

# Energy Conservation and Public Health Benefits with Increased Residential Insulation

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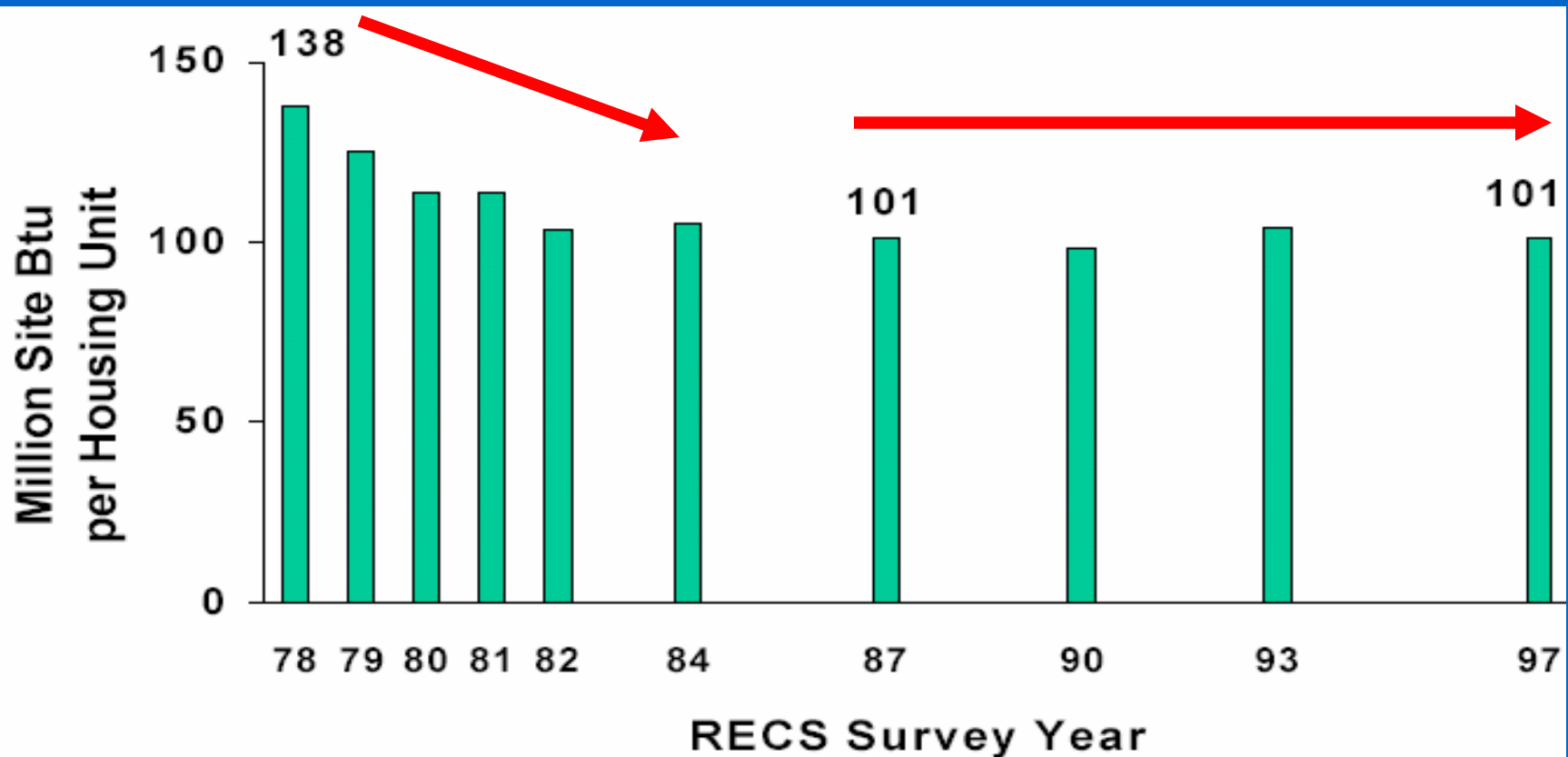
# Outline

- ◆ Introduction
- ◆ Phase 1: End use energy conservation and public health benefits: a risk-based approach
- ◆ Phase 2: The net public health benefits of increased insulation with life-cycle perspective
- ◆ Conclusions and Outlook

# Background

- ◆ Energy consumption leads to pollution (primary and secondary PM<sub>2.5</sub>, CO<sub>2</sub>, etc)
- ◆ >90 % of US energy derived from fossil fuels
- ◆ 21 % of energy consumed by residential sector

# Energy Consumption per US House (1978-1997)



Sources: EIA; *Residential Energy Consumption Surveys 1978 – 1997*



# Consumer or Government?

Efficiency Gap/Market Barrier  
Consumer does not act rationally  
High discount rate

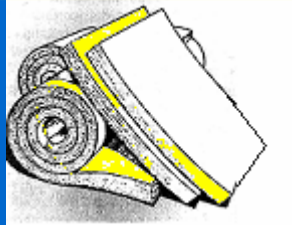
Government intervention to promote energy  
efficiency?



External costs of energy efficiency programs?

# Overview of Research (Phase 1)

## Phase 1



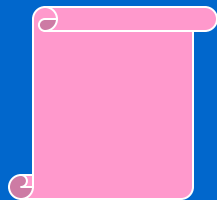
Material inputs



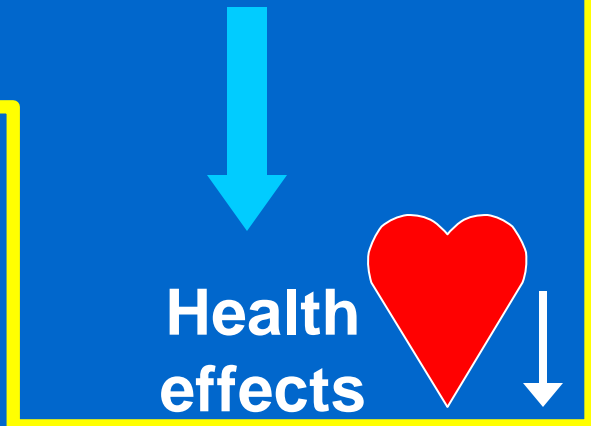
Energy Pollution



Health effects



Stricter codes



# Analytical Framework: Risk-Based Approach

Estimated residential energy consumption (BTUs) ↓

Emission coefficients for various  
fuel sources (tons/BTU)



PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> Emissions (tons) ↓

Exposure analysis w/ intake  
fractions



Exposure (tons) ↓

C-R functions from epi studies



Premature mortality and morbidity associated  
with energy and pollution reduction ↓

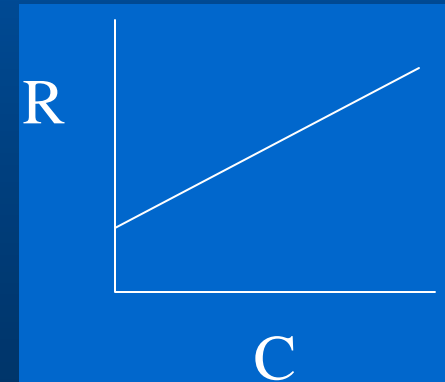
# Computation Tools: Exposure Reduction

$$iF_{PM} = \frac{\textit{Intake}}{\textit{Emissions}} = \frac{\sum \textit{Pop} \times \textit{Conc} \times \textit{BreathingRate}}{\textit{EmissionRate}}$$

- ◆ Regression-based  $iF$  calculations for  $PM_{2.5}$ 
  - Levy 2002:  $iF_{PM} = f$  (population, 1/stack height, climatic factors, etc)

# Computation Tool: Risk reduction

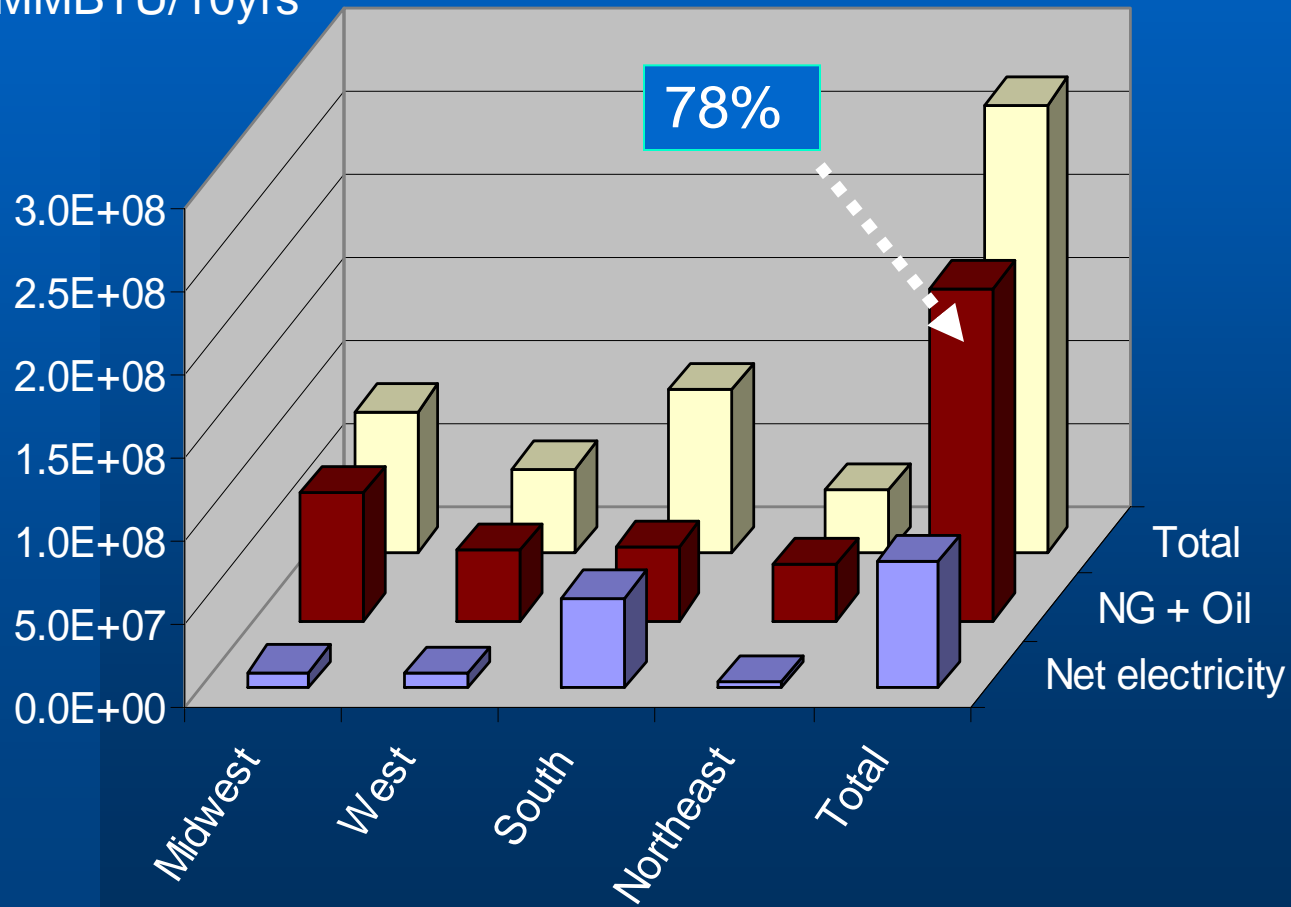
- ◆ Health effects =  $f$ (exposure, concentration-response function, background incidence rate, population, % affected)
- ◆ C-R function (linearity, no threshold, equal toxicity)
  - PM2.5 mortality (HEI 2000)  
ACS cohort of >500,000 people
  - PM2.5 morbidity  
Asthma Attacks (Whittmore and Korn 1980)  
RAD (Ostro and Rothchild 1986)



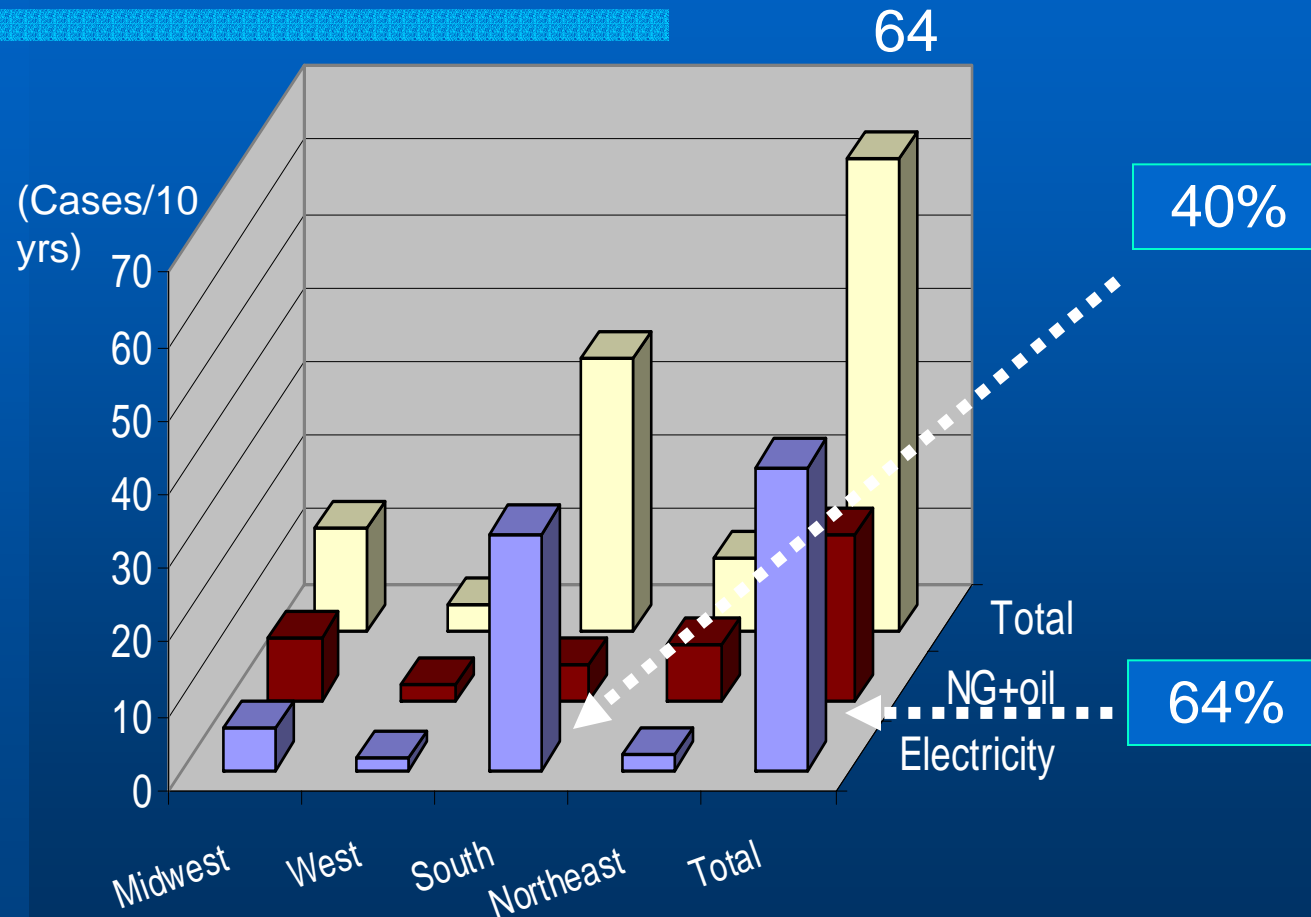
# Results: End-use Energy Savings

$3 \times 10^{14}$  BTUs

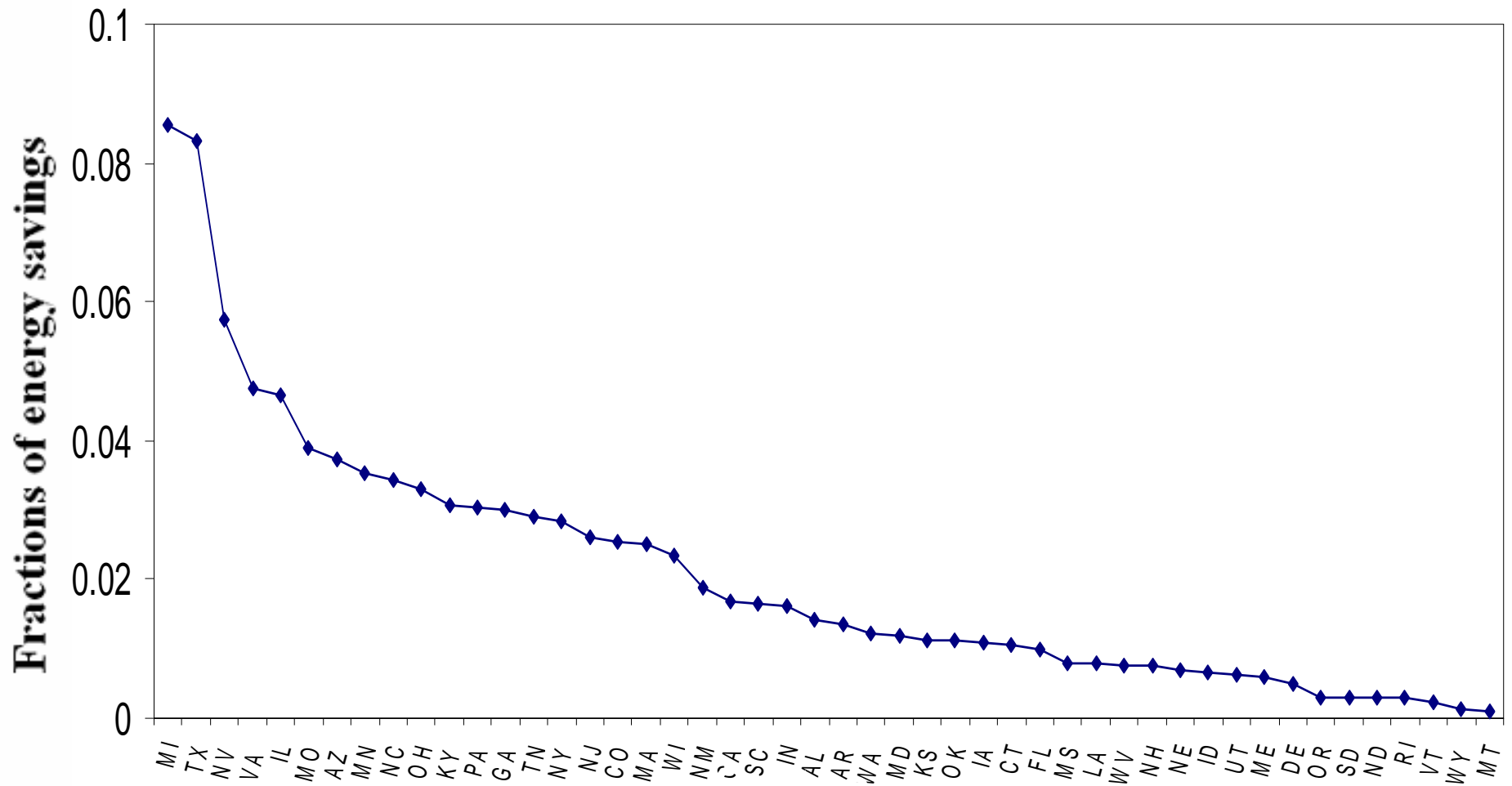
MMBTU/10yrs



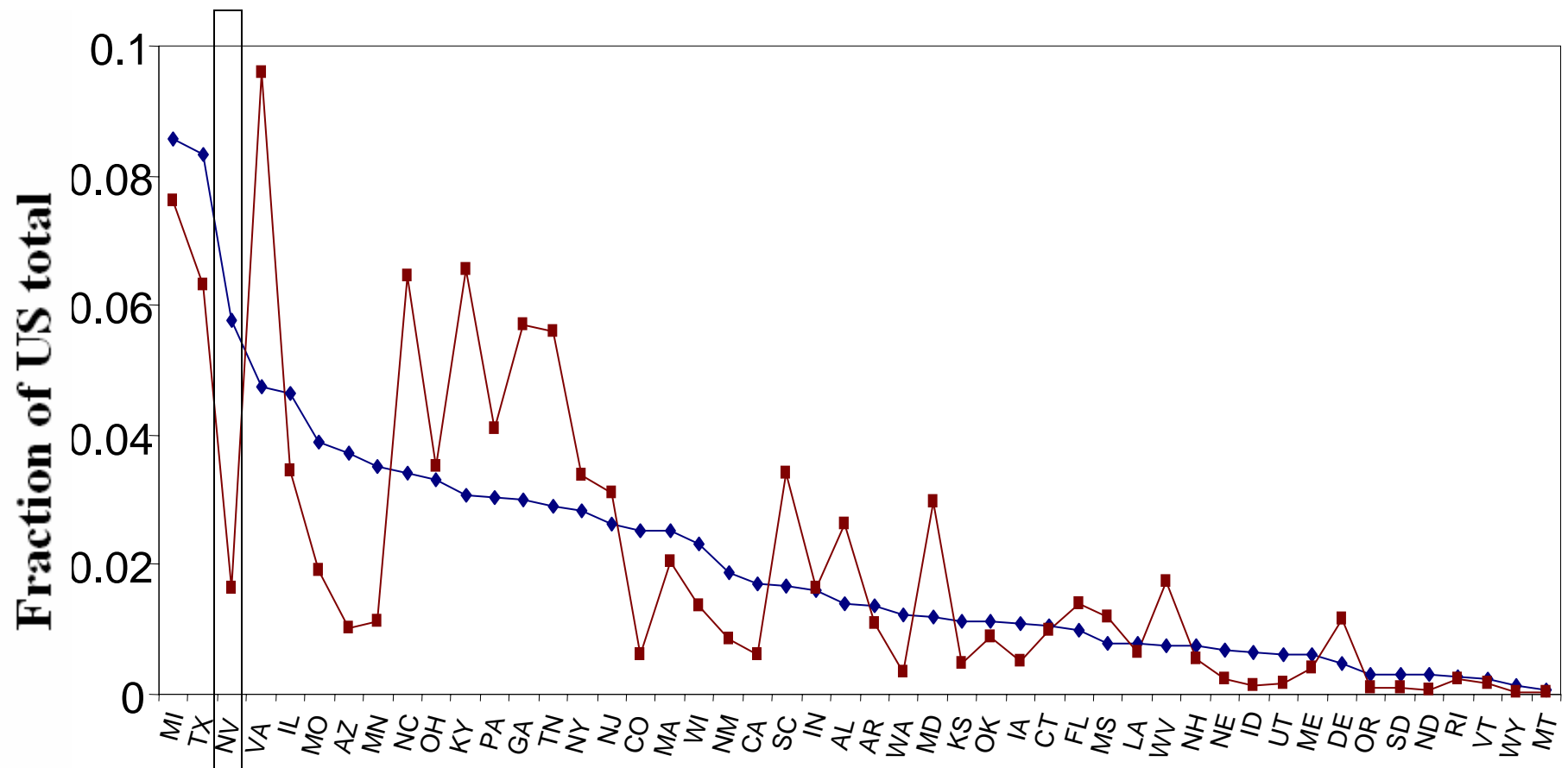
# Results: Total Premature Mortality Avoided



# Variability in end-use energy savings by State



# Variability in end-use energy savings and health outcomes by State



# Conclusions (Phase 1)

- ◆ If all states comply with IECC for all new single-family homes, 64 premature deaths can be avoided over 10 years
- ◆ The geographical distribution of health benefits differs from the distribution of energy savings due to fuel types, population patterns, and meteorology
- ◆ Area with high population density and high emitting power plants have more health benefits from end-use energy savings

# Part 1: Insulation case study

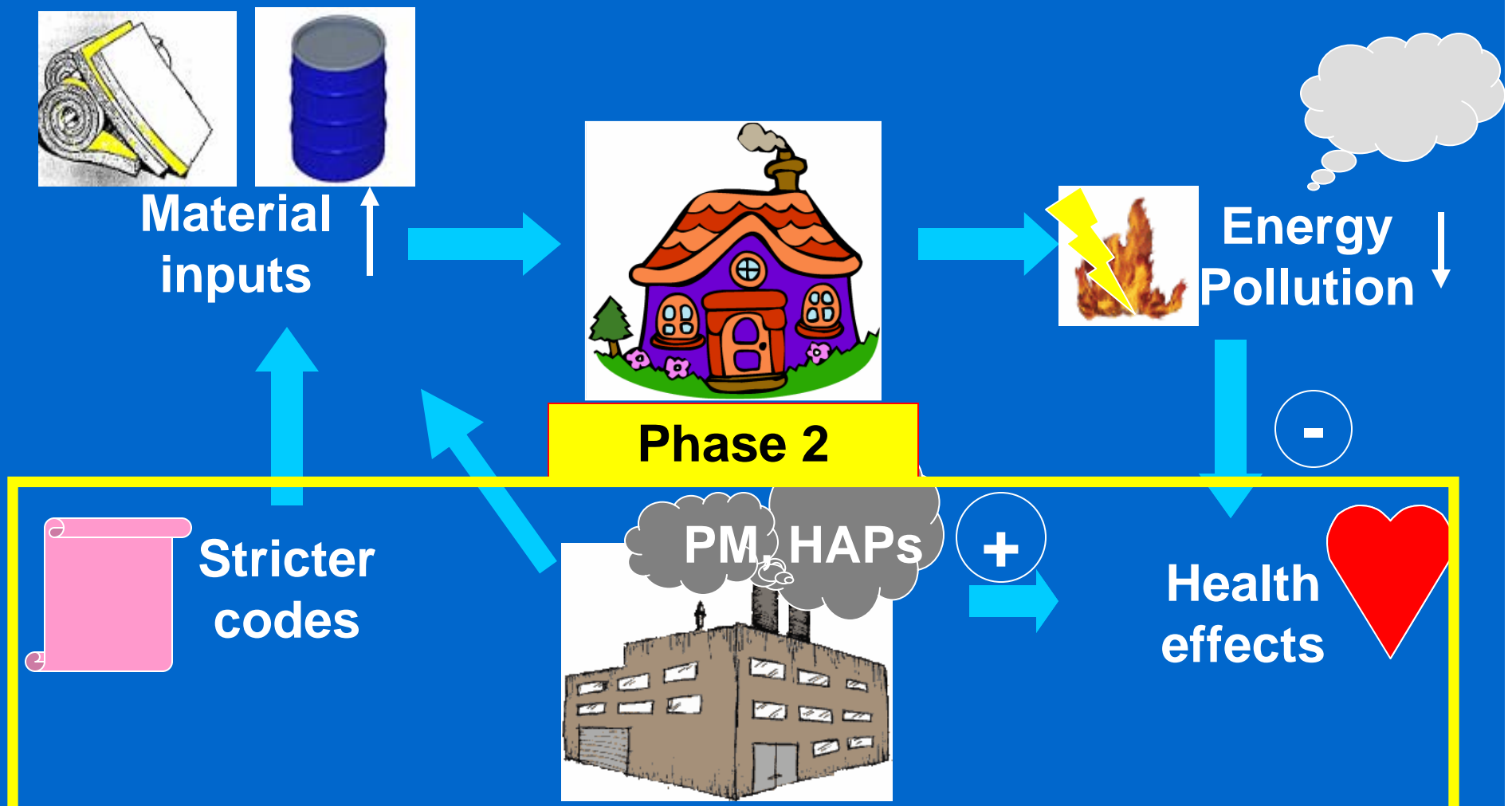
## Objectives

- ◆ Estimate the public health benefits of end-use energy conservation with increased residential insulation

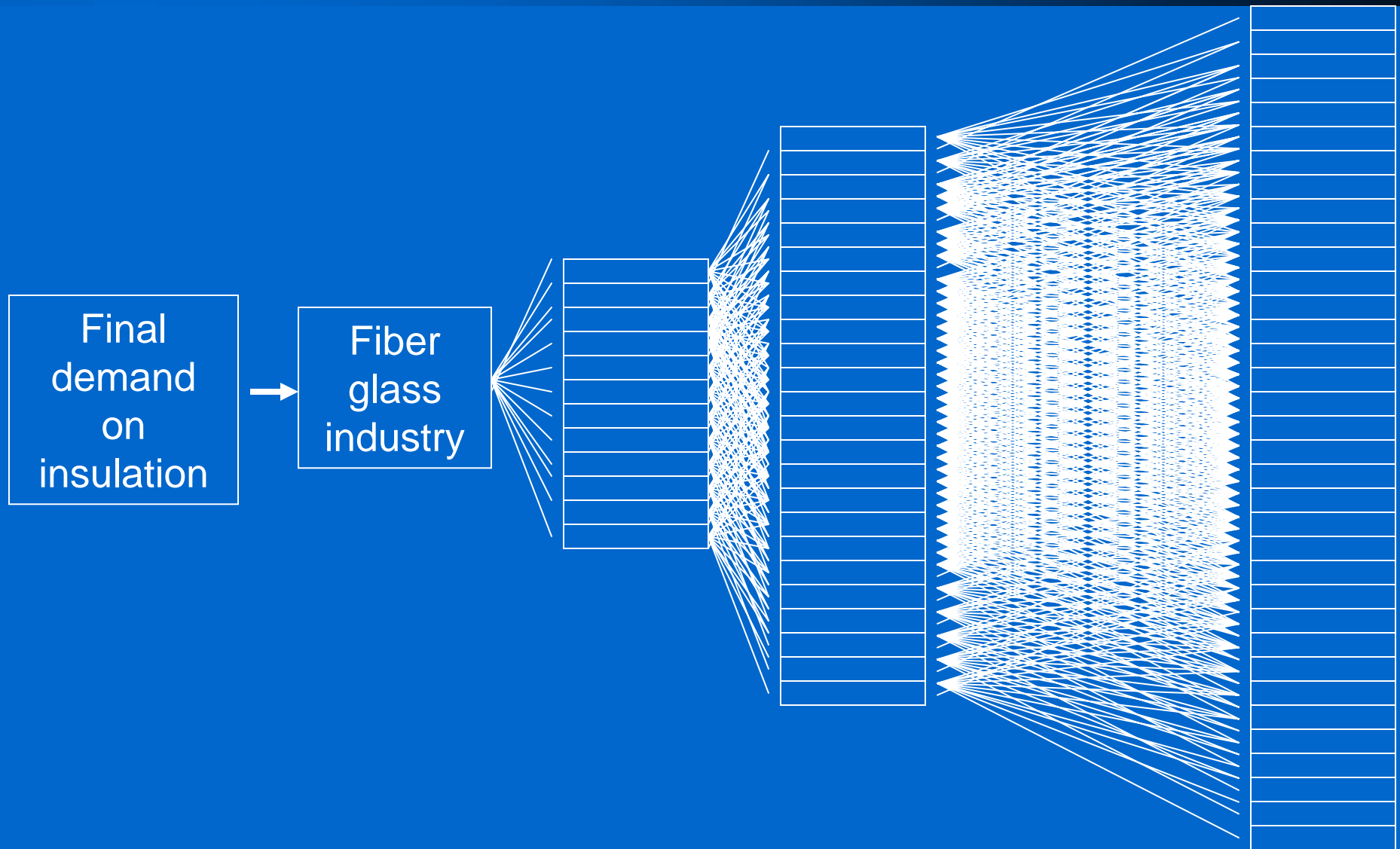
## Scenario

- ◆ Increased fiberglass insulation  
current practice (2000) → recommended level by International Energy Conservation Code 2000
- ◆ All new single-family homes (1.2 million / yr)
- ◆ Time horizon: 10 years

# Part 2: Supply Chain Analysis: Insulation and Fuels



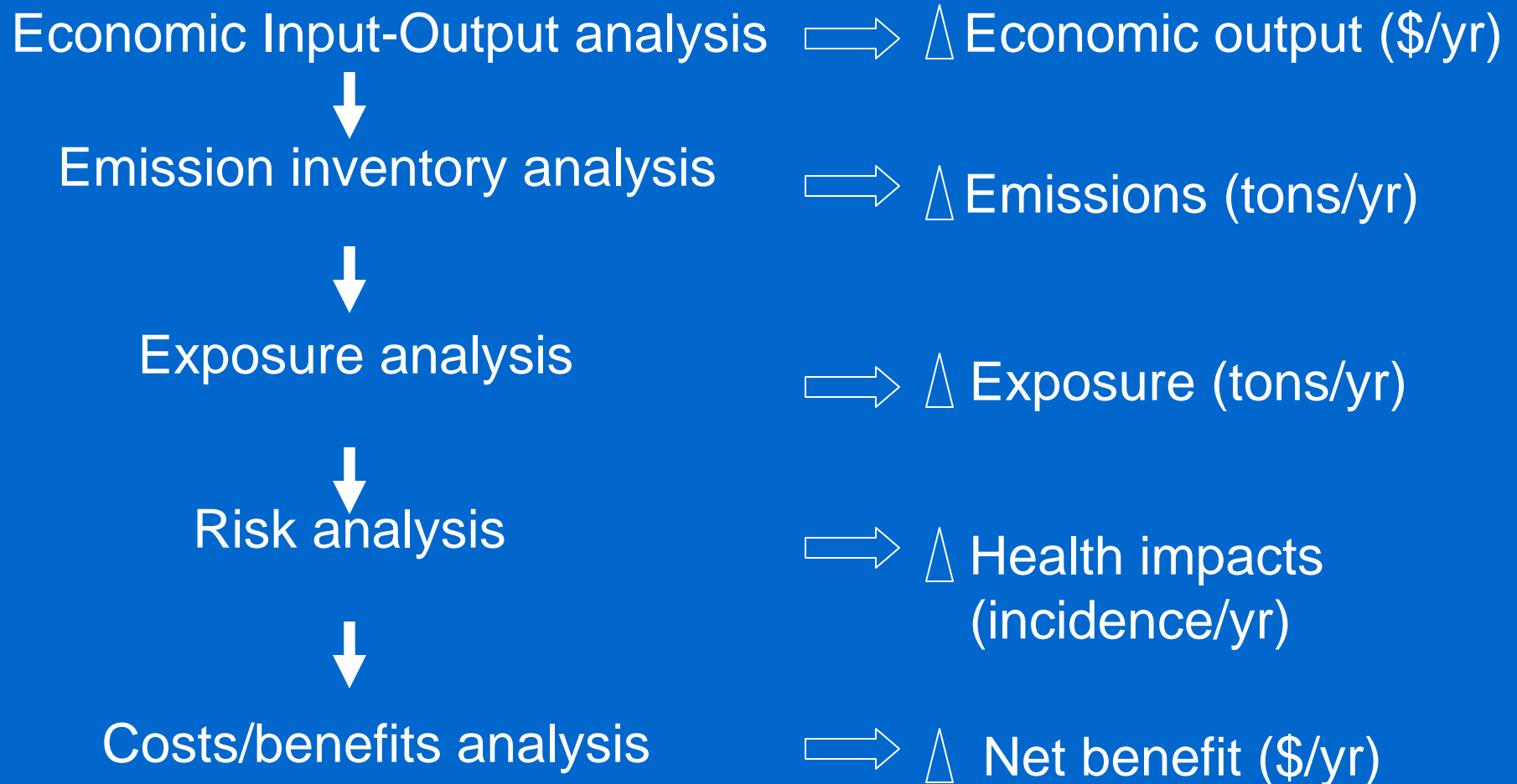
# Economic I/O analysis (Supply Chain Analysis)



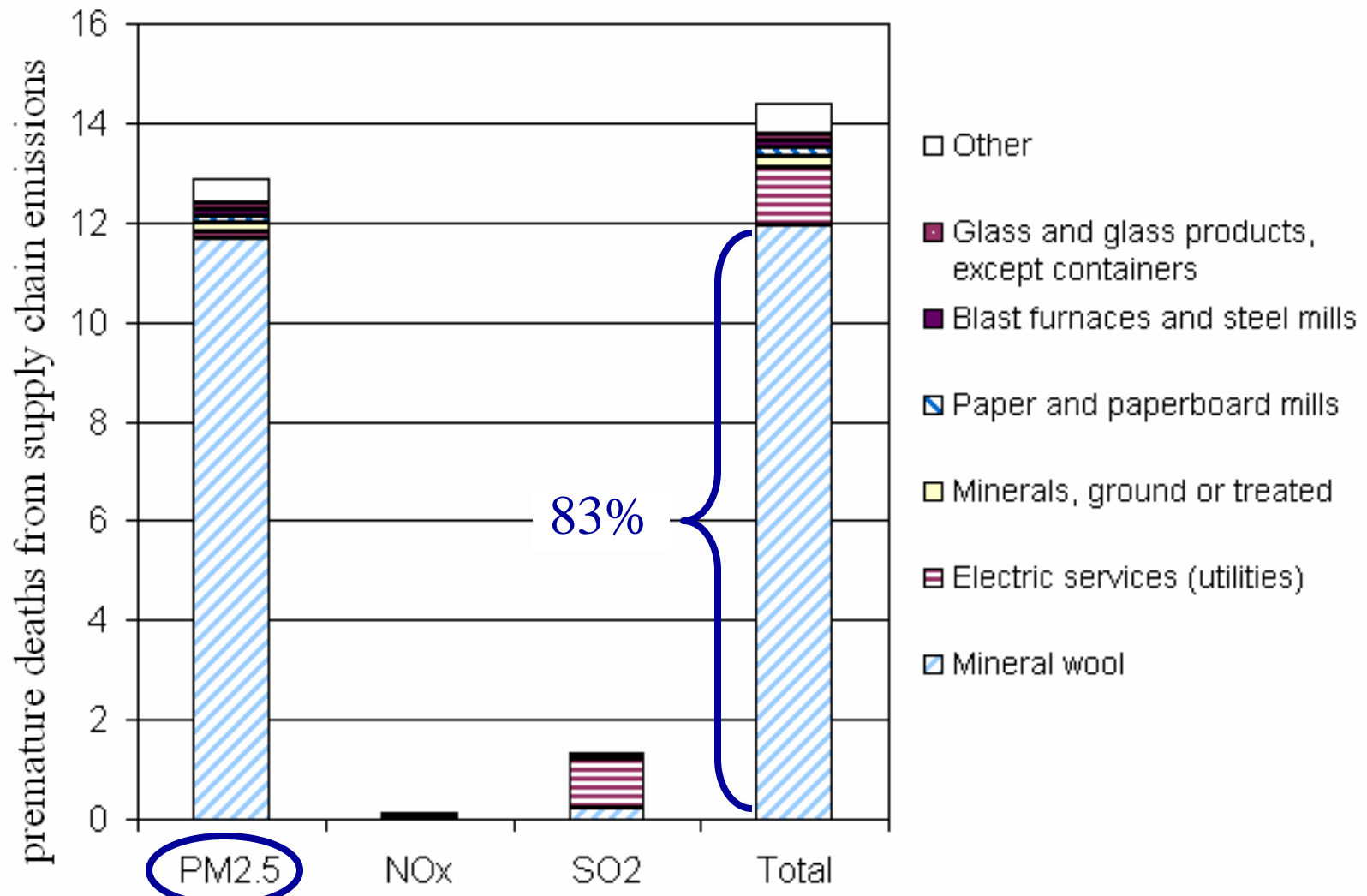
# Analytical Framework: I-O and Risk Model

## Model

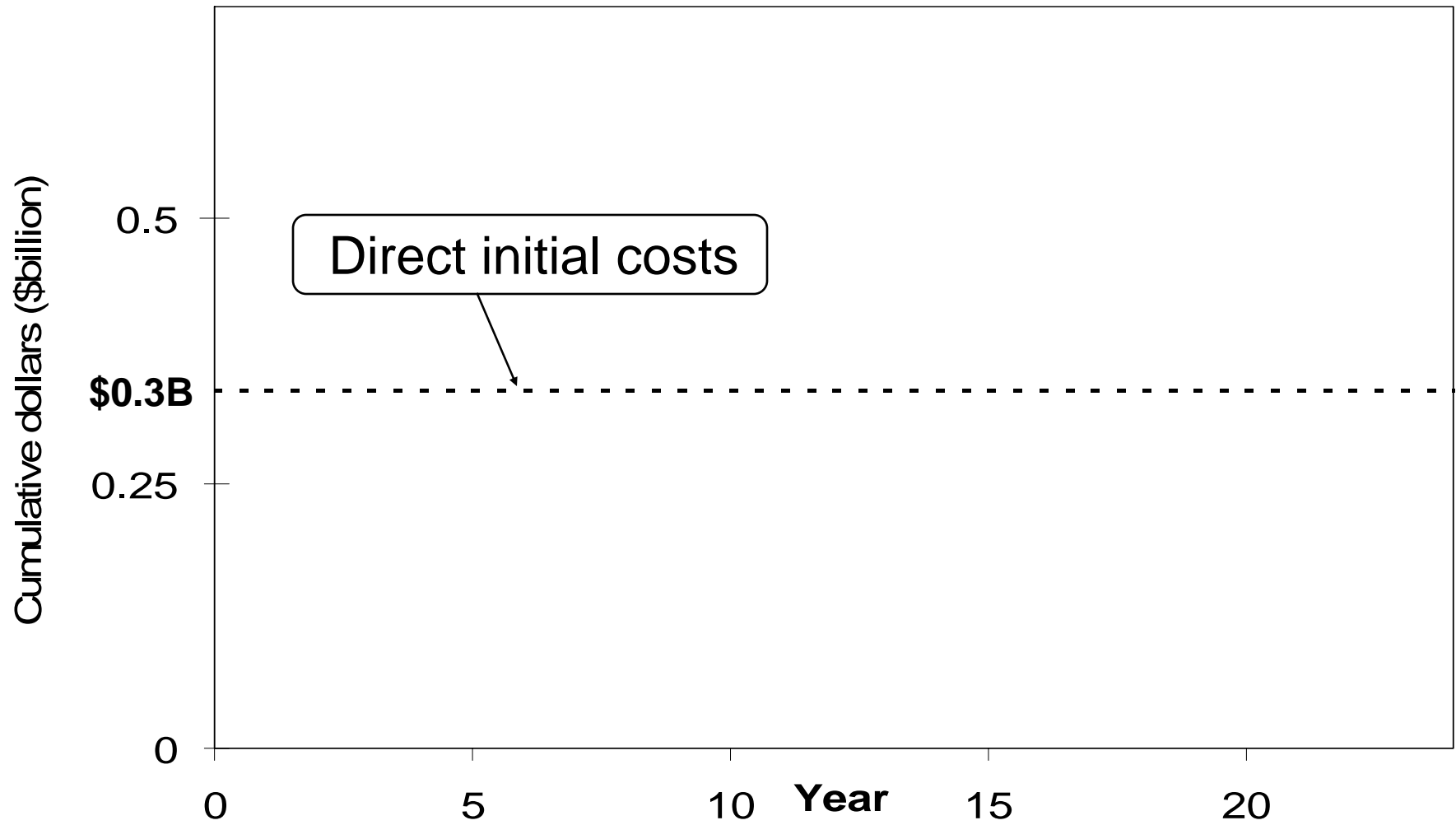
## Output



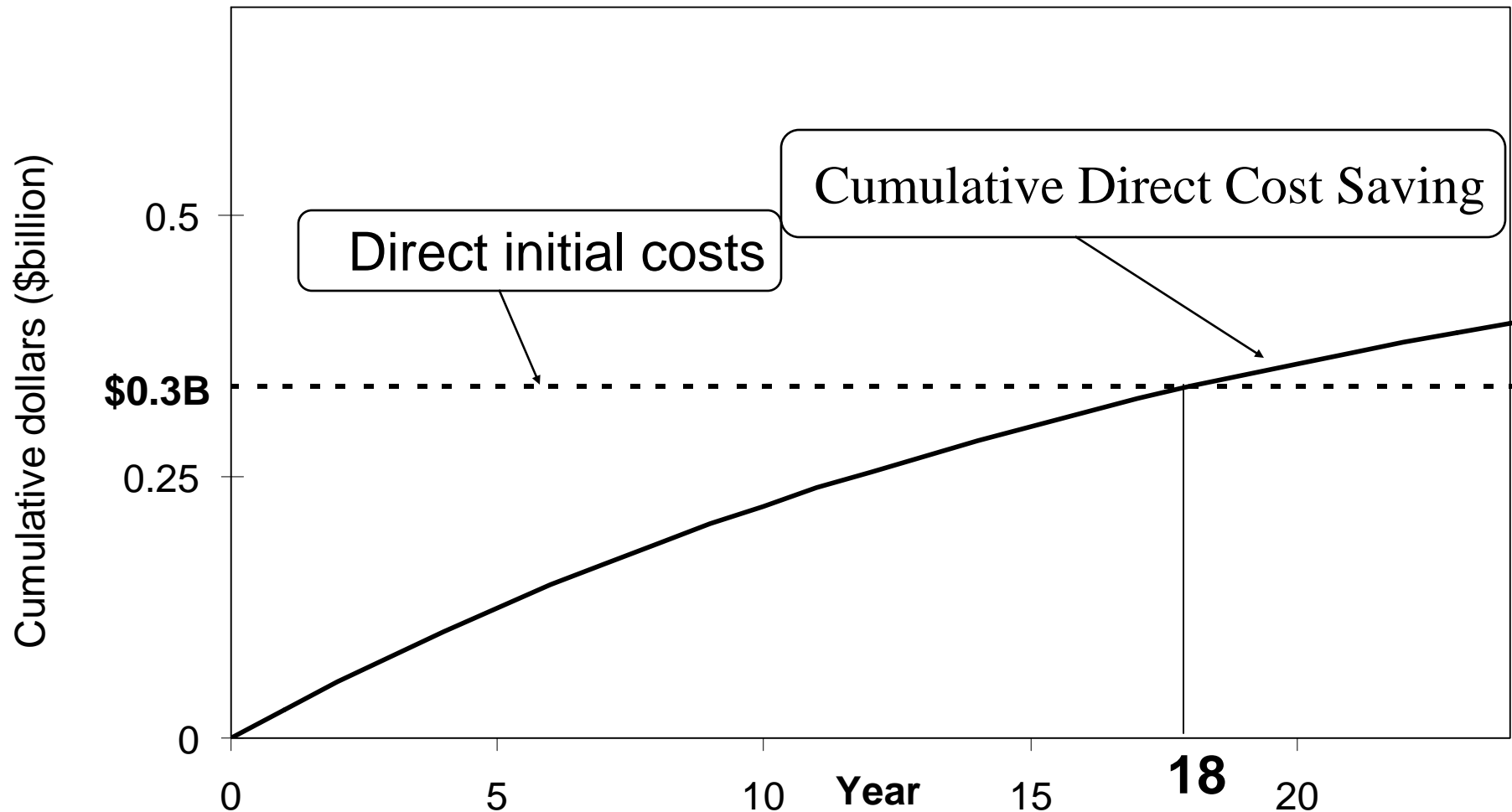
# Results: Supply chain health impacts associated with mineral wool



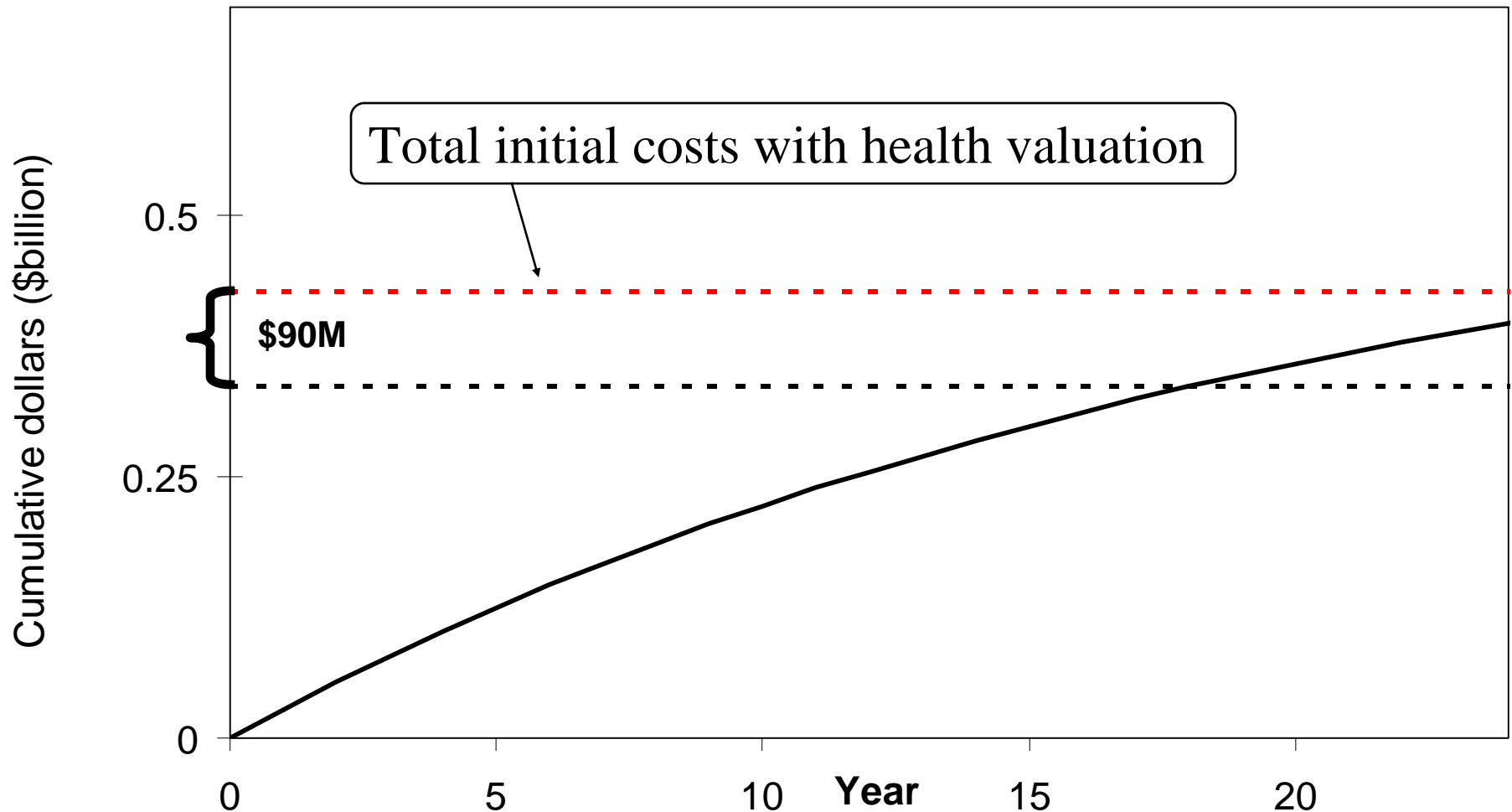
# Costs vs. benefits of insulation for single-year cohort



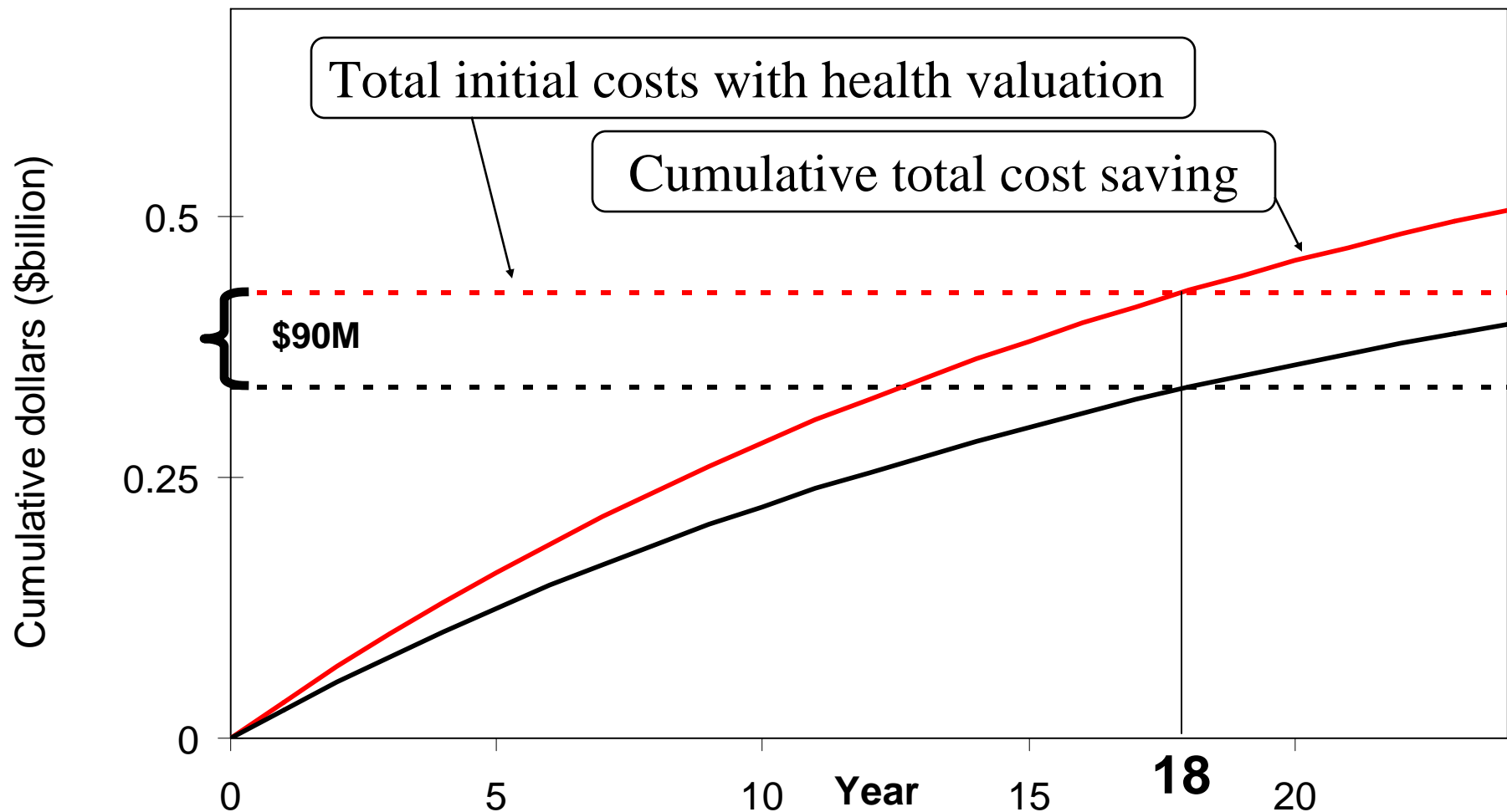
# Costs vs. benefits of insulation for single-year cohort (discount rate = 0.05)



# Costs vs. benefits of insulation for single-year cohort (discount rate = 0.05)



# Costs vs. benefits of insulation for single-year cohort (discount rate = 0.05)



# Conclusions (Phase 2)

- ◆ Cost of insulation and the associated health effects from manufacturing are recovered in 15-20 years by savings in energy and the associated health effects
- ◆ For the fiberglass manufacturing the direct emissions account for > 80% total health effects
- ◆ For insulation and energy, health effects from PM >> HAPs

# Outlook

- ◆ A comprehensive health impact analysis
  - public policy decision
    - tax incentives; code enforcement;
    - technology enforcement
- ◆ Other C/B consideration
  - post consumption phases
  - other impact categories (GWP, etc)
  - other HAPs (PACs, dioxin)
  - occupational health effects / IAQ issues
  - health effects via socio-economic effects

# Acknowledgments

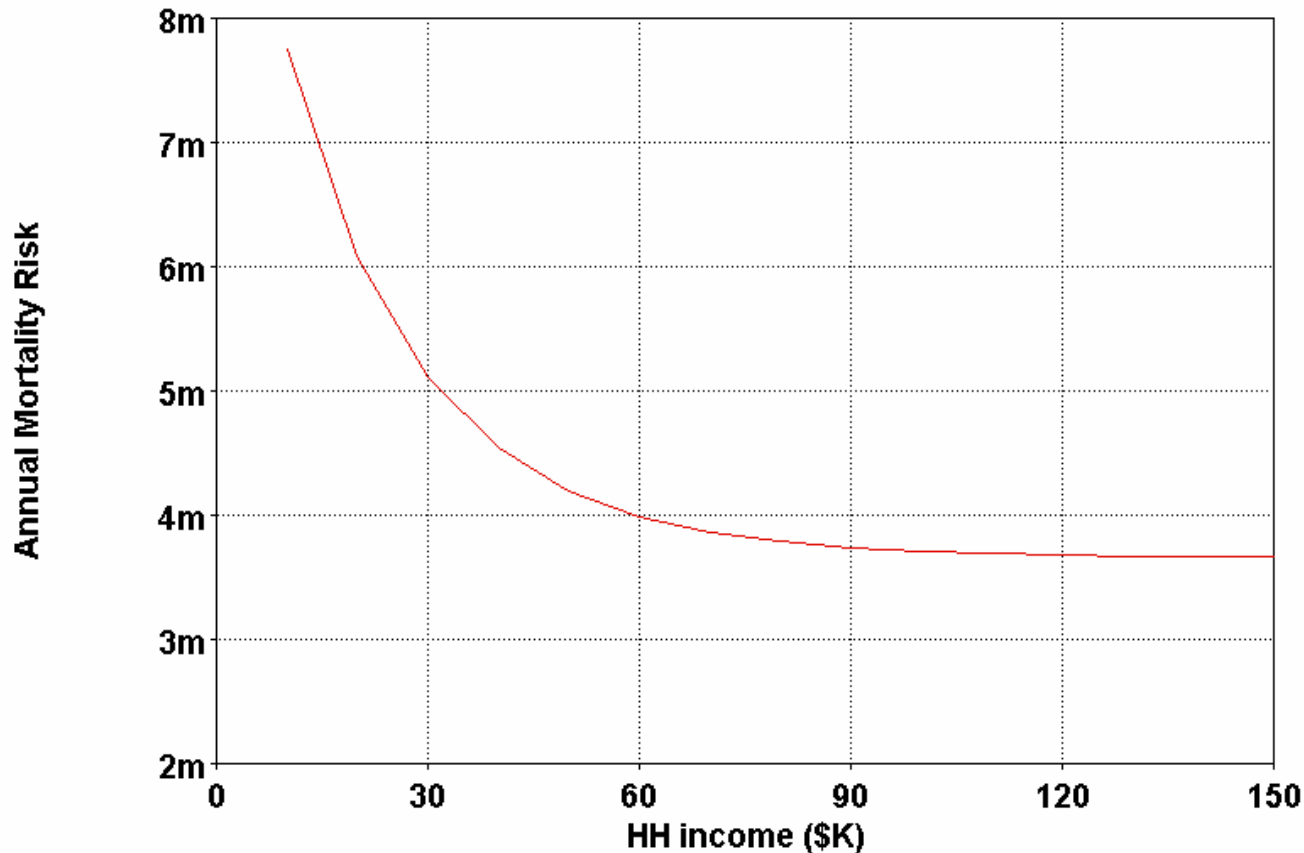
- North American Insulation Manufacturers Association
  - George Phelps
  - Ken Mentzer
- Angus Crane (NAIMA)
- Doug Norland; Laura Lind (ASE)
- Merle McBride (Owens Corning)
- Dave Roberts (Architectural Energy Corporation)

# For More Information

- Phase 1: *Risk Anal* 2002 Vol. 22 (5): 1003-1017 (October 2002)
- Phase 2: *International Journal of LCA* (Submitted)
- [ynishiok@hsph.harvard.edu](mailto:ynishiok@hsph.harvard.edu)

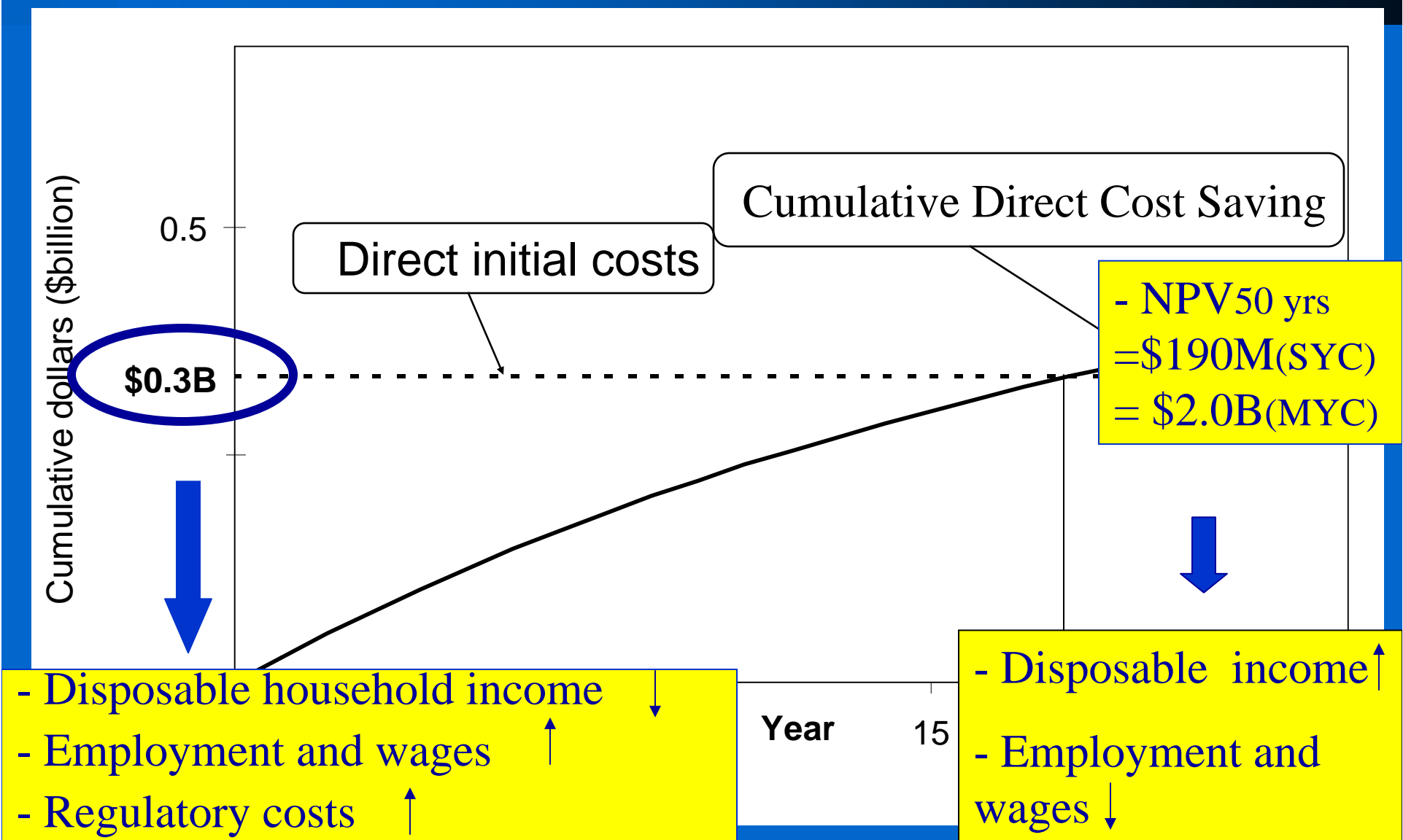
# Socio-Economic Impacts on Health?

Relationship between household income and life expectancy (e.g., Keeney, 1997)

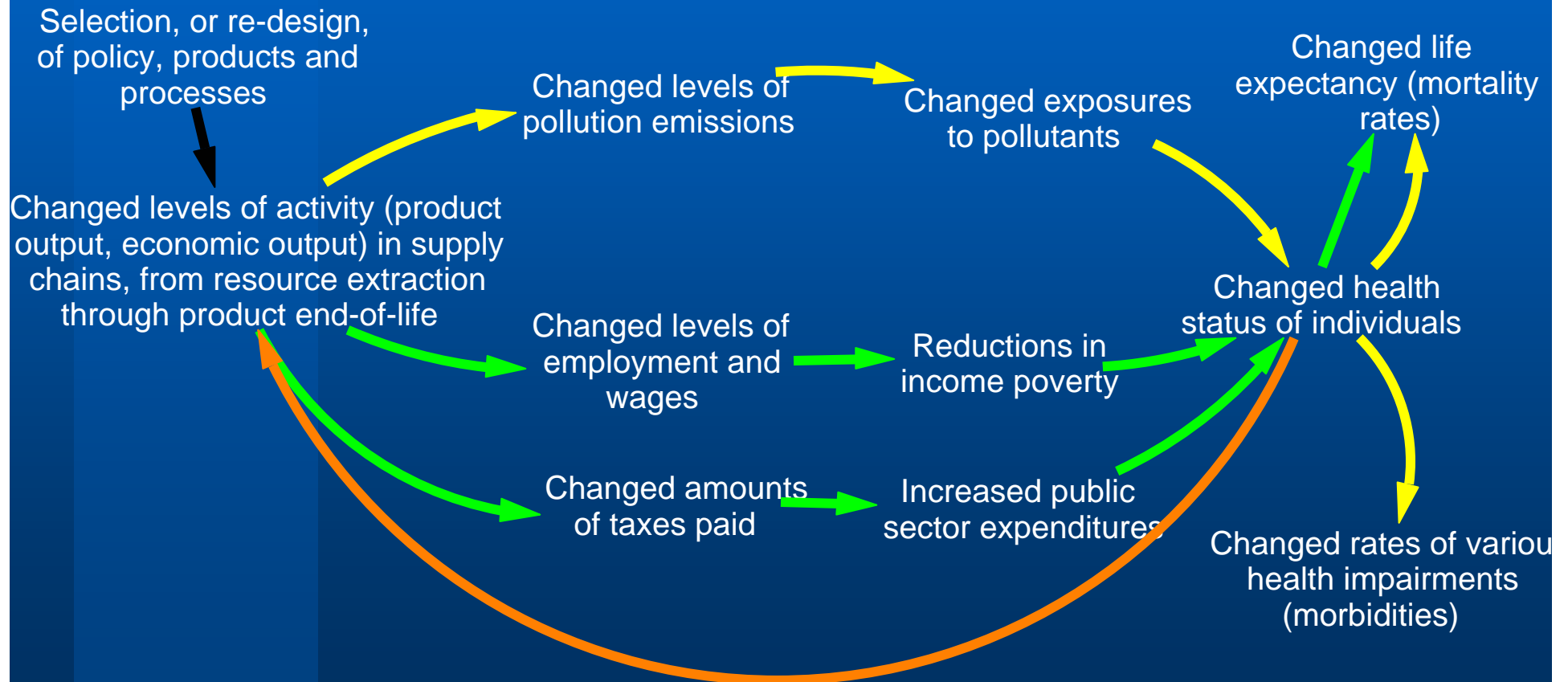


- Long-term effect, observed in cross sectional and time series, within and between countries

# Costs vs. benefits of insulation for single-year cohort (discount rate = 0.05)



# Fuller view of impact pathways



Source: Norris, 2004

# Economic-health effects for insulation policy

- **Economic-health effects via:**
  - increased housing costs of ~\$300 per household
  - reduced energy costs
  - US wage increase for fiberglass, decrease for fuel industry
  - More benefits if wage increase in developing countries are included in supply chain

14 PDs from increased insulation's LC processes

1.2 PDs from energy conservation

NPV 50 yrs  
= \$190M(SYC)  
= \$2.0B(MYC)

Costs of insulation



- Disposable household income ↓
- Employment and wages ↑
- Regulatory costs ↑

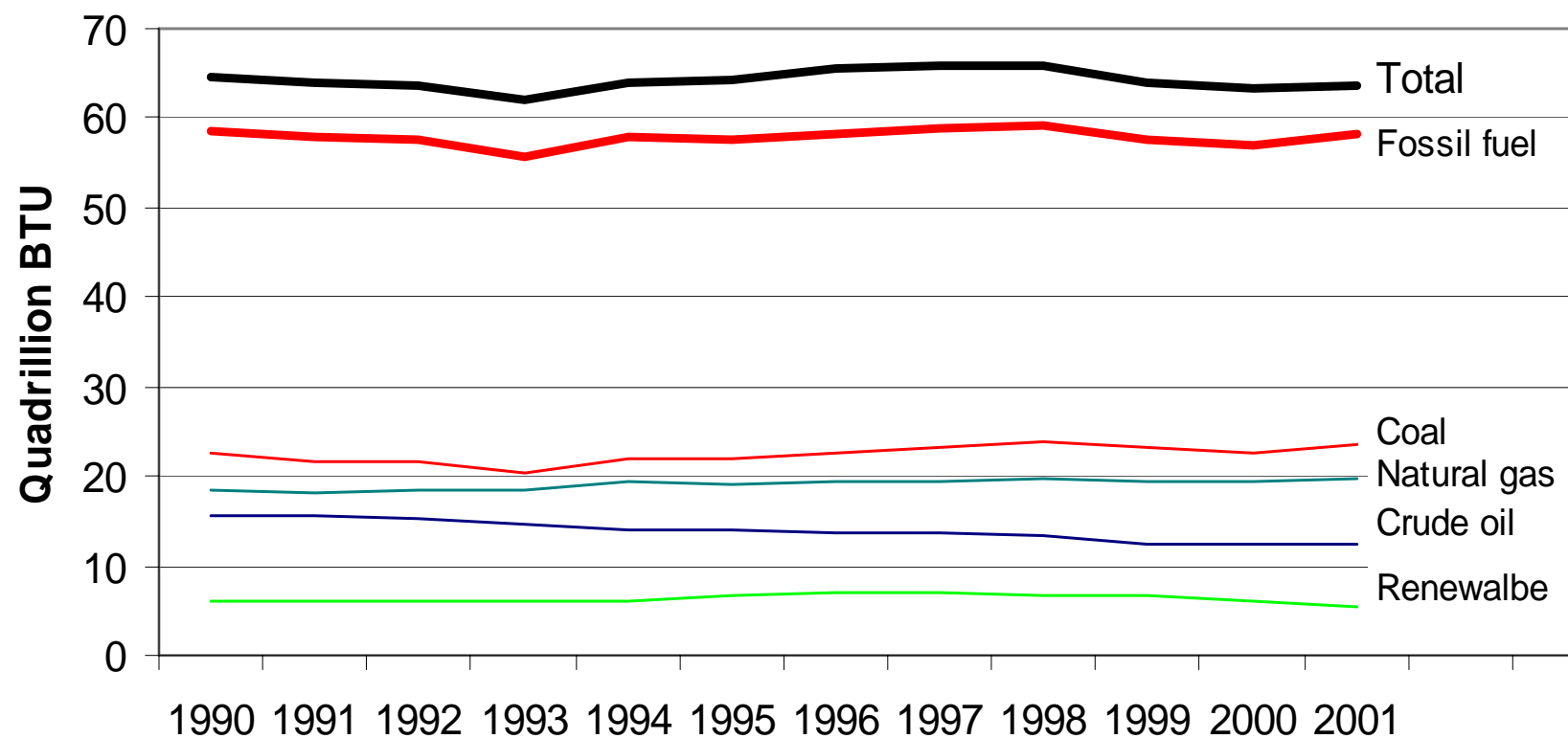
Cost saving with energy conservation



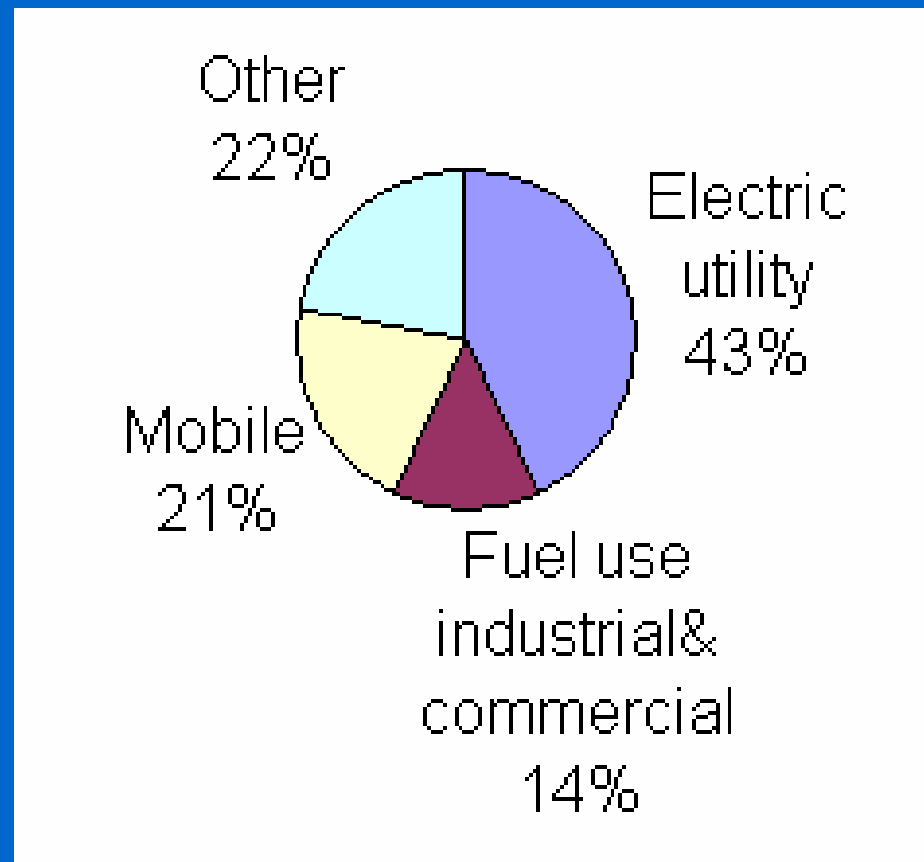
- Disposable income ↑
- Employment and wages ↓



# US Energy Consumption

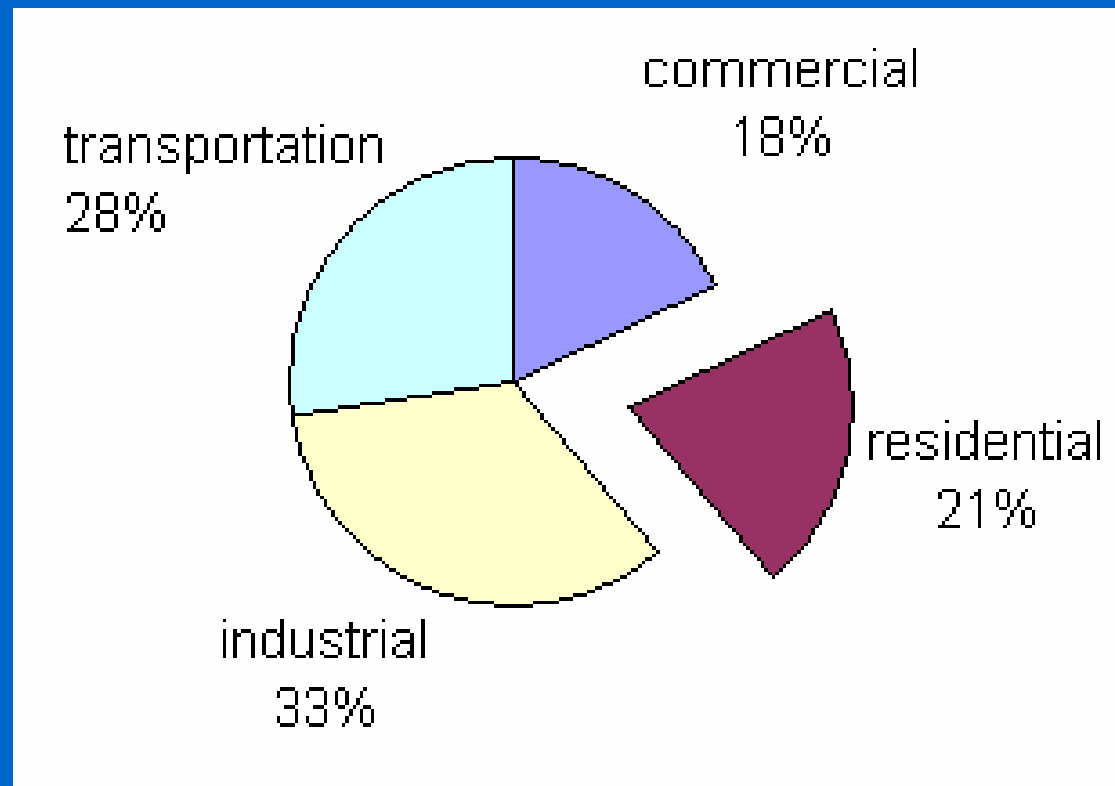


# PM<sub>2.5</sub> Emissions (primary+secondary)



Sources: Spengler and Wilson (1996). *Particles in Our Air*

# Energy Consumption by Sector



Source: DOE (2001); *Annual Energy Review 2001: Energy Consumption by Sector*

# Integrating Risk Assessment and Life-Cycle Assessment: A Case Study of Insulation (NAIMA Phase 1)

Yurika Nishioka, Jonathan I. Levy, Gregory A. Norris, Andrew Wilson, Patrick Hofstetter, John D. Spengler

*Risk Anal* 2002 Vol. 22 (5): 1003-1017 (October 2002)

# A Risk-Based Approach to Health Impact Assessment for Input-Output Analysis: Case Study of Insulation (NAIMA Phase 2)

Yurika Nishioka, Jonathan I. Levy, Gregory A. Norris,  
Deborah H. Bennett, John D. Spengler

Submitted to: *International Journal of LCA* (January 2003)

# Data Sources

## Model

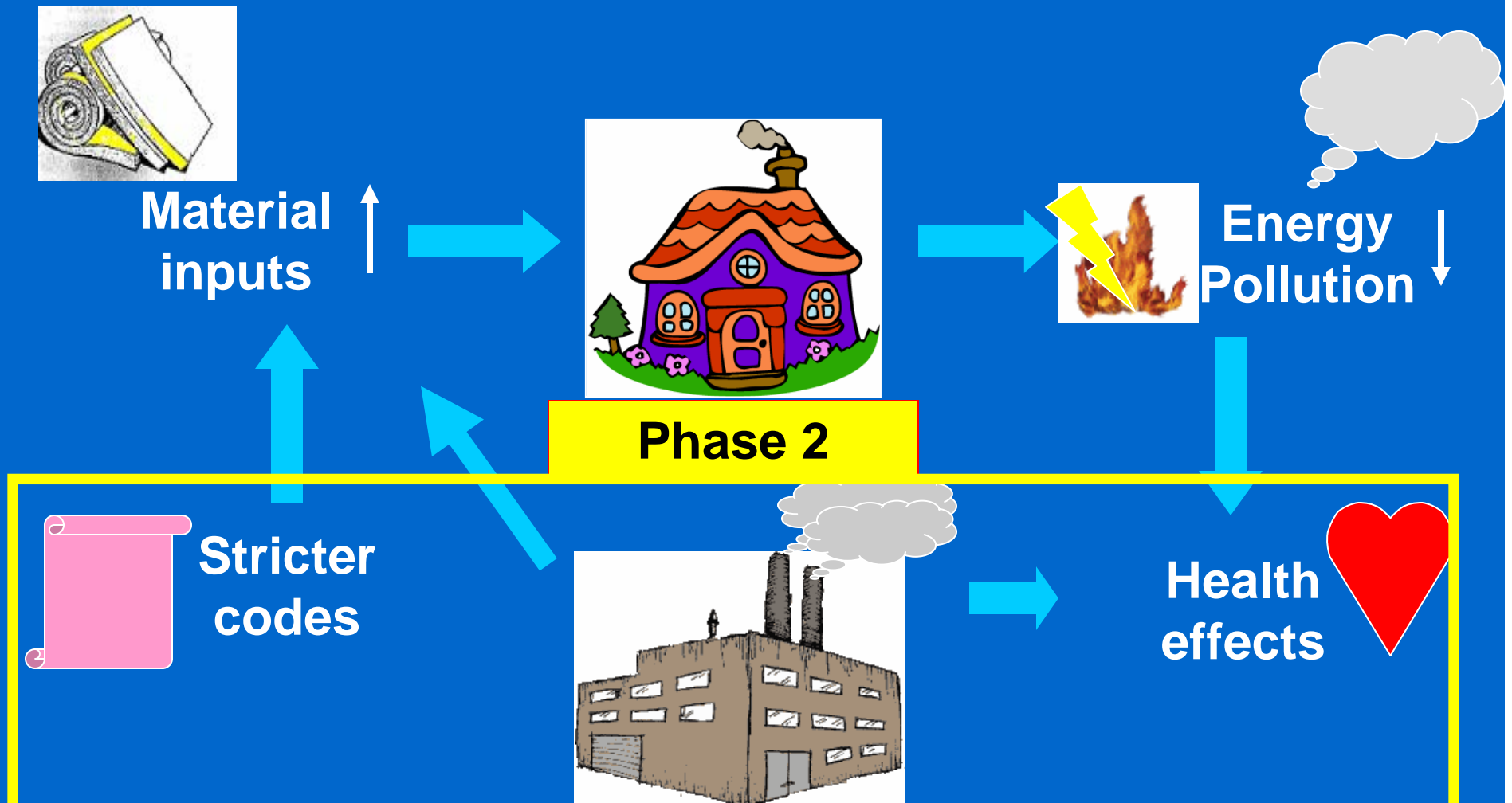
## Data sources

Economic Input-Output analysis	—	BEA 1998 Input-Output Tables
Emission inventory analysis	—	<u>PM</u> : EPA AIRS 1998 <u>HAPs</u> : EPA TRI 1998
Exposure analysis	Screen	<u>PM</u> : iF (Levy 2002) <u>HAPs</u> : iF (Bennett 2002)
	Refined	EPA ISCST/ Met; EPA NEI1998 US Census
Risk analysis	—	<u>PM</u> : C-R functions (Epi studies) <u>HAPs</u> : CPF; EPA or Cal-EPA
Costs/Benefits analysis	—	Census Bureau, DOE, EPA B/C of the Clean Air Act

# Objectives

- ◆ Estimate the net economic and public health benefits of increased insulation
- ◆ Combine the risk model (Phase 1) with Input-Output analysis

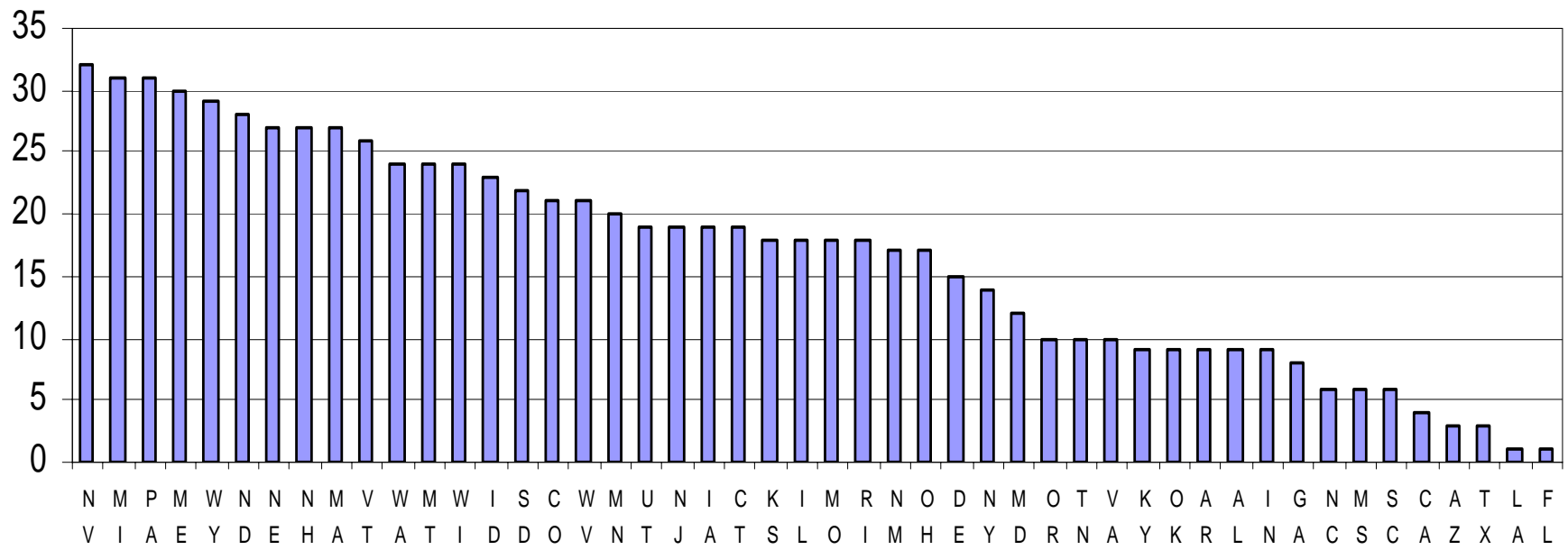
# Overview of Research



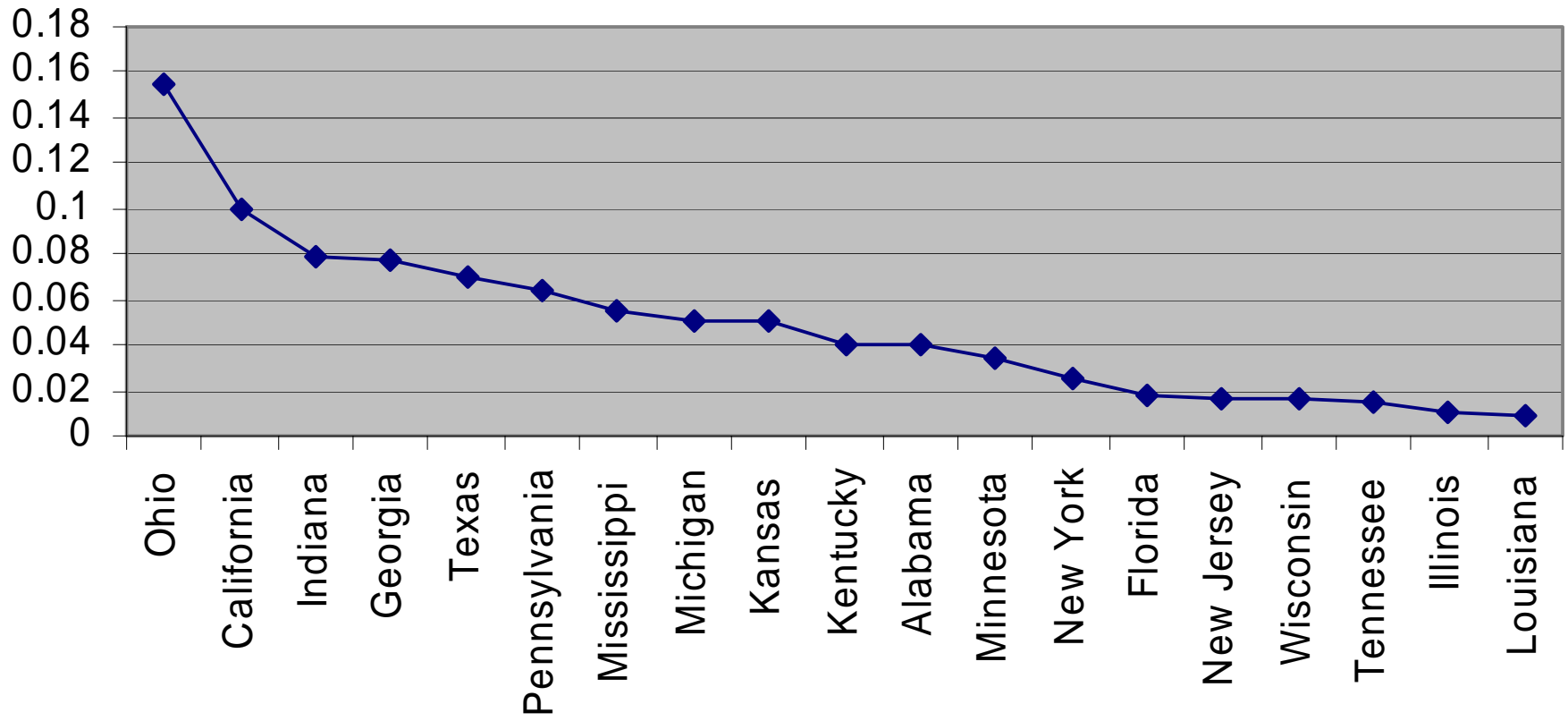
# Computation Tools: Residential Energy and Emissions Savings

- ◆ REM/Design: Residential energy simulation model
- ◆ Regression model based on ASHRAE heat loss equations
- ◆ Emission factors for fuel sources
  - EPA's AP-42 database
  - EPA's 1997 E-GRID database

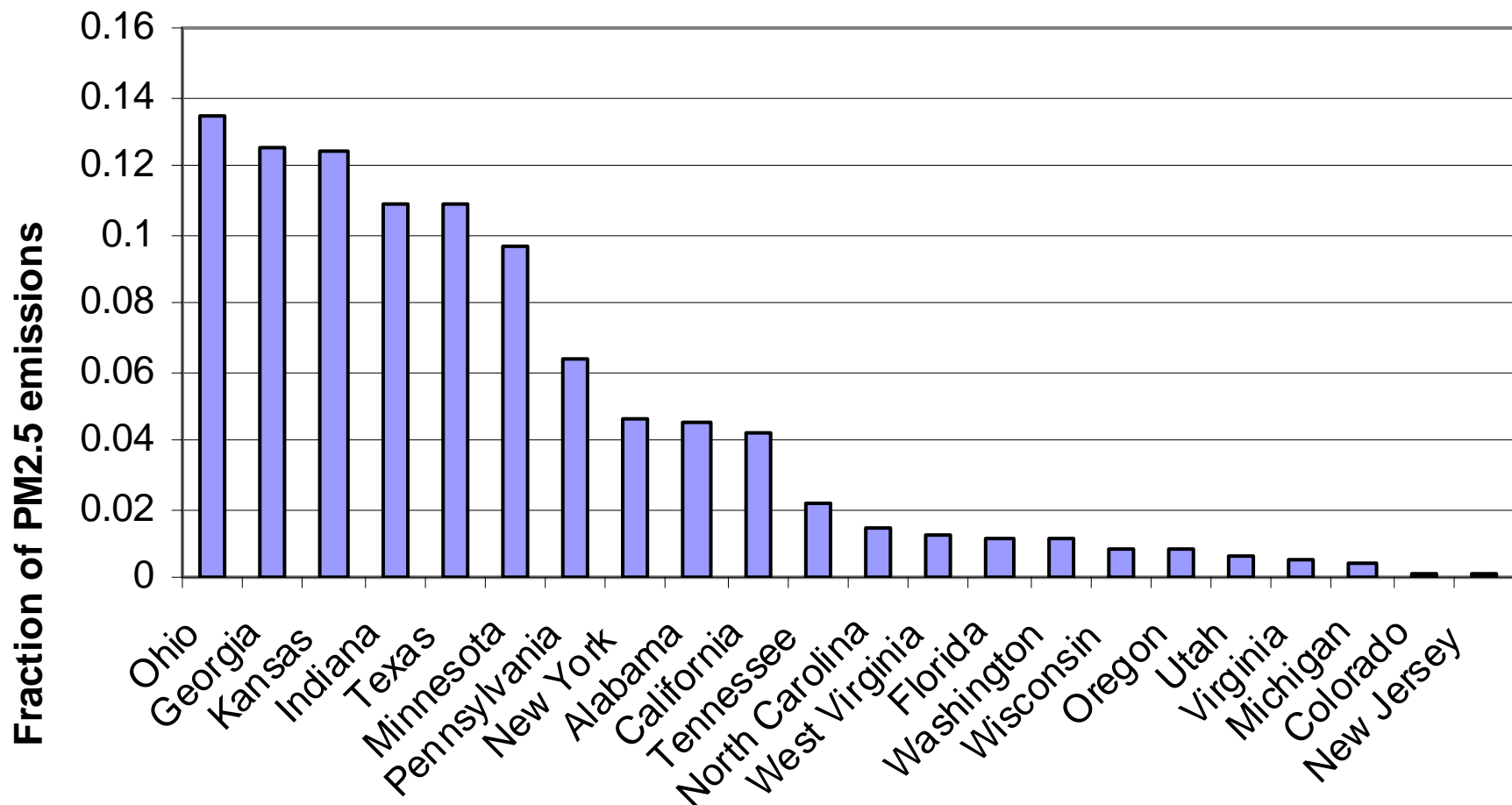
# Insulation gap



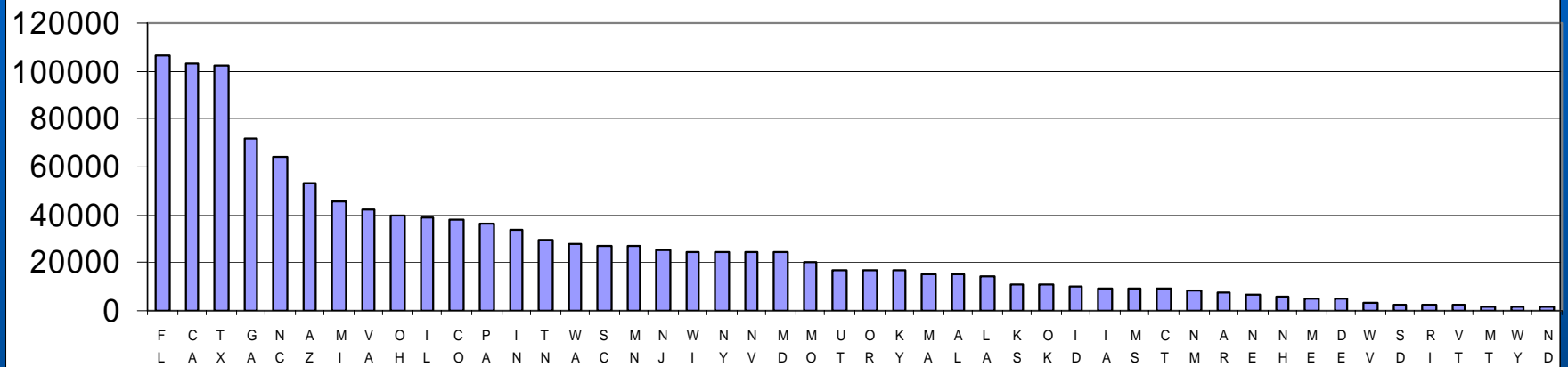
### Mineral wool industry



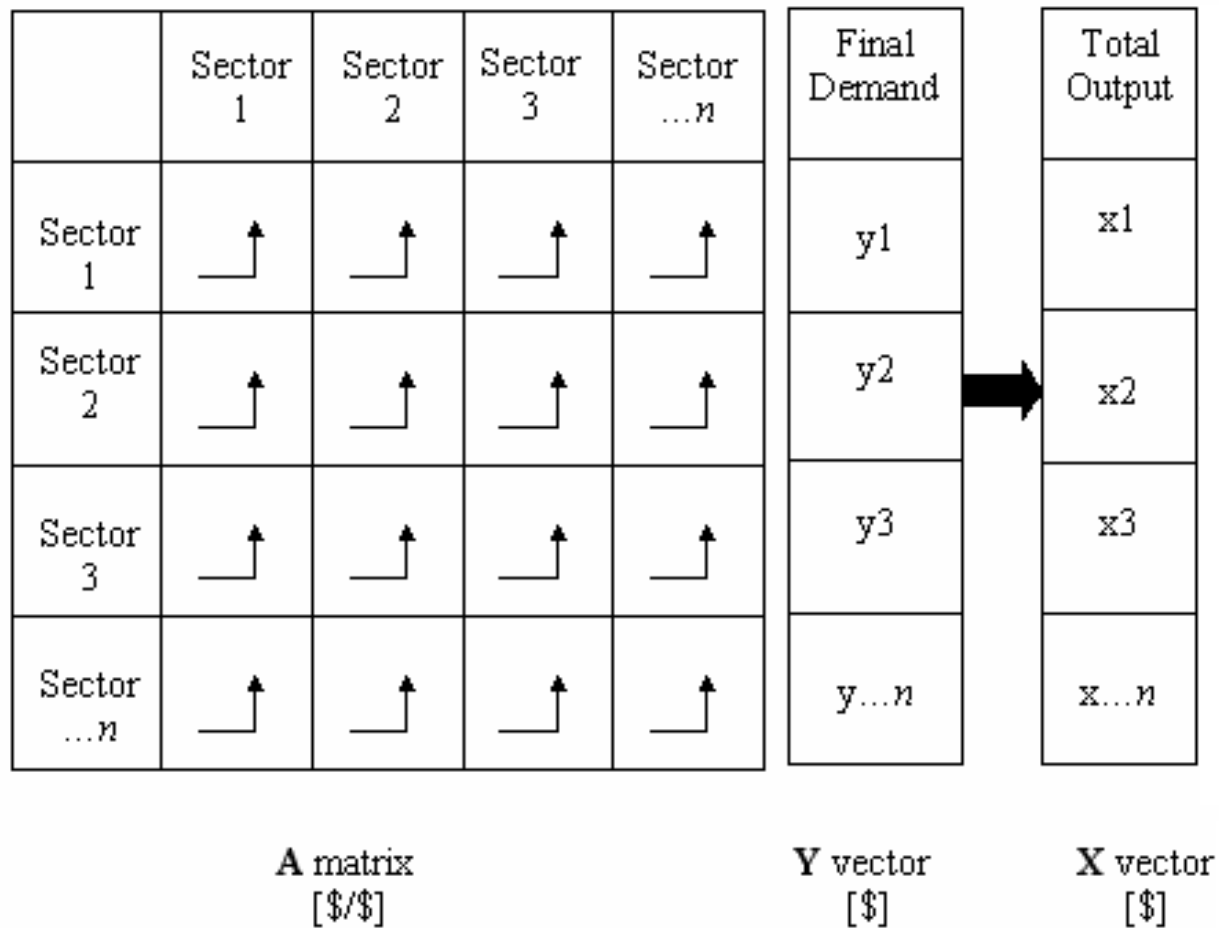
# Mineral Wool Industry: fraction of PM2.5 emissions by state



# new houses



# I-O LCA Computation



# I-O LCA Computation

