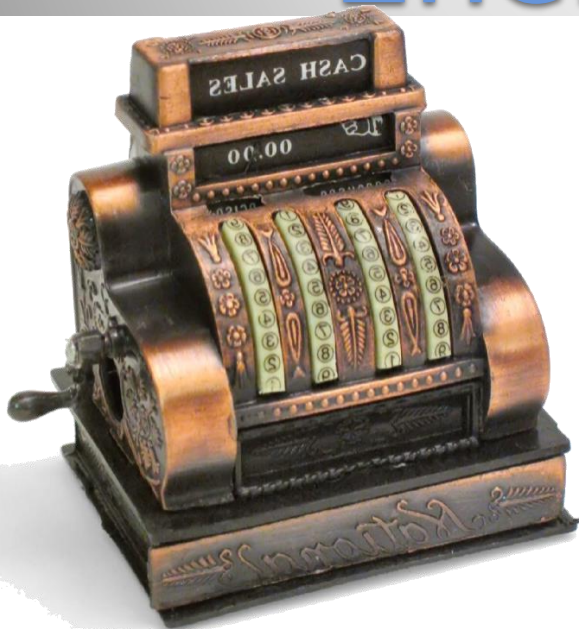
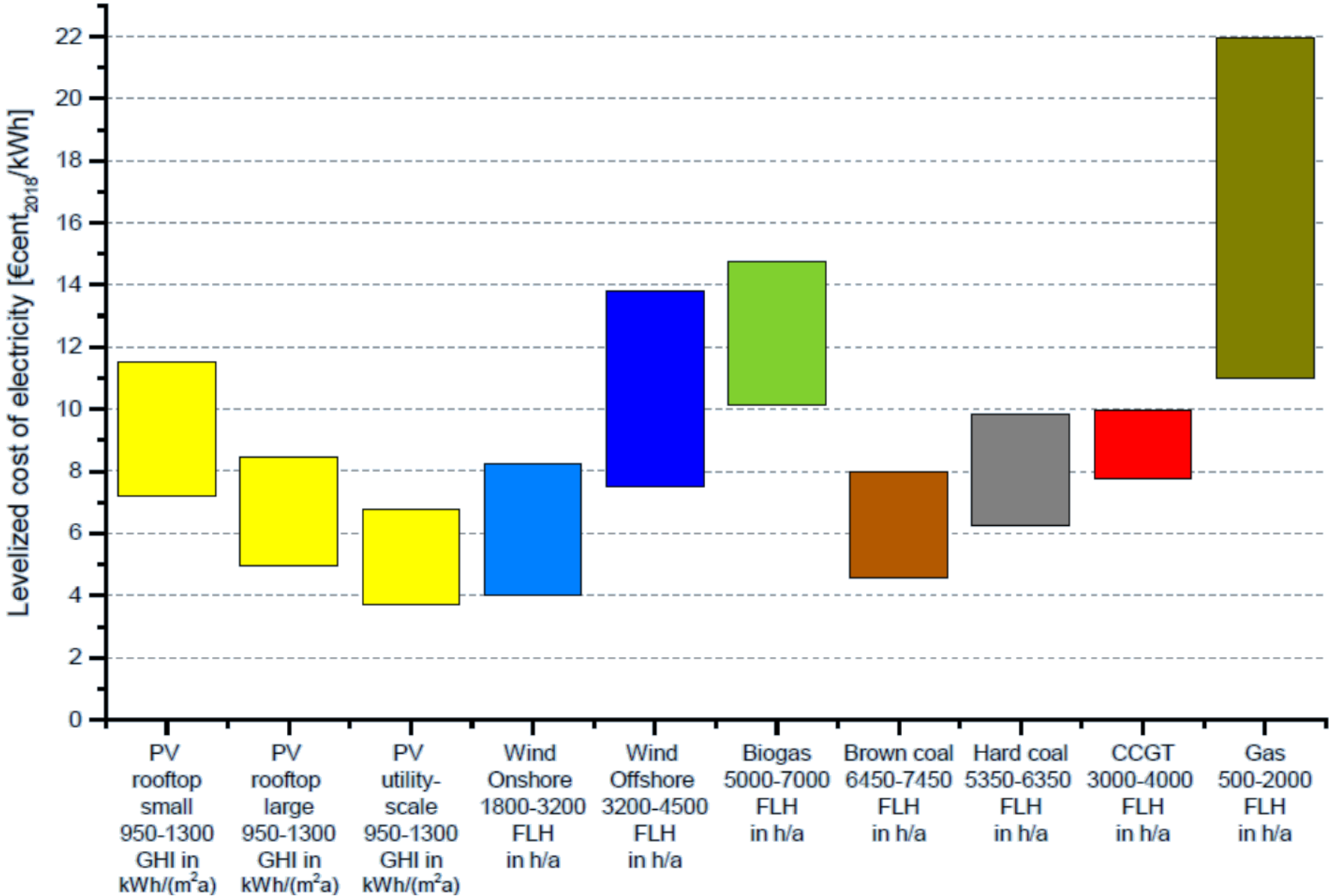


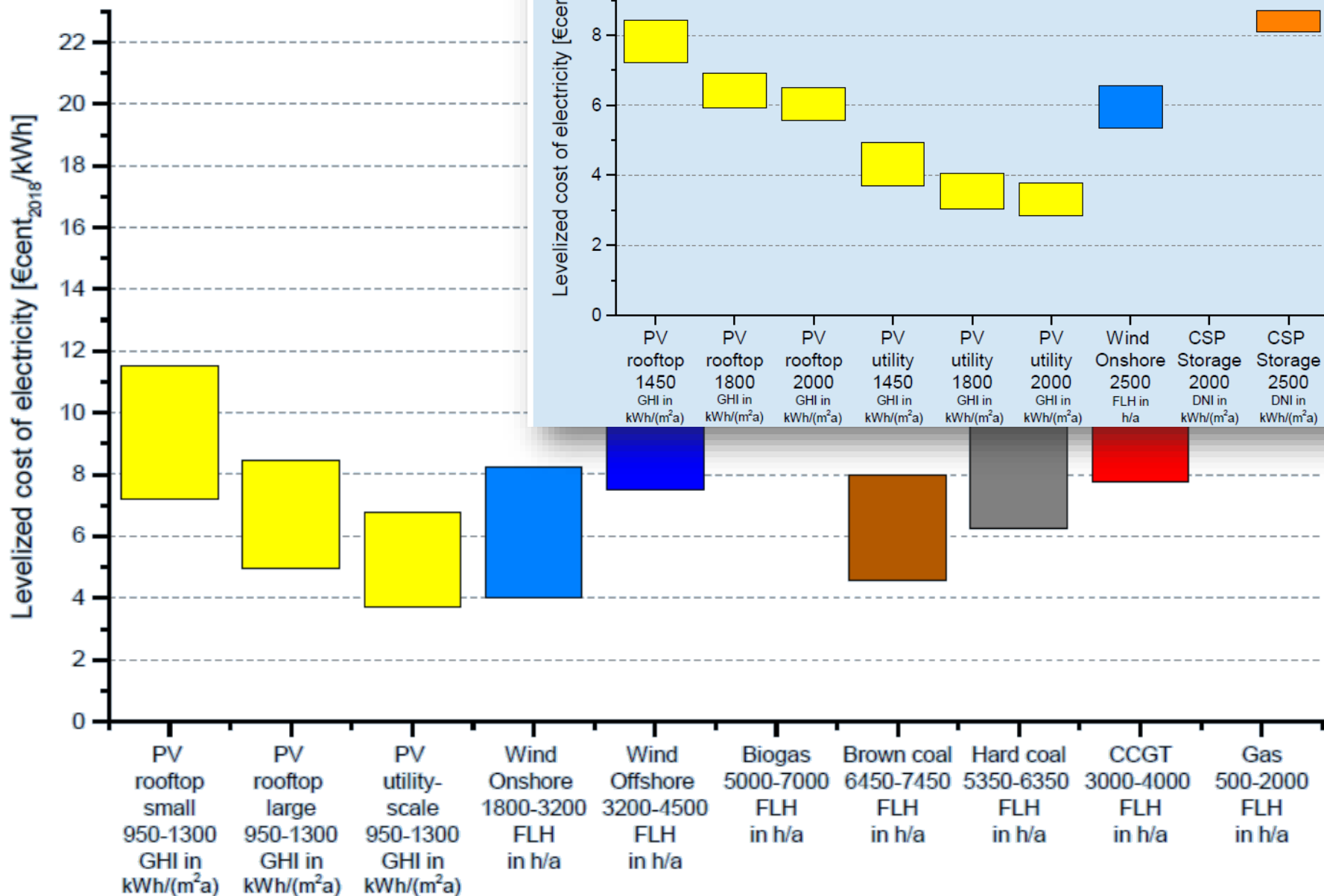
# CUSTOS

# Energias Renováveis

Miguel Centeno Brito







## **EXTERNALIDADES**

todos os custos que não estão incluídos no preço!

### Exemplos:

- Custos de saúde, associados ao fumo de tabaco
- Mortalidade, associado a acidentes rodoviários
- Custos ambientais, associados ao transporte de petróleo
- Custos associados a emissão de CO2

(adaptação/mitigação/extreme weather)

- Custos militares, garantia abastecimento combustíveis fósseis
- Custos escondidos (e.g. nuclear ou carros eléctricos!)
- ...

**Não é fácil calcular!!**

## EXTERNALIDADES

***ExterneE***

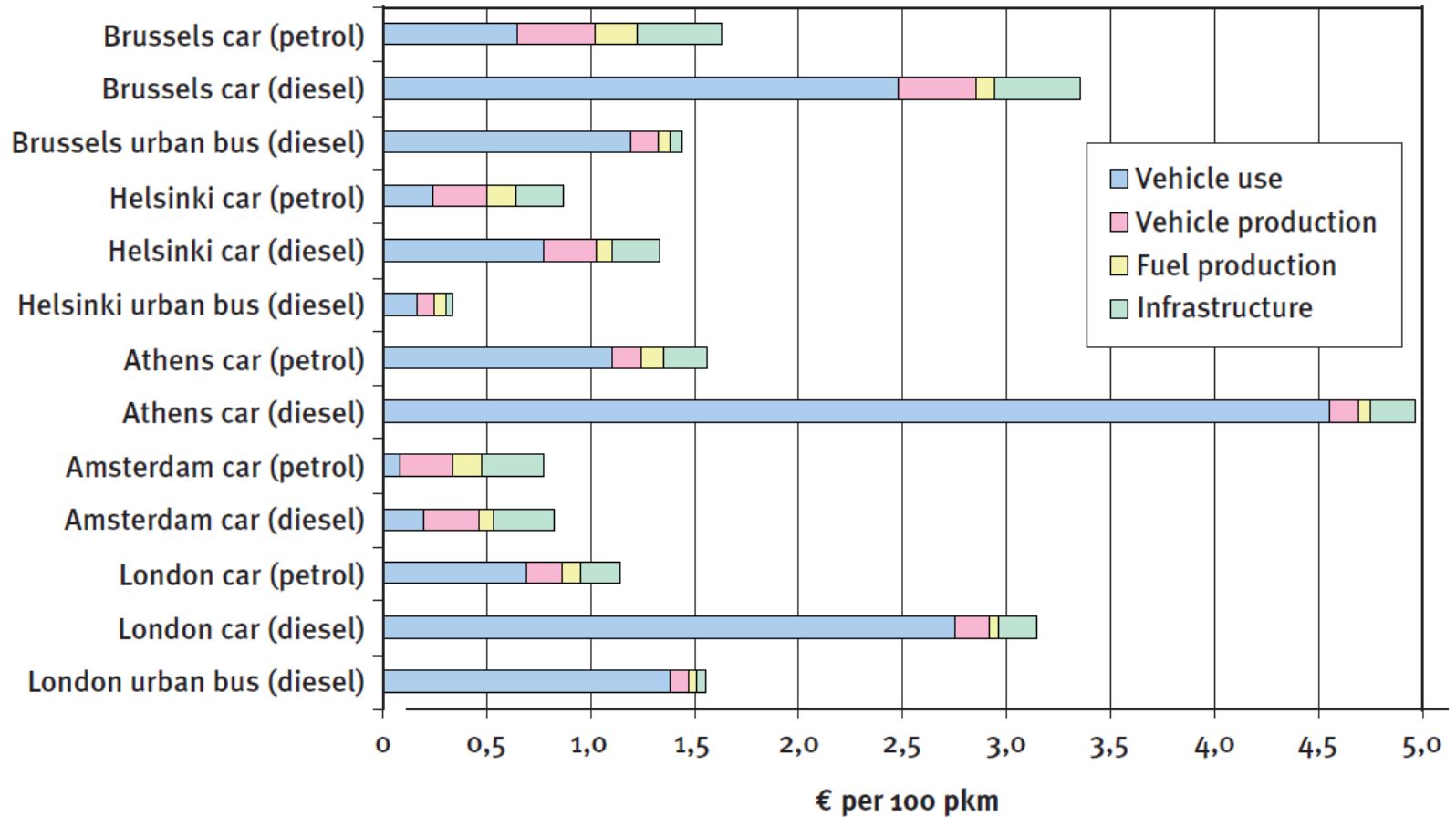
ExterneE - Externalities of Energy. A Research Project of the European Commission

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<http://www.externe.info/>

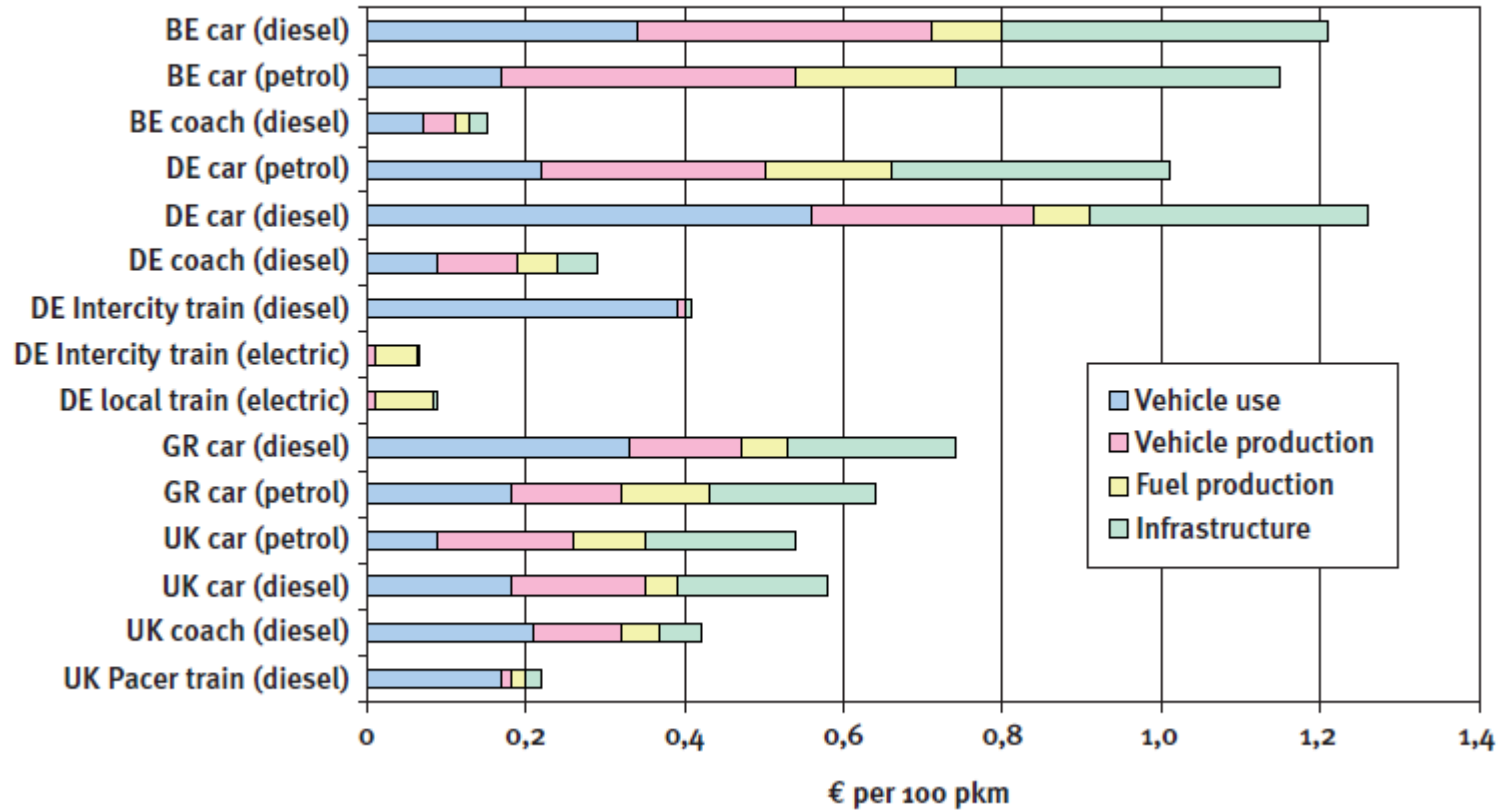
# EXTERNALIDADES

## Air pollution costs due to urban passenger transport<sup>2</sup>



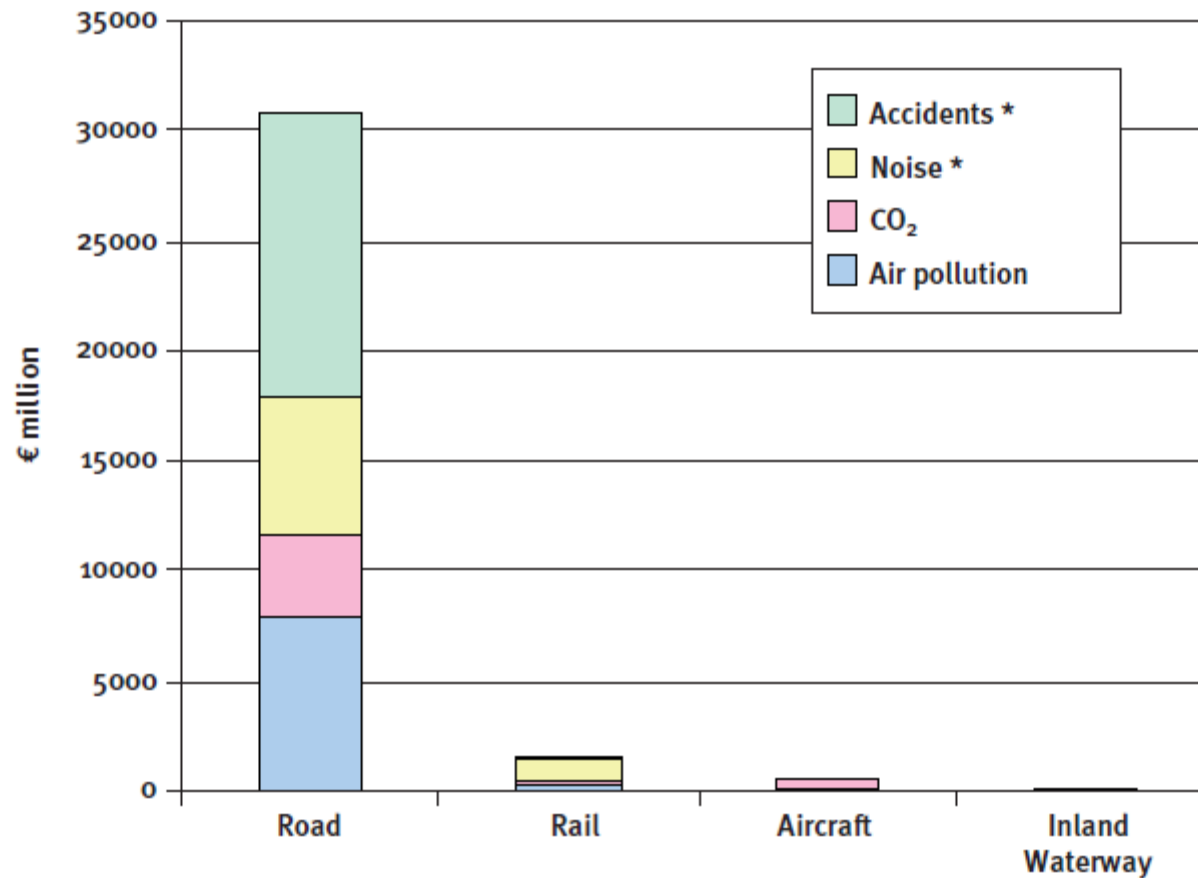
# EXTERNALIDADES

## Air pollution costs due to extra-urban passenger transport<sup>2</sup>



# EXTERNALIDADES

## Quantifiable externalities due to transport in Germany



\* accidents and noise only available for road and rail; airborne emissions include direct emissions and emission due to fuel and electricity production; air pollution aircraft: emissions at cruising height not included



# EXTERNALIDADES

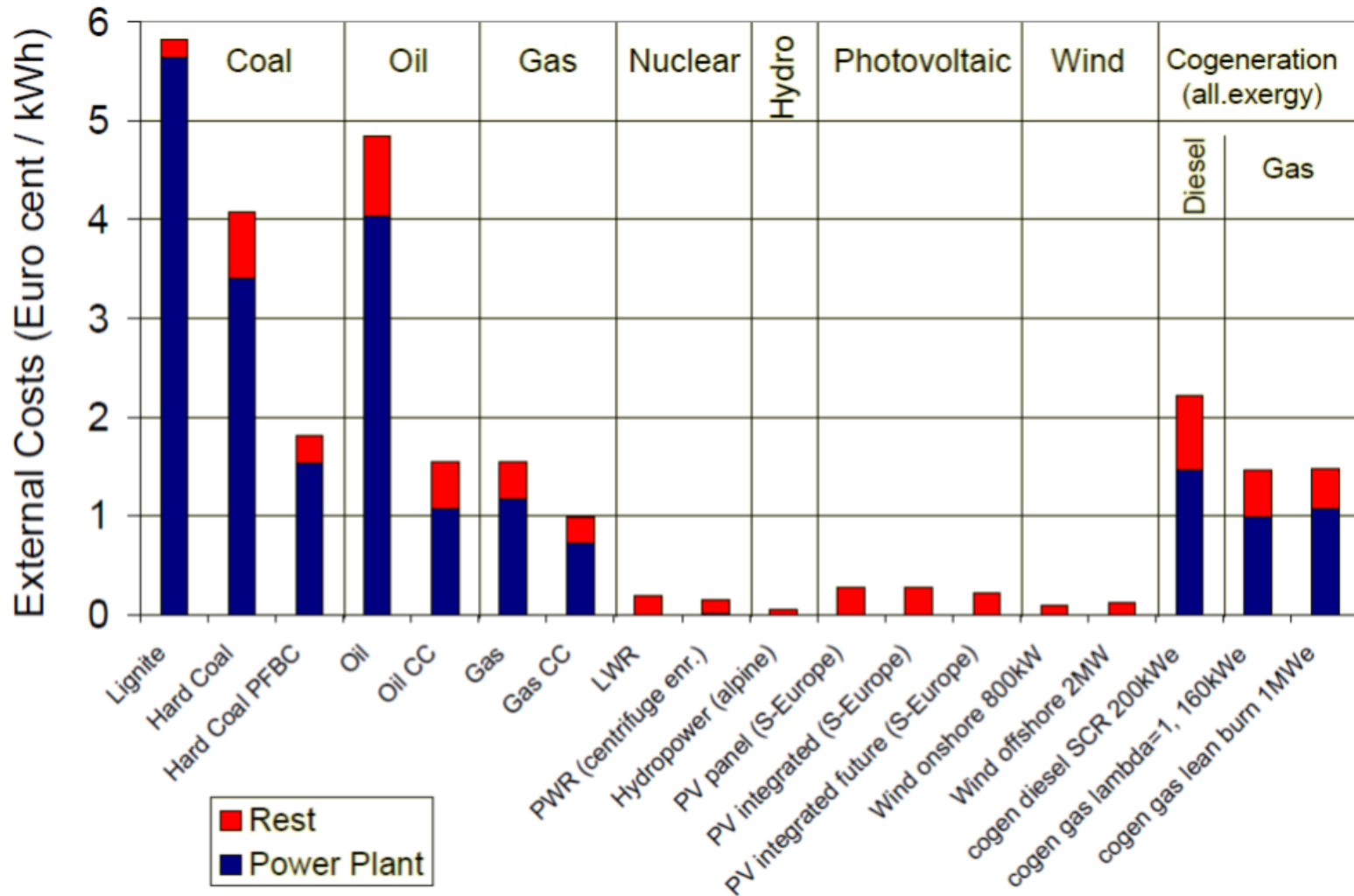
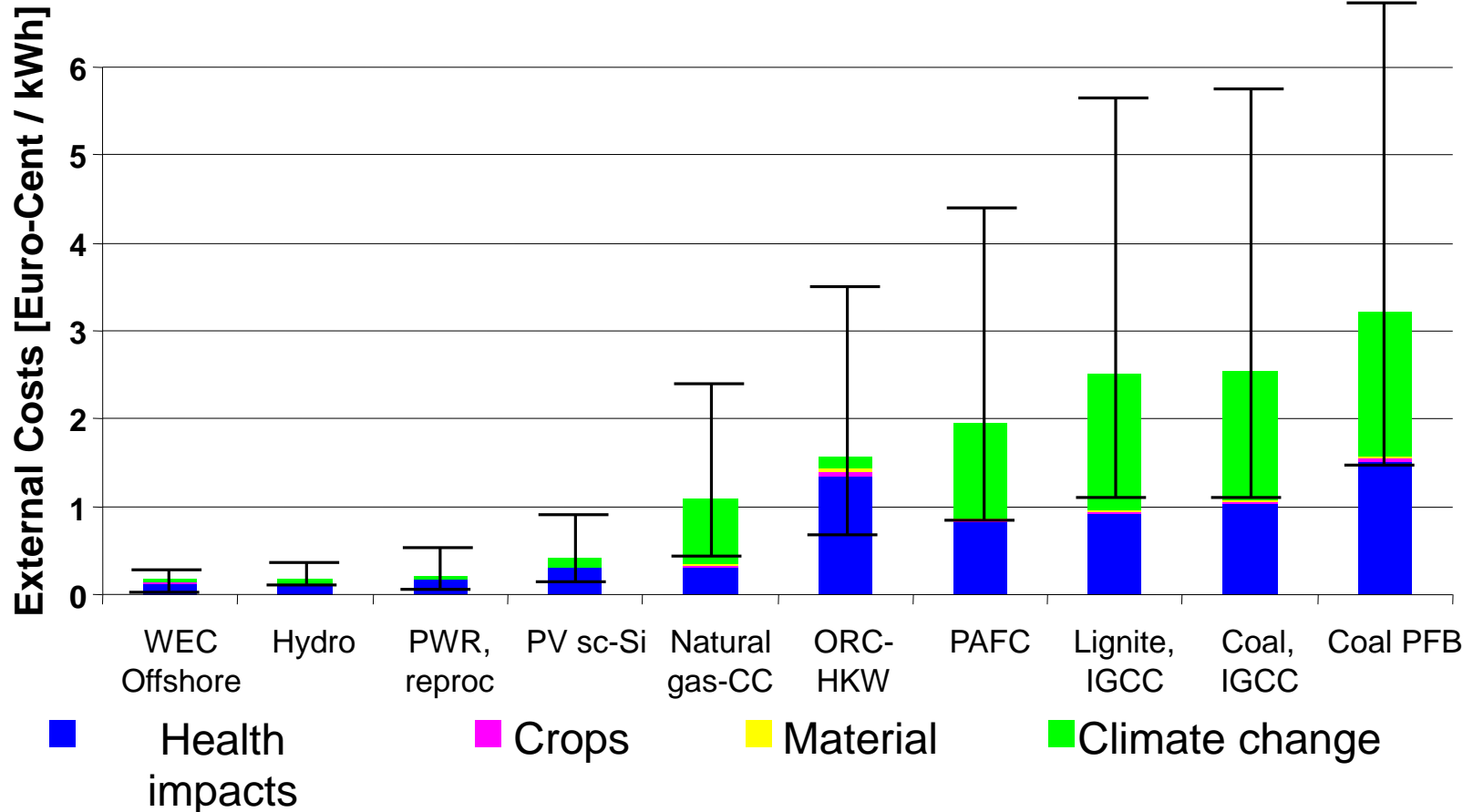


Figure 1

External costs of current and advanced electricity systems, associated with emissions from the operation of power plant and with the rest of energy chain.

# EXTERNALIDADES

Custos para diferentes tecnologias c€/kWh [19€/tonCO<sub>2</sub>]

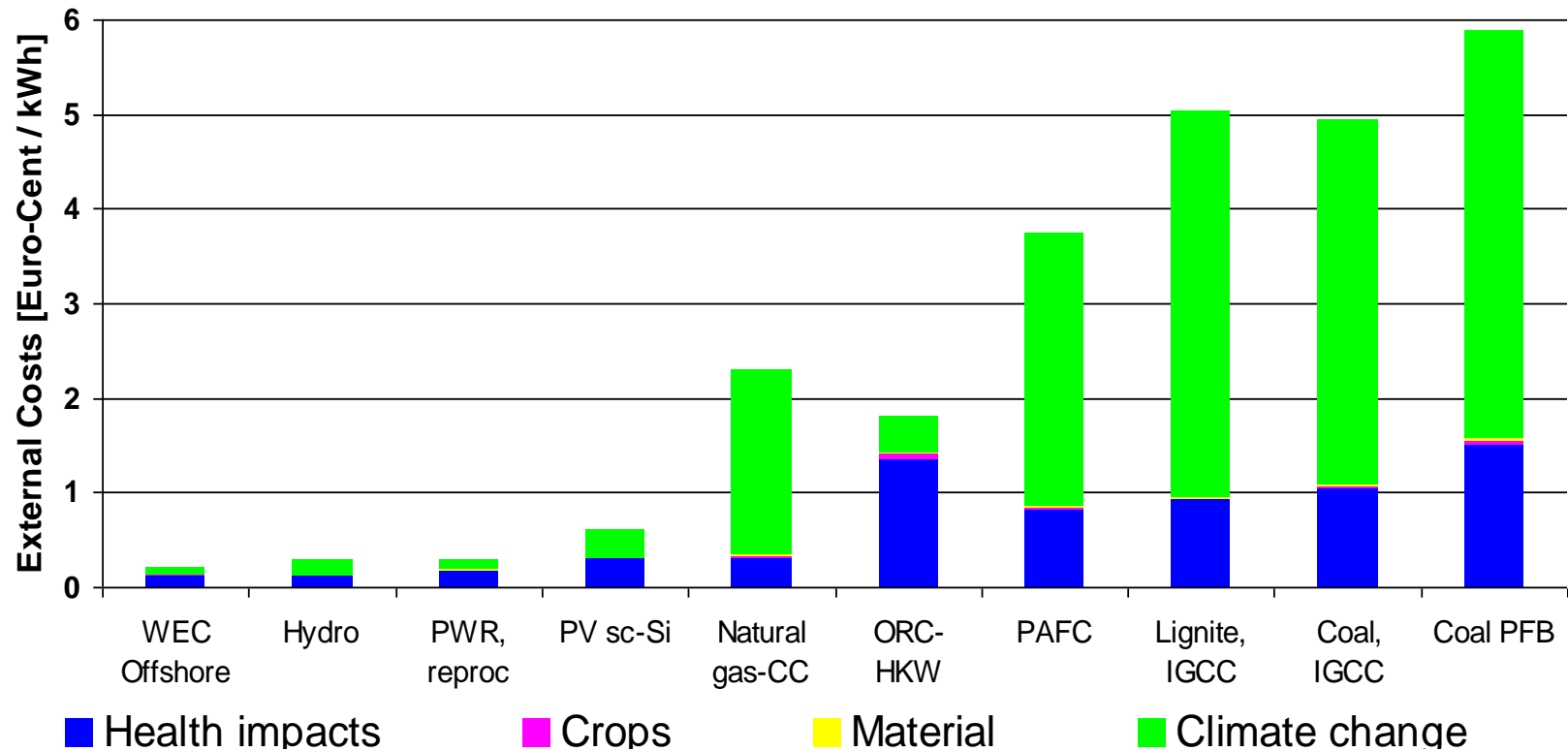


PWR – pressurized water reactor - nuclear  
 ORC - Organic Rankine Cycle - biomass  
 PAFC – phosphoric acid fuel cell

IGCC - integrated gasification combined cycle  
 PFB – pressurized fluidized bed

# EXTERNALIDADES

Custos para diferentes tecnologias c€/kWh [50€/tonCO<sub>2</sub>]



PWR – pressurized water reactor - nuclear  
ORC - Organic Rankine Cycle - biomass  
PAFC – phosphoric acid fuel cell

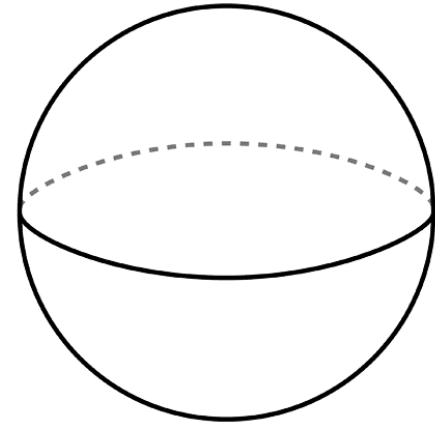
IGCC - integrated gasification combined cycle  
PFB – pressurized fluidized bed

## ECONOMIAS DE ESCALA

'fazer mais é mais barato'

$$\frac{C}{K} \approx \frac{S}{V} = \frac{4\pi R^2}{\frac{4}{3}\pi R^3} = \frac{3}{R} \approx \frac{1}{V^{1/3}}$$

$$\rightarrow S \approx V^{2/3}$$



## **ECONOMIAS DE ESCALA**

'fazer mais é mais barato'

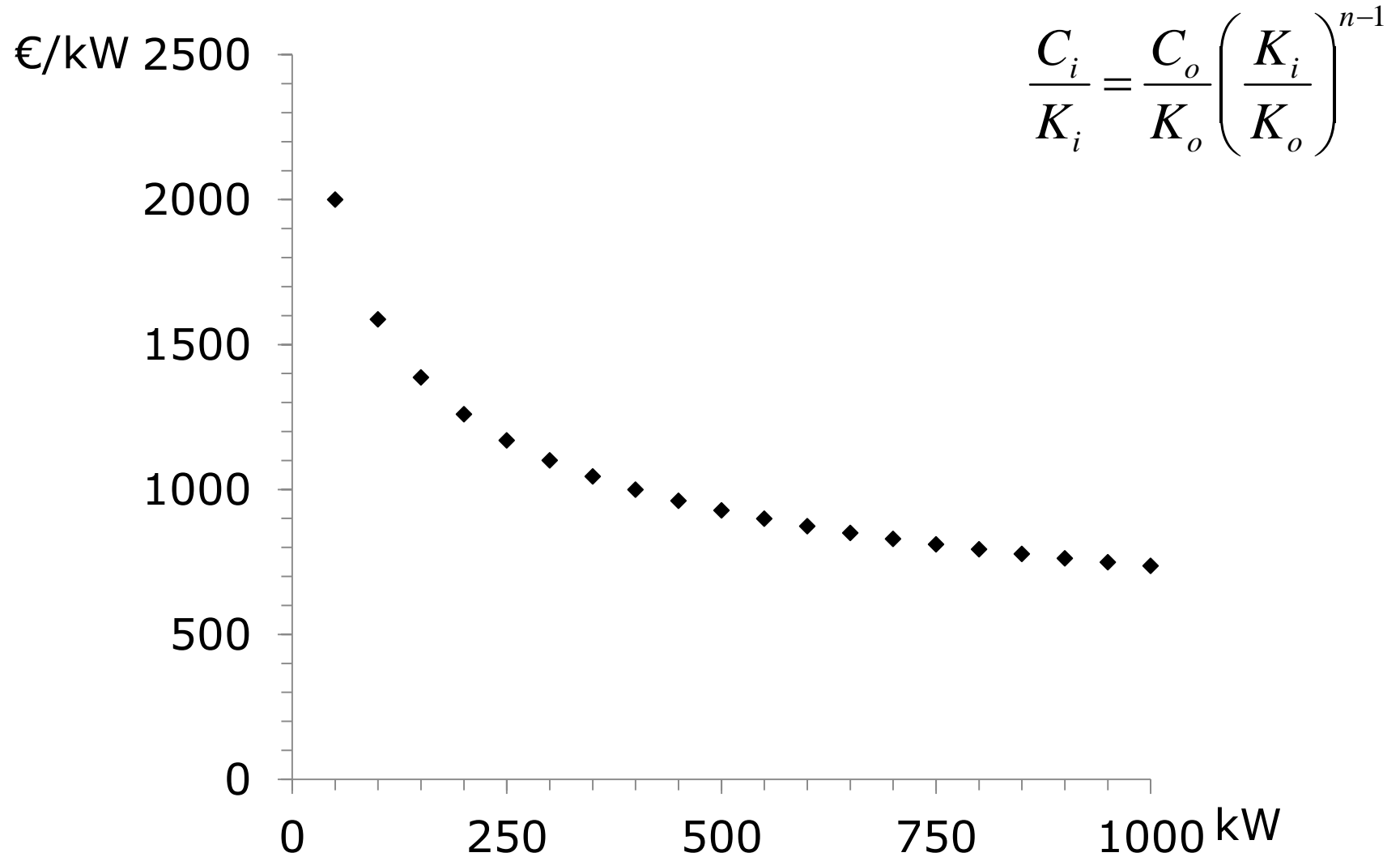
### **Exemplo**

Central de 50MW custa 2000€/kW.

Quanto custa uma central de 1000MW?

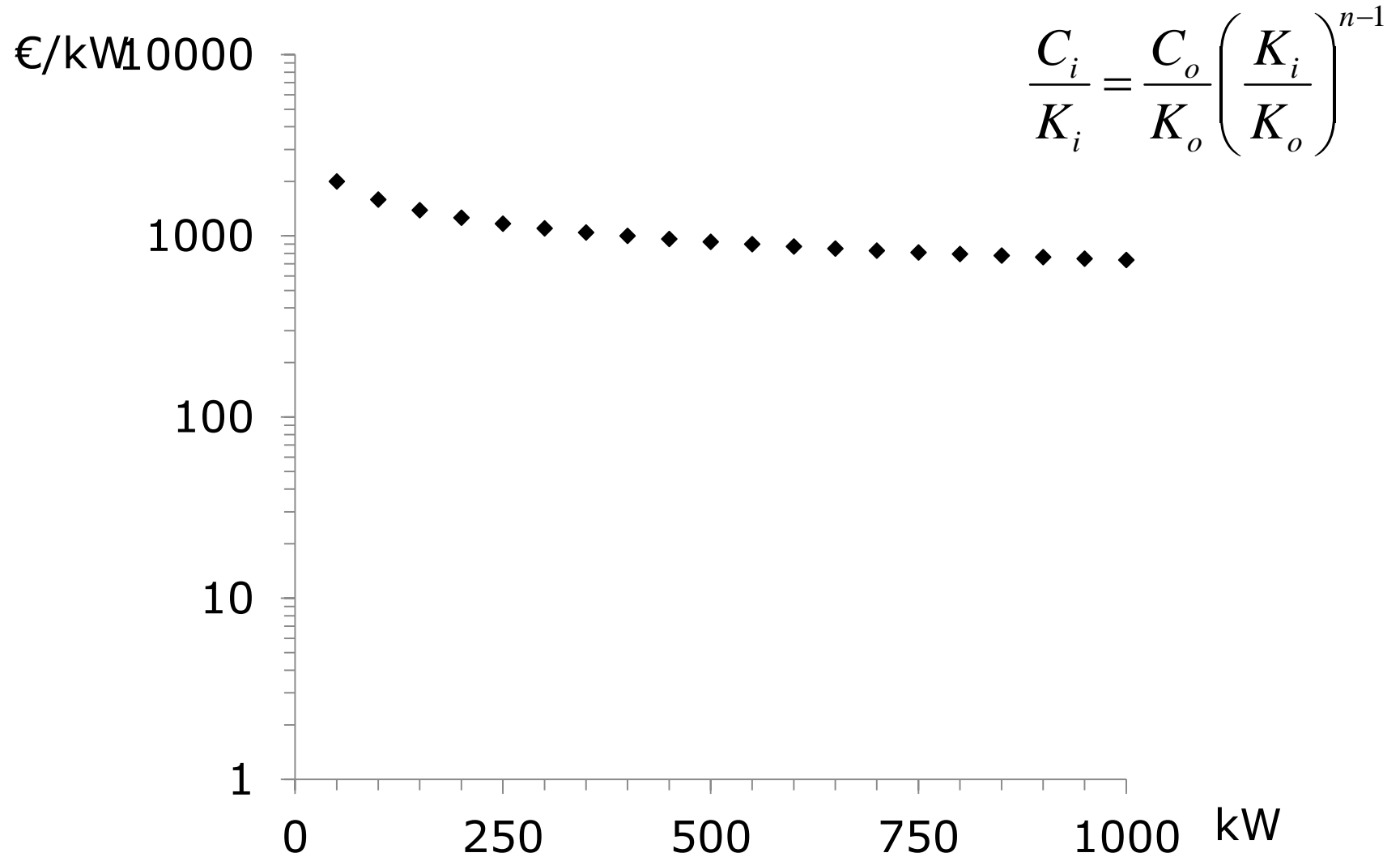
# ECONOMIAS DE ESCALA

'fazer mais é mais barato'



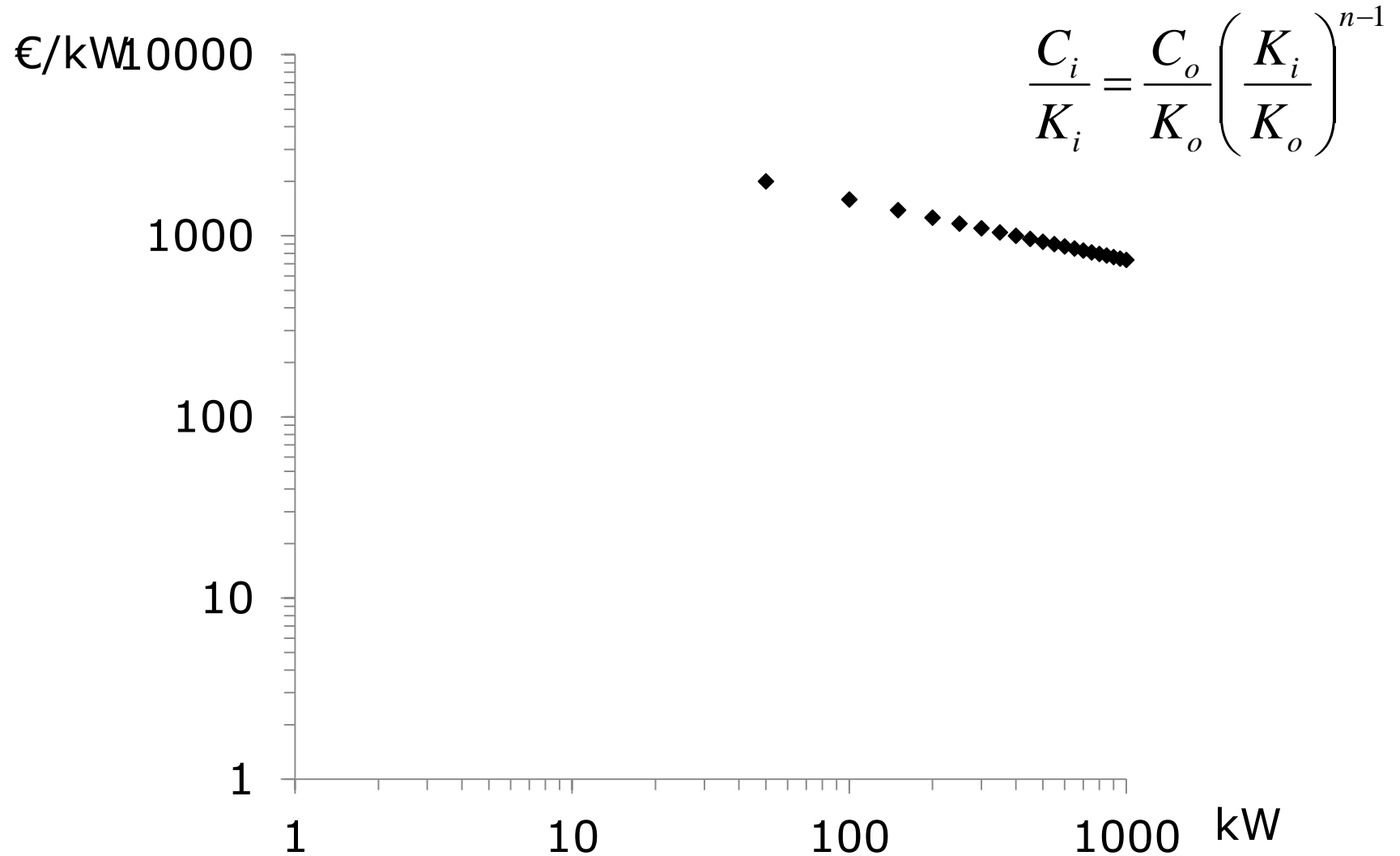
# ECONOMIAS DE ESCALA

'fazer mais é mais barato'



# ECONOMIAS DE ESCALA

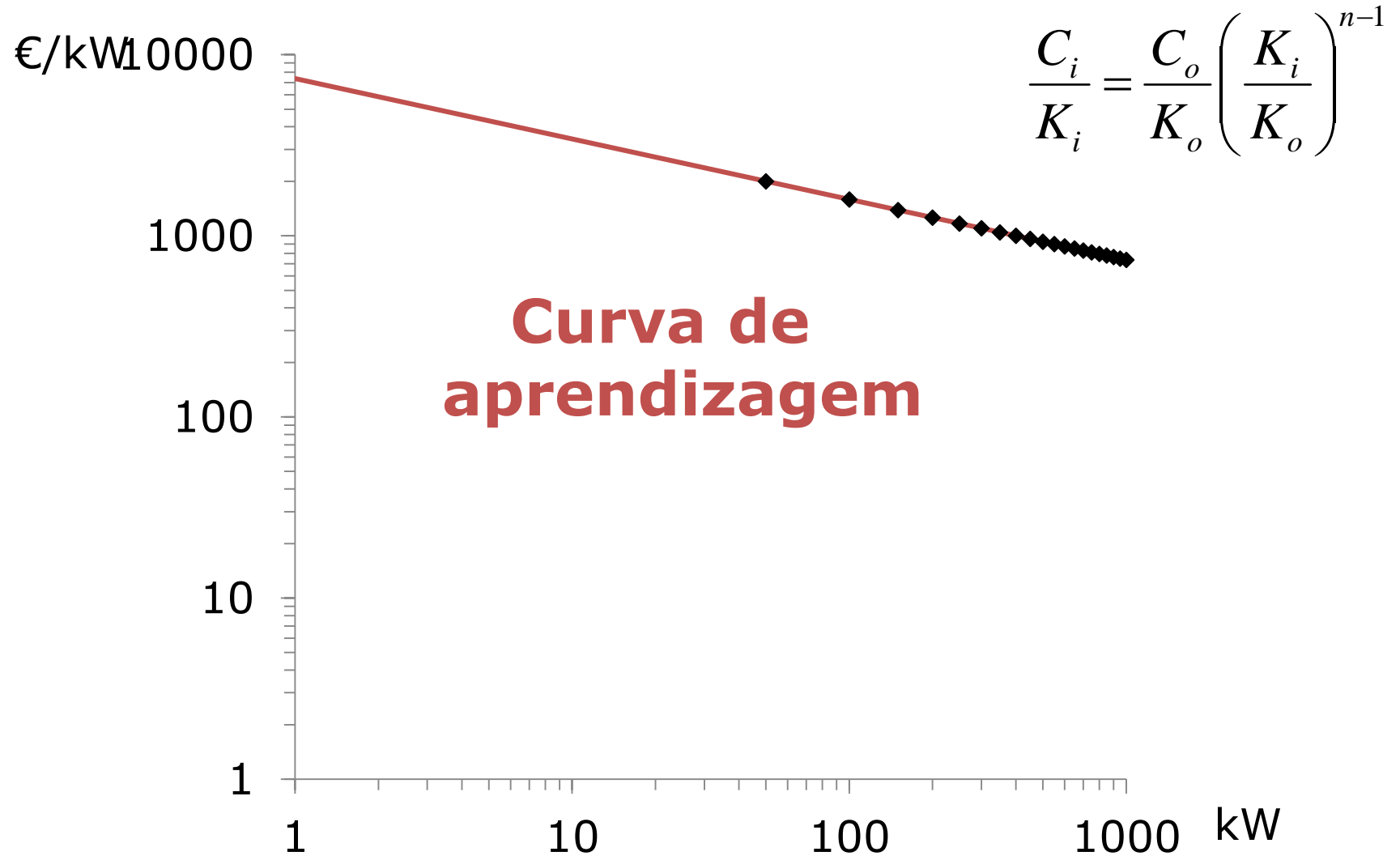
'fazer mais é mais barato'





# ECONOMIAS DE ESCALA

'fazer mais é mais barato'

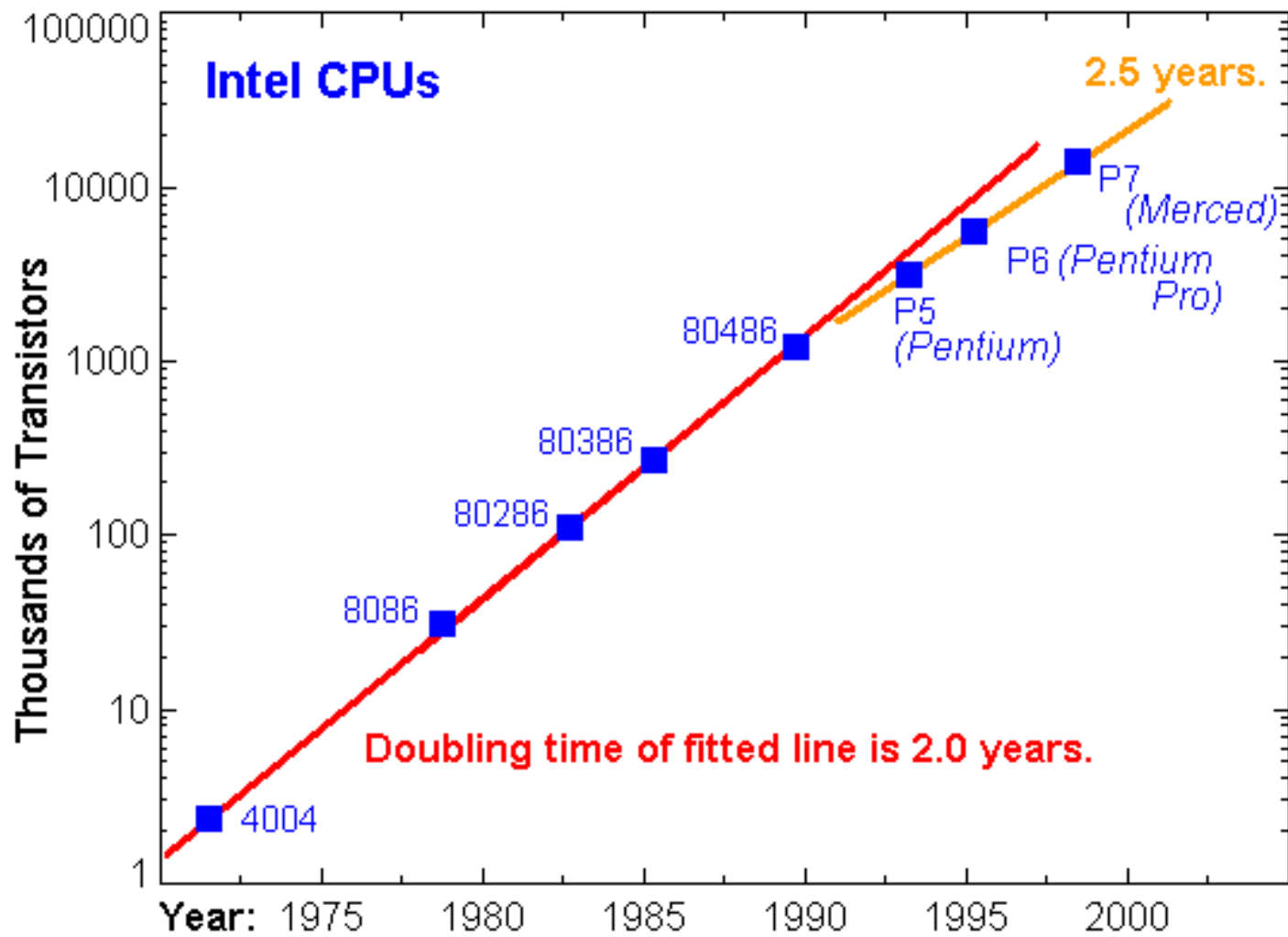


## ECONOMIAS DE ESCALA

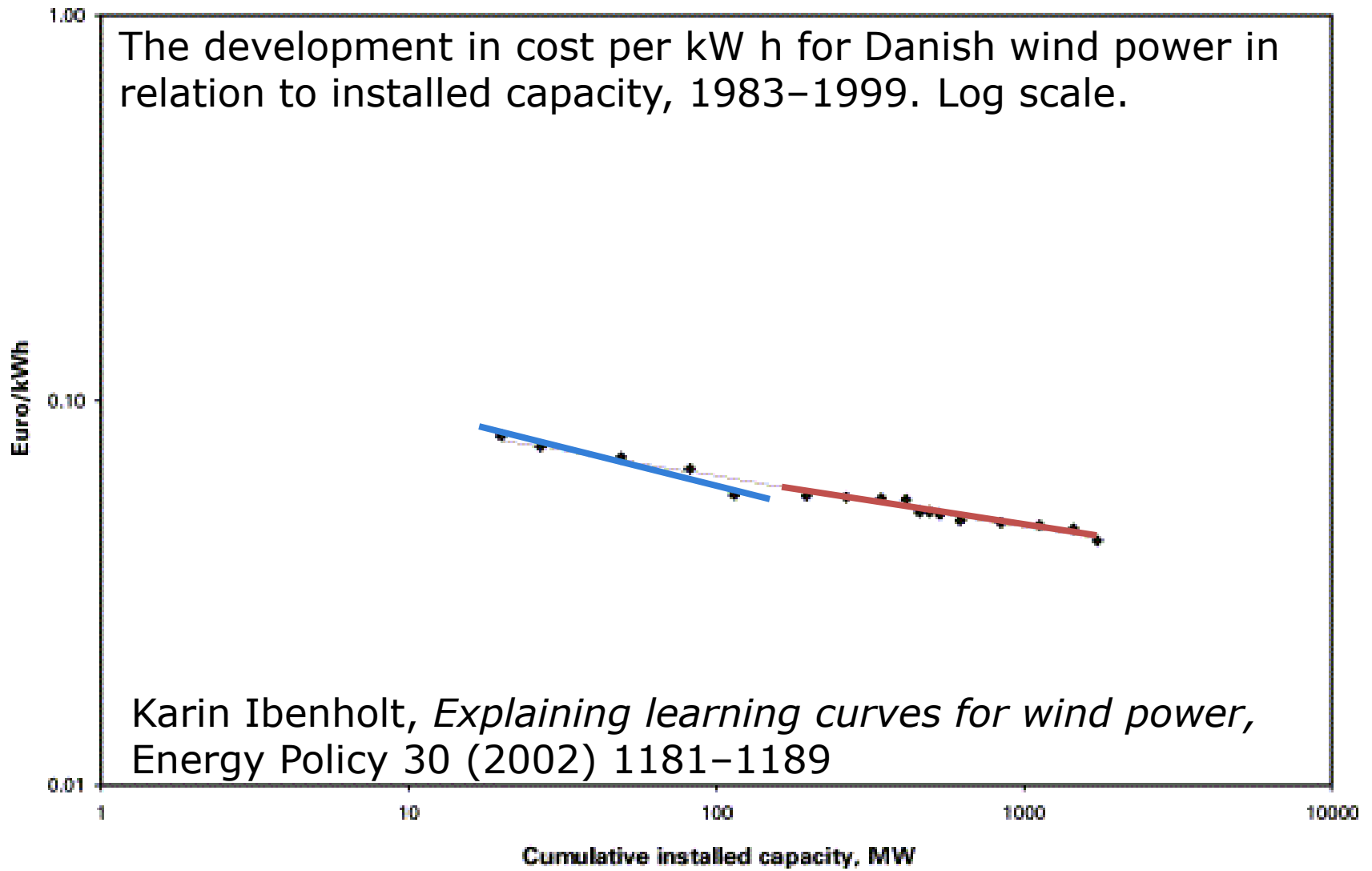
'fazer mais é mais barato'

### CURVA DE APRENDIZAGEM

- *Válido* para uma fábrica que produz as *mesmas unidades*, com o *mesmo equipamento*, os *mesmos materiais* mas em *mais quantidade*.
- Quando consideramos outros factores como pressão sobre os *custos da matéria prima* ou incorporação *externalidades*, *inovação tecnológica*, etc., a curva de aprendizagem pode **acelerar** ou **desacelerar**.

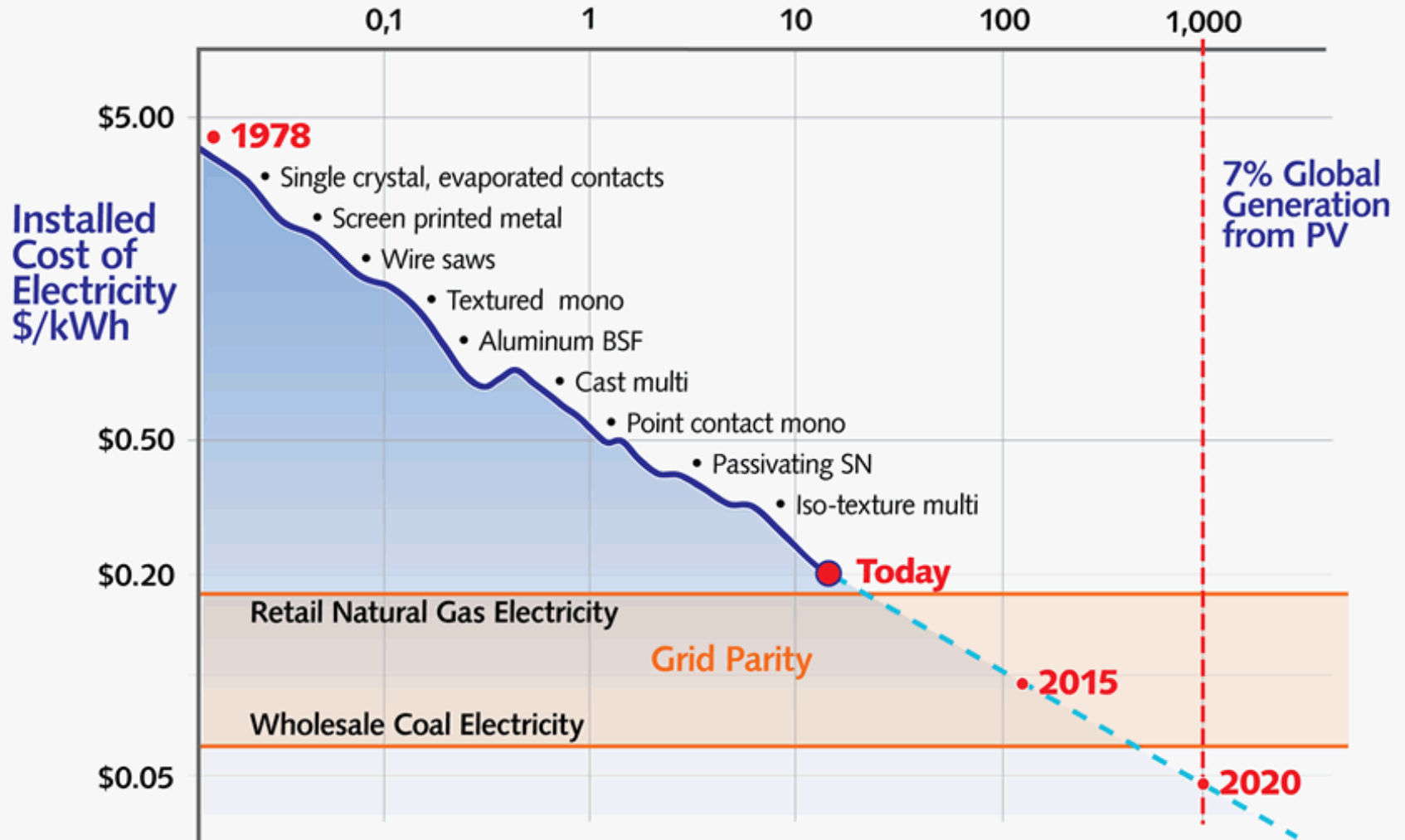


The development in cost per kW h for Danish wind power in relation to installed capacity, 1983–1999. Log scale.



Karin Ibenholt, *Explaining learning curves for wind power*,  
Energy Policy 30 (2002) 1181–1189

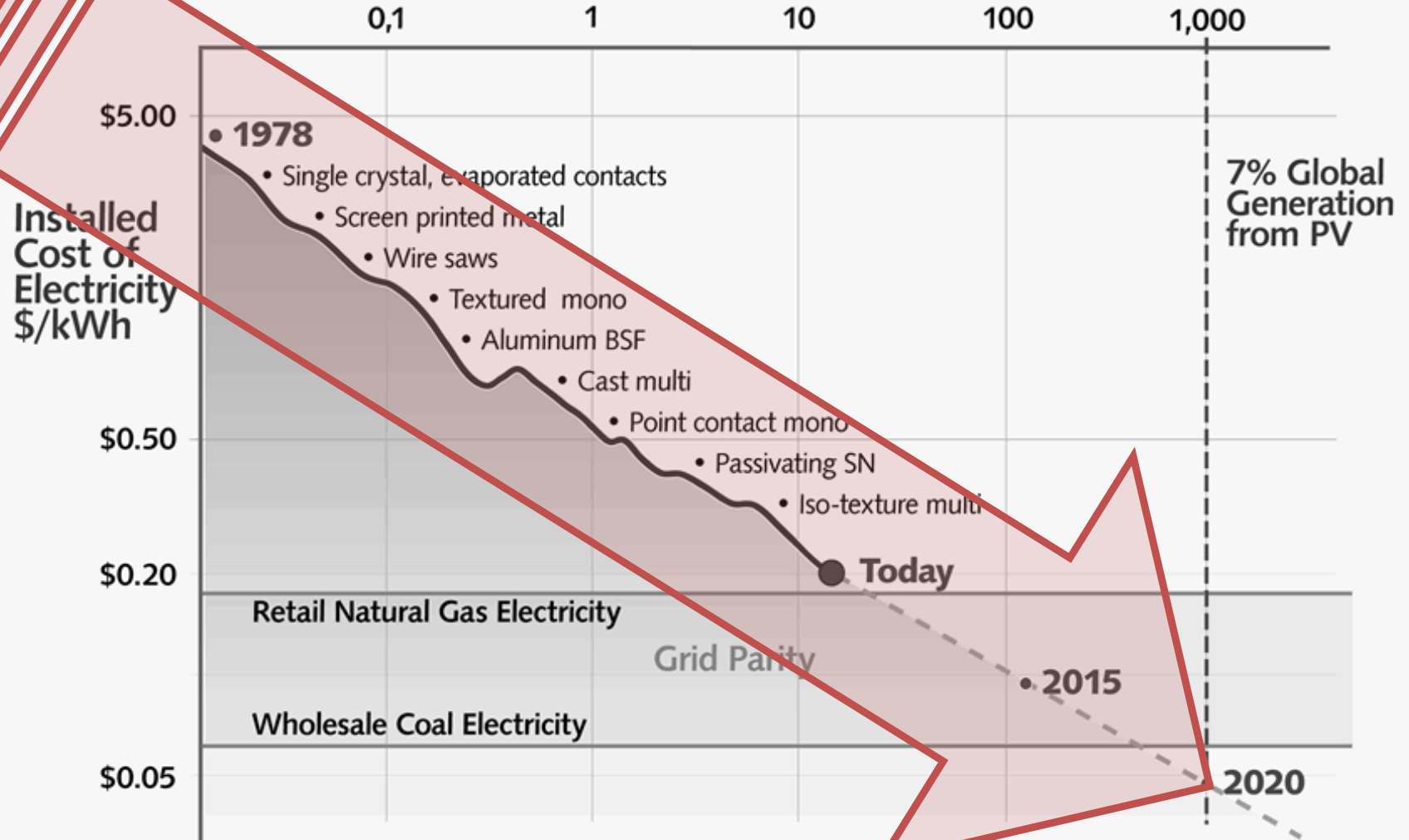
# Cumulative production GigaWp



Source: Professor Emanuel Sachs, Massachusetts Institute of Technology.

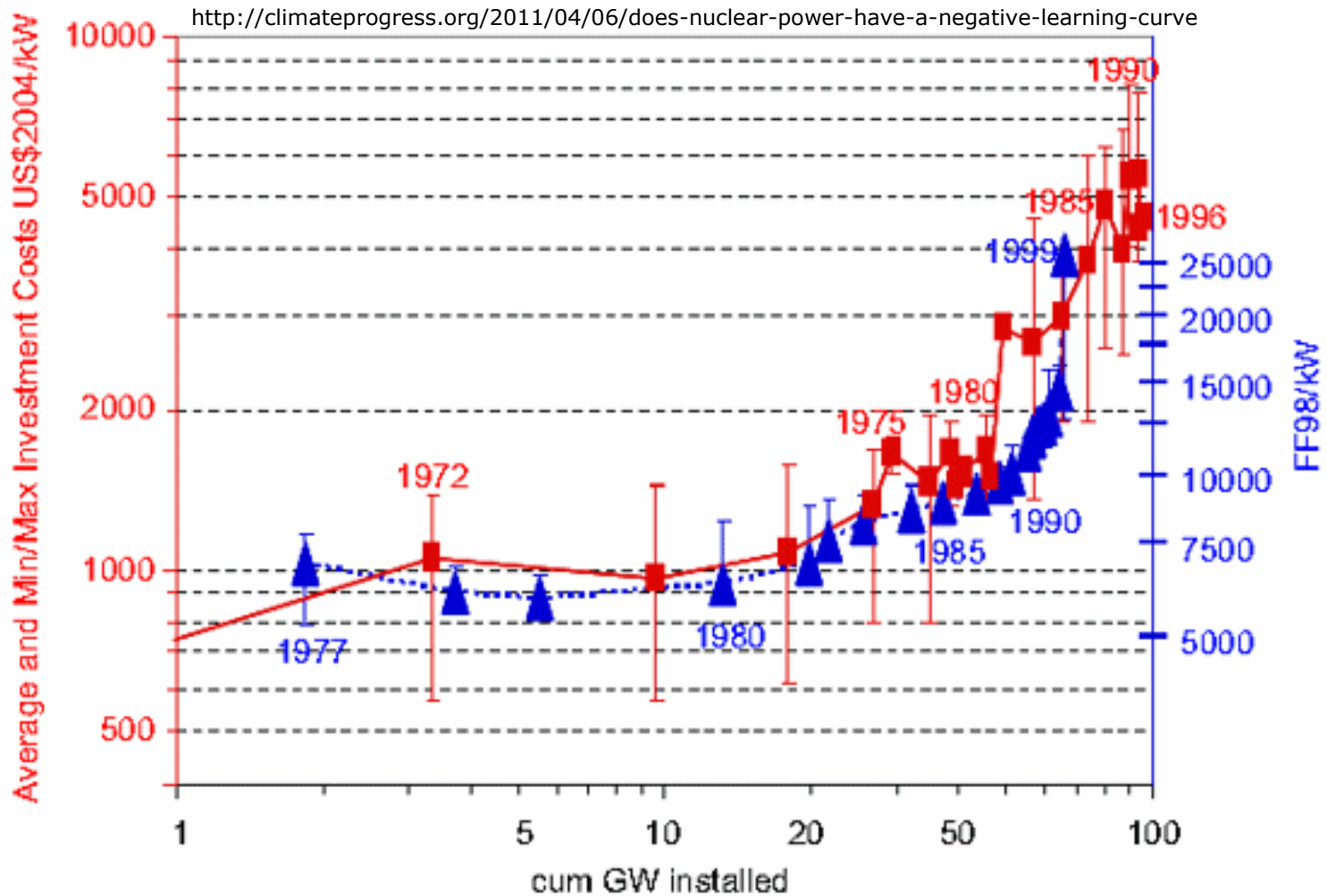
\* Assumes annual production growth of 35% and an 18% learning curve. PV costs based on 18% capacity factor and 7% discount rate.

# Cumulative production GigaWp



Source: Professor Emanuel Sachs, Massachusetts Institute of Technology.

\* Assumes annual production growth of 35% and an 18% learning curve. PV costs based on 18% capacity factor and 7% discount rate.



A. Grubler, *The costs of the French nuclear scale-up: A case of negative learning by doing*, Energy Policy 38 (2010) 5174–5188

# INCENTIVOS PARA ENERGIAS (RENOVÁVEIS)

Para acelerar a curva de aprendizagem

## Categorias

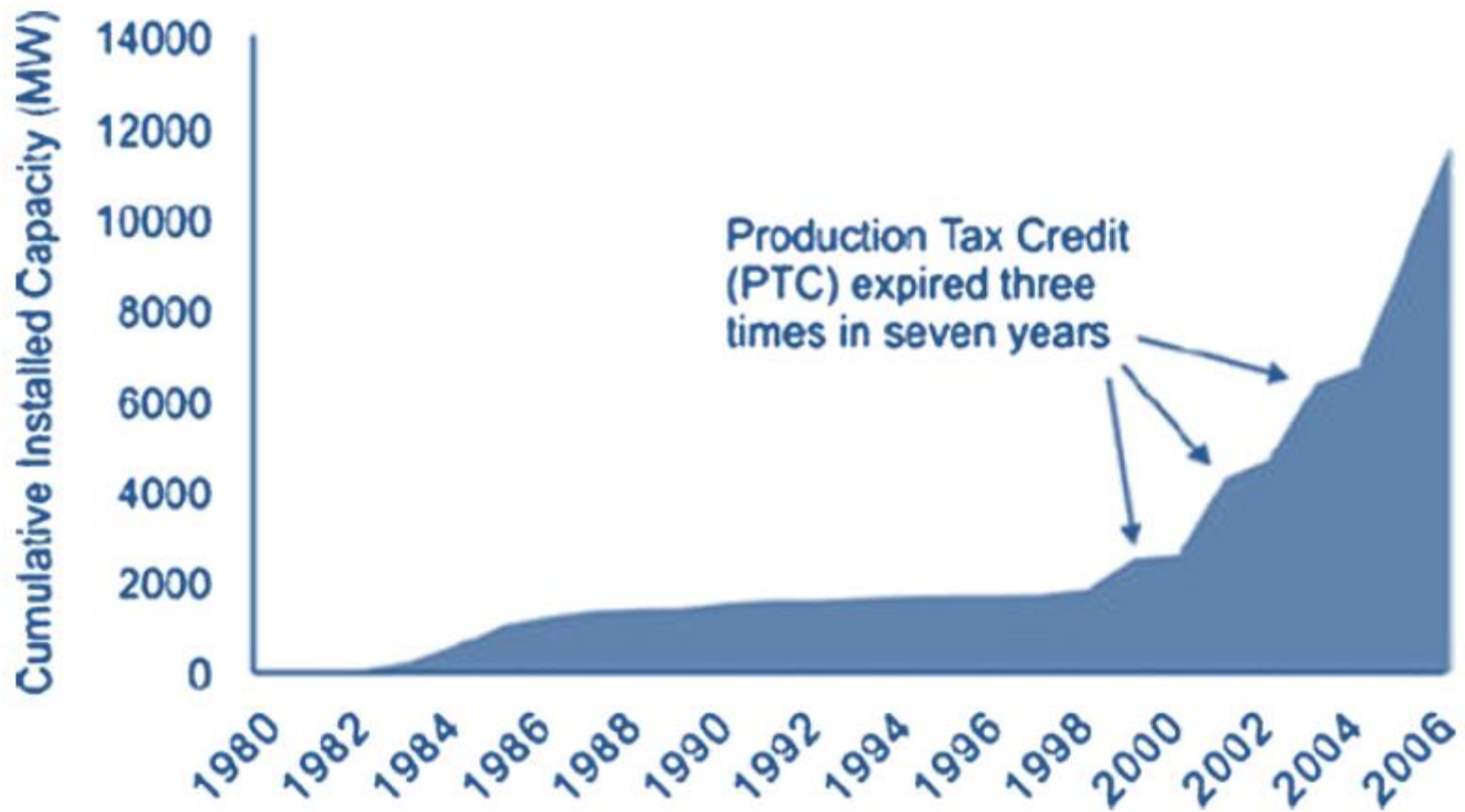
### • Subsídios financeiros

- Financiamento para R&D
- Externalidades

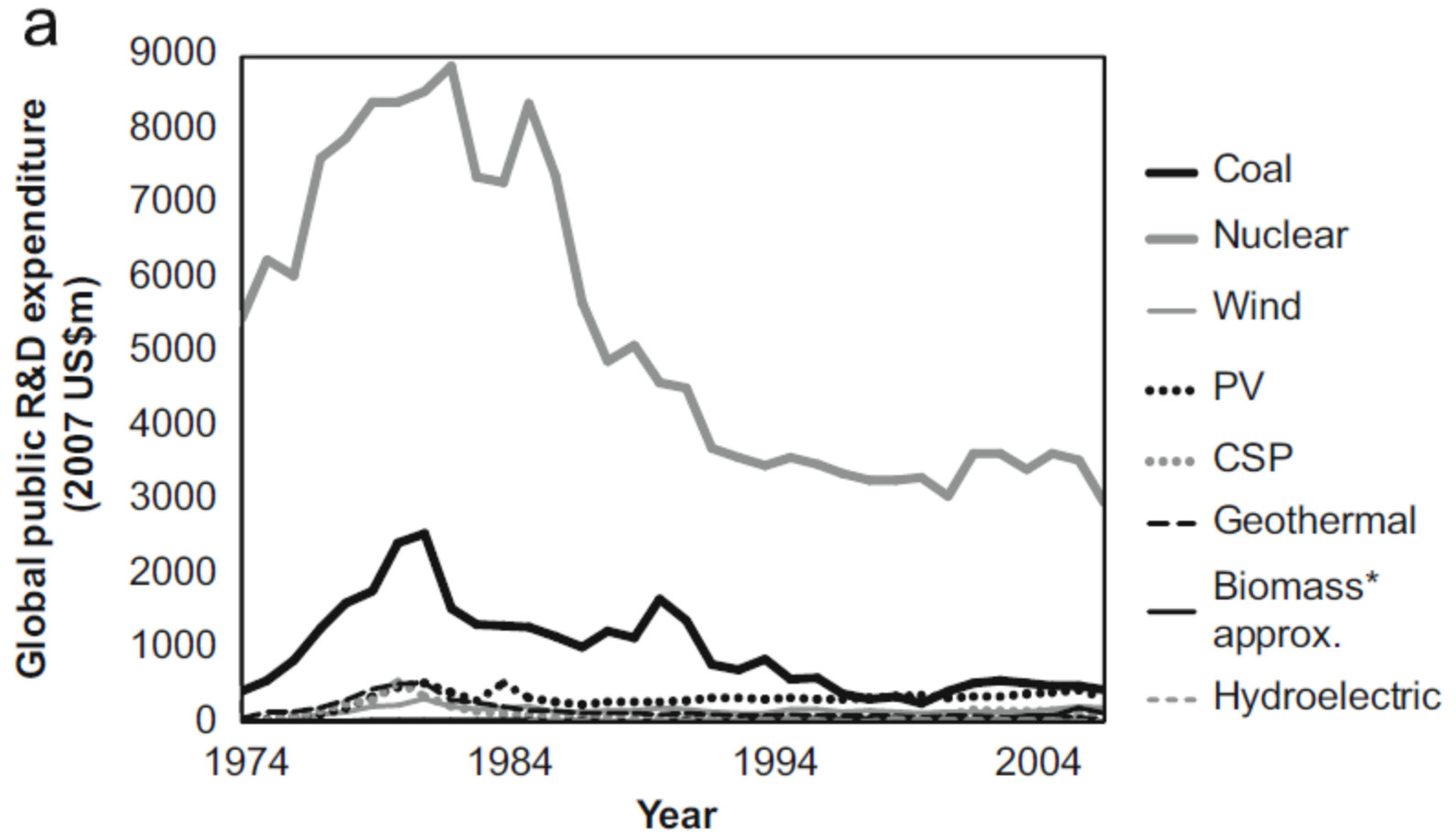
- Sistema de quotas
- Subsídios a investimento
- subsídios à produção

- Apoios directos
- Apoios fiscais
- Tarifas importação/exportação
- ...



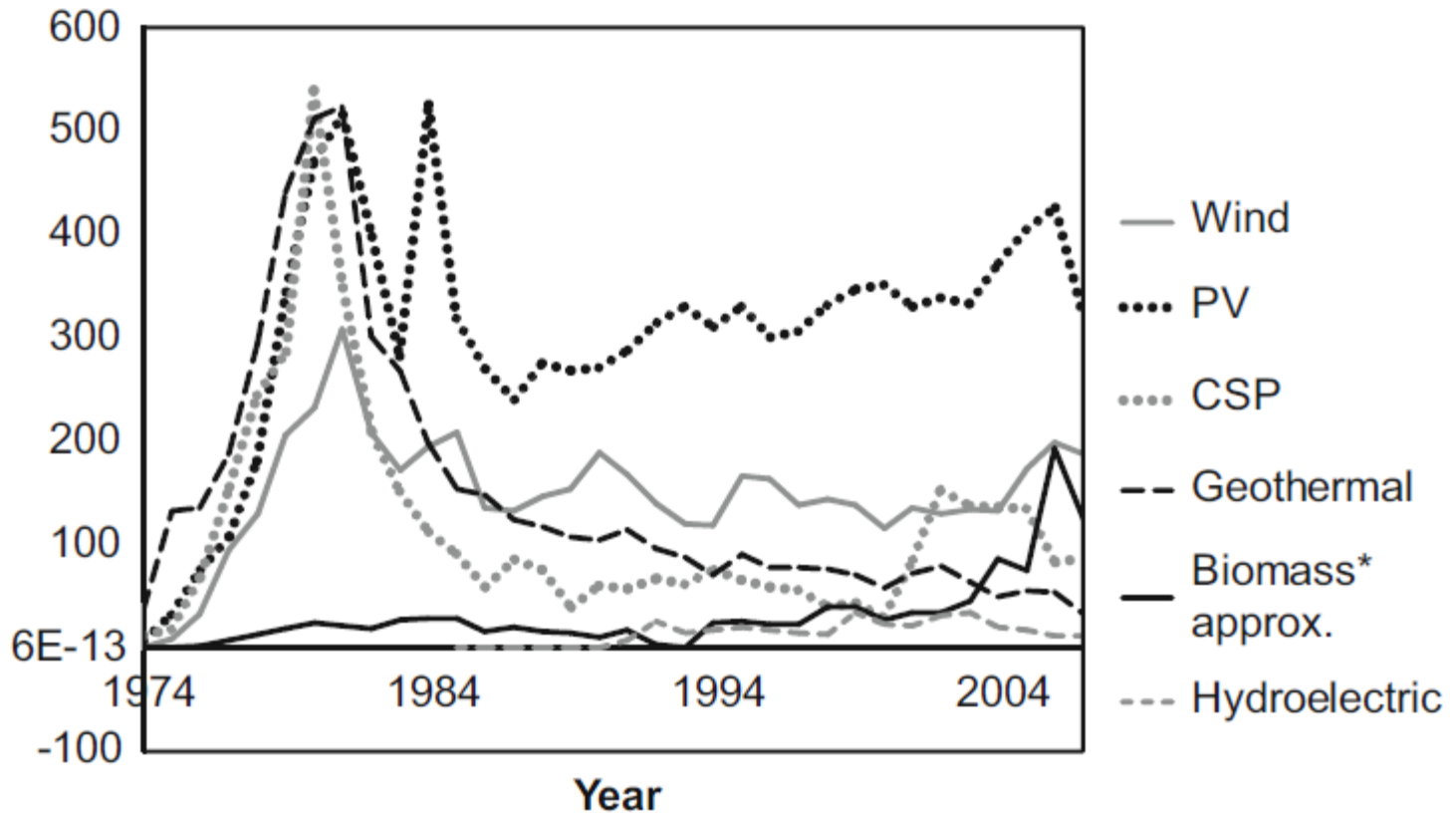


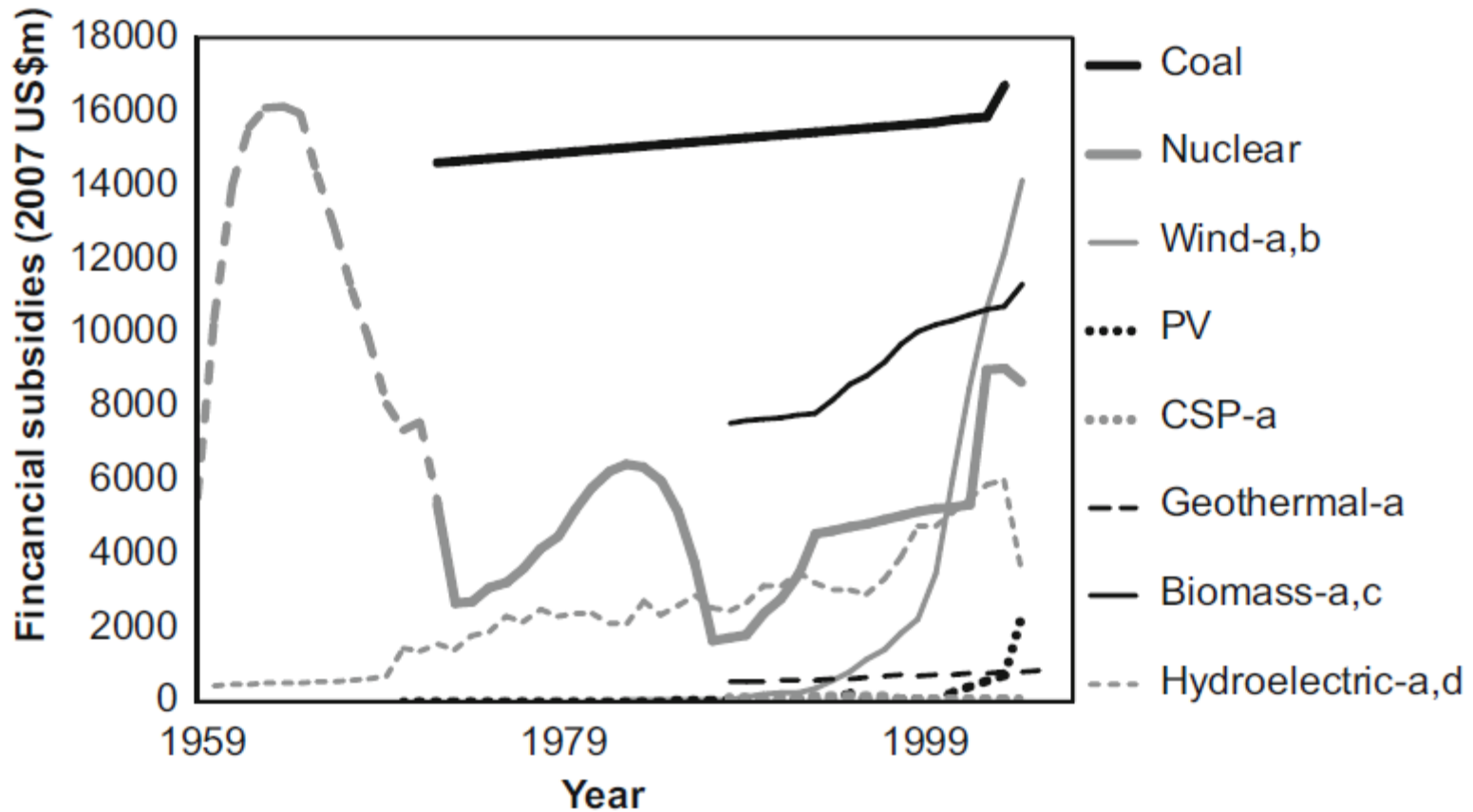
**Fig. 1.** Cumulative wind energy capacity in the US showing stagnation of industry development at the each expiration of the PTC (taken from EIA, 2008a).



**b**

Global public R&D expenditure  
(2007 US\$m)

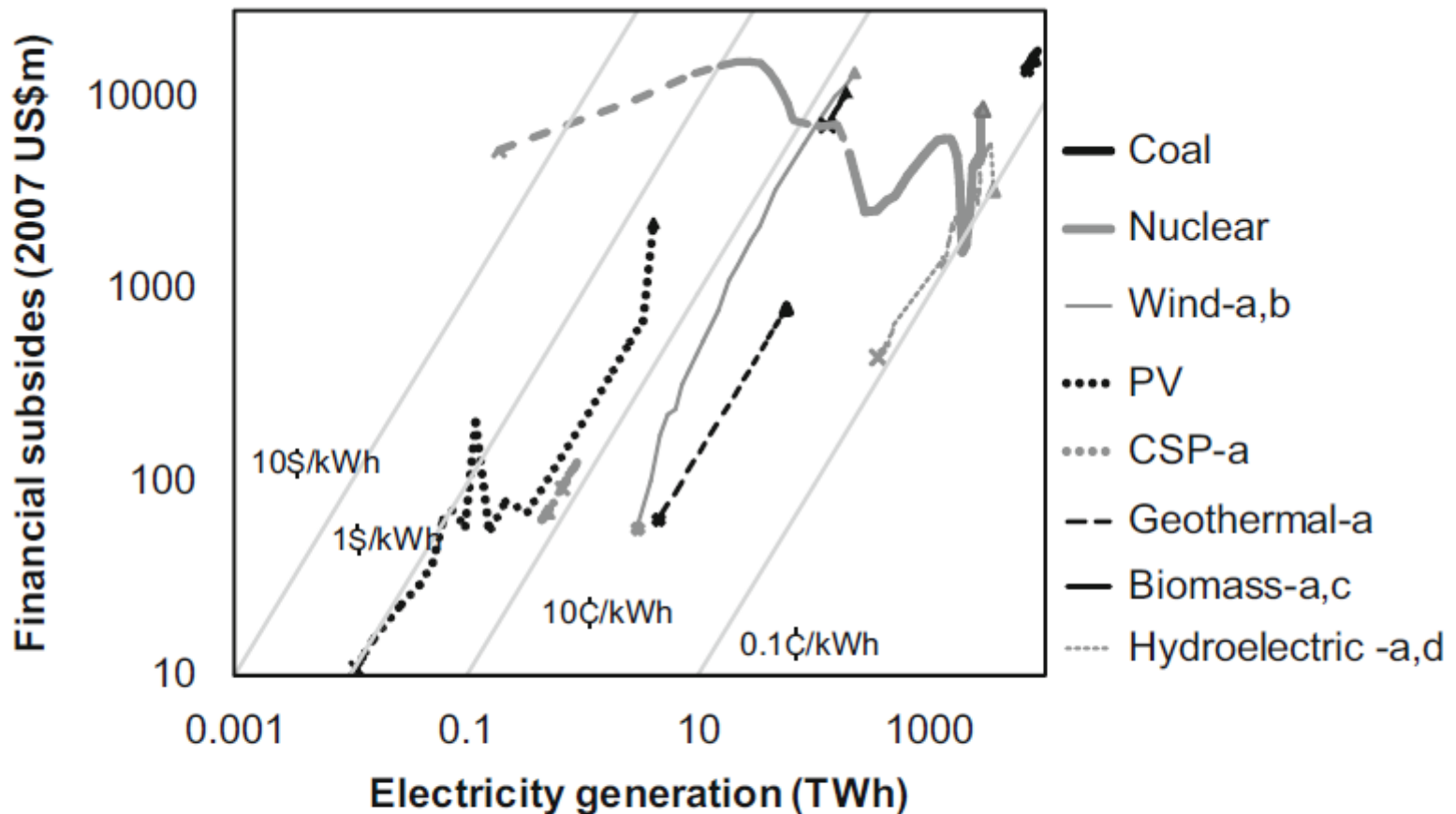




<sup>a</sup> Highly uncertain; <sup>b</sup> Based on FiTs of Denmark and PTC in the US;

<sup>c</sup> Based on FiTs in Germany, Austria and Netherlands and PTC in the US;

<sup>d</sup> Based on FiTs in Germany, Austria, Netherlands and France and PTC in the US.



<sup>a</sup> Highly uncertain; <sup>b</sup> Based on FiTs of Denmark and PTC in the US;

<sup>c</sup> Based on FiTs in Germany, Austria and Netherlands and PTC in the US;

<sup>d</sup> Based on FiTs in Germany, Austria, Netherlands and France and PTC in the US.

# CRÍTICAS A INCENTIVOS SOBRE-DIMENSIONADOS

## TARIFAS GARANTIDAS PARA PV NA ALEMANHA

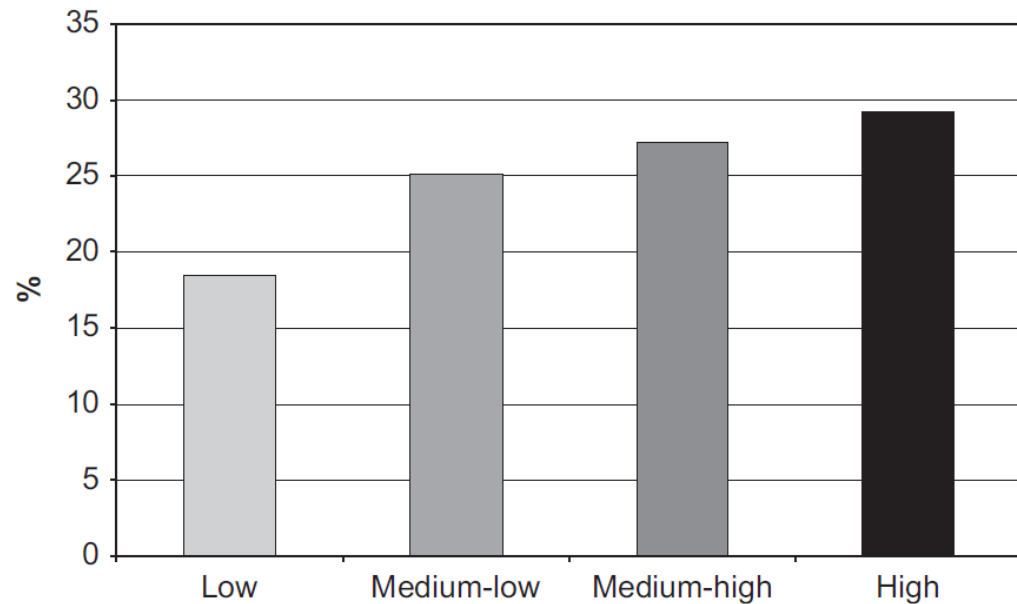
M. Frondel, et al, *Germany's solar cell promotion: Dark clouds on the horizon*, Energy Policy 36 (2008) 4198–4204

- Produção insignificante <0.5% (2007)
- Custo redução emissões 760€/tonCO<sub>2</sub>
- Factura para os próximos 20 anos: 63T€
- Défice para a indústria local: ~50% importações
- Criação emprego: 205k€/ano/emprego

# CRÍTICAS A INCENTIVOS SOBRE-DIMENSIONADOS

## TARIFAS GARANTIDAS NA AUSTRALIA

A. Macintosh, et al, *Searching for public benefits in solar subsidies: A case study on the Australian government's residential photovoltaic rebate program*, Energy Policy 39 (2011) 3199–3209



**Fig. 9.** Proportion of successful PVRP applicants from postal areas with low, medium-low, medium-high and high SES ratings (ABS, 2006a; ADEWHA, 2010).

## Conceitos que importa reter...

### PARA SE PODER *DISCUTIR* CUSTOS ENERGIAS (RENOVÁVEIS)

- Factor de capacidade
- Custos de operação e manutenção fixos
- e variáveis, e.g. combustível
- (... e outras coisas como variabilidade do recurso)

### OUTROS CONCEITOS ESSENCIAIS

- Externalidades
- Curvas de aprendizagem
- Incentivos para acelerar curvas de aprendizagem