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Estimating the Economy-wide Rebound Effect for U.S. Households

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Limits to Energy Efficiency

- Market failures
- Behavioral failures
  - Rebound effects

Research Questions:

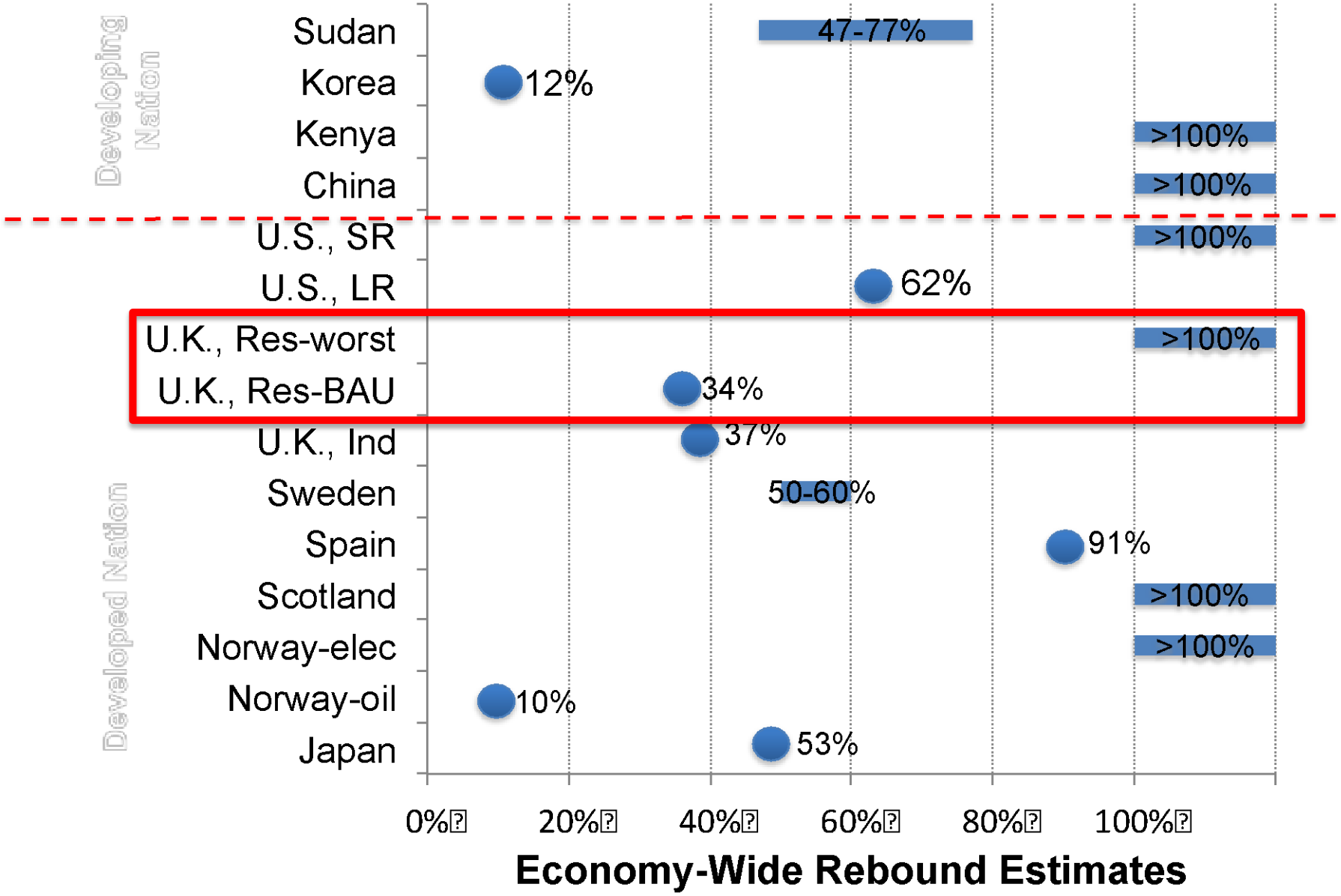
- How large is the rebound effect for U.S. households?
- How does the rebound effect vary by type of efficiency investment and income bracket?

Rebound Effect Taxonomy

potential energy savings (macroeconomic or engineering estimate)	actual energy savings			
	economy-wide rebound effect	direct rebound effect	substitution effect	own-price elasticity for energy services
			income/output effect	income elasticity of demand for energy
		indirect rebound effect		income elasticity of demand for non-energy goods; cross-price elasticity
			embodied energy	life-cycle assessment
			secondary effects	economic structure; macro energy price effects

Adapted from Sorrell, 2007

Previous Estimates of Economy-wide Rebound Effect



Sorrell, 2007; Guerra and Sancho, 2010; Saunders, 2010; Druckman et al., 2011

Method: Household Rebound Effect from Respending Energy Cost Savings

$$\text{Rebound} \begin{cases} = 1 - \dfrac{\text{Actual Savings}}{\text{Potential Savings}} = 1 - \dfrac{\text{Base - Efficiency w/ Respending}}{\text{Base - Efficiency w/o Respending}} \\ = \dfrac{E(\text{Respending in Goods})/\$_{\text{other-goods}}}{E(\text{Energy Efficiency Savings})/\$_{\text{energy}}} \end{cases}$$

Base Case: 2002 U.S. GDP per Capita/ 2003 Consumer Expenditure Survey

GTAP Income Elasticities

2002 EIO-LCA model

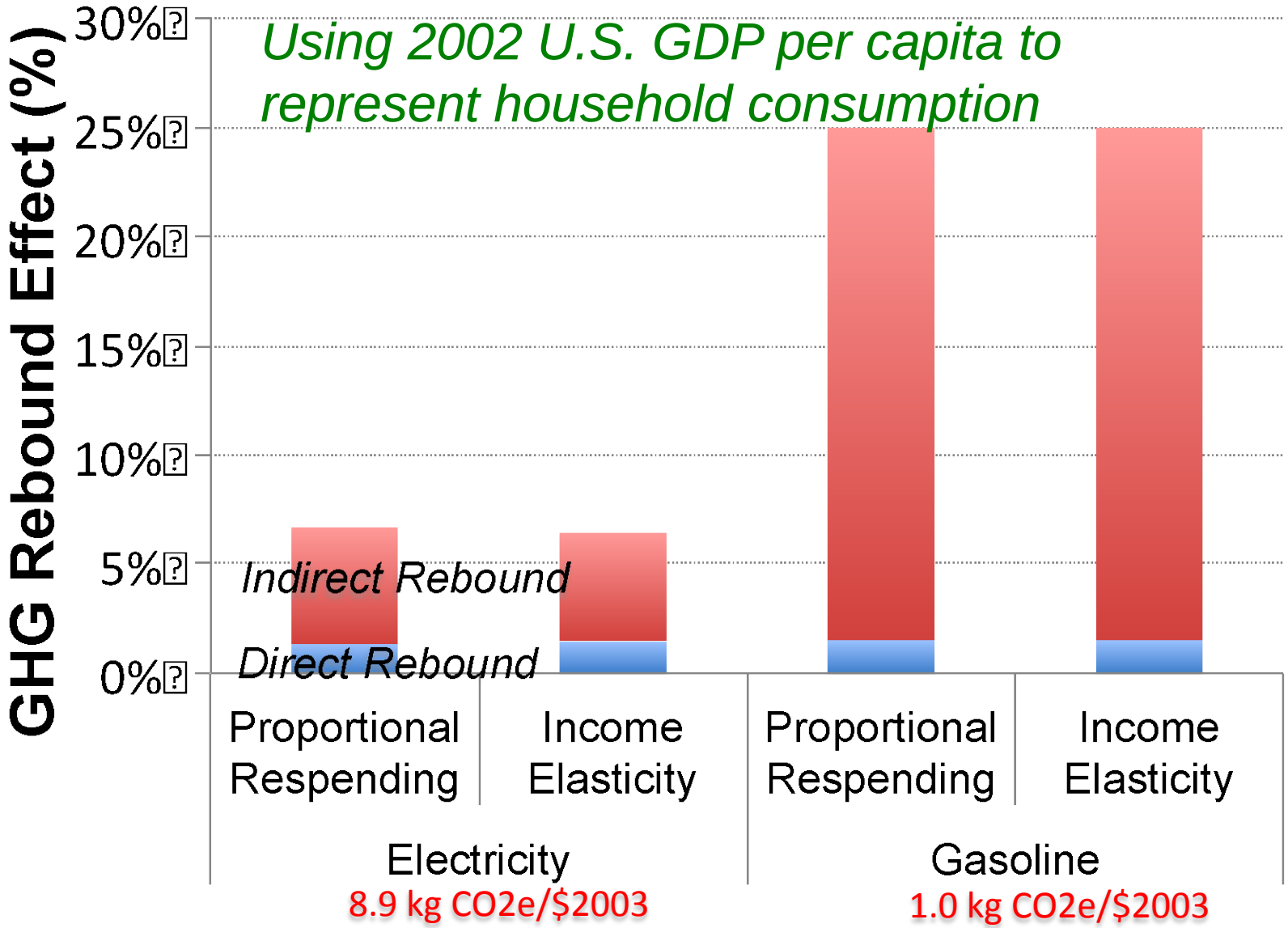
→

Rebound Estimate: by Fuel Type, Income-Level

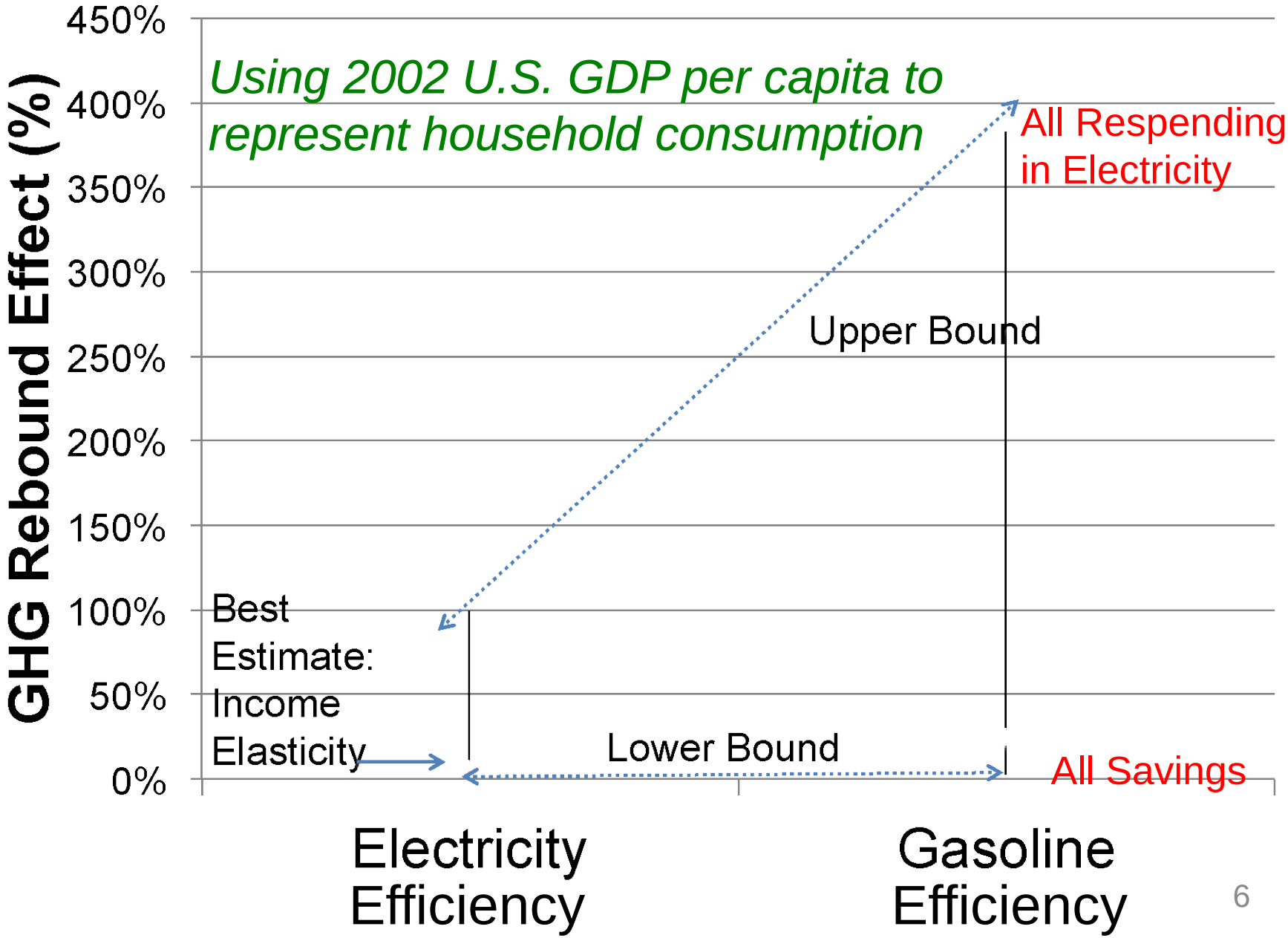
Efficiency Case:

- Relative (5%) Reduction in Final Demand for Electricity & Gasoline (in $)
- Technology agnostic
- Ignores capital costs

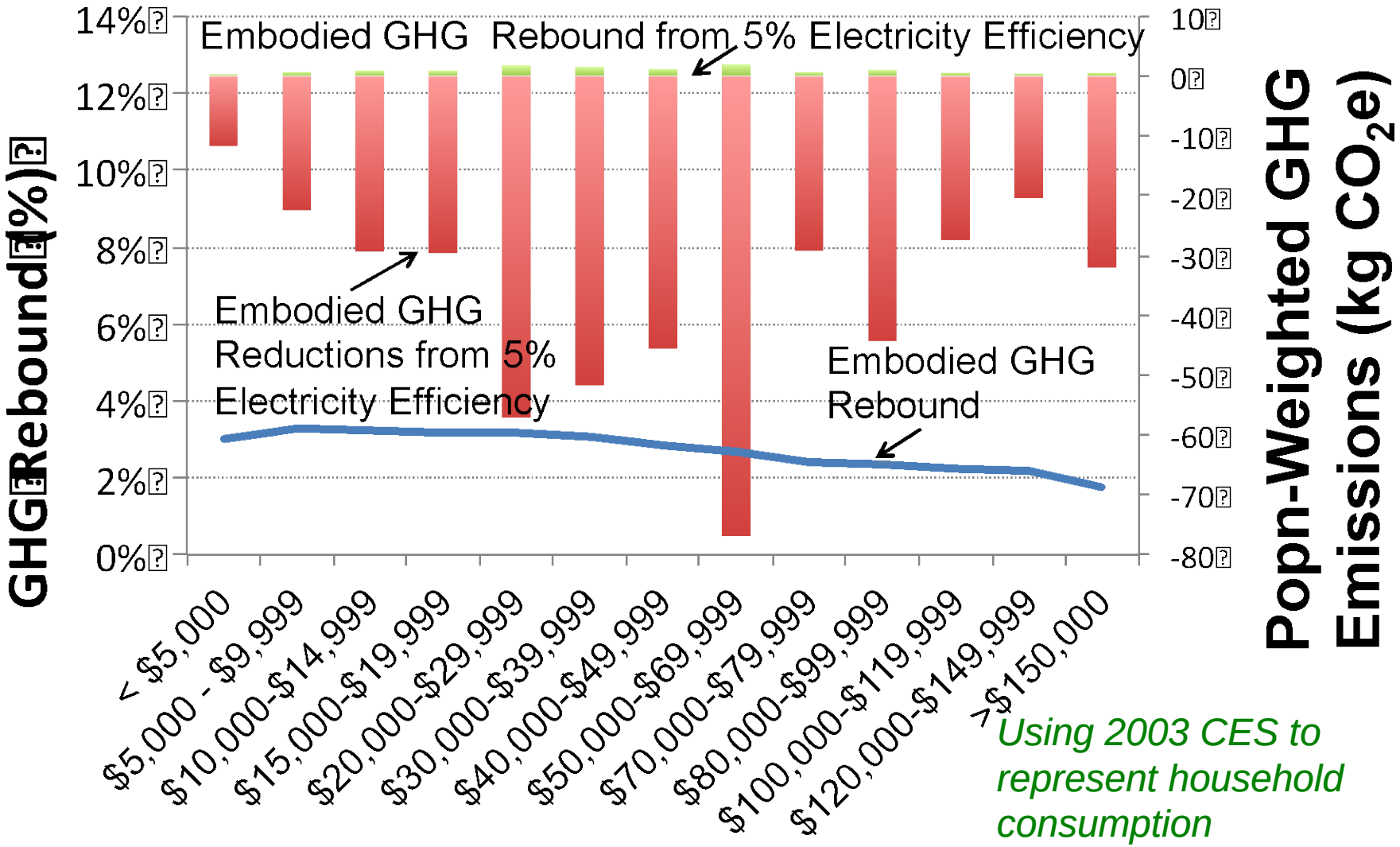
Results: Indirect Rebound is Much Larger Than Direct Rebound (excluding Price Effect)



Results: Wide Bounds for Rebound Effect



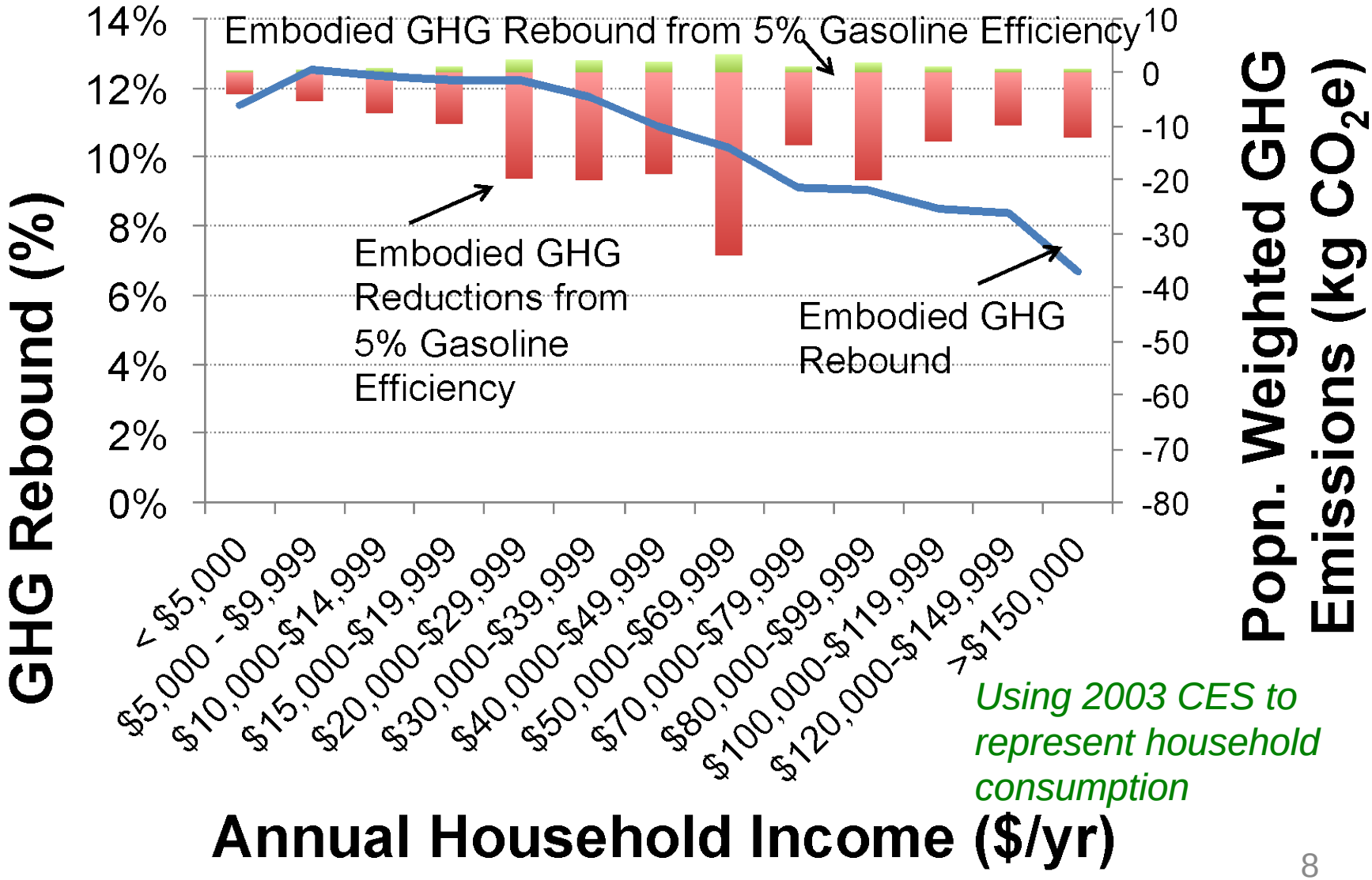
Results: Rebound Effects for Electricity Efficiency Vary by Income



Using 2003 CES to represent household consumption

Annual Household Income ($/yr)

Results: Rebound Effects for Gasoline Efficiency Vary by Income



Using 2003 CES to represent household consumption

Conclusions & Implications for Stakeholders

- Energy Modelers
  - Rebound varies more by relative emissions intensity and household income vs. income elasticity
  - Rebound depends heavily on energy prices & grid emissions factors
- Policymakers
  - Greater indirect rebound (%) with gasoline efficiency
  - Limited rebound effects for electricity efficiency
  - Large bounds on rebound (Energy mental account?)
- Households
  - Consumption patterns matter

Acknowledgements

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- Funding by:

- Contact Info: Brinda Thomas, brindat@cmu.edu

Back-up Slides

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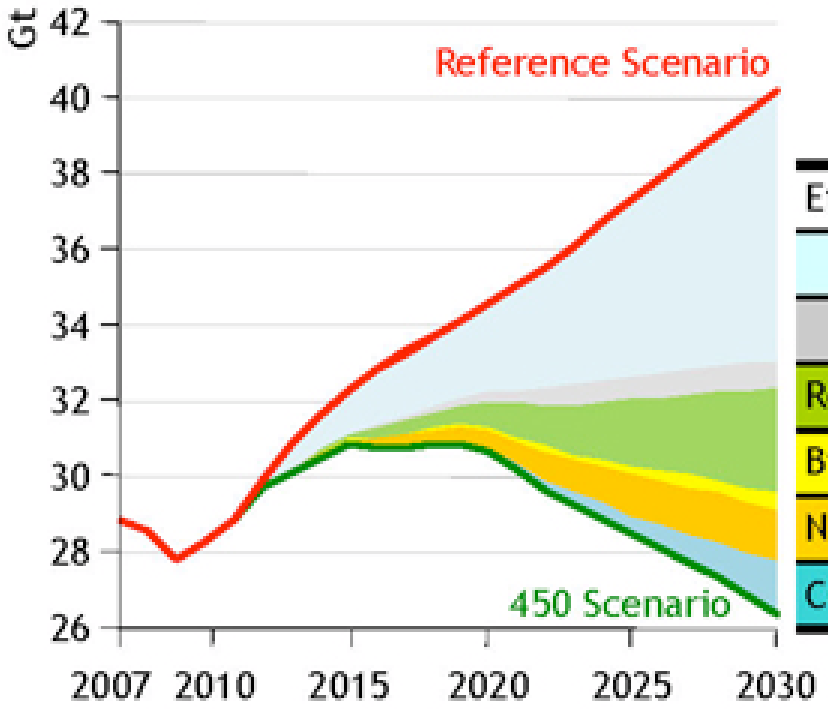
Energy Efficiency Opportunities are Substantial

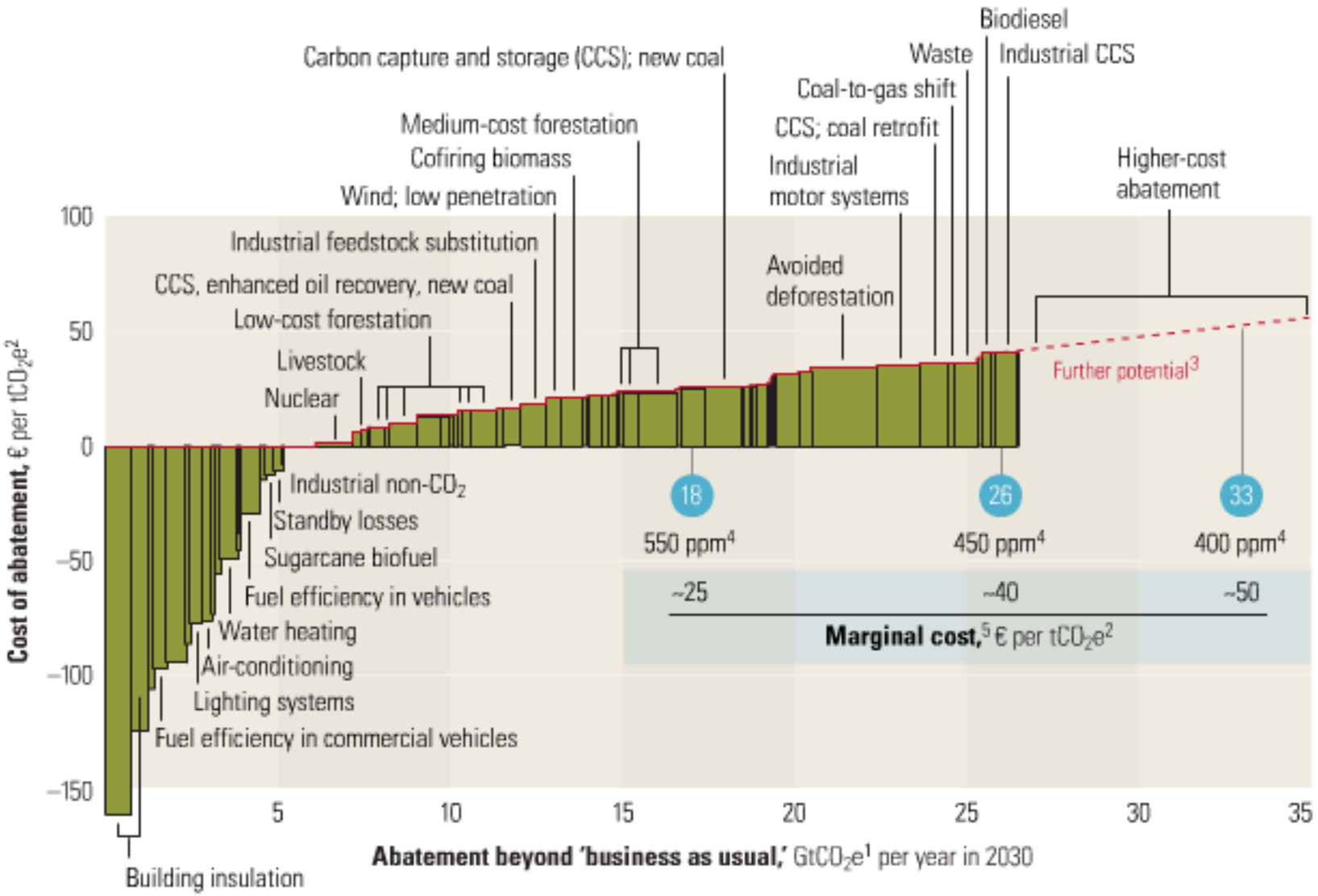


	Abatement ($Mt CO_2$)		Investment ($2008 billion)	
	2020	2030	2010-2020	2021-2030
Efficiency	2 517	7 880	1 999	5 586
End-use	*2 284*	*7 145*	*1 933*	*5 551*
Power plants	*233*	*735*	*66*	*35*
Renewables	680	2 741	527	2 260
Biofuels	57	429	27	378
Nuclear	493	1 380	125	491
CCS	102	1 410	56	646

IEA 2009

Efficiency contributes 66% of CO_2 abatement in 2020 and 52% of CO_2 abatement in 2030

… and Cheap



McKinsey & Company 2007

Rebound Effect Taxonomy v.2

potential energy savings (macroeconomic or engineering estimate)	actual energy savings		
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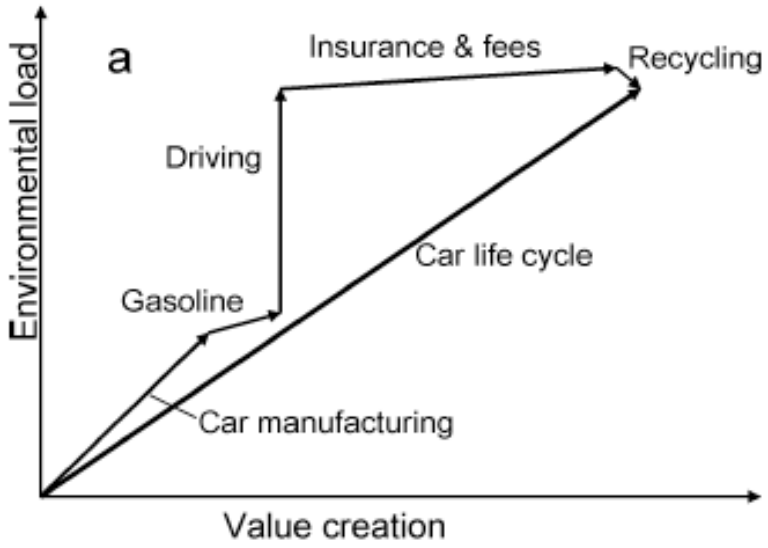
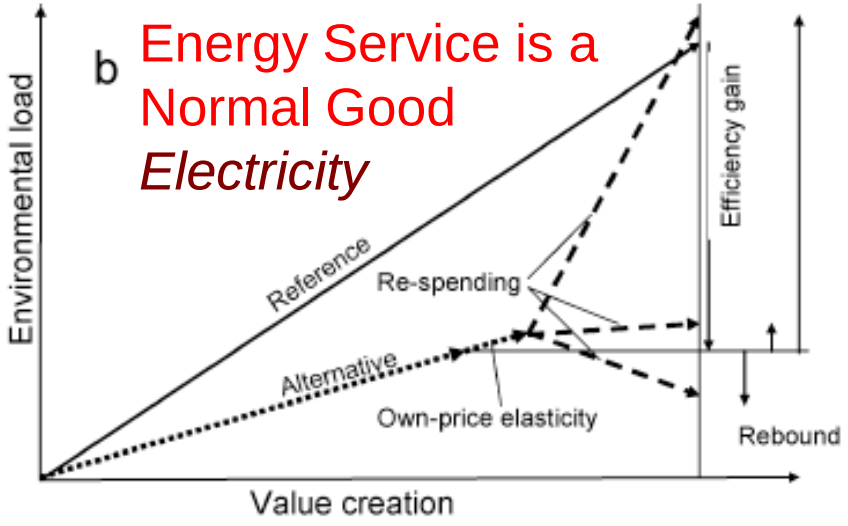
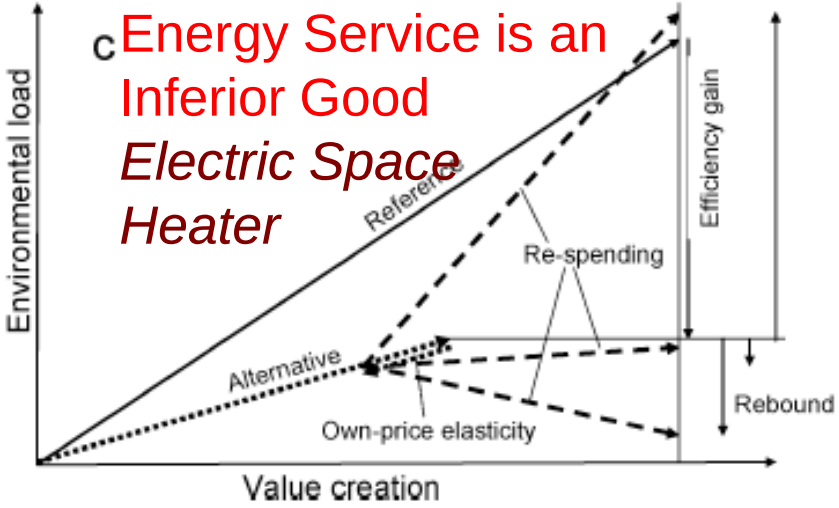
		embodied energy	life-cycle assessment
	economy-wide rebound effect	secondary effects	economic structure; macro energy price effects

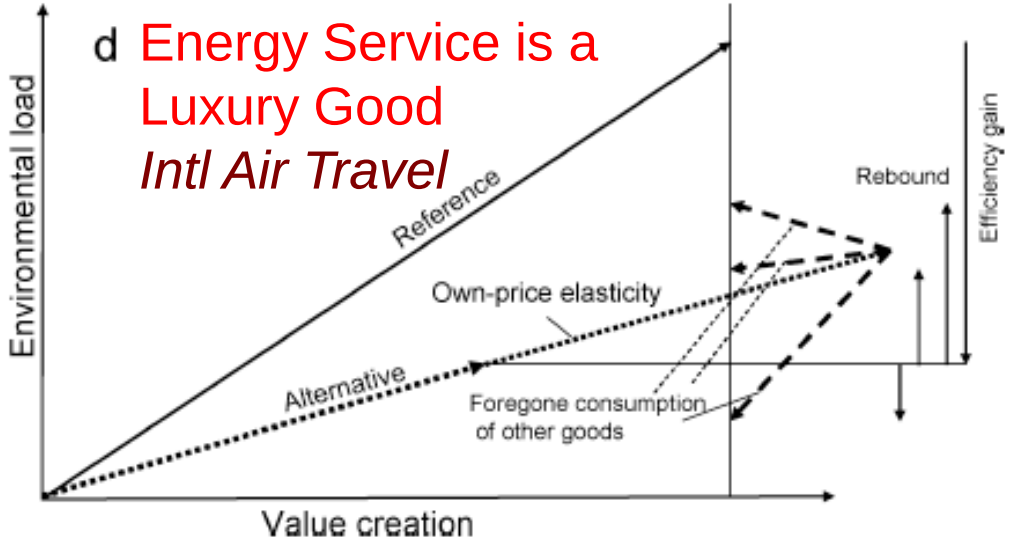
Adapted from Sorrell, 2007

Indirect Rebound Varies by Income Elasticity, Respending & Environmental Impact





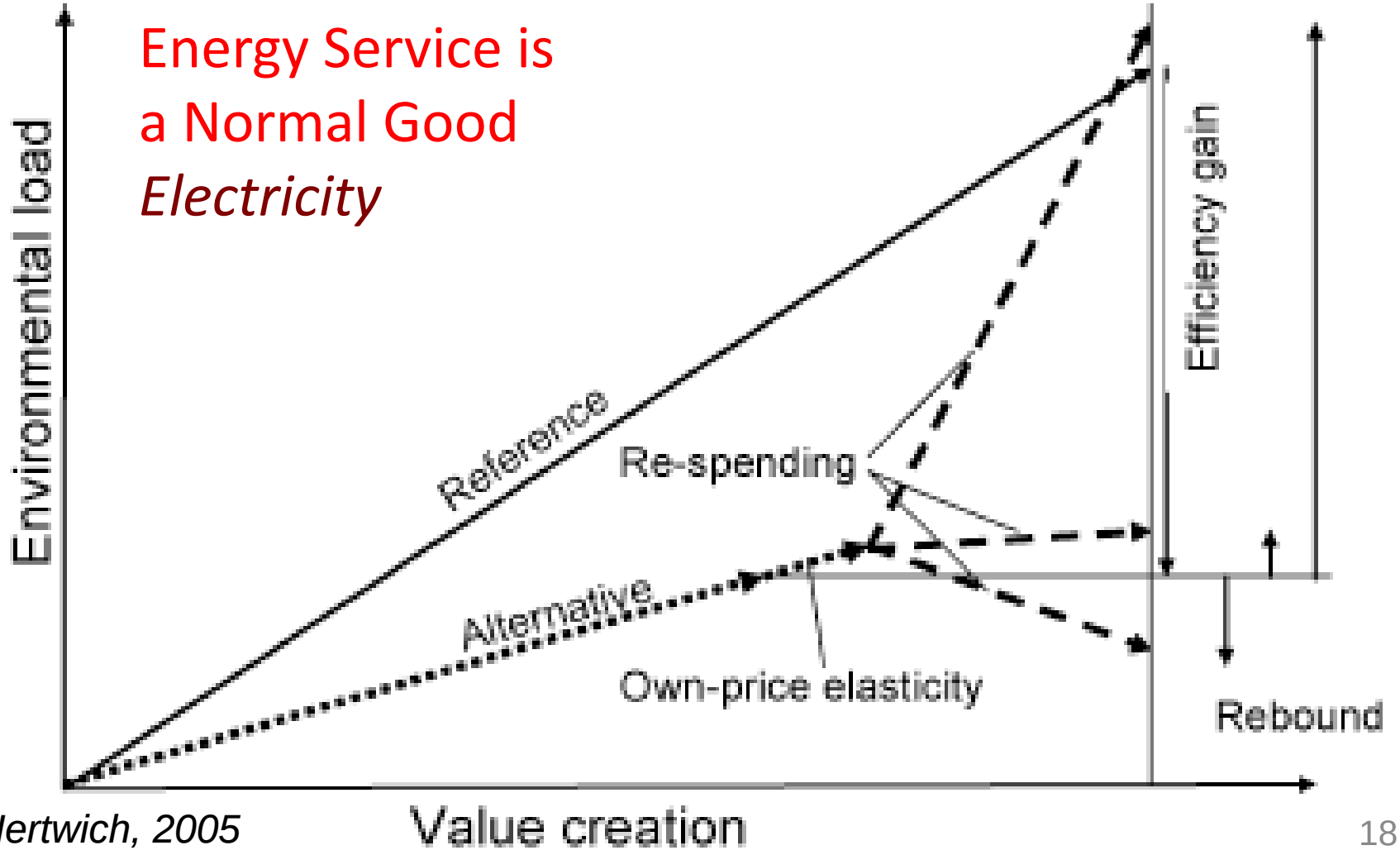




Hertwich, 2005

Income Elasticity, Respending & Environmental Impact Affect the Indirect Rebound Effect

Energy Service is
a Normal Good
Electricity

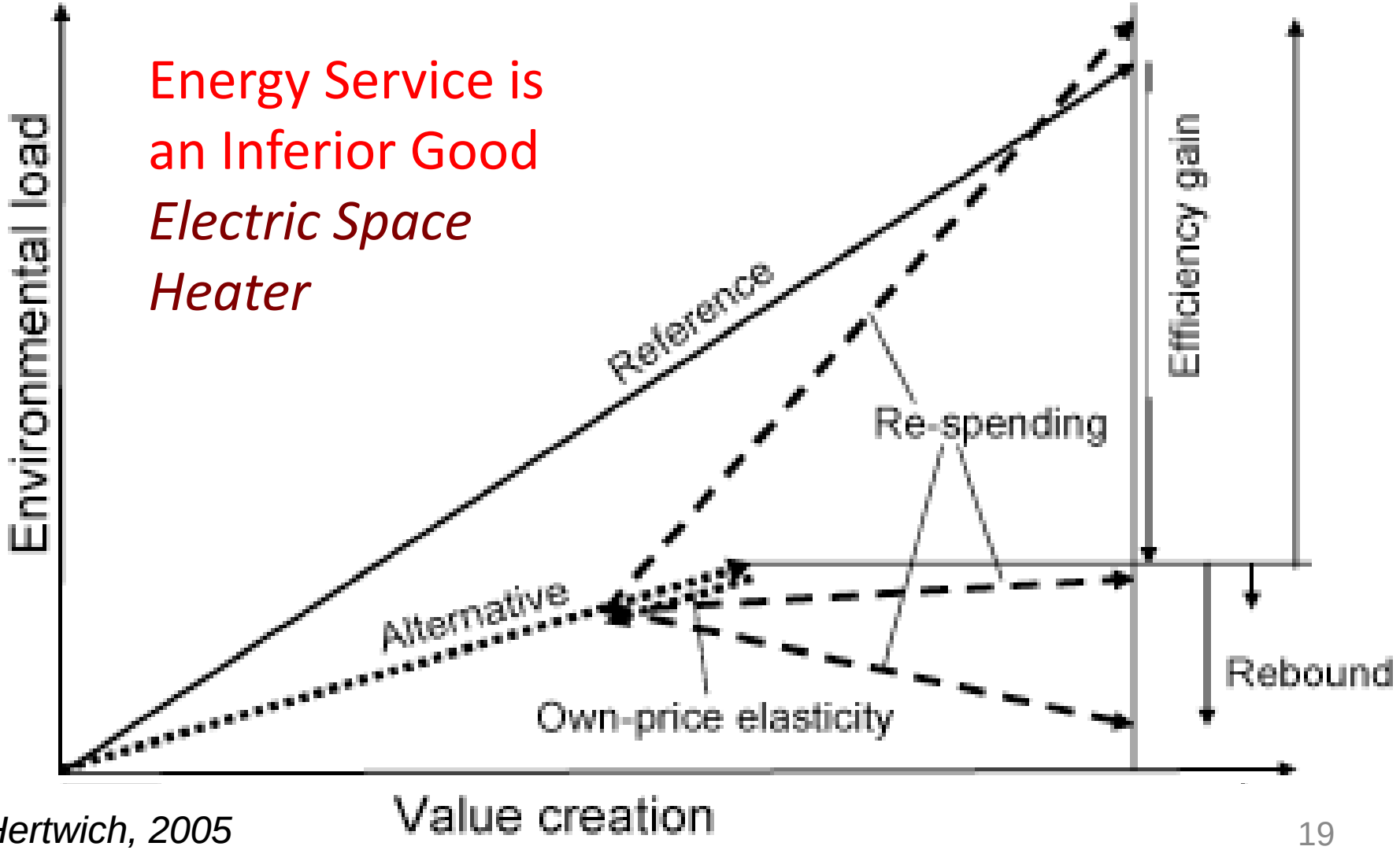


Hertwich, 2005

Income Elasticity, Respending & Environmental Impact Affect the Indirect Rebound Effect

Energy Service is an Inferior Good

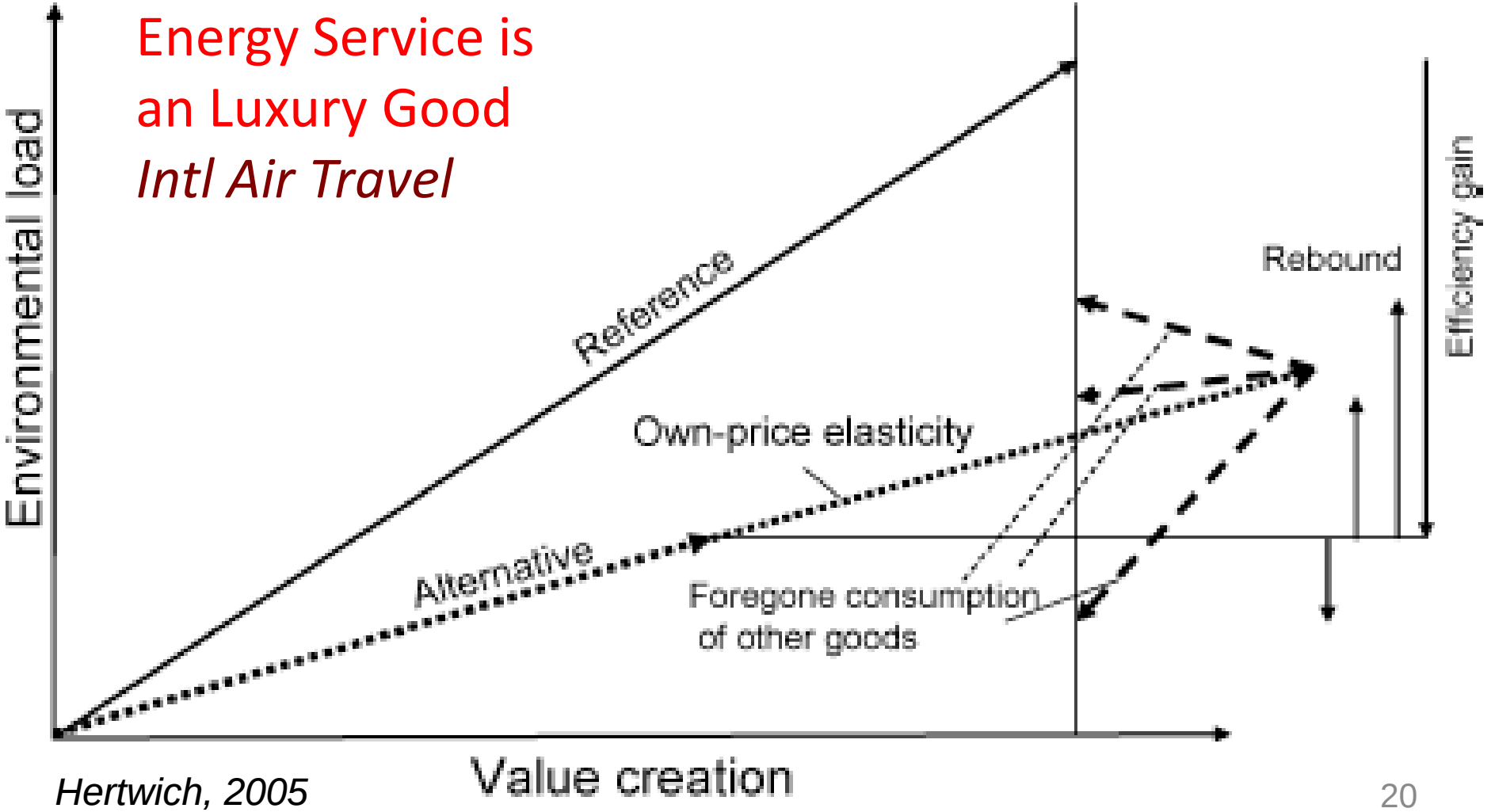
Electric Space Heater



Hertwich, 2005

Income Elasticity, Respending & Environmental Impact Affect the Indirect Rebound Effect

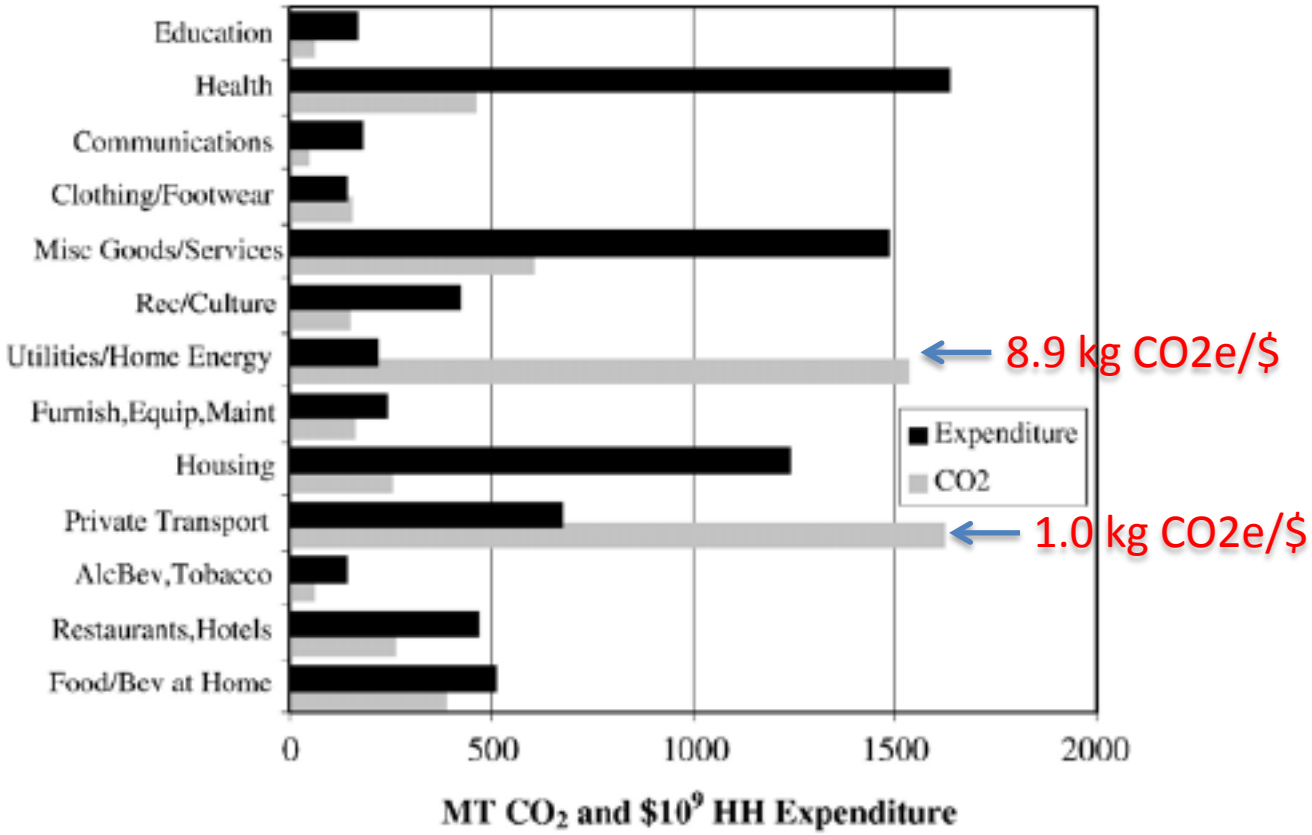
Energy Service is
an Luxury Good
Intl Air Travel



Hertwich, 2005

U.S. Consumer Expenditure Survey

- Defines the household's consumption bundle
- Annual Interview Survey & Diary Survey by Bureau of Labor Statistics (n = 7,500 households)
- 74 Consumption Sectors



2004 Total U.S. Household Emissions and Expenditures

Source: Weber et al., 2008

Global Trade Analysis Project (GTAP) Income Elasticities

$$Exp_i = (1 + Inc\_Elast_i * \frac{energy\_savings * share_i}{Income}) * Exp_{base,i}$$

- Multi-country, multi-sector CGE model (Purdue Univ)
- Strength: 37-sector coverage
- Weakness: Doesn't agree with literature on key U.S. income elasticities of demand:

U.S. Income Elasticity		
Sector	GTAP	Literature
Electricity, Water, and Gas	1.1	0.15-0.40 Short-Run (Branch, 1993)
Oil, Transport	1.1	0.18 Short-Run 1.00 Long Run (Graham, 2002)

- Exploring income-elasticities estimated from Consumer Expenditure Survey (highly aggregated, ~6 sectors)

Economic Input-Output Life-Cycle Assessment (EIO-LCA) Model

- Provides embodied energy/GHG of household demand
- 2002 model: 428 commodities & industries
- Linear Leontief production function
  - fixed prices
  - fixed input factors
  - no returns to scale
- Available at www.eiolca.net

$$Z = EX = E(I - A)^{-1}Y$$

Z = embodied emissions(tons GHG/$)

X = total output($)

A = production function matrix

Y = final demand($)

Two Rebound Effect Theory & Methods Workshops

- Sponsored by Intl Risk Governance Council (IRGC)
- Jointly organized by Carnegie Mellon University & University of Stuttgart
- Goal: To develop research agenda for rebound effects
- **27-28 June 2011**, Washington, DC

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  http://cedm.epp.cmu.edu/rebound.php
- **13-14 October 2011**, Stuttgart, Germany

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