HOW ENERGY EFFICIENCY WORKS

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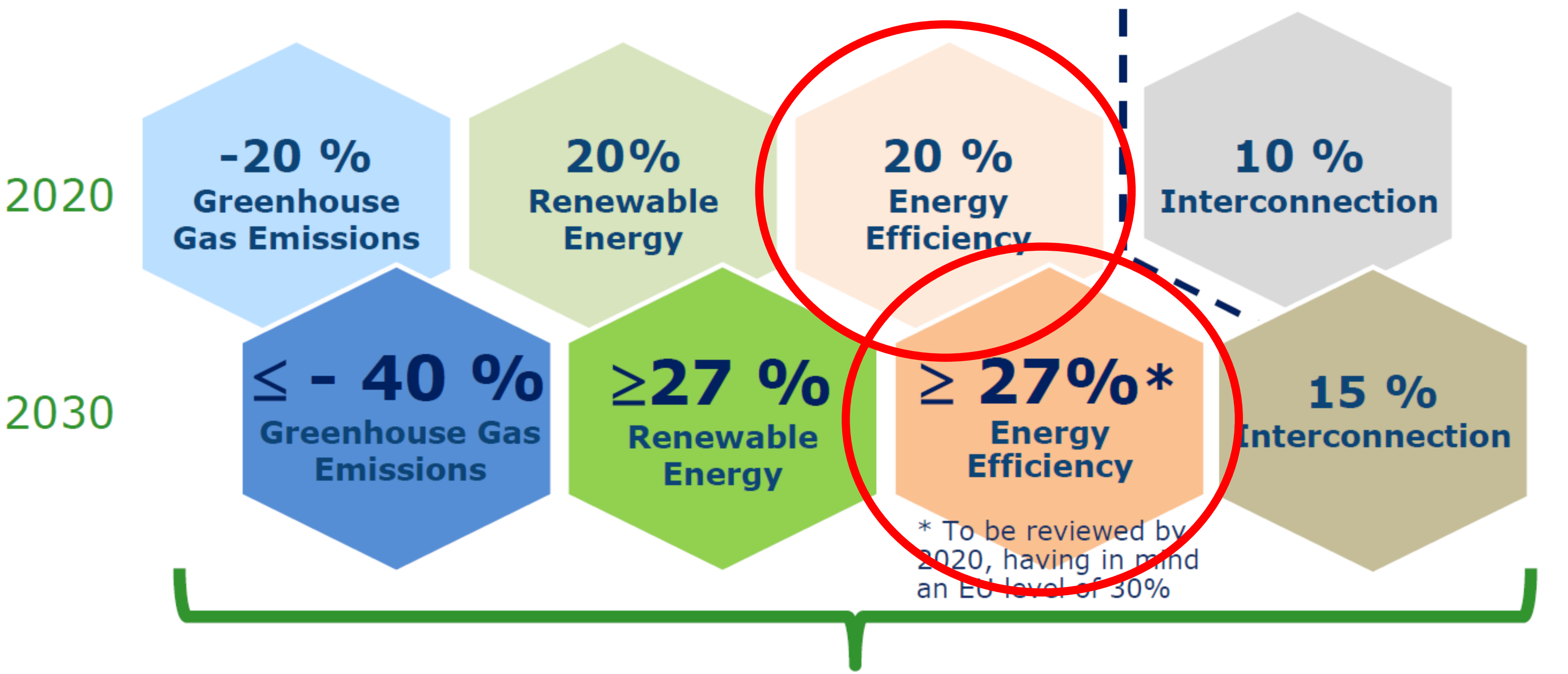
CONTENT:

1. Motivation
2. Basic principle: Providing energy services – not consumption of energy
3. History
4. Rebound
5. Conservation cost curves
6. Conclusions

1. INTRODUCTION

Strategic decision by European Council in 2014



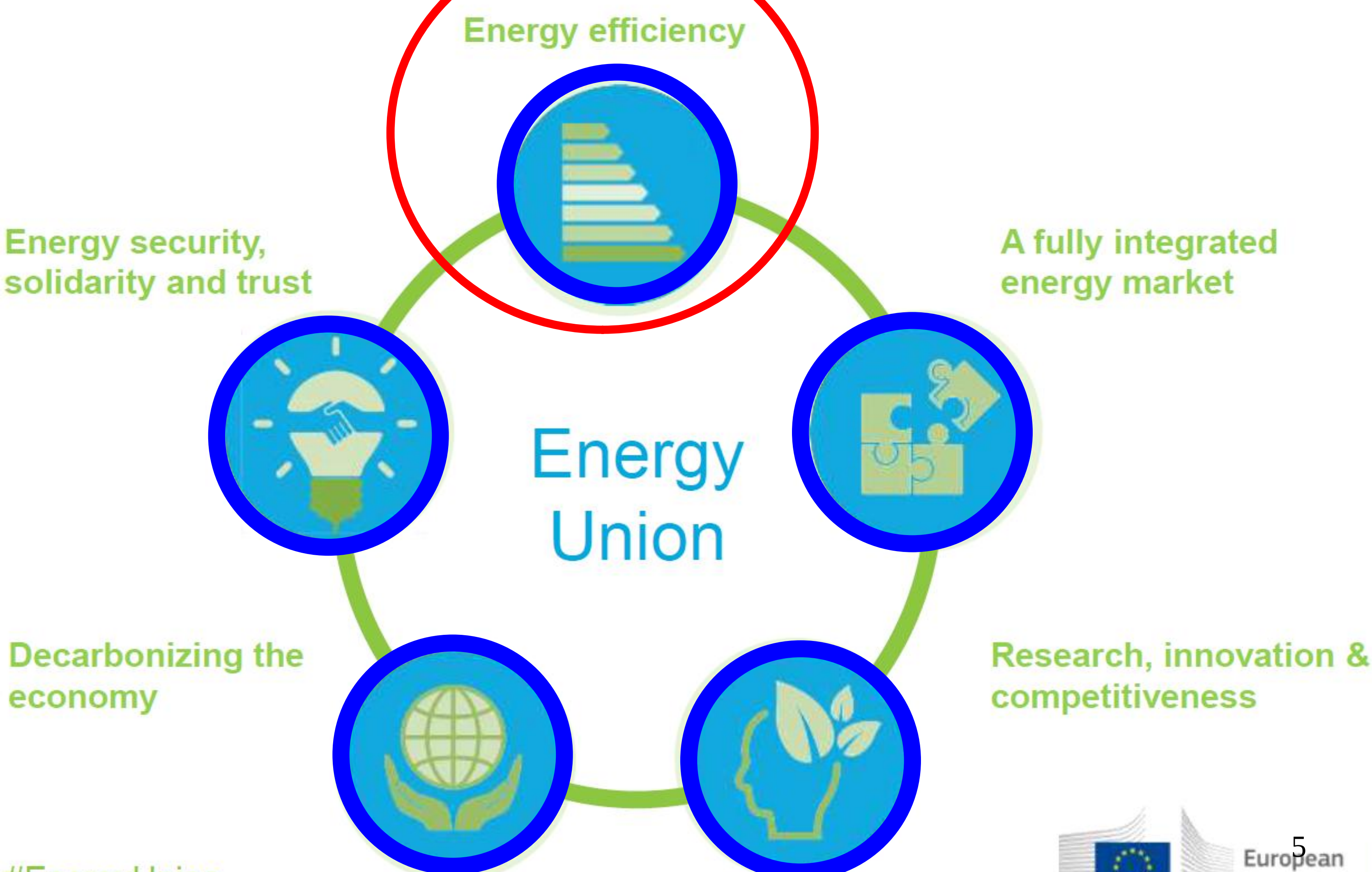
New governance system + indicators

MOTIVATION:

Why promoting energy efficiency?

To reduce energy consumption & CO_2 emissions

Energy Union Strategy



#EnergyUnion

European Commission

Goals of the Clean Energy For All Europeans Package

Putting energy efficiency first

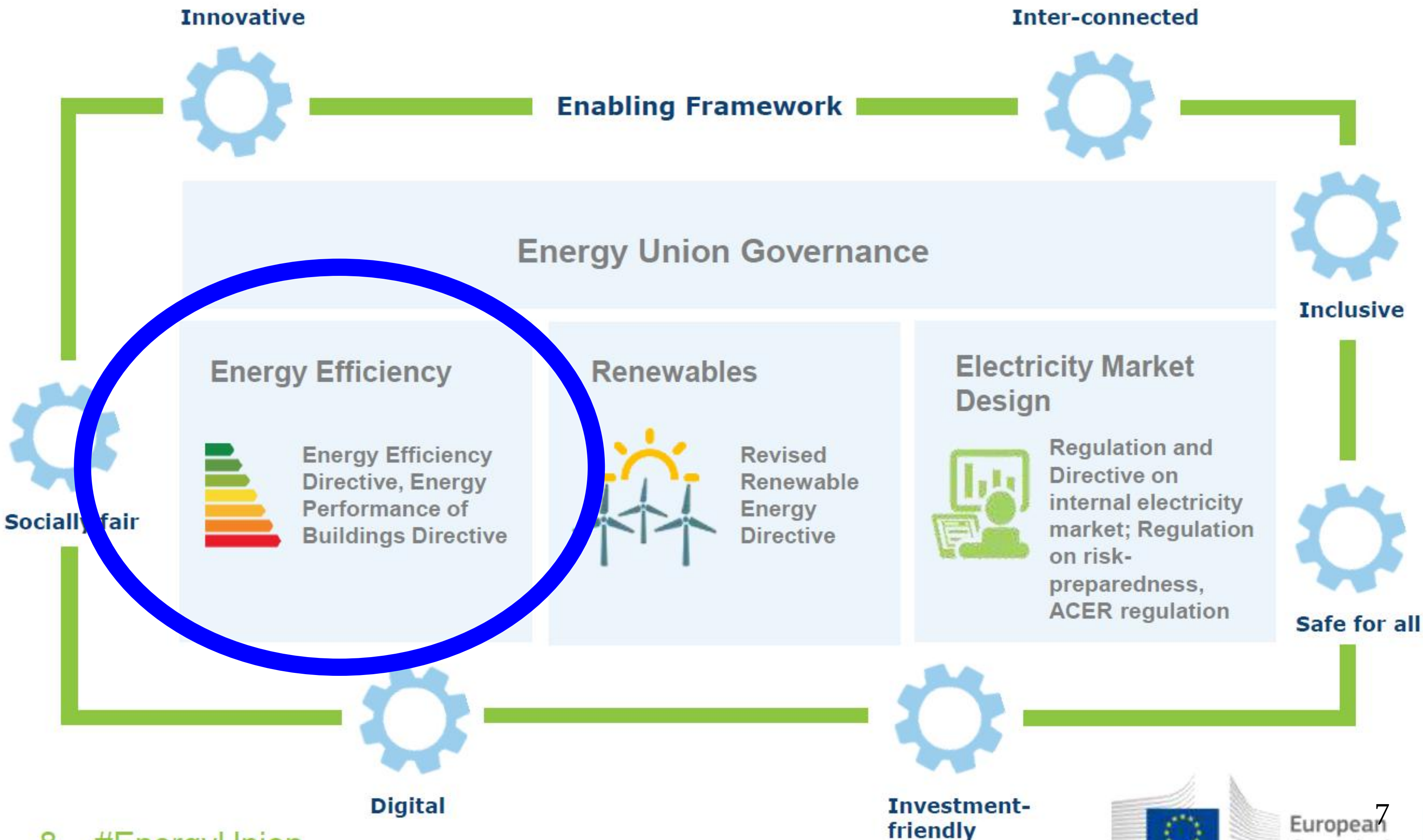
Demonstrating global leadership in renewables

Delivering a fair deal for consumers

An opportunity to…

- …create jobs & growth
- …spur investment
- …secure energy supply
- …make the market fit for purpose
- …bring down GHG emissions
- …foster innovation

Structure of the Package

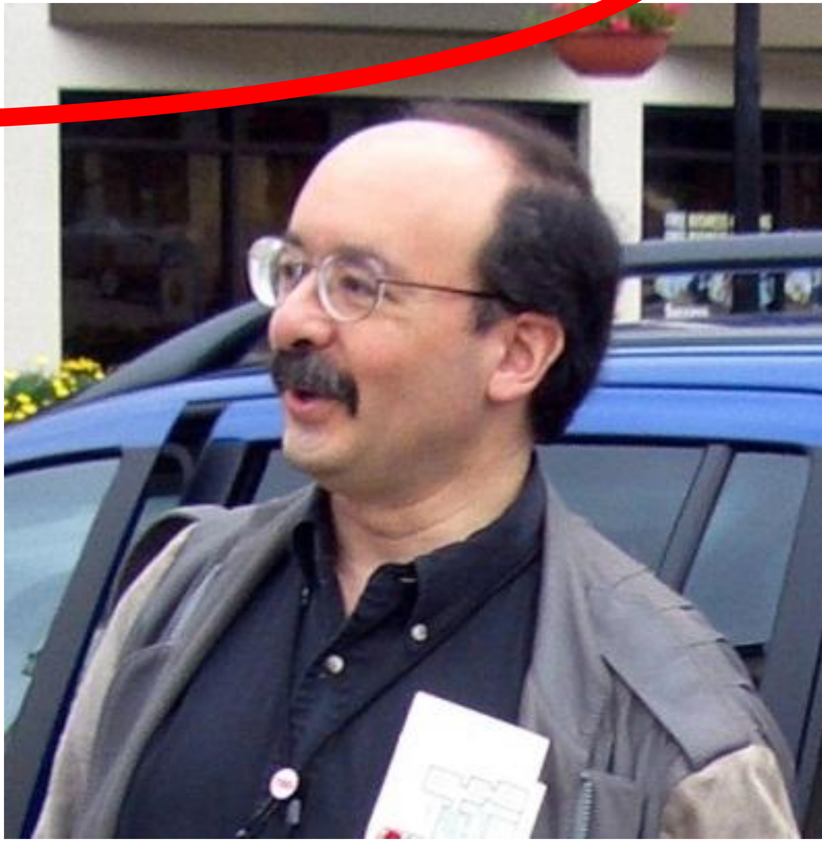


Amory Lovins' approach

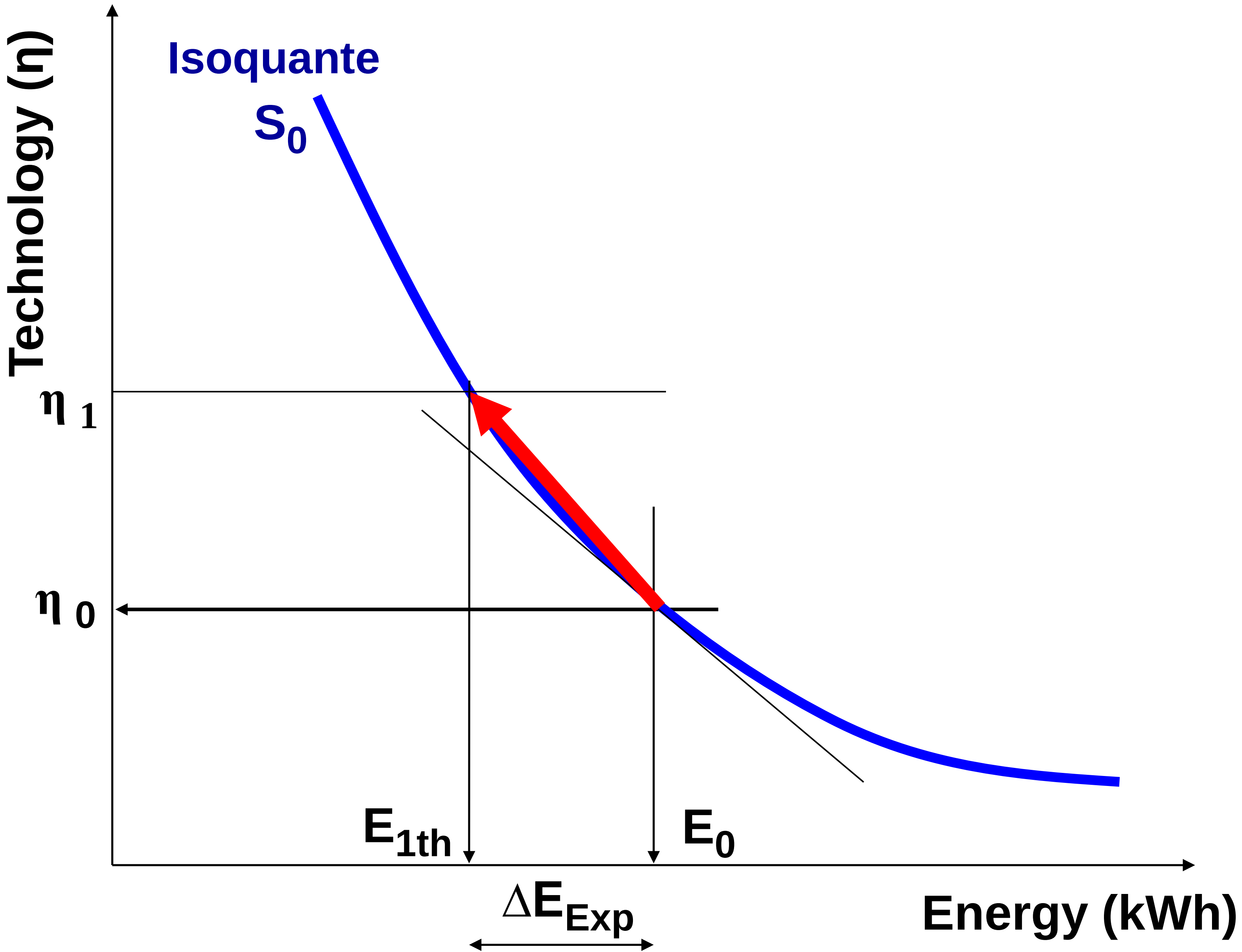
- If it is cheaper to save energy than to generate it …. →

Amory B. Lovins:

- „Negawatt vs. Megawatt“



Expected energy conservation



2. The basic concept of providing energy services

- There is no interest to consume energy. There is a demand for energy services: clean shirts, warm and bright rooms, cold beer, hot coffee, mobility ...

- Inputs: Energy, Technology, human capital, environment

The model

Basic principle:

Efficiency of Infrastructure: buildings, streets, electricity grids

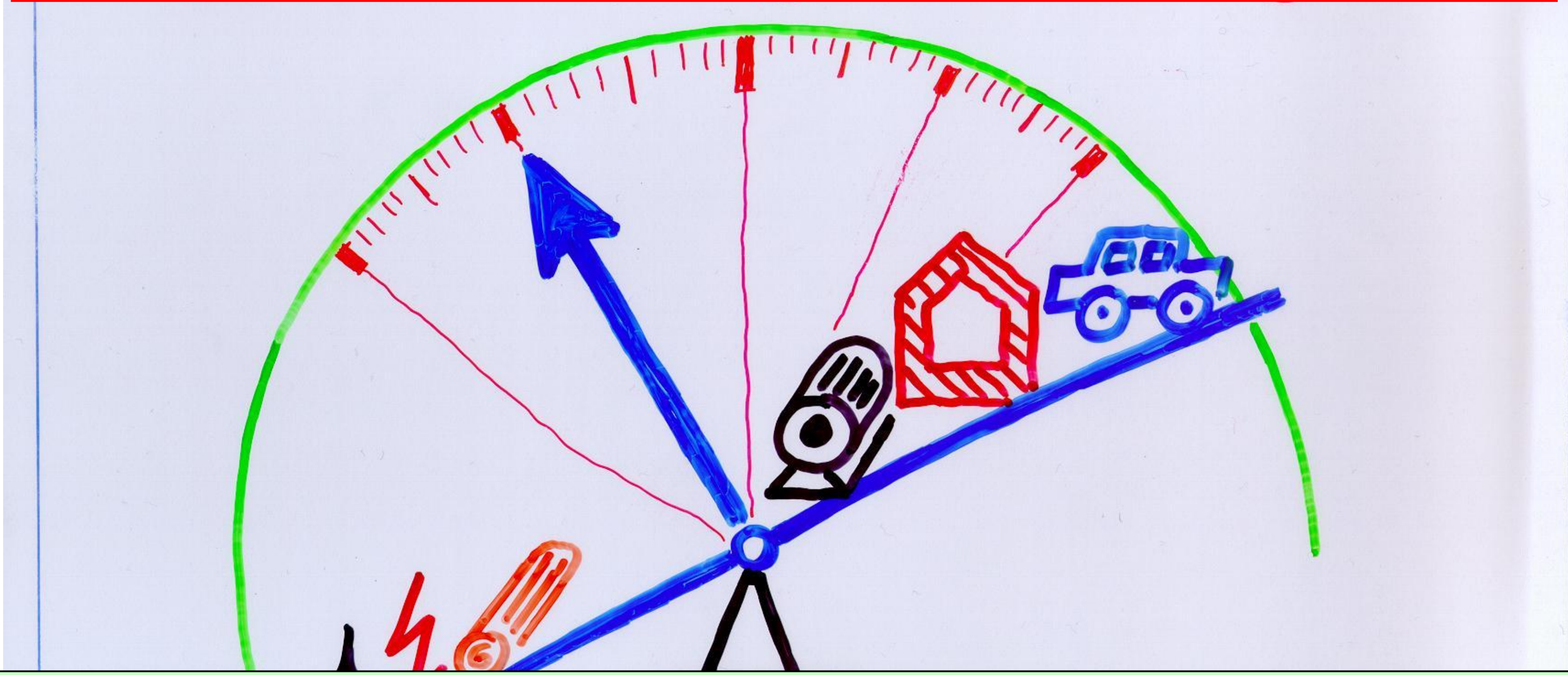
$$S = f(E, \eta\,(T_c), \eta\,(T_{is}))$$

Service:
heating area, litre/km driven, Size fridge

Energy:
Final energy mix, share renewables

Efficiency of conversion technology:
kWh/fridge, kWh per m² heating area, litre/100 km driven

Service = Energy x Technology !



- ***But currently the balance is biased tremendously: To much energy, far to less technical efficiency!***

Basic principle: Production of energy service S

Short-term, if sufficient infrastructure is available :

- Technically: $S = E \;\eta\,(T)$

E…energy, η (T) … efficiency of technology

- Economically: $S = f(p_s, Y)$

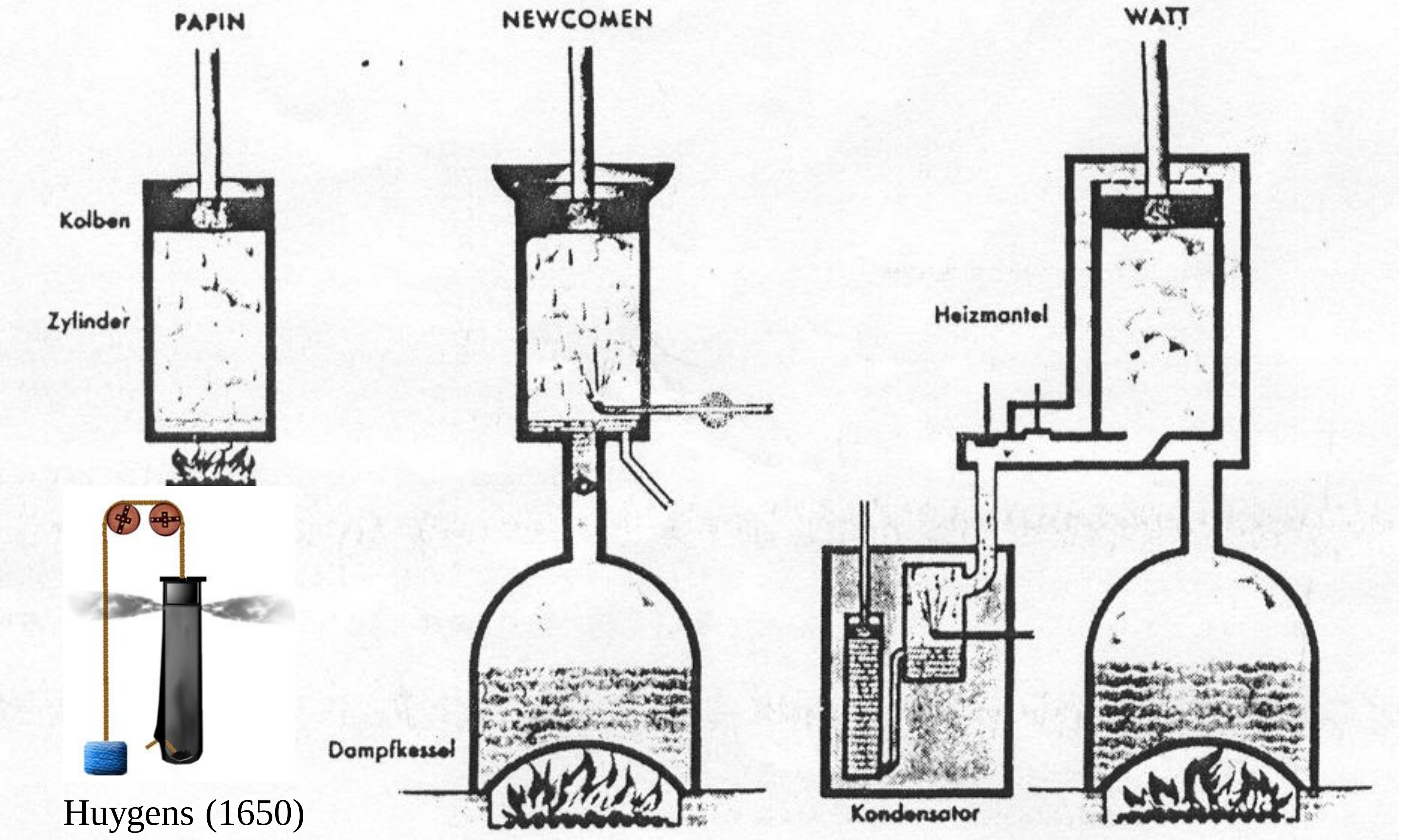
p_s … price of service, Y … income

- Service price: $p_S = p_E \,/\, \eta\,(T)$

p_E … price of energy, Y … income

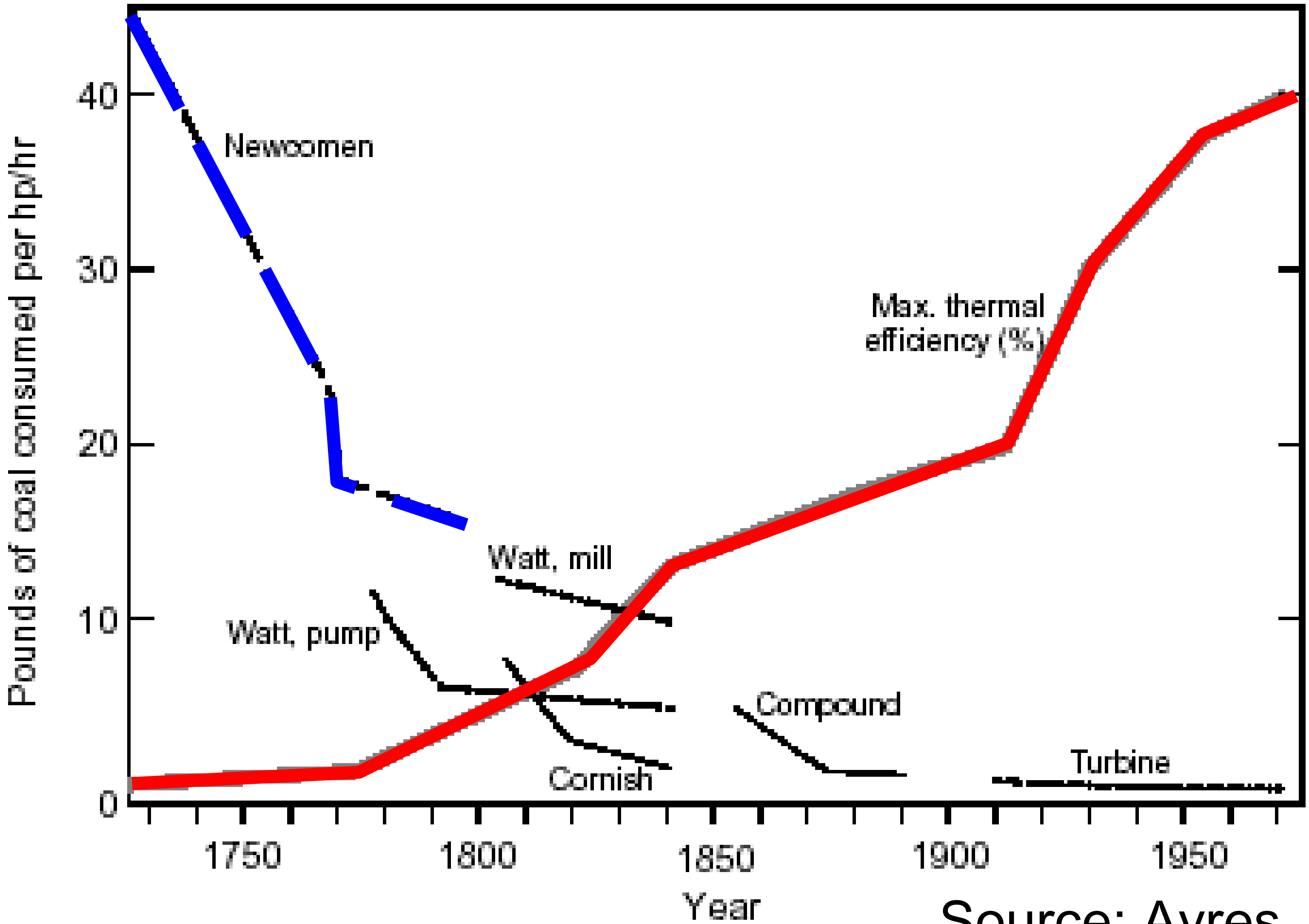
3. History: Development of the steam machine

Ca. 1695: 0.01% Ca. 1720: 2 % Ca. 1770: 5%!



Huygens (1650)

Performance of Steam Engines



Source: Ayres, 1989

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W. Stanley Jevons:
„The coal question (1865)",

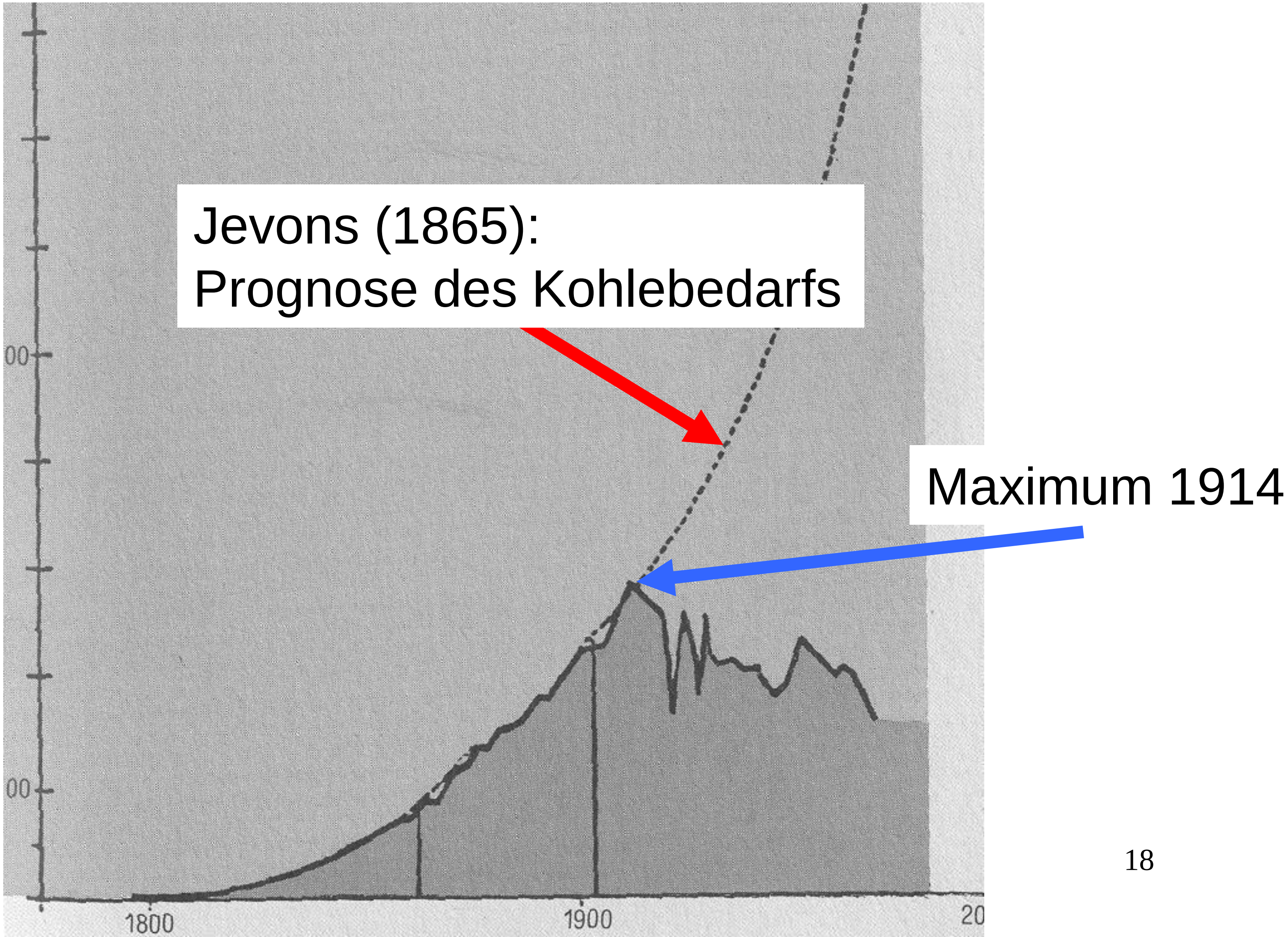
… Expansion problems:

- **continously growing number of steam machines → How long will coal last?**
- **Extention of the railway grid: How long will coal last?**

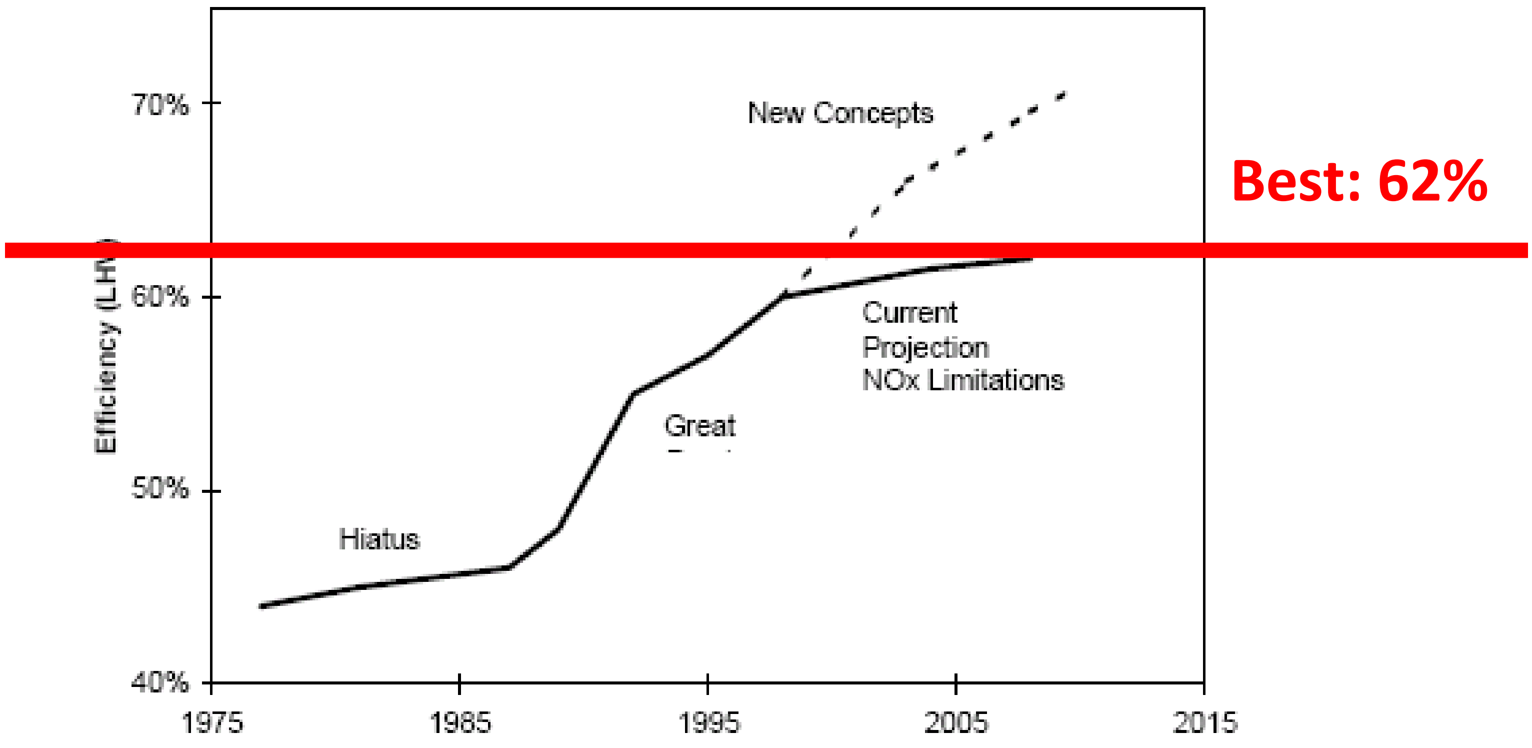
W. Stanley Jevons major findings

- Exponential growth of energy consumption is not possible
- There is a rebound if efficiency is improved (steam engine: Newcomen → Watt!)
- A looming coal (price) crisis could have heavy impacts on the British economy

Coal production in Great Britain 1800 - 1970



Recent Combined cycle plant technologies (combined gas and steam turbine, CC)



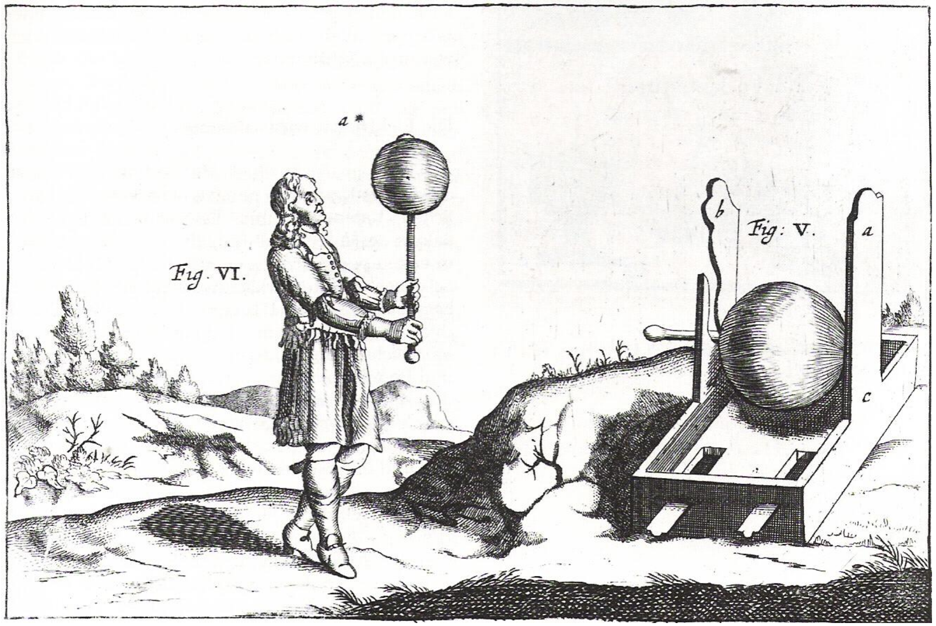
Source: Cohn, Electric Power Research Institute

- Electrical net efficiency of modern CC plants: ~58%
- Latest Siemens “H” type gas turbine:

  CC electrical net efficiency: ~60%

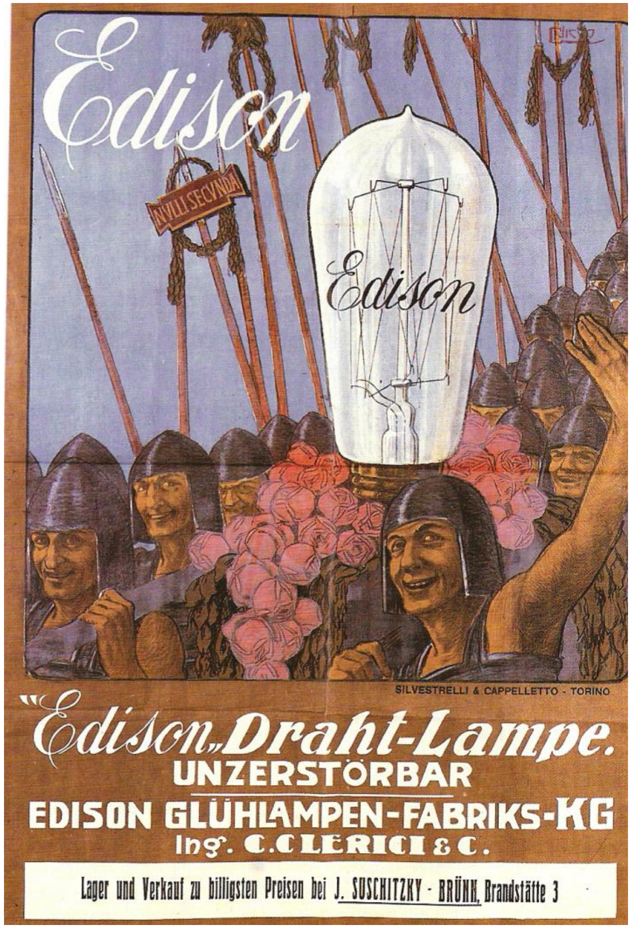
HISTORICAL BACKGROUND:

17th century: Otto v. Guericke



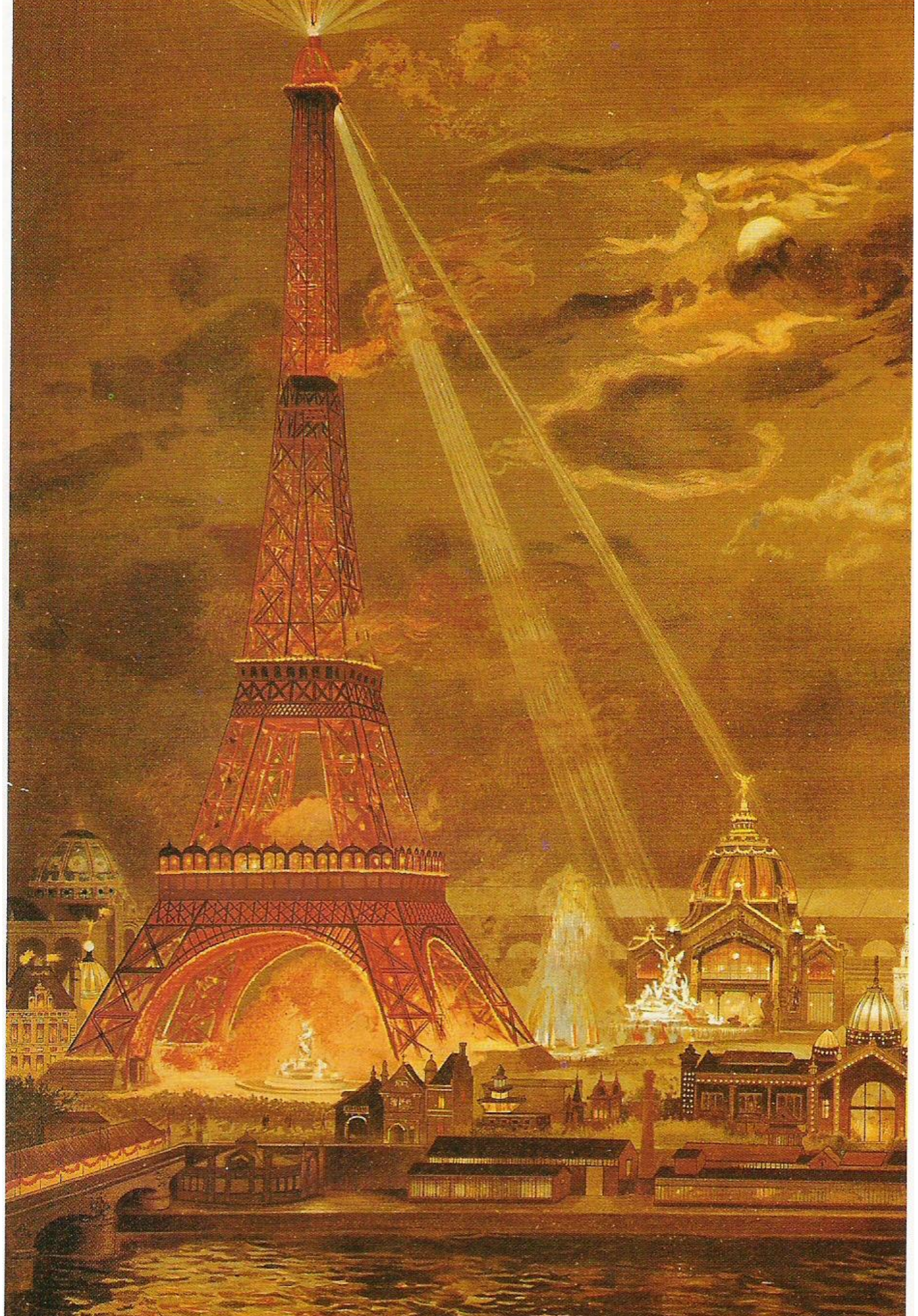
experiments with Sulphur balls which under friction drew light scraps; was the first who used the term „vis elektrica“

Electricity –
THE energy carrier

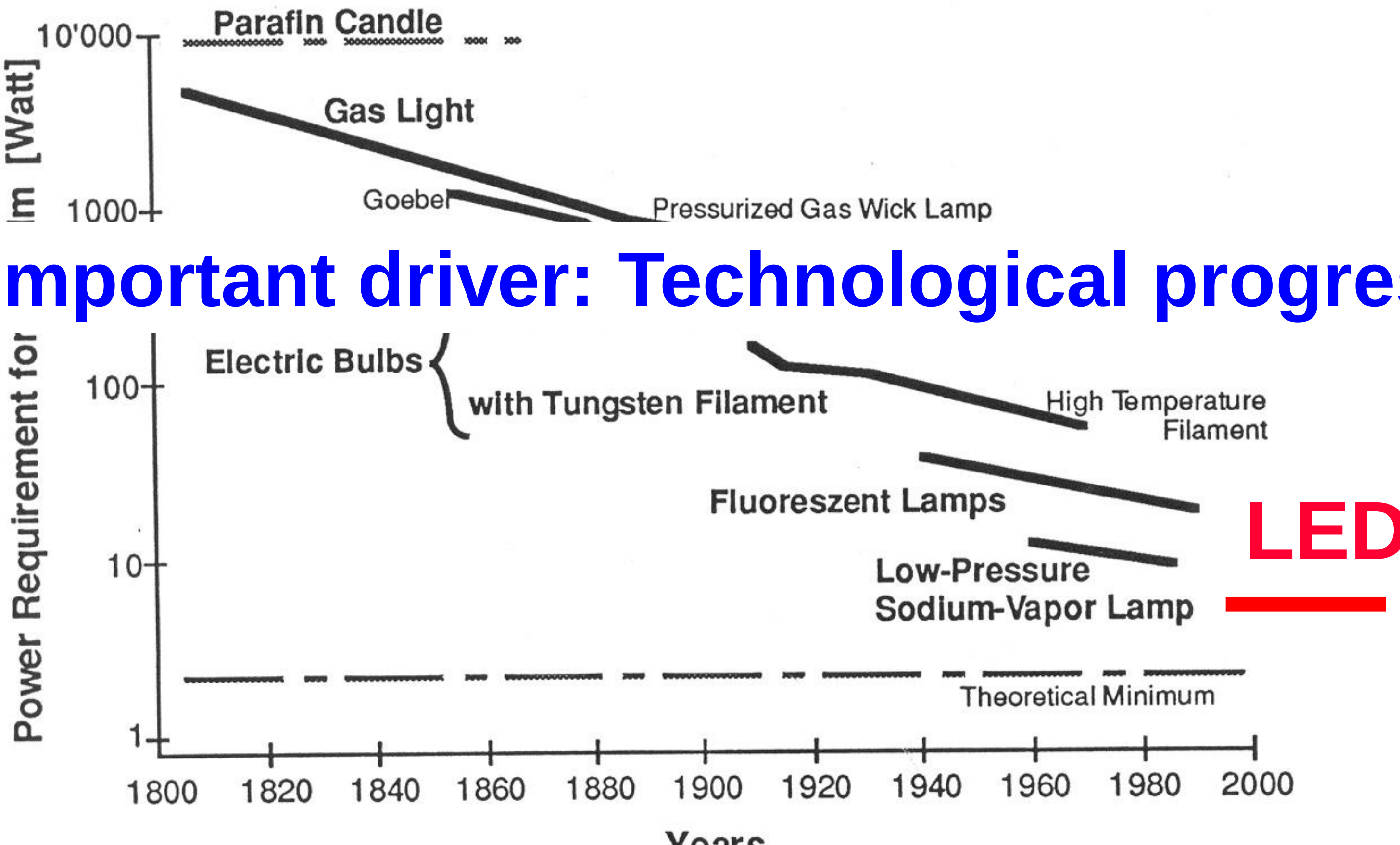


1878: Edison founds the “Edison electric light company”

Eiffeltower
1889



The example of LIGHTING

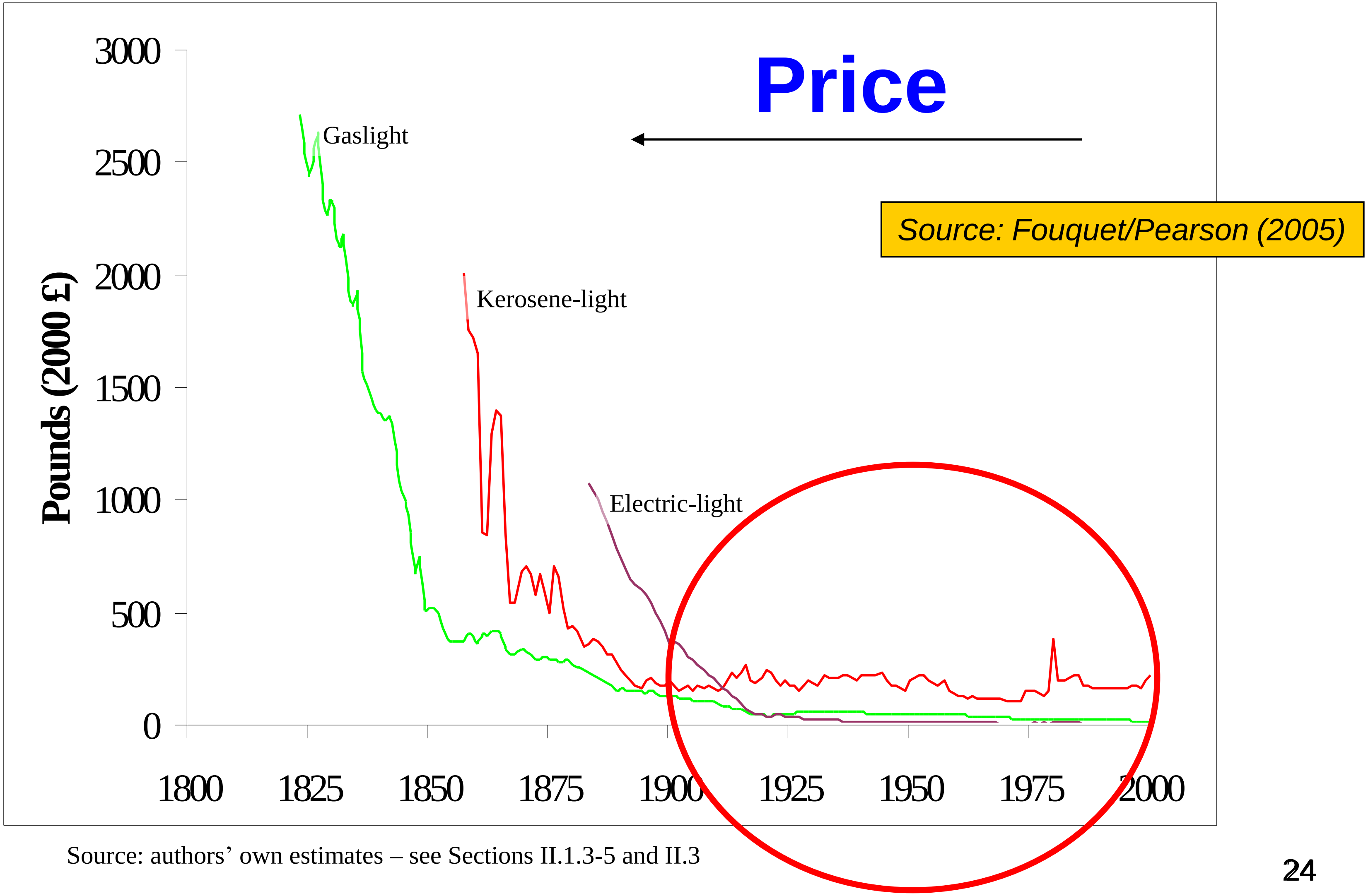


Most Important driver: Technological progress!

Figure 1: Technical development lead to a rapid decrease of power requirement for producing the same amount of light

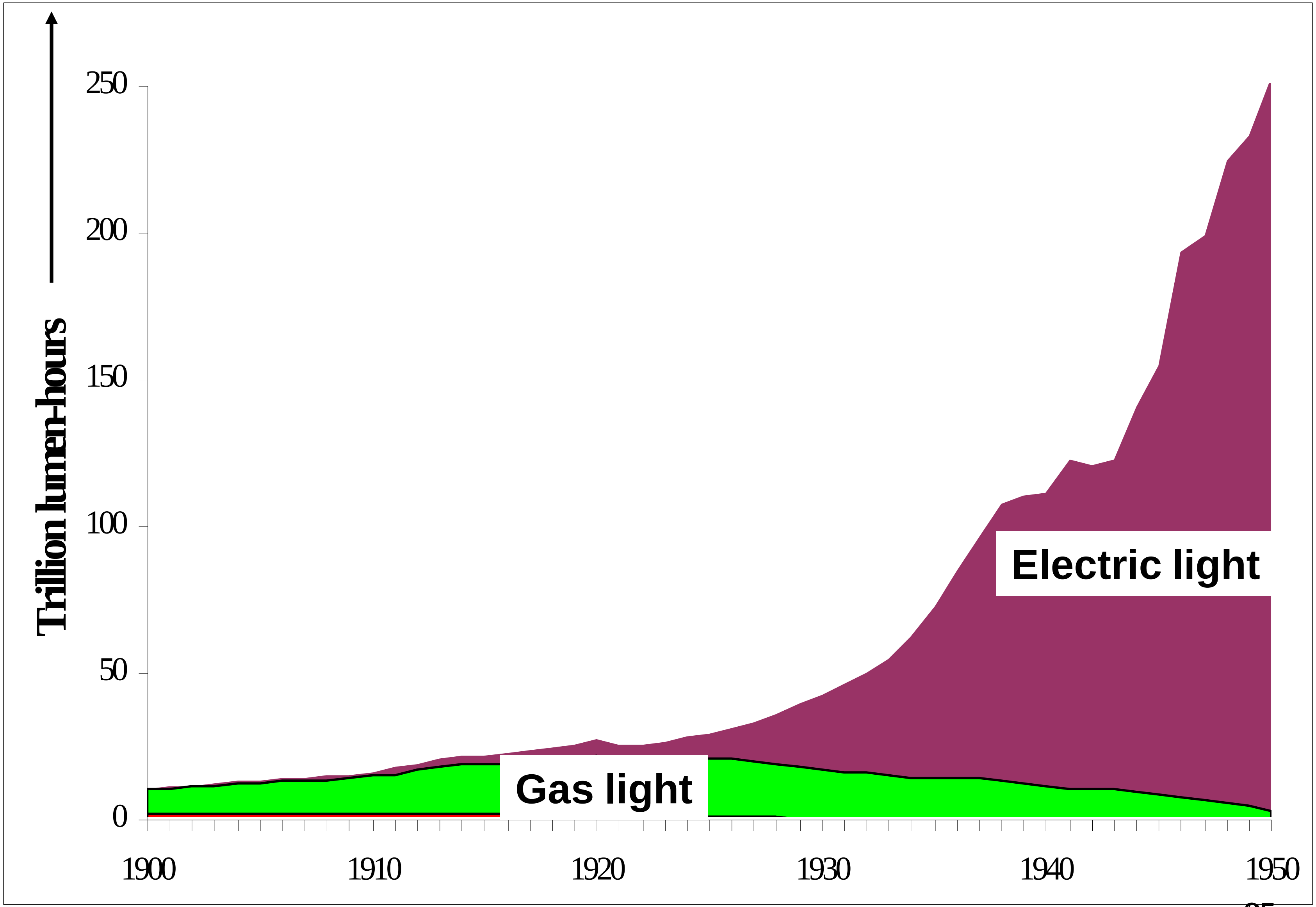
The servive price of lighting

Figure 6. Price of Lighting from Gas, Kerosene and Electricity in the United Kingdom (per million lumen-hours), 1800-2000



Source: authors' own estimates – see Sections II.1.3-5 and II.3

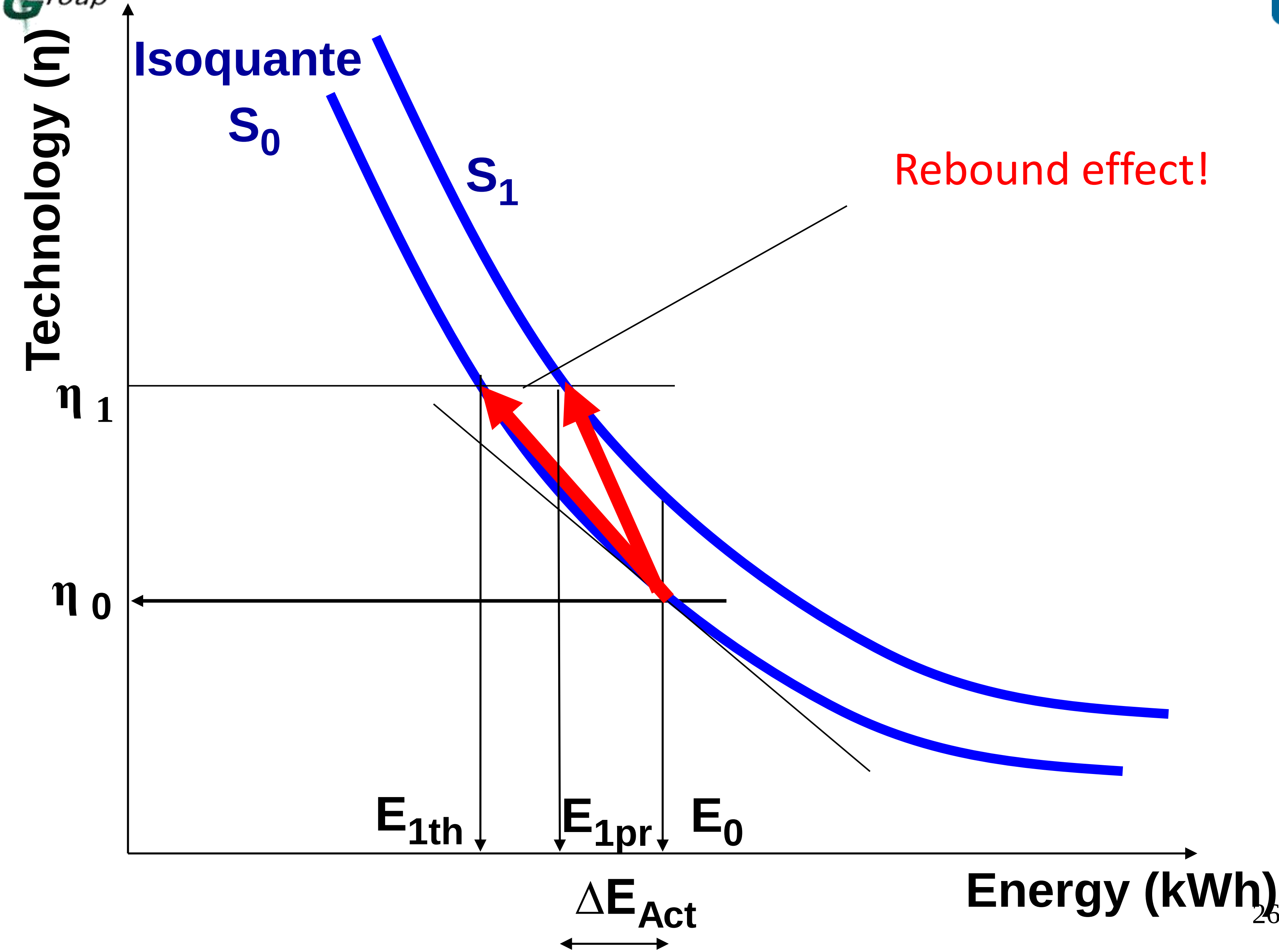
The example of LIGHTING



Source: authors' own estimates – see Sections II.2.3-5 and II.3 Trillion: 10^{12} (i.e. one million million)

Source: Fouquet/Pearson (2005)

4. The Rebound Effect



How the direct rebound effect works

η is improved

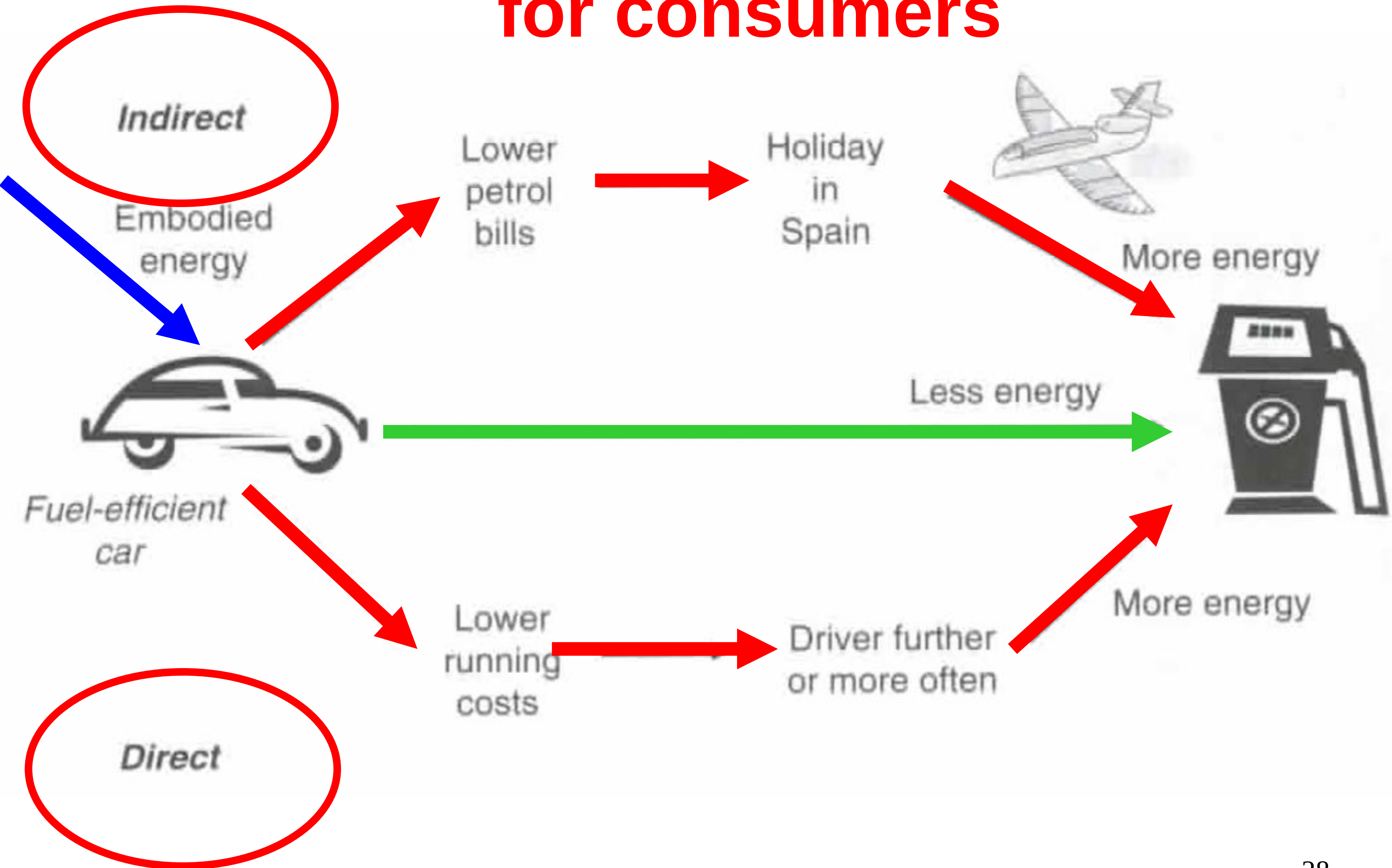
→ p_S decreases

→ S increases

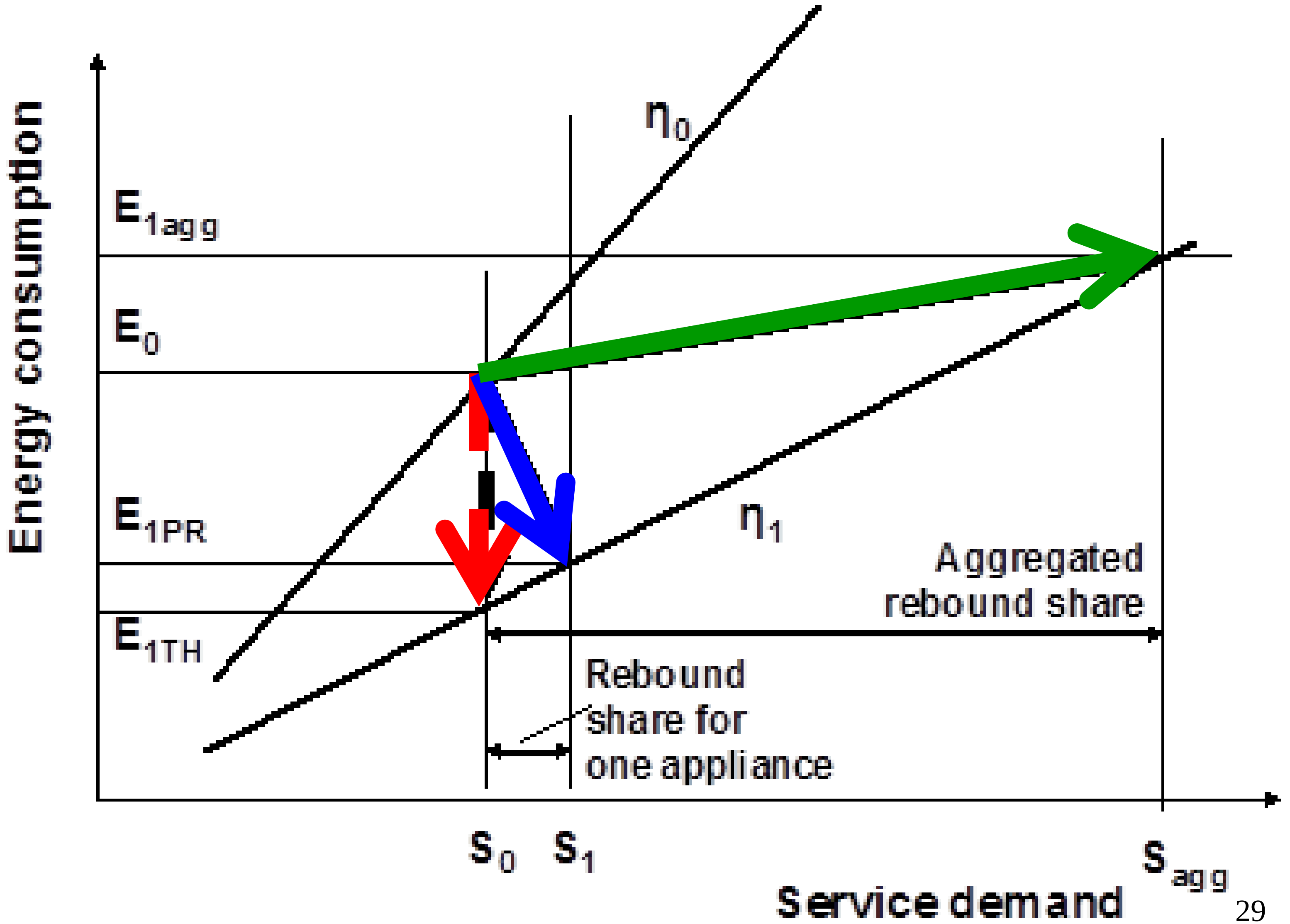
→ ΔE_{act} decreases

References:
Haas/Biermayr (2000) for Heating;
Ajanovic/Haas (2012) for transport

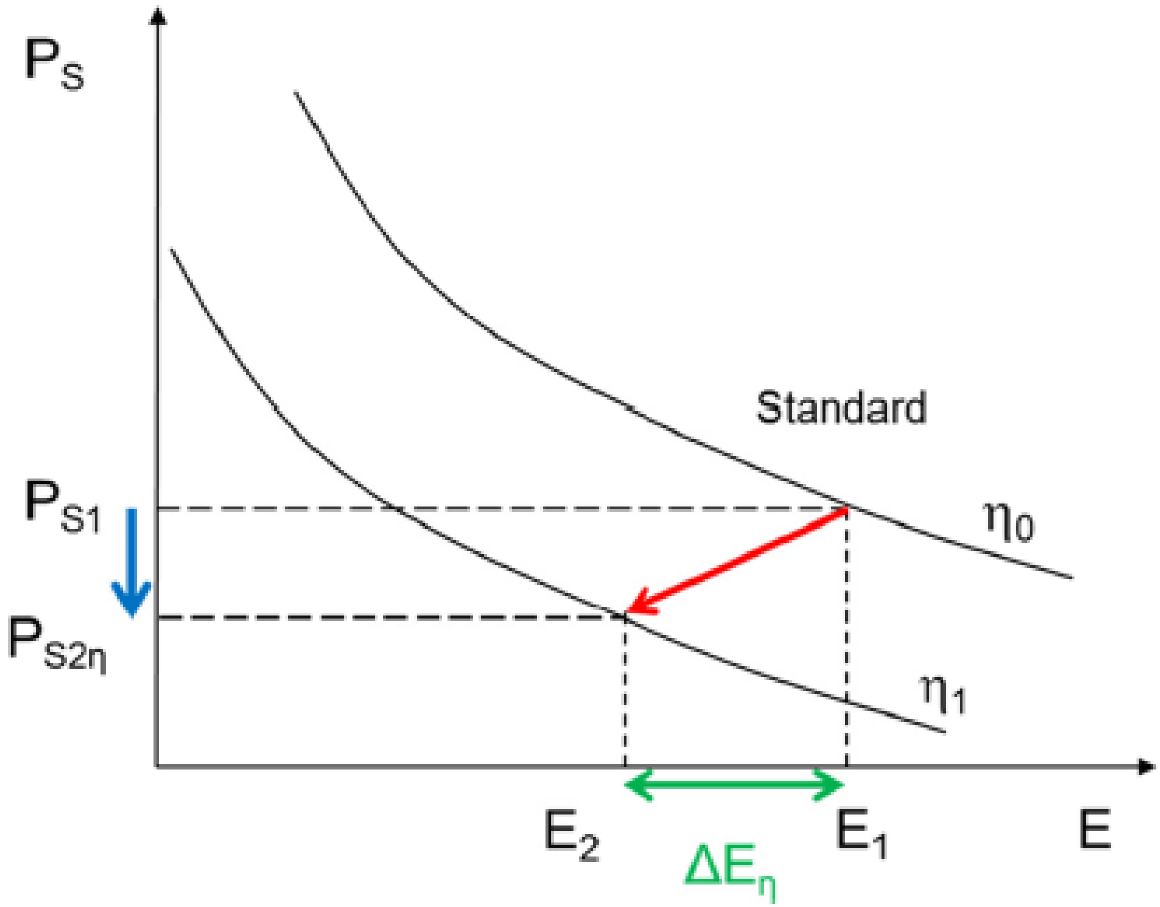
Illustration of rebound effects for consumers



The rebound of an economy

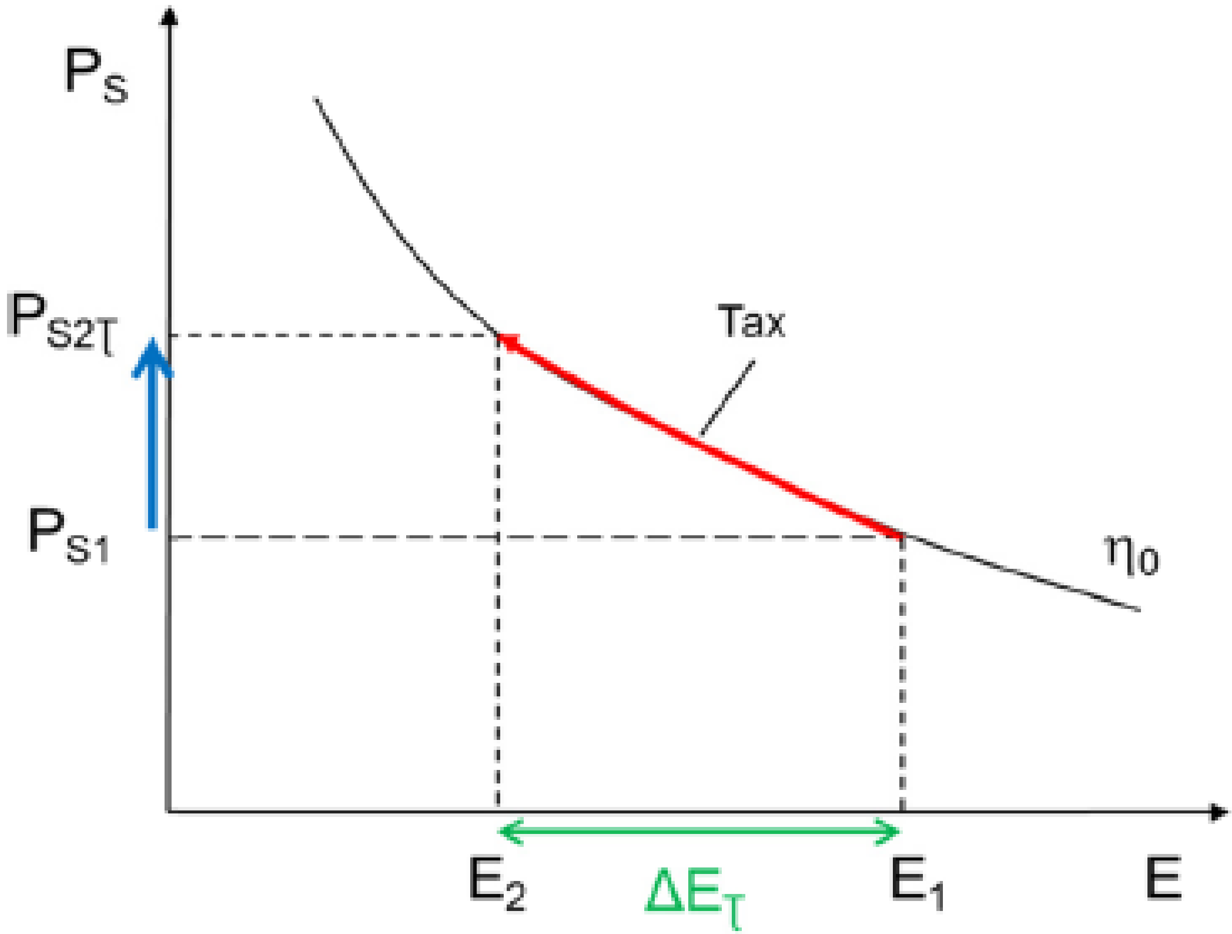


Effect of standards



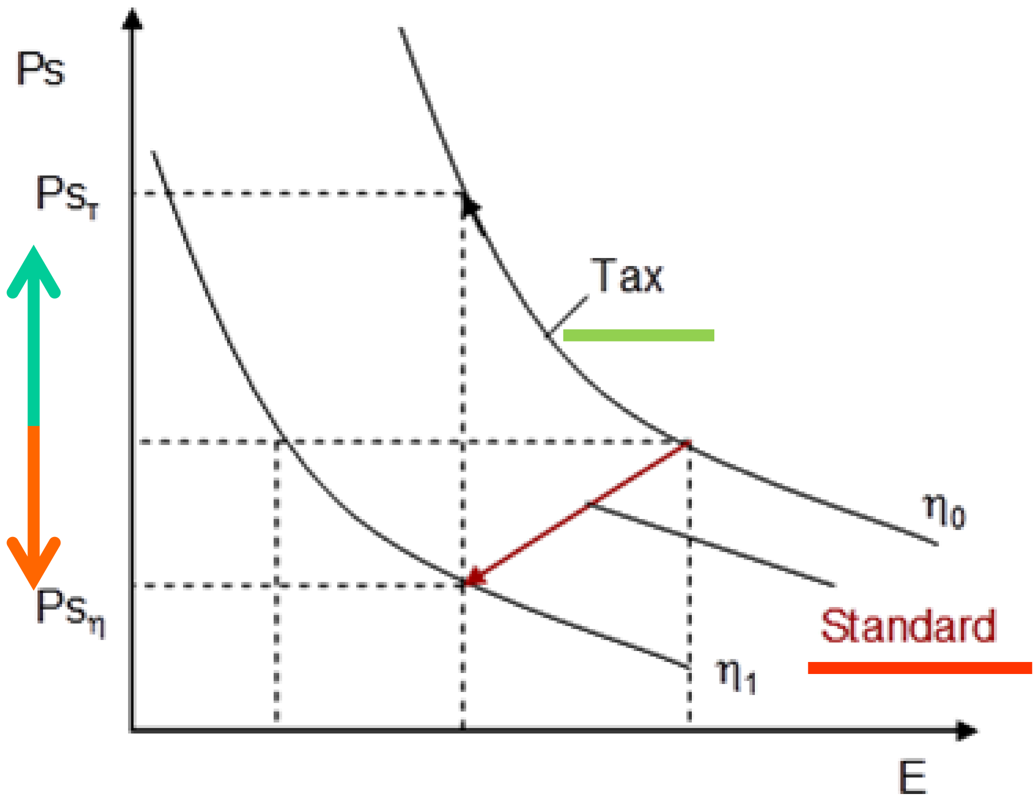
How a standard works

Effect of taxes

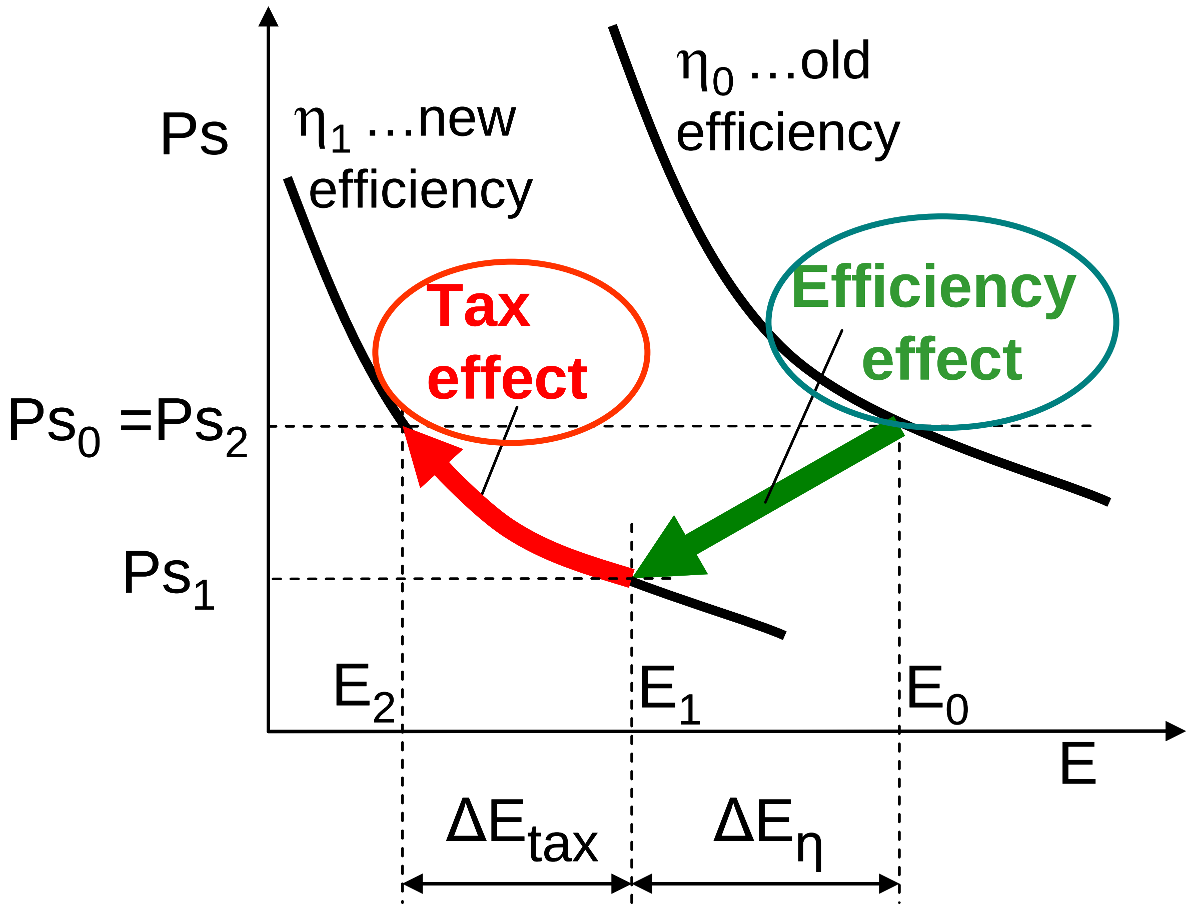


How a tax works

How a tax vs a standard works



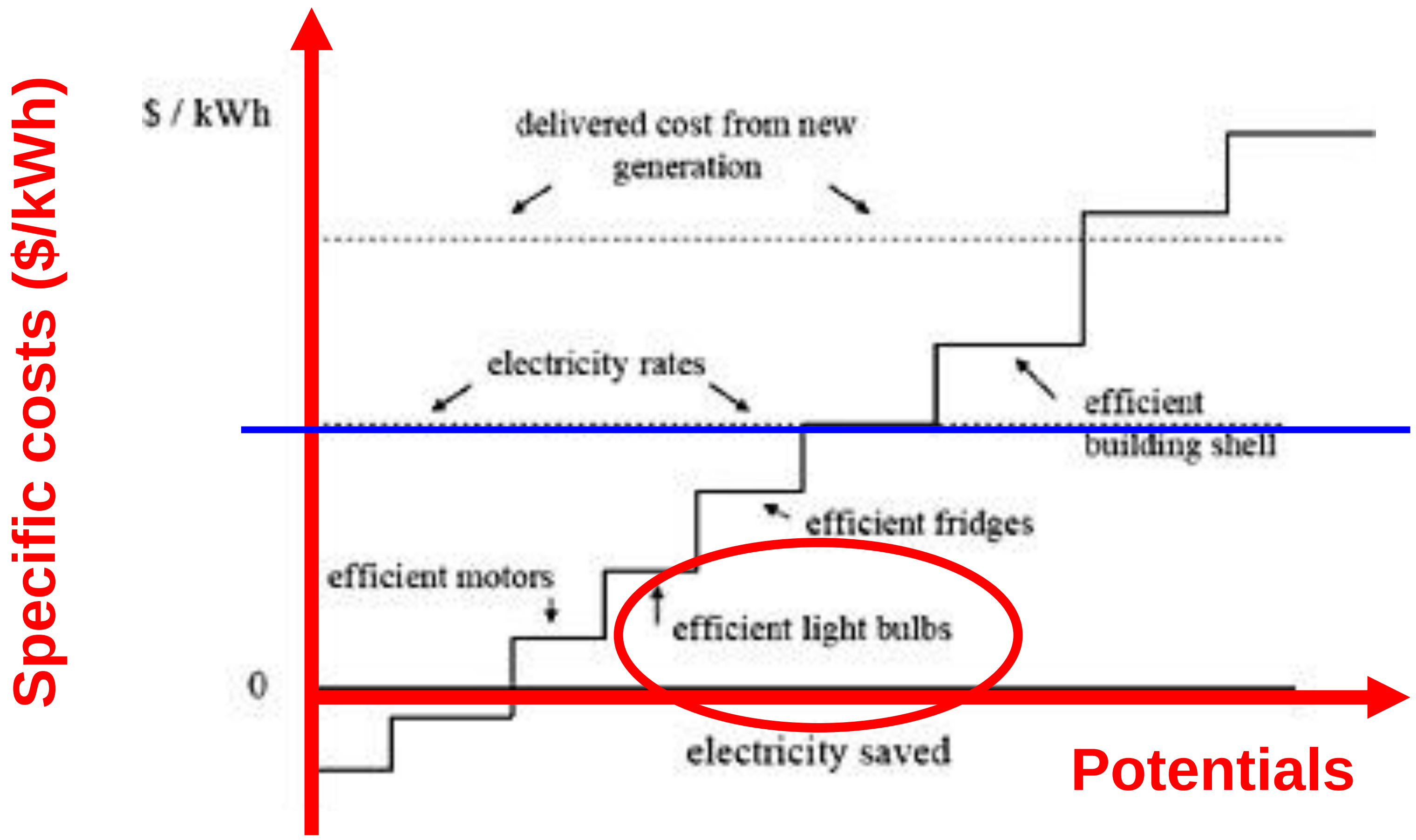
Standards & taxes



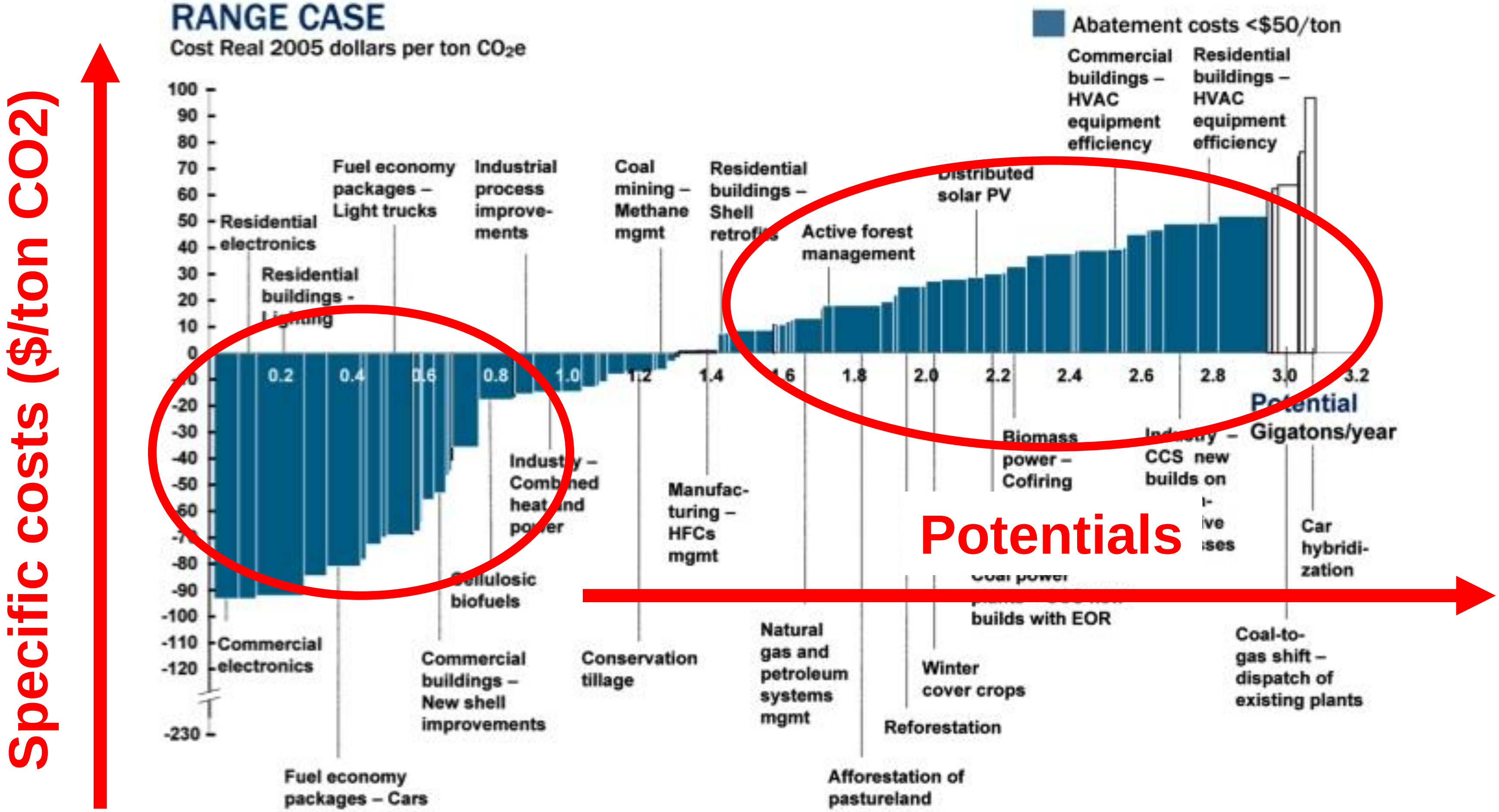
How taxes and standards interact and how they can be implemented in a combined optimal way for society

5. Costs and Potentials of Energy Conservation

A simple conservation cost curve



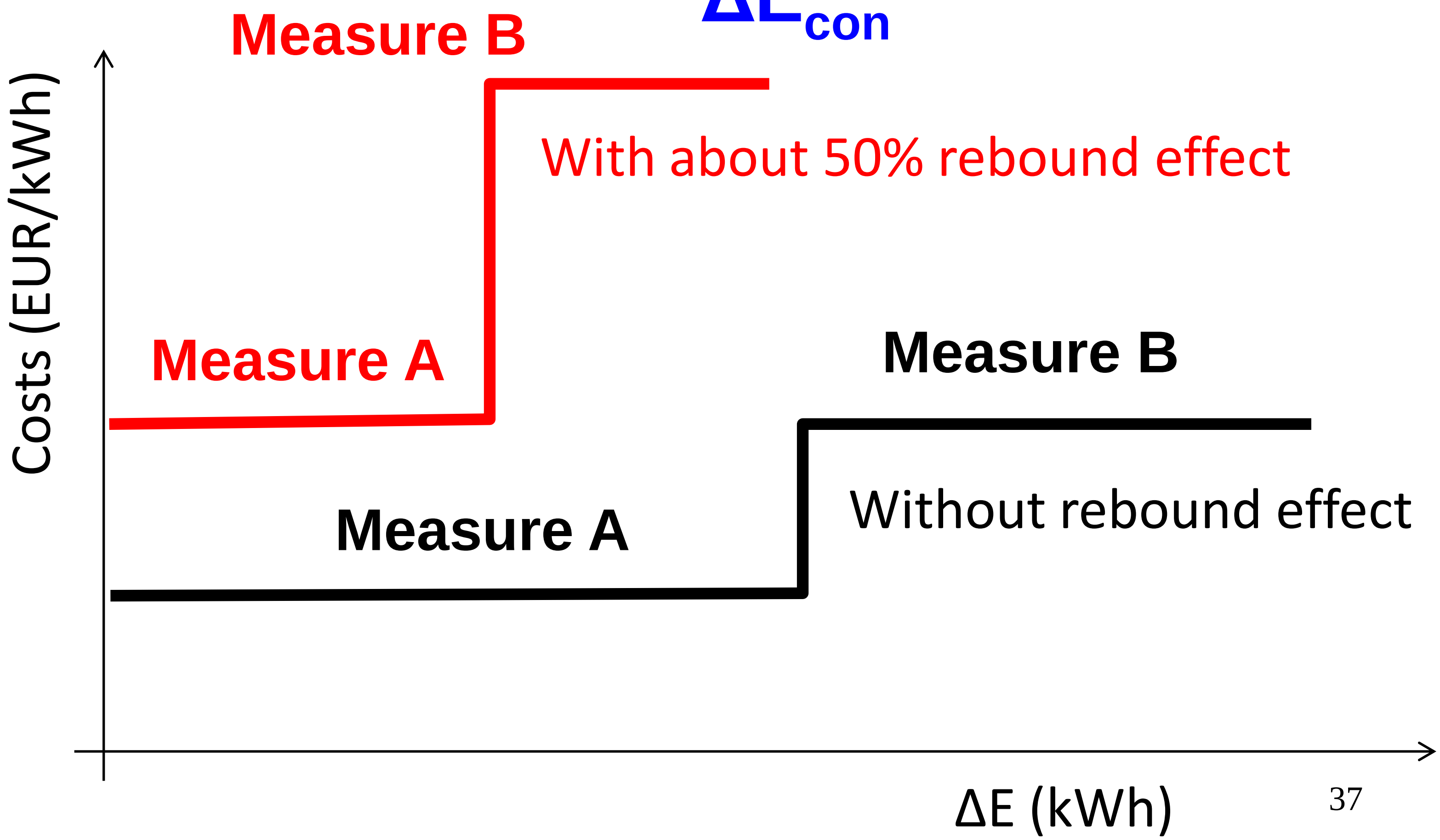
GHG REDUCTION OPPORTUNITIES WIDELY DISTRIBUTED - 2030 MID-RANGE CASE



The analysis found that abatement options are highly fragmented and widely spread across the economy. Almost 40 percent of abatement could be achieved at "negative" marginal costs, i.e., the savings over the lifecycle of these options would more than pay for the incremental investment, operating, and maintenance costs. Realizing the potential of many negative-cost options would require overcoming persistent barriers to market efficiency.

Conservation cost curves

$$c_{CON} = \frac{C_{ges} \; CRF}{\Delta E_{con}}$$



6. Conclusions

→ Increasing energy efficiency is important for an economy

→ … leads to cheaper services (as lighting, heating, transport, cooking technologies

→ … cheaper services lead to increase in service demand → Rebound effect!

→ … in turn: higher efficiency may not lead to expected energy conservation amounts

→ Yet, overall more and cleaner energy e.g. In developing countries