiversity damage [*area, not quality]
  - Nutrient cycle disruptions (eg. eutrophication)
- Human capital* [overall life expectancy only]
  - Respiratory, cardiovascular disease,
  - Cancers and neurological disorders
  - Heat stress / dehydration
  - Workplace accidents

Human capital: How do changes to the environment damage human health?



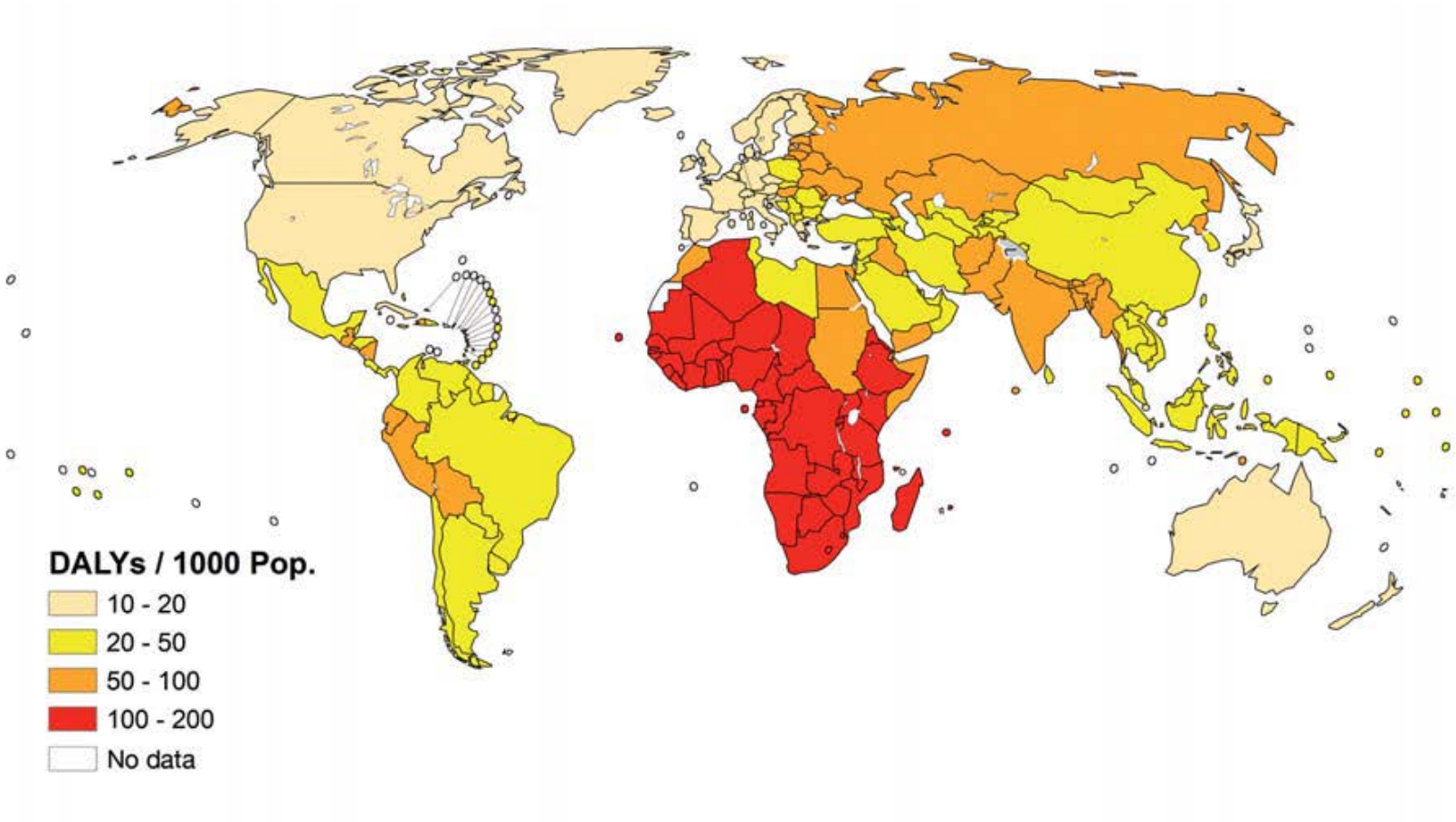
(MEA, 2005)

Quantifying health impacts of Energy

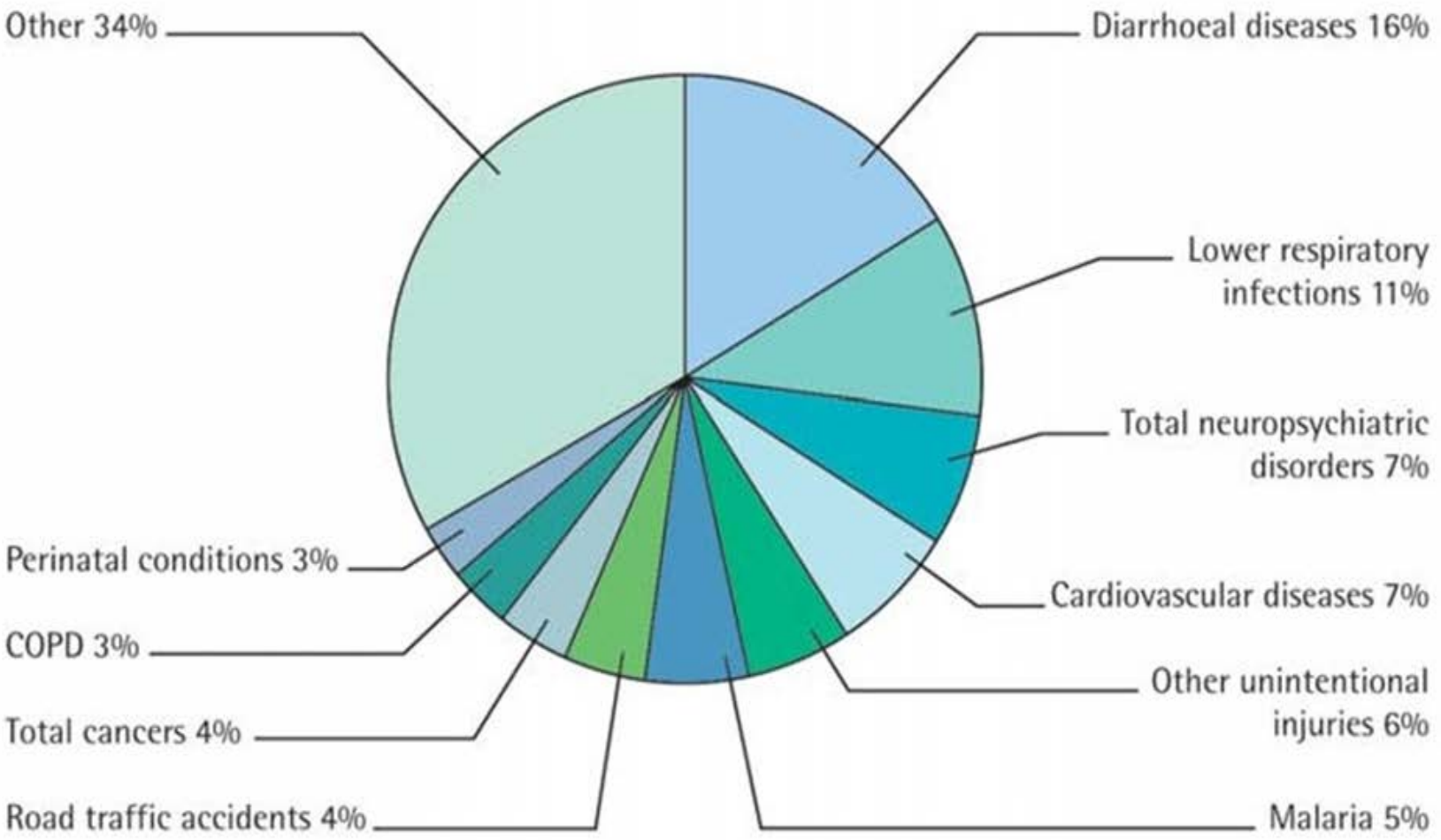
Insights from the Global Burden of Disease Survey

- What is the Global Burden of Disease Survey?
- What portion of the total burden of disease is due to environmentally-mediated causes?
  - About 25% (10-40% as 95% confidence limits)
- How is the total burden of disease cause by all environmental impacts distributed …
  - Across places…
  - Diseases
  - Environmental risks (including energy)

Disease burden attributable to Environmentally-mediated Disease



How is the total environmental burden partitioned among diseases? (%GBD*e*)



How is the total environmental burden partitioned among risks (%GBD*e - 2010*)

- Water sanitation and hygiene (10%)
- Noise
- Radiation
- Occupation
- Land use
- Climate change

Small in 2010, mostly changed impacts of comunicable diseases

- Indoor air pollution (50%)
- Outdoor air pollution (35%)

Mostly energy….

→ Conventional pollution (PM, SOx) dominates near term health picture, needs to drive policy

Integrating all air pollution damage in capital accounts for sustainability?

- Best we have is for
  - China (Ho and Jorgensen, MIT Press, 2007)
  - US (Muller, Mendelsohn and Nordhaus AER, 2011)
- Impacts across natural, manuf, health capital
- For all air emissions by industry sector
- Compare damages to benefits for society…

Contributions to Well Being by Industry Sectors in US Economy

Industry	GED/VA	GED
Solid waste combustion and incineration	6.72	4.9
Petroleum-fired electric power generation	5.13	1.8
Sewage treatment facilities	4.69	2.1
Coal-fired electric power generation	2.20	53.4
Dimension stone mining and quarrying	1.89	0.5
Marinas	1.51	2.2
Other petroleum and coal product manufacturing	1.35	0.7
Steam and air conditioning supply	1.02	0.3
Water transportation	1.00	7.7
Sugarcane mills	0.70	0.3
Carbon black manufacturing	0.70	0.4
Livestock production	0.56	14.8
Highway, street, and bridge construction	0.37	13.0
Crop production	0.34	15.3
Food service contractors	0.34	4.2
Petroleum refineries	0.18	4.9
Truck transportation	0.10	9.2

Notes: GED in $ billion per year, 2000 prices. Industries included in Table 2 have either a GED/VA ratio above 45 percent or a GED above $4 billion/year.

(Muller et al, 2011)

The Challenge?