fcn Institute for Future Energy Consumer Needs and Behavior

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# Energy Efficiency Policies and Rebound Effects in the Light of Radical Technical Change

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# Presentation Outline

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1. Introduction
2. Energy Efficiency Policies
3. Rebound Effect
4. Reaching Environmental Policy Goals by Technological Solutions? – e.g.
   - Smart Lighting
   - ICT
5. Conclusions




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# Motivation

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- Energy efficiency, in recent years, is seen as a panacea for policies aiming at energy supply security and climate change mitigation

Raises three questions:

- Is energy efficiency a silver bullet?
- Can energy efficiency goals be economically justified?
- Are we really “doing more with less” (EC Green Paper, 2005)?



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# 1. Introduction



- Worldwide, **energy intensities** are decreasing, while **energy consumption** is growing, despite significant **energy efficiency** increases

➡ Casts doubts on effectiveness of energy efficiency policies, and begs the question about the relevance of rebound effects

- Different countries and regions exhibit **wide discrepancies in energy use per capita** and energy **demand saturation** (WEC: energy cons. 1.5 toe /cap*a minimum for adequate development; sustainable energy visions 2000 W/cap or 1 t $CO_2$/cap society)
- **IEA** (and other major institutions) are **increasingly concerned** about rising GHG emissions and security of energy supply
- Hope of governments that an **energy-efficient knowledge society** will use much less (energy) resources

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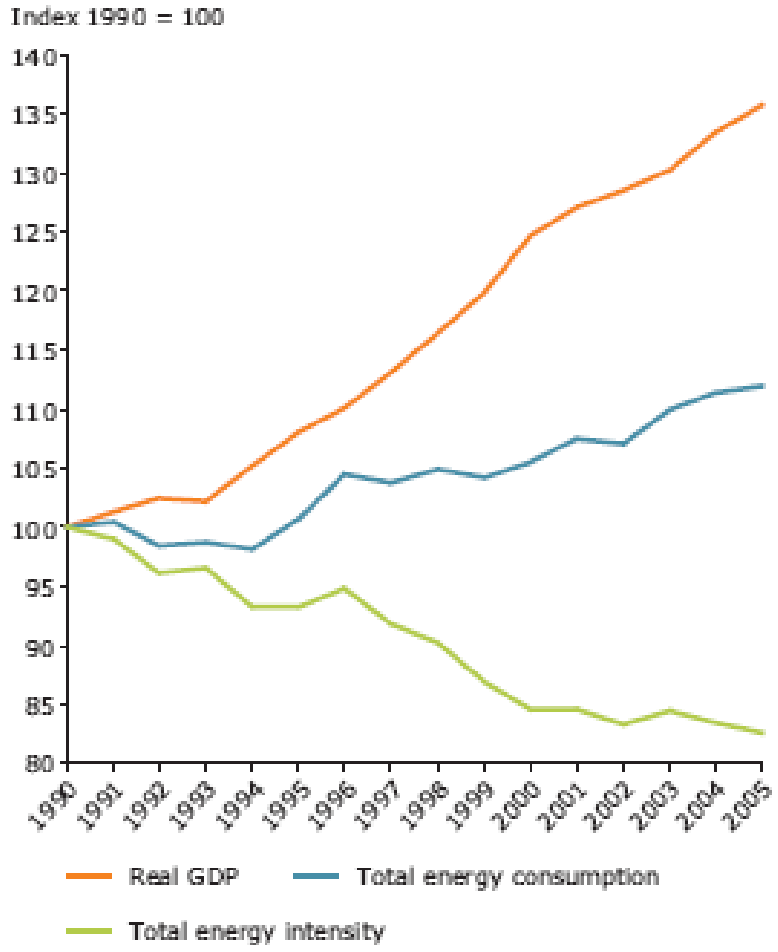
## **EU-27 Trends:** GDP, energy intensity, and energy consumption




Source: EEA (2008)



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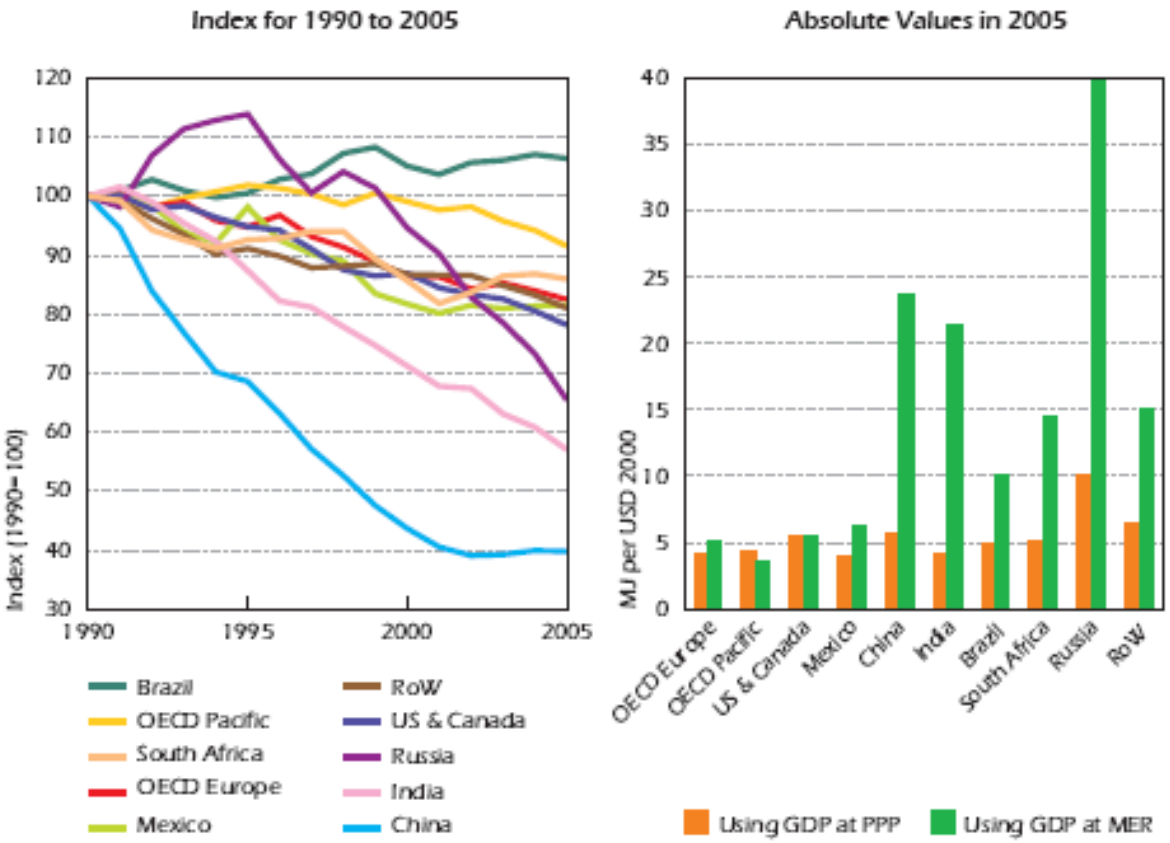
## **Decreasing energy intensities** as an indicator for sustainability?

**Figure 2.5** ▶ *Total Final Energy Consumption per Unit of GDP*




Sources: IEA, 2007c; IEA, 2007d; IEA estimates.



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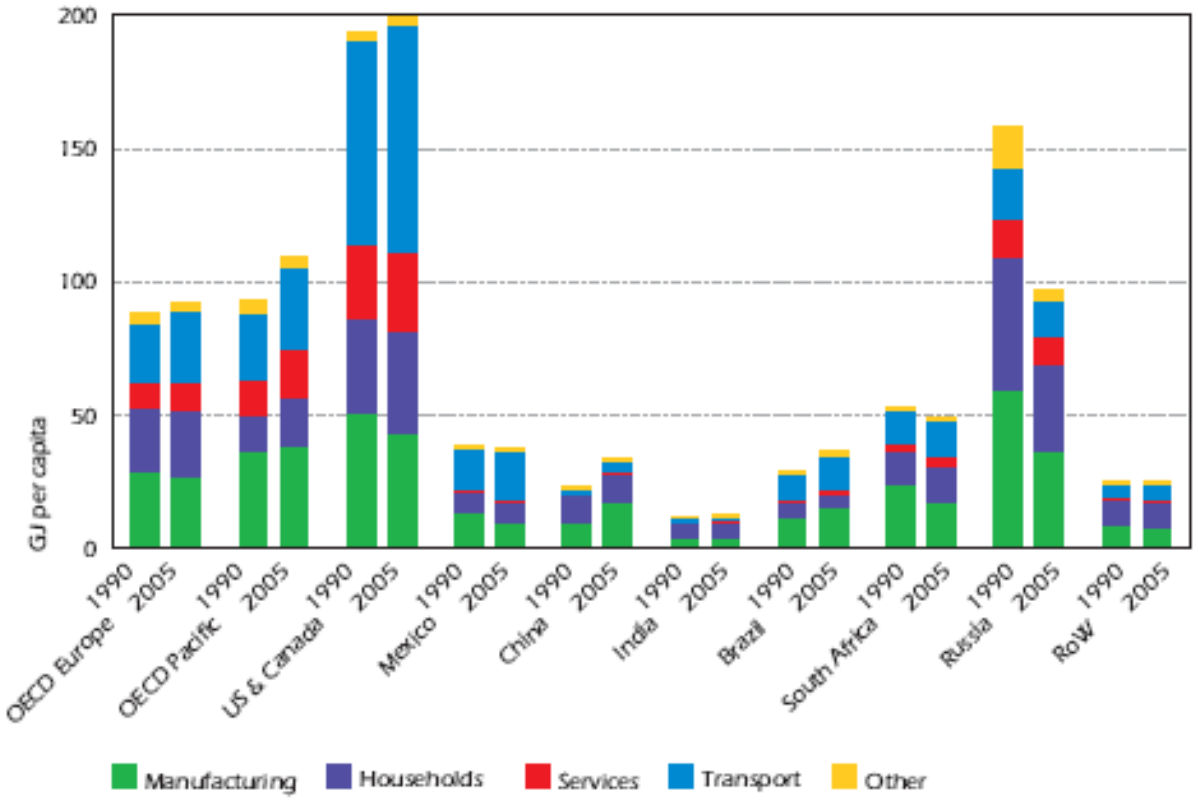
Does **final energy consumption** per capita reflect energy efficiency gains?

**Figure 2.6** ▶ *Total Final Energy Consumption per Capita*




Sources: IEA, 2007c; IEA, 2007d; IEA estimates.
Note: Other includes construction and agriculture/fishing.



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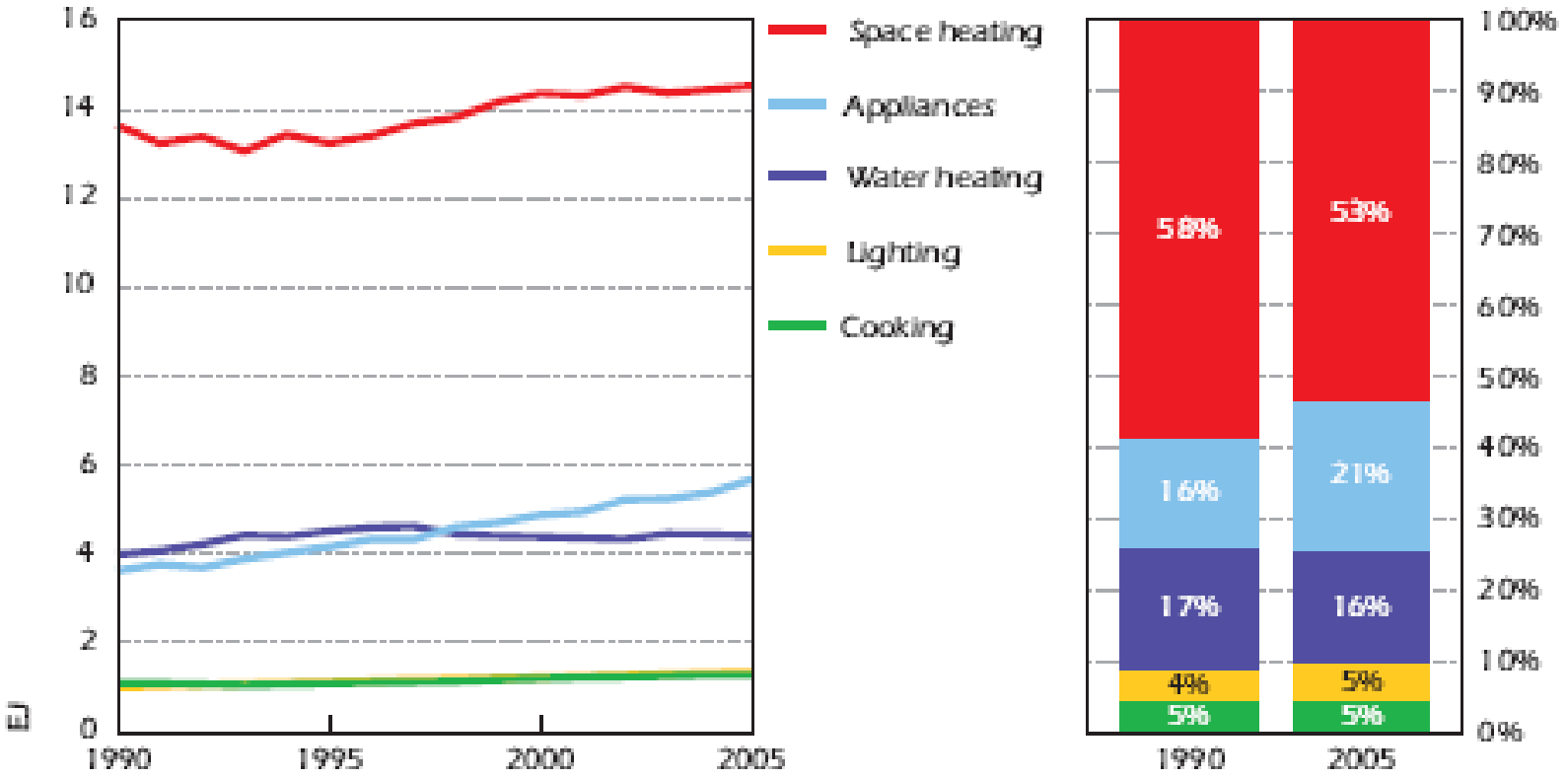
Trends in **household energy use** in the industrialized world, 1990-2005

**Figure 4.3** ▶ *Household Energy Use by End-Use, IEA19*




Source: IEA Indicators database.



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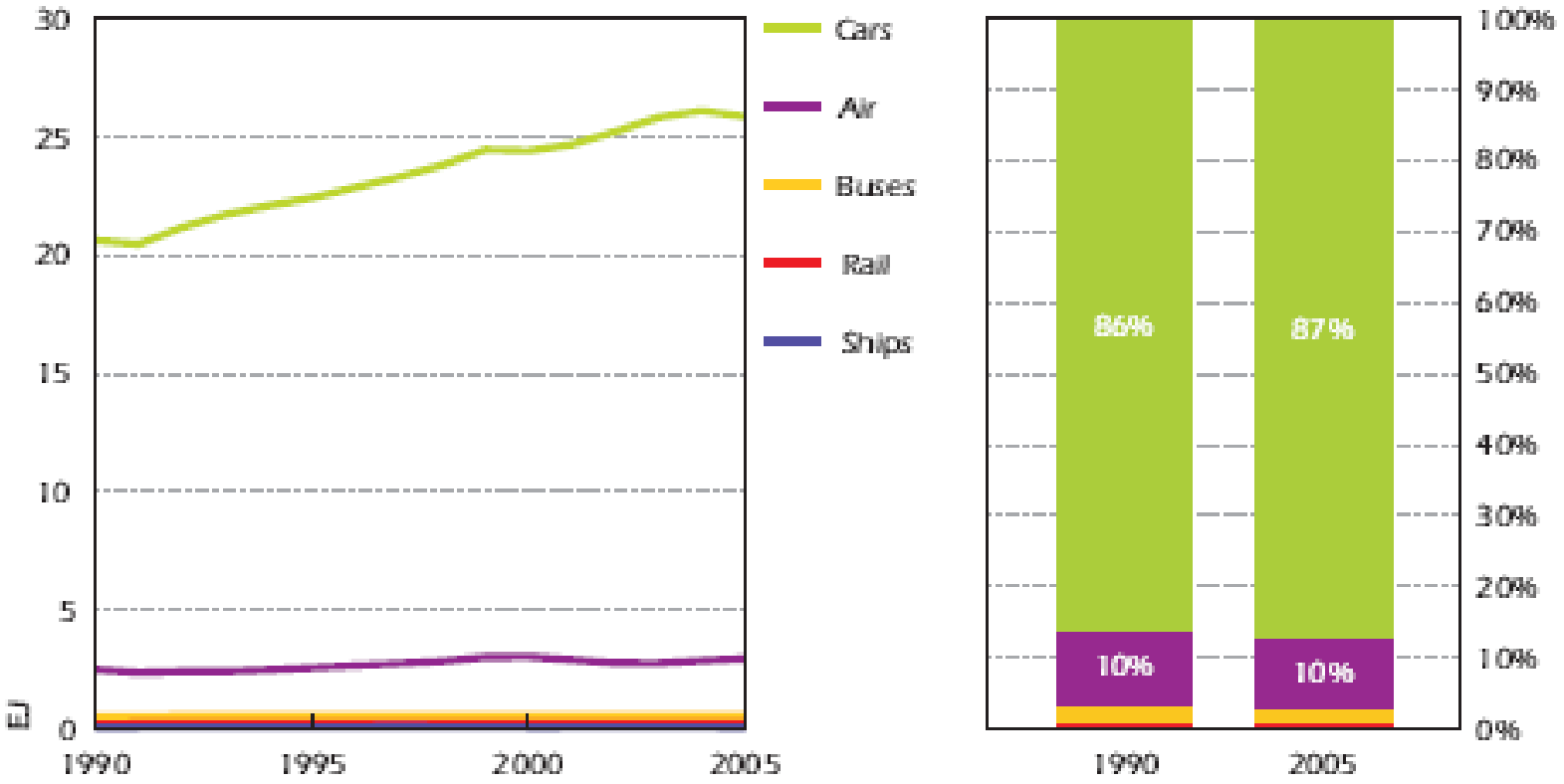
## Copying Western **passenger (road) transport** to the whole world? 1/2

**Figure 6.2** ▶ *Passenger Transport Energy Use by Mode, IEA18*




Source: IEA Indicators database.



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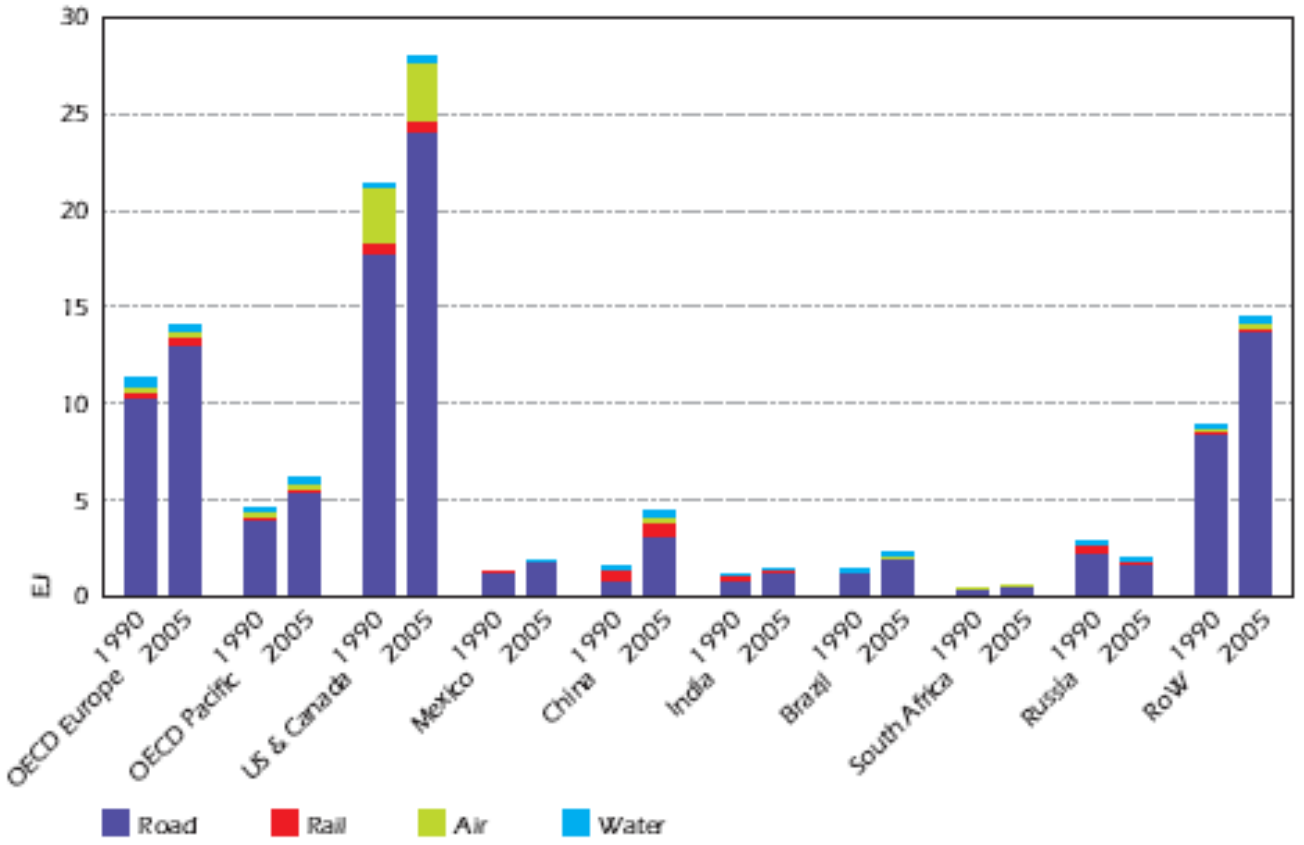
## Copying Western **(road) transport** to the whole world? 2/2

**Figure 6.1** ▶ *Transport Energy Use by Mode*




Sources: IEA, 2007c; IEA, 2007d; IEA estimates.



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- Widespread belief that increased energy efficiency (EE) will solve our energy supply and environmental problems
- Misconceived:
  - Expected **savings by engineering calculations,** ignore **price-demand mechanism and behavioral change**, and may grossly over-estimate *achievable* energy savings and GHG mitigation potentials
  - **EE seen as a means, rather than an ends** (of economic efficiency)
- Welfare economics / government intervention: **Market failure?**
  - Principal-agent problems (landlord-tenant dilemma – apartments, hotels, …)
  - External effects
  - Information asymmetries
- Removal of energy **efficiency barriers**: **trade-off** between **energy efficiency vs. cost efficiency**!
  - Transaction costs, Split incentives, Opportunity costs, …

# 2. Energy Efficiency Policies and Scenarios

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- **EU**: +20% by 2020, **US**: +30% from 2003 till 2015 – energy efficiency targets on top of many political agendas
- Quotes from **IEA** “Work for the G8 – 2008 Messages”:
  - “Energy efficiency improvements are a top priority throughout the economy and they can be applied right now. In industry alone, application of proven technologies and best practice on a global scale could save 18% to 26% of current industrial energy use.”
  - “Any path to sustainability begins with improving energy efficiency throughout the global economy. […] If energy efficiency had not improved since 1973, energy use in IEA countries would have been 58% higher in 2005 than it actually was. The equivalent of 59 EJ of energy was saved.”

➡ What size of **rebound effect** is assumed in such calculations?

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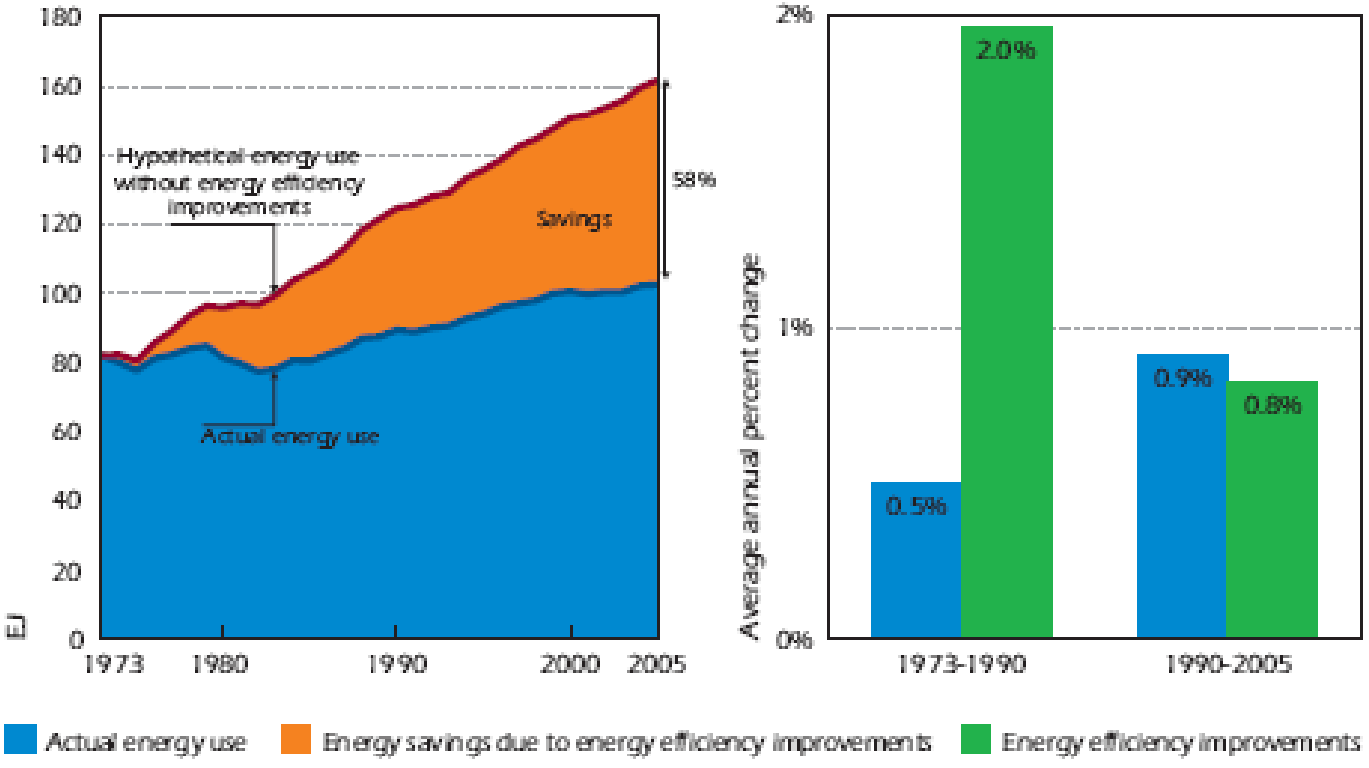
How much **energy saving from efficiency improvements** (IEA-11)?

**Figure 2.9** ▶ *Long-Term Energy Savings from Improvements in Energy Efficiency, All Sectors, IEA11*




Source: IEA Indicators database.



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# 3. Rebound Effect

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- The question is whether **economically (seemingly) worthwhile improvements** in the technical efficiency of energy use can be expected to reduce energy consumption by the amount predicted by simple engineering calculations

- **Classification** of rebound effects:
  - Direct (primary) rebound effect
  - Indirect (secondary) rebound effect
  - Economy-wide effect
  - Price effect
  - Substitution effect
  - Income effect

- Empirical evidence: Mainly for **direct rebound effects** only, a limited number of energy services, and **industrialized countries** (satiated markets)
- Neglected in many policy designs and calculations of efficiency potentials



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# 3. Rebound Effect

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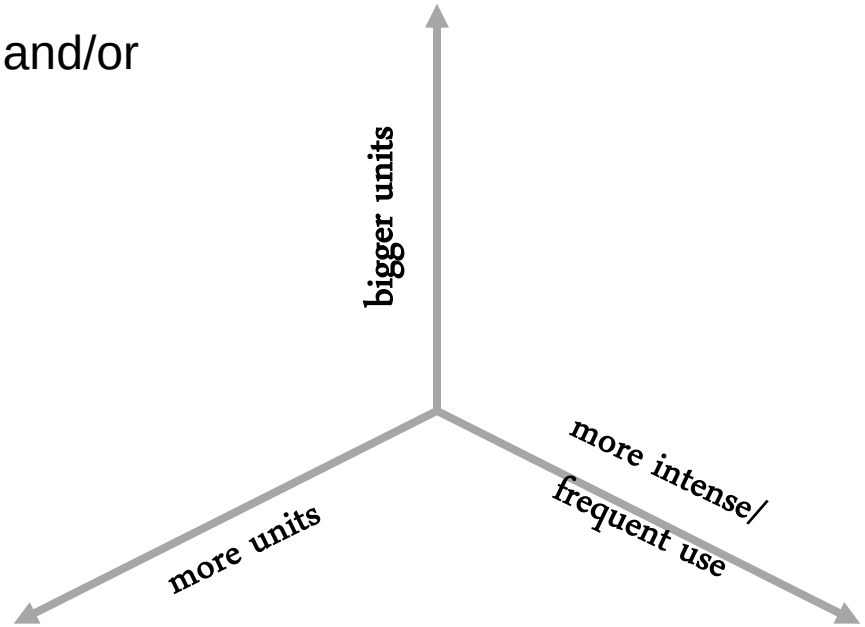
- **Technological improvements** in energy efficiency may lead to an increase in:
  - the number of energy conversion devices (*NO*),
  - their average size (*CAP*),
  - their average utilization (*UTIL*), and/or
  - their average load factor (*LF*).

- Example: cars



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# 3. Rebound Effect

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- **Empirical evidence sparse** and from **very diverse studies** differing in their methodological quality
- Competing definitions, notations, measures, and terminology
- **Methodological challenges** (quasi-experimental and econo-metric approaches), e.g. selection bias, measurement errors, lack of counterfactual estimate
- **Research bias** towards direct rebound effects, household energy services (esp. heating, personal automotive transport), and studies from the U.S.
- **Lack of suitable data** for other sectors of the economy, (developing) countries, and types of energy services
- Considerable **progress in clarifying methodological issues** in recent years (e.g. thanks to extensive UK ERC study)



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## Direct rebound estimates

| | |
|---|---|
| Residential space heating | 10 – 30% |
| " " space cooling | 0 – 50% |
| " " water heating | < 10 – 40% |
| " " lighting | 5 – 12% |
| " " appliances | 0% |
| Automobiles | 10 – 30% |
| Firms' lighting | 0 – 2% |
| " process uses | 0 – 20% |

Source: Greening et al. (2000)



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## Direct rebound estimates (updated, reviewed)

| End-use | Range of values | Best guess | No. of studies | Degree of confid. |
|---|---|---|---|---|
| Personal auto-motive transp. | 3-87% | 10-30 | 17 | High |
| Space heating | 0.6-60% | 10-30 | 9 | Medium |
| Space cooling | 1-26% | 1-26 | 2 | Low |
| Other consumer energy services | 0-41% | < 20 | 3 | Low |

Source: Sorrell et al. (2009)



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# 3. Rebound Effect



- Higher in the absence of satiation
  - Developing countries
  - Low-income population
  - Needs of existing and/or new consumers of energy services
- Opportunity costs of increasing energy demand
  - Space constraints (size of households)
  - Time constraints (↑ with rising income)

## Recent rebound estimates

- Frondel et al. (EnJ 2008)
  - Study on individual passenger transport in Germany (direct rebound)
  - Econometric model (household panel / travel diary data, 1997-2005)
  - Main (and robust) finding: rebound effect of between **56-66%**
  - Conclusion that fuel efficiency standards might be ineffective compared to fuel taxes
- Hanley et al. (EcolEcon 2009)
  - Study on the macroeconomic rebound effect in Scotland
  - CGE model
  - Main finding: for general energy efficiency improvement in the production sectors initially rebound effect **> 100%** (‘backfire’)
  - Conclusion that energy efficiency policies alone are insufficient to induce environmental improvements

# 3. Rebound Effect

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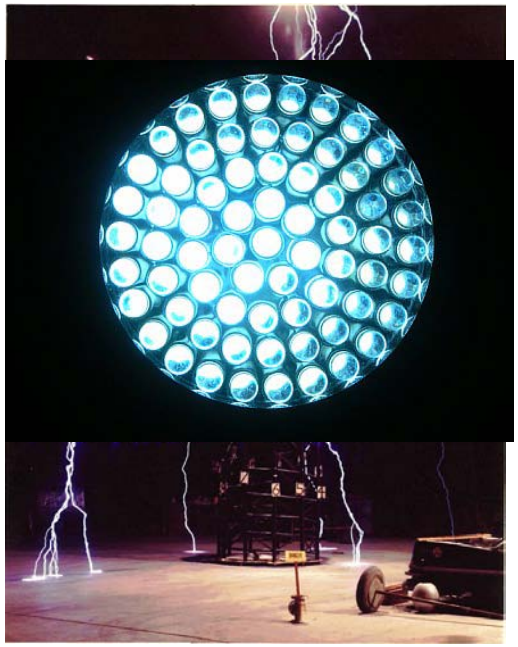
- **Improvements in energy efficiency** could be a result from
  - energy-saving technological change
  - substitution between energy and other inputs
  - substitution between useful work and other output attributes
- In practice, many energy services have **multiple attributes** (e.g. size, comfort, reliability, speed) and each attribute may have a **non-zero elasticity** with respect to the energy cost of useful work

→ The long-term response to a reduction in energy costs will depend upon the trade-offs between useful work and these multiple attributes

# 4. New Technology and Environmental/Energy Policy Goals



- **Smart Lighting:**
  - Lighting: 5% of final energy (19% of prim. energy use for el.)
  - Phase-out of incandescent bulbs (banned in AUS, NZ, Germany) – 15 lumens/W
  - CFLs (65 lumens/W) / Halogen lamps
  - LEDs (132 lumens/W)
  - OLEDs (presently 60 lumens/W, but revolutionary development under way)
- $100 bn global market
- Huge energy efficiency potentials
  - Totally new architectural designs (OLEDs)
  - Automatic dimming by daylight
  - Movement sensors (person tracking)
- Risk of substantial rebound effects (demand for mood lighting & stylish interior vs. energy saving & environmental protection),
- Example: Lighting of UK homes rises despite rapid CFL diffusion and significant policy efforts (Crosbie et al., 2008)



- **Information and Communication Technology (ICT):**
  - 2% of electricity consumption for ICT equipment
  - Energy consumption of ICT equipment itself helps to save energy in other devices (e.g. cars, refrigerators)
  - Market failures: e.g. set-top boxes (cable TV)
  - Trend: Virtualization / “Cloud computing” (better use of idle capacities in highly efficient data centers)

- ICT and energy efficiency
  - Integration of centralized / decentralized power and heat generation, Smart Metering and grid automation (‘Smart Grid’) with market participants
  - *Income effect* (economic boost from increased use of ICT, increases energy consumption) and *substitution effect* (change in industrial structure and capital stock towards higher productivity, decreases energy consumption)
  - Empirical evidence: case studies (e.g. data centers); aggregate econometric studies: mixed evidence (Bernstein/Madlener, 2009)

# 5. Conclusions



- **Energy efficiency** is seen by many as **a means rather than an ends**, an important pillar of sustainable development, and a weapon to combat peak-oil and climate change (technical fix)
- The **rebound effect** has largely been ignored, despite recently revived academic activities, and an increasing collection of empirical evidence indicating that (direct) rebound effects are **not negligible**
- **Increased recognition that behavioral change is needed** (revival of energy conservation and sufficiency debate?), incorporated into modern lifestyles (bottom-up behavioral change, rather than top-down policies)
- **Recommendation 'get the prices right' applies**, but is politically challenging, may have undesirable (unpopular) social consequences
- Will **increasing scarcity** of (cheap) fossil fuels and **paradigm changes** (Smart Light, Smart Metering, Smart Grid, e-Mobility etc.) induce **behavioral and value changes** towards **sustainable development**?

# Thank you for your kind attention!

# Any questions?

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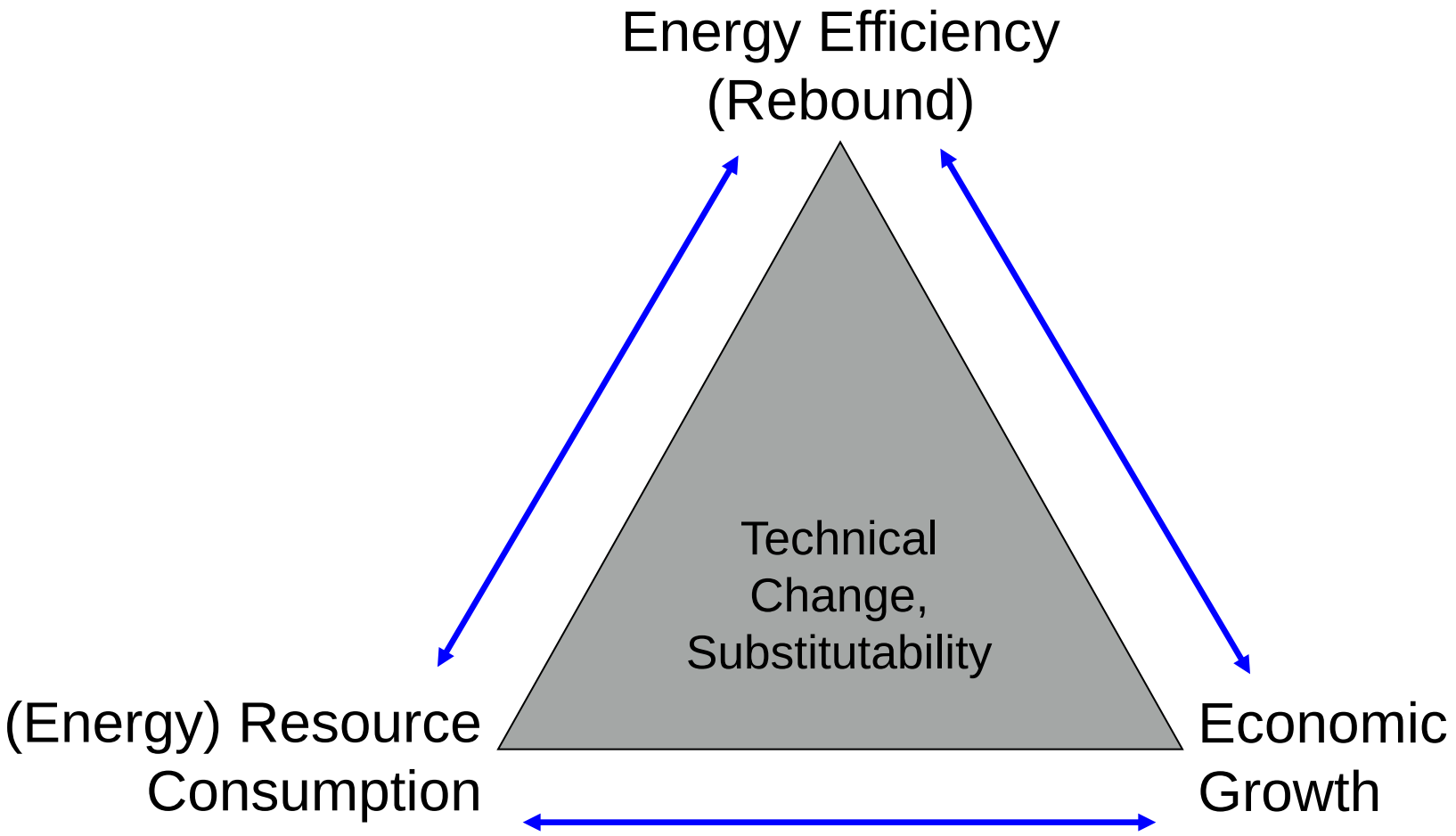
# 3. Rebound Effect




Source: Madlener / Alcott (2009)