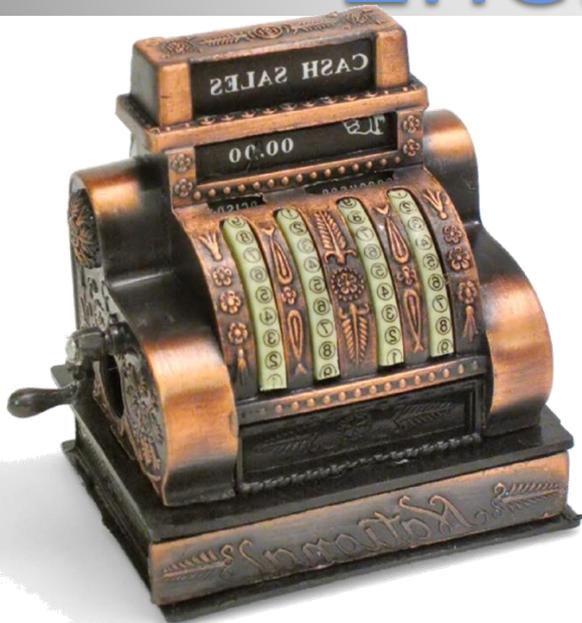


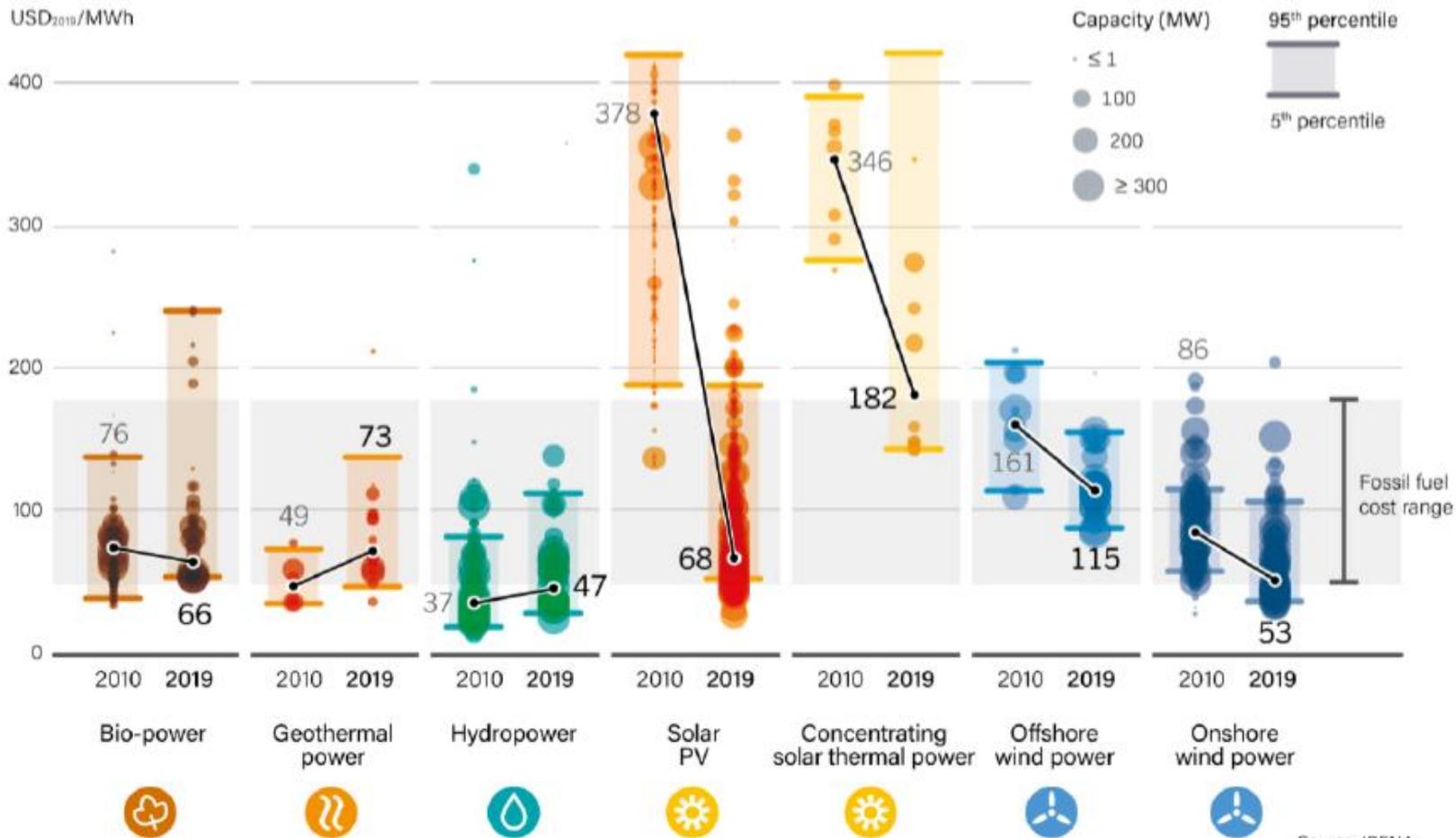
CUSTOS

Energias Renováveis

Miguel Centeno Brito



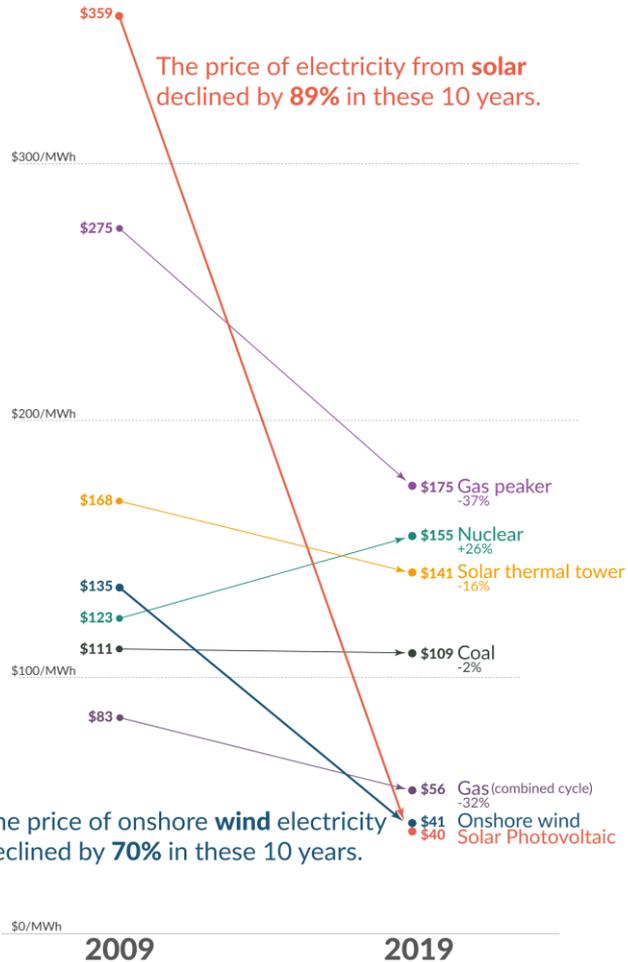
RENEWABLE POWER COSTS KEEP FALLING



The price of electricity from new power plants

Our World
in Data

Electricity prices are expressed in 'levelized costs of energy' (LCOE). LCOE captures the cost of building the power plant itself as well as the ongoing costs for fuel and operating the power plant over its lifetime.



Data: Lazard Levelized Cost of Energy Analysis, Version 13.0

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Soft Costs—Others (PII, Land Acquisition, Transmission Line, Sales Tax, Overhead and Profit)

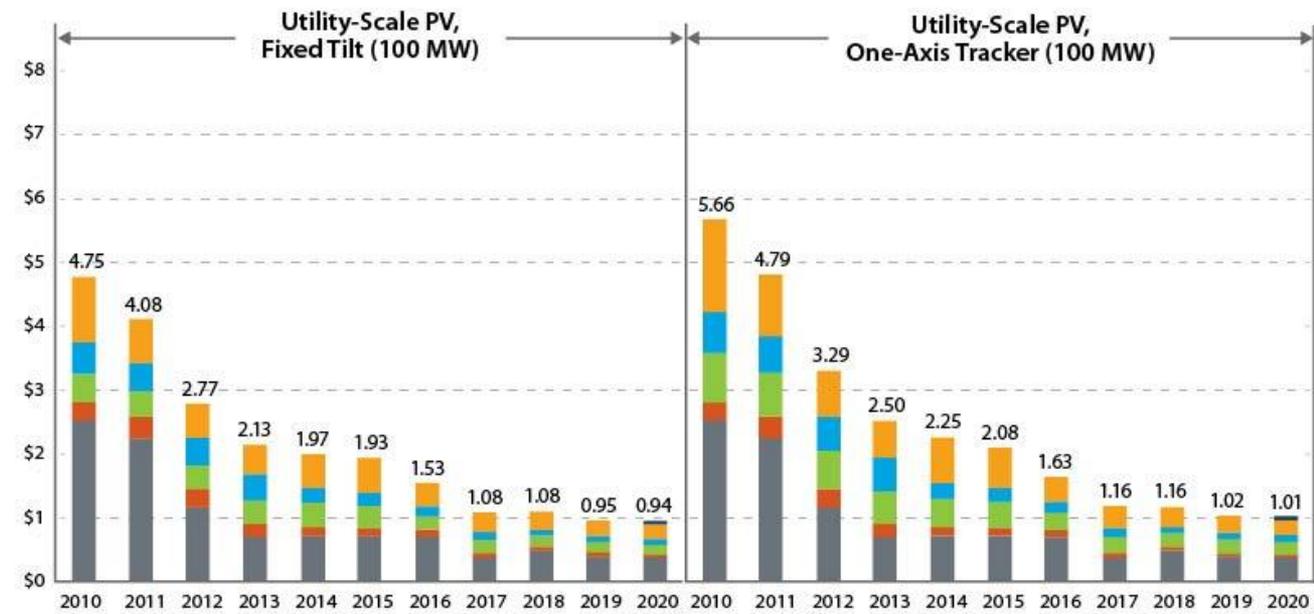
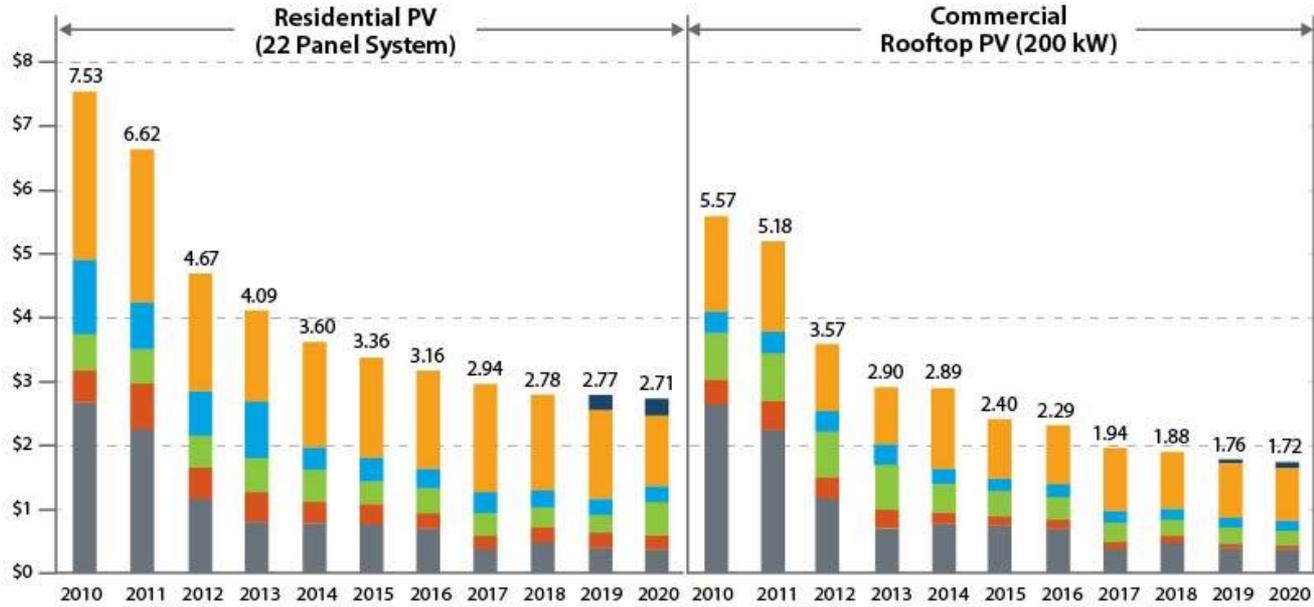
Soft Costs—Install Labor

Hardware BOS—Structural and Electrical Components

Inverter

Module

Additional Costs from Model Updates*



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

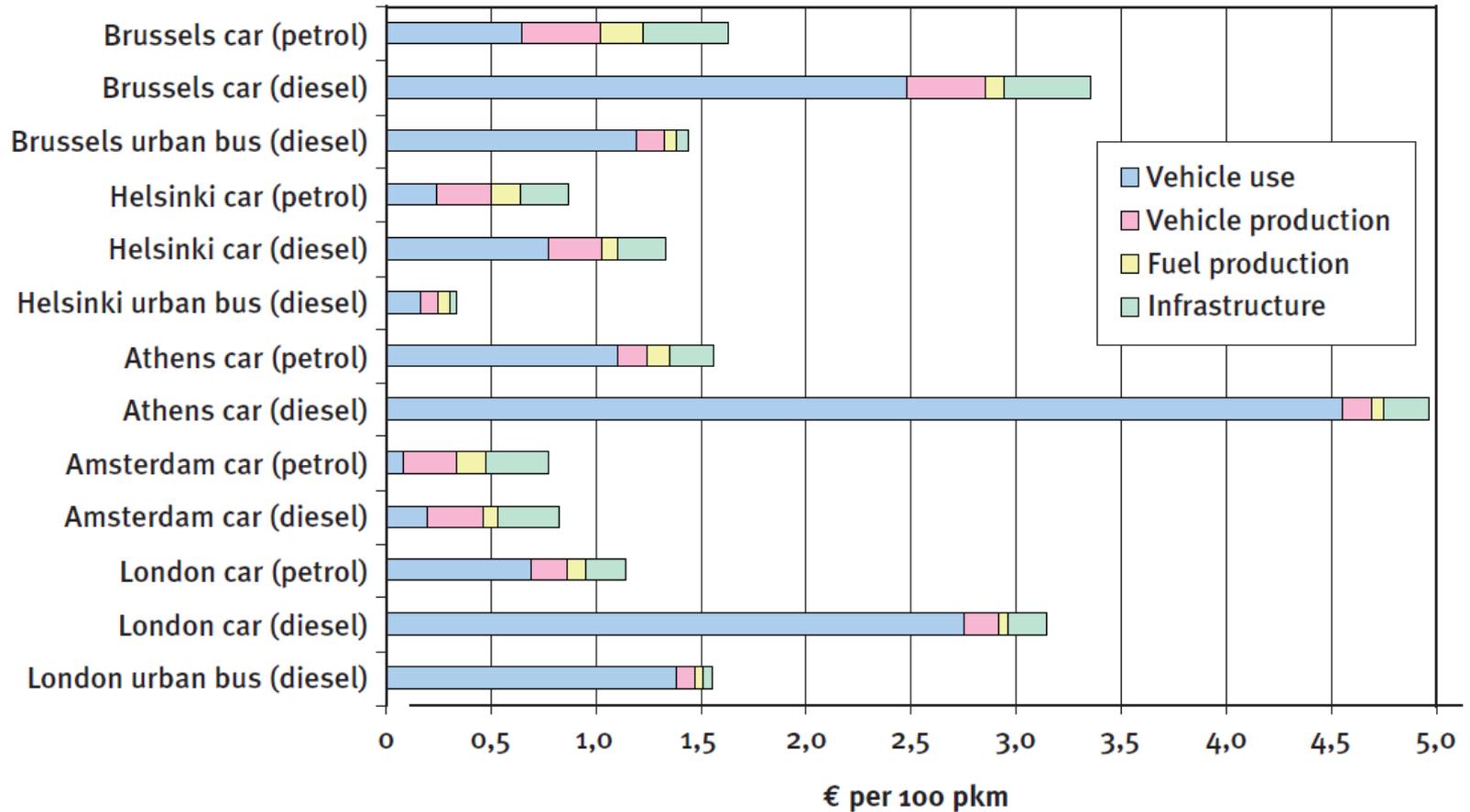
ExterneE

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

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

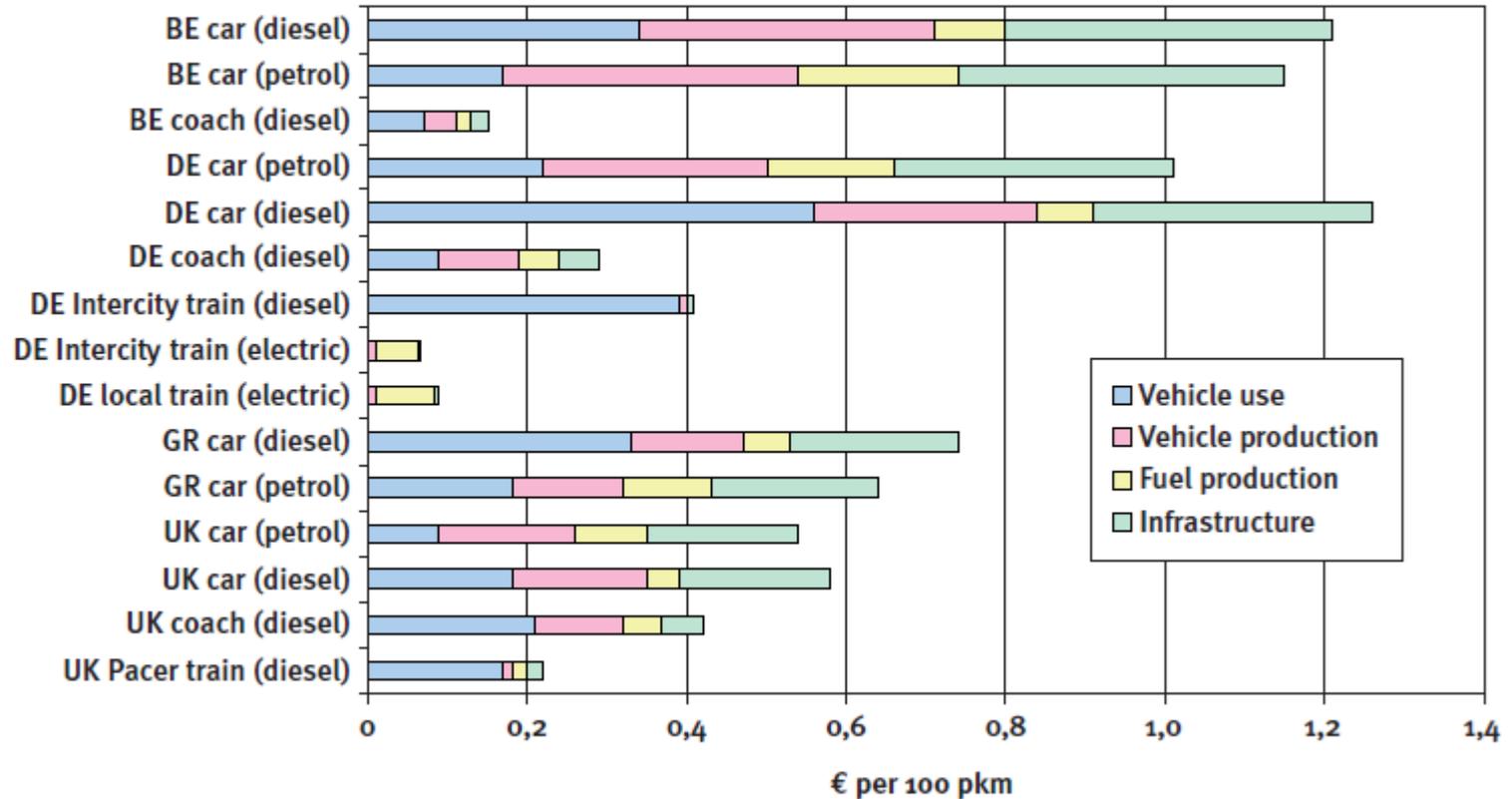
EXTERNALIDADES

Air pollution costs due to urban passenger transport²



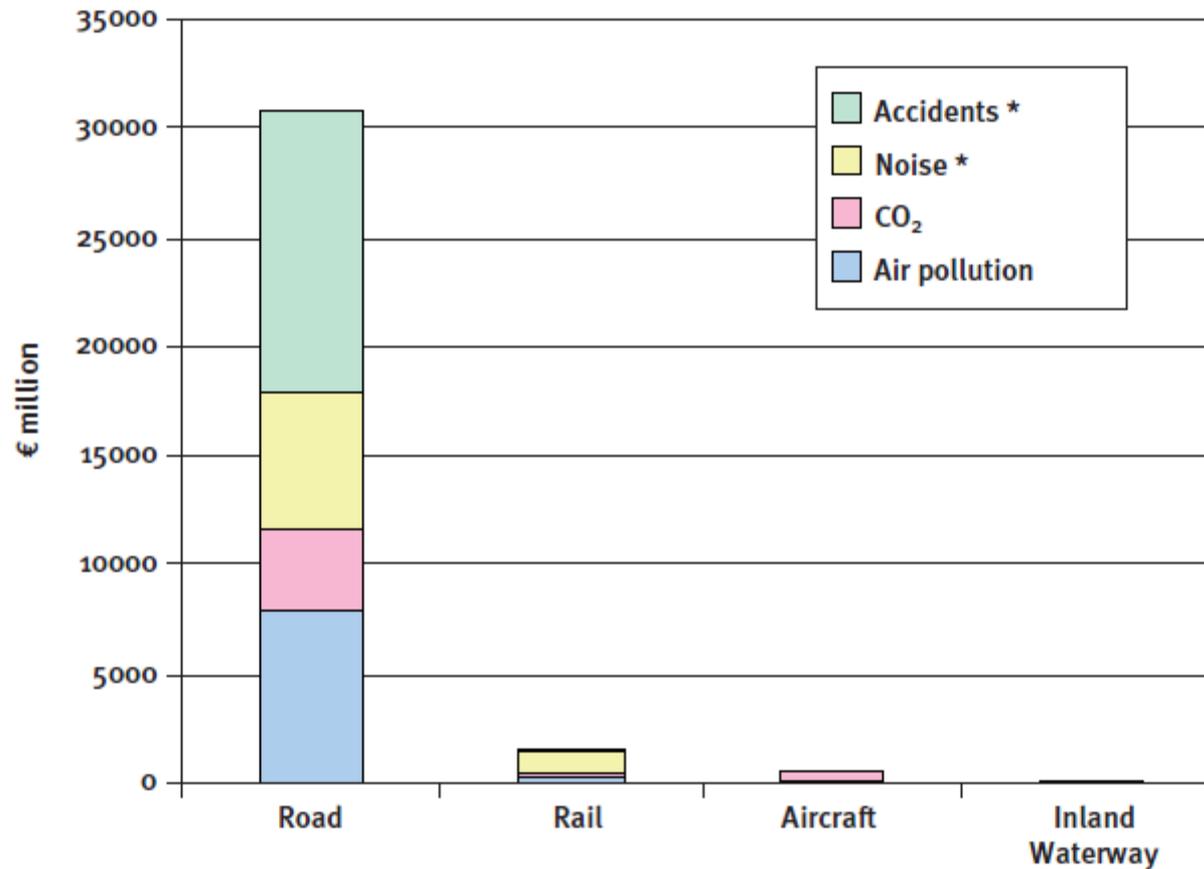
EXTERNALIDADES

Air pollution costs due to extra-urban passenger transport²



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

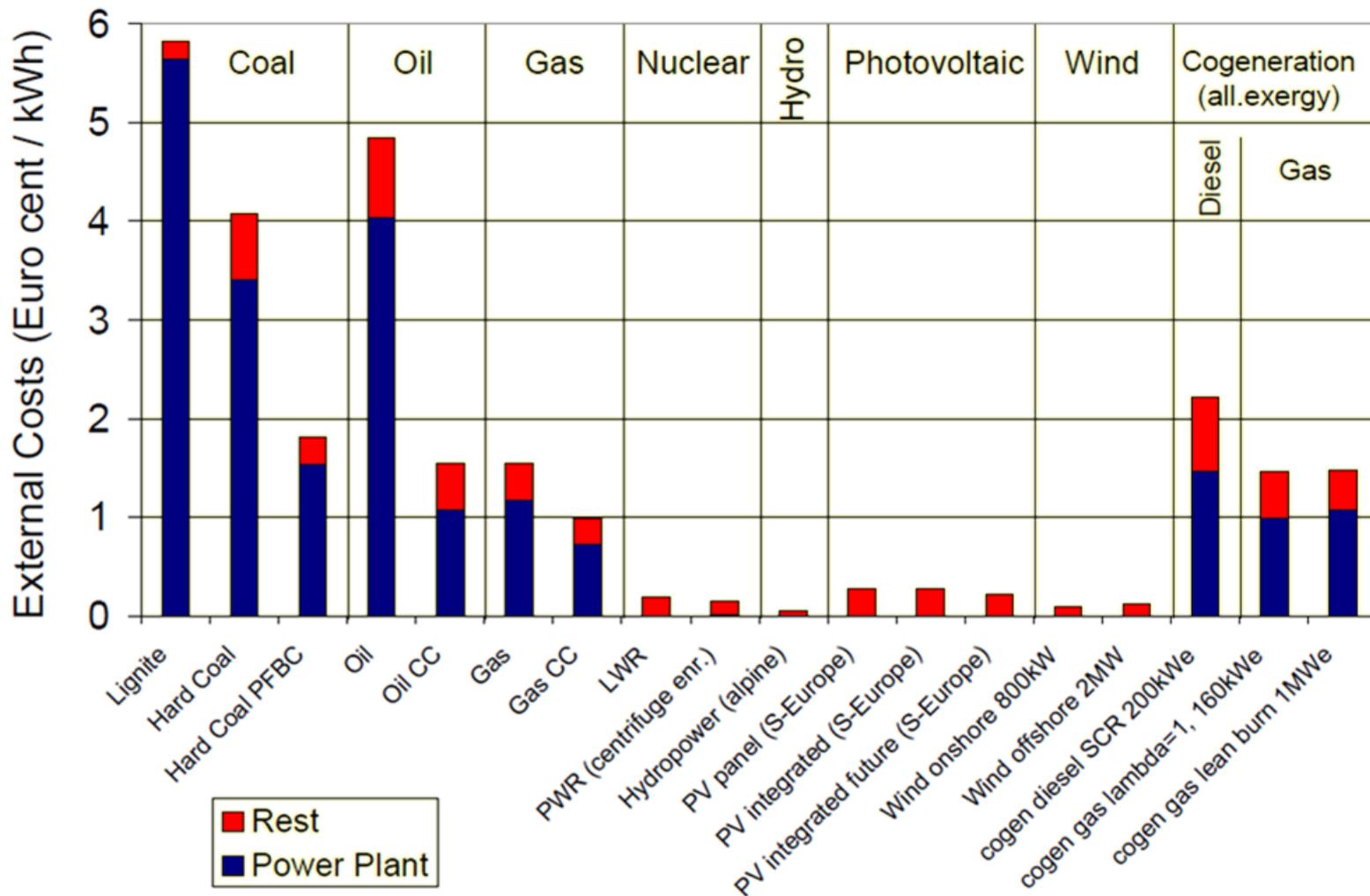
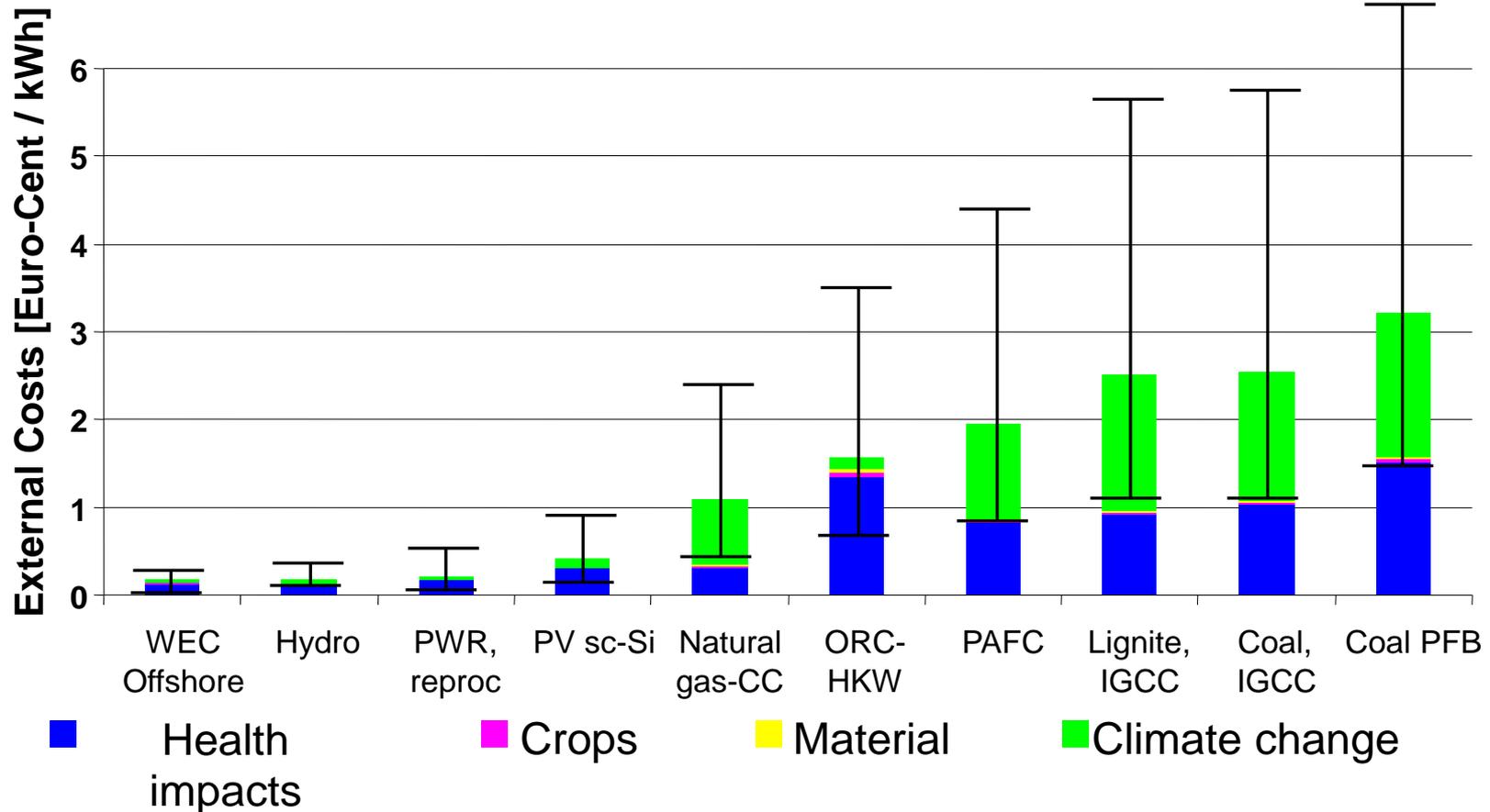


Figure 1

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€/tonCO₂]

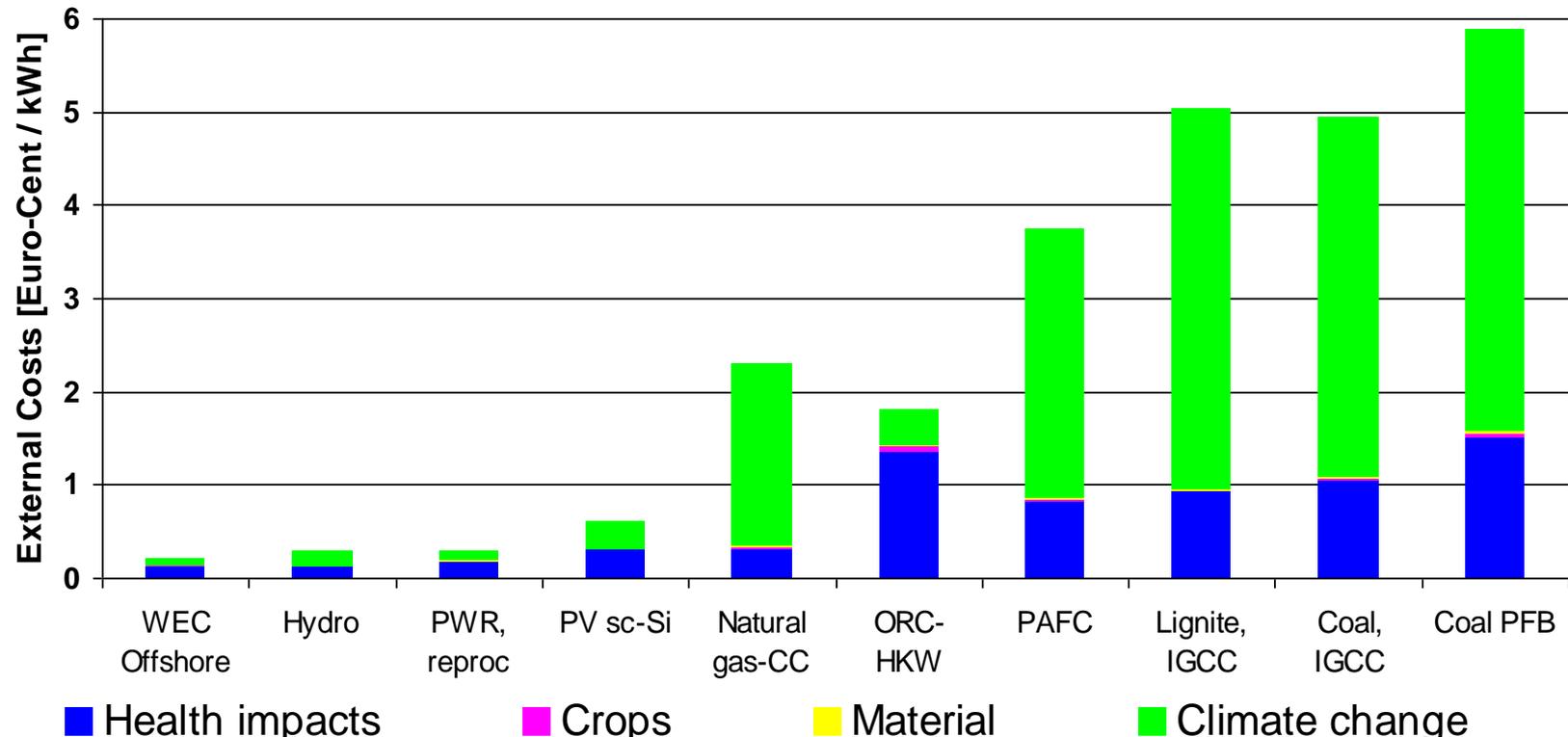


PWR – pressurized water reactor - nuclear
 ORC - Organic Rankine Cycle - biomass
 PAFC – phosphoric acid fuel cell

IGCC - integrated gasification combined cycle
 PFB – pressurized fluidized bed

EXTERNALIDADES

Custos para diferentes tecnologias c€/kWh [50€/tonCO₂]



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

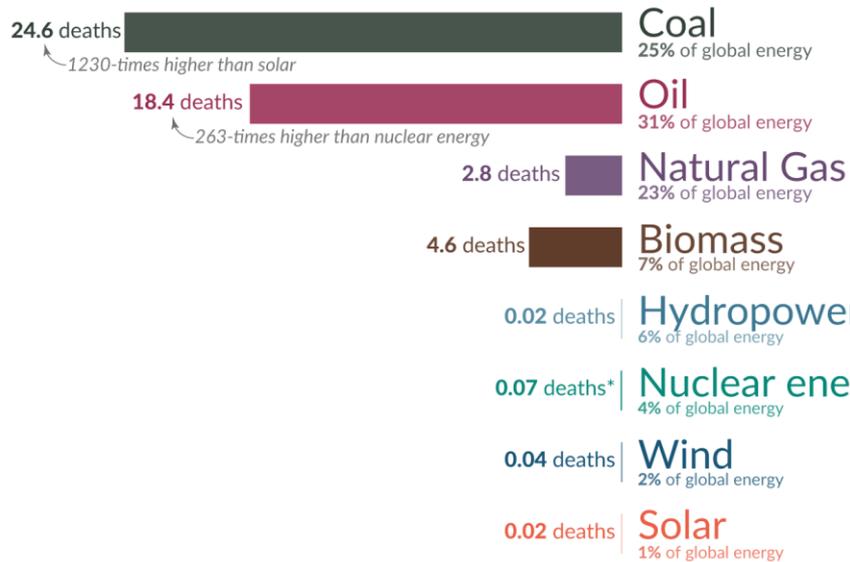
IGCC - integrated gasification combined cycle
PFB – pressurized fluidized bed

What are the **safest** and **cleanest** sources of energy?

Death rate from accidents and air pollution

Measured as deaths per terawatt-hour of energy production.

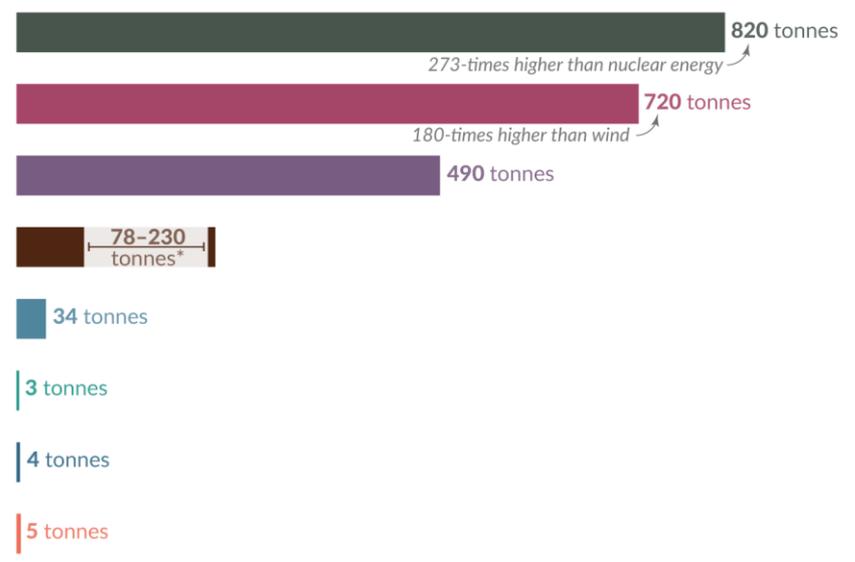
1 terawatt-hour is the annual energy consumption of 27,000 people in the EU.



Greenhouse gas emissions

Measured in emissions of CO₂-equivalents per gigawatt-hour of electricity over the lifecycle of the power plant.

1 gigawatt-hour is the annual electricity consumption of 160 people in the EU.



*Life-cycle emissions from biomass vary significantly depending on fuel (e.g. crop residues vs. forestry) and the treatment of biogenic sources.

*The death rate for nuclear energy includes deaths from the Fukushima and Chernobyl disasters as well as the deaths from occupational accidents (largely mining and milling).

Energy shares refer to 2019 and are shown in primary energy substitution equivalents to correct for inefficiencies of fossil fuel combustion. Traditional biomass is taken into account.

Data sources: Markandya & Wilkinson (2007); Sovacool et al. (2016); IPCC AR5 (2014); Pehl et al. (2017); BP (2019); Smil (2017).

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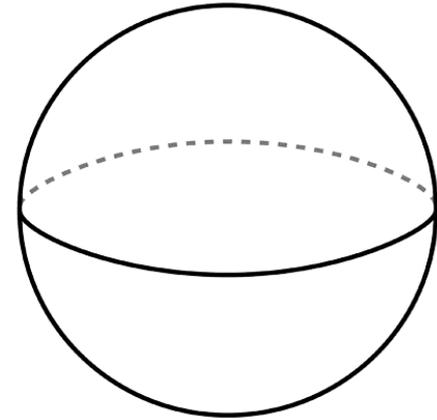
Licensed under CC-BY by the authors Hannah Ritchie and Max Roser.

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'

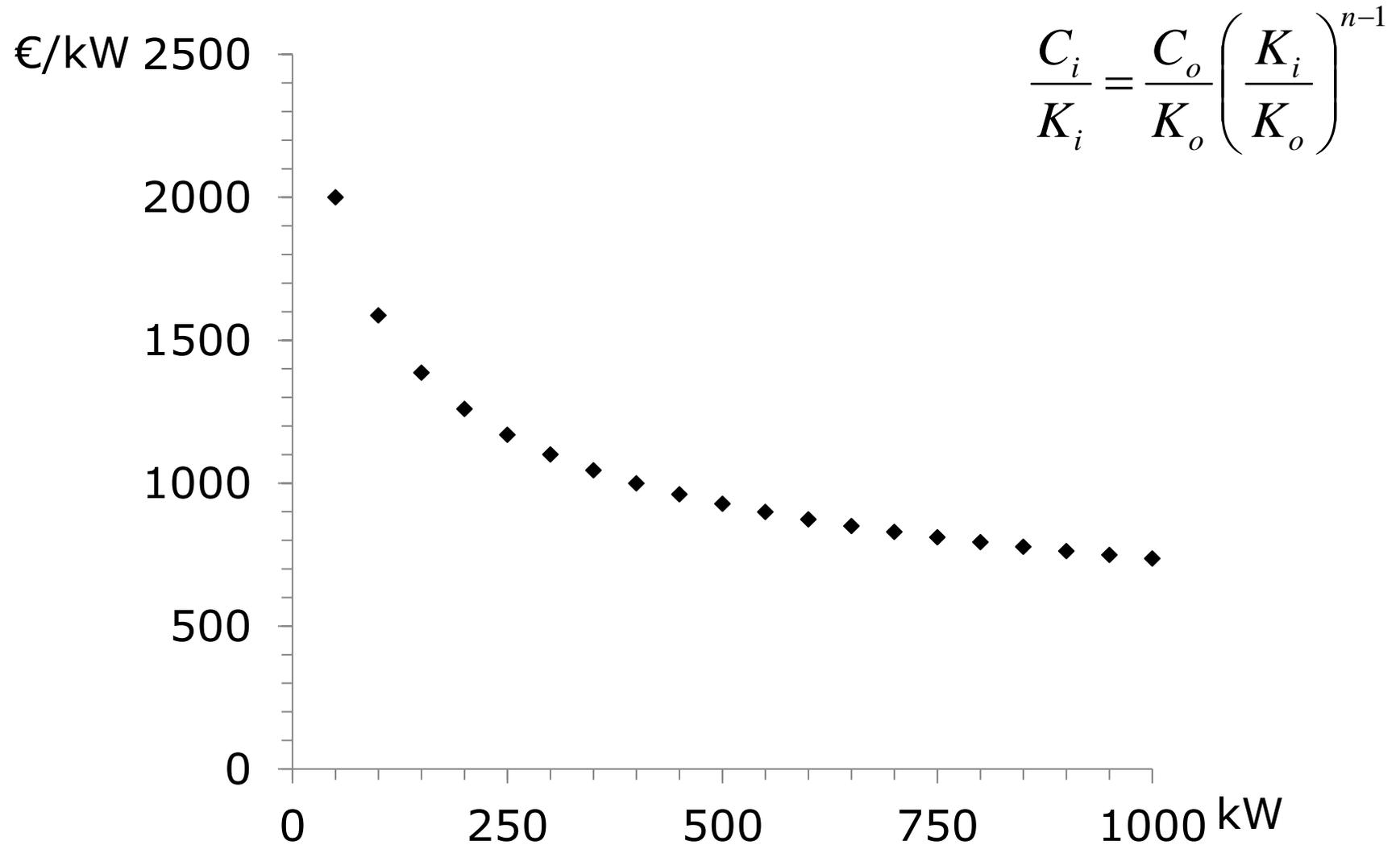
Exemplo

Central de 50MW custa 2000€/kW.

Quanto custa uma central de 1000MW?

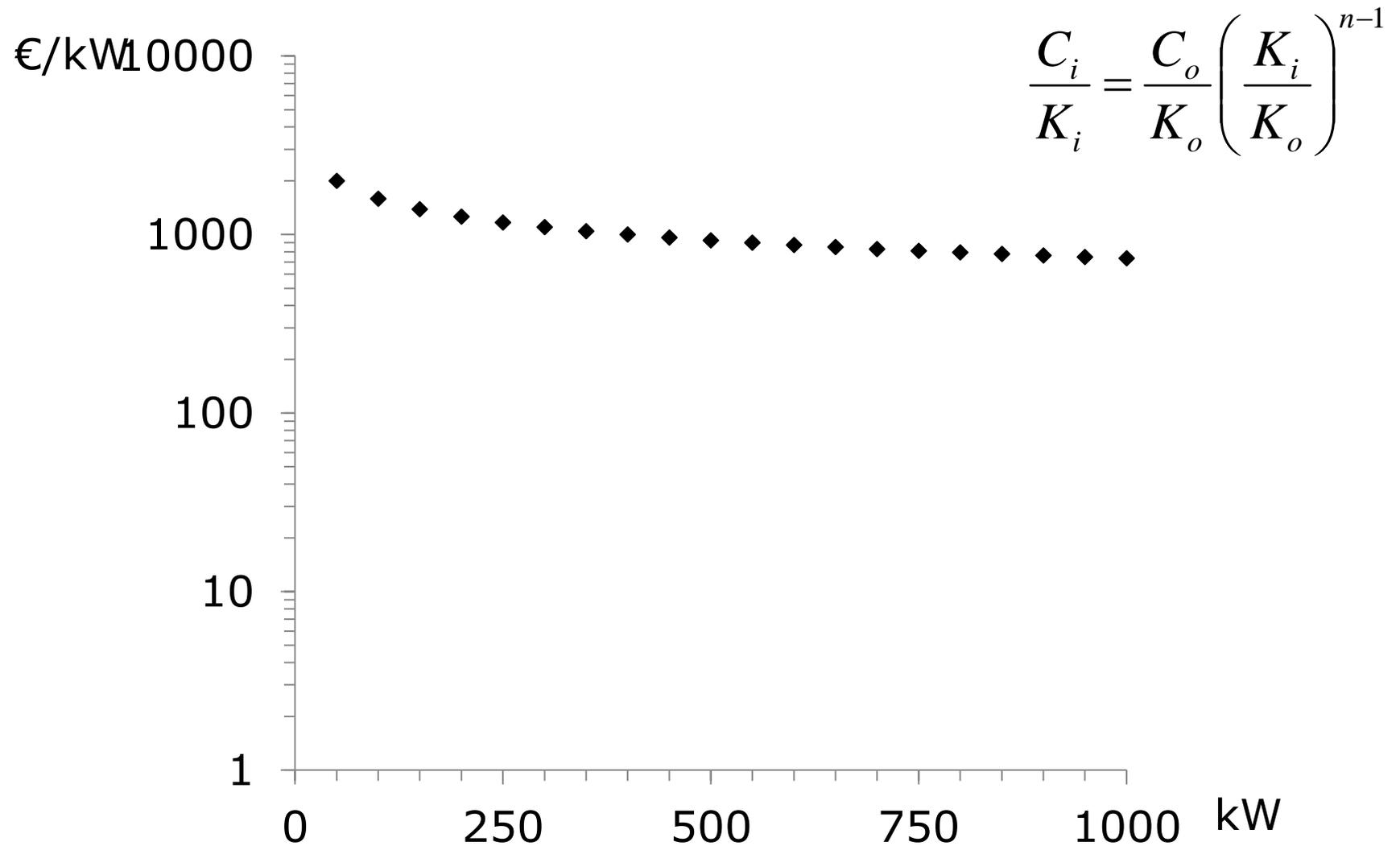
ECONOMIAS DE ESCALA

'fazer mais é mais barato'



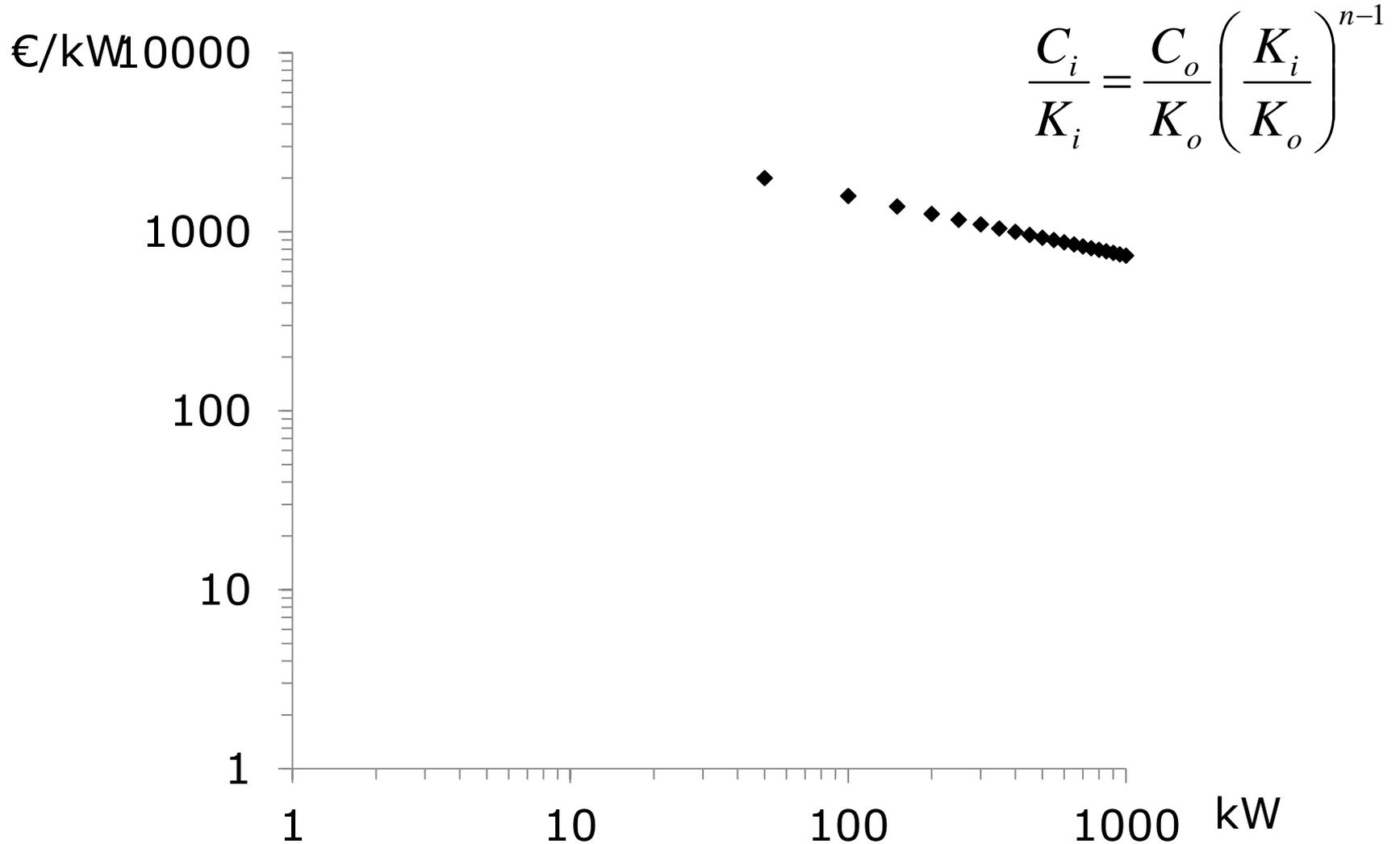
ECONOMIAS DE ESCALA

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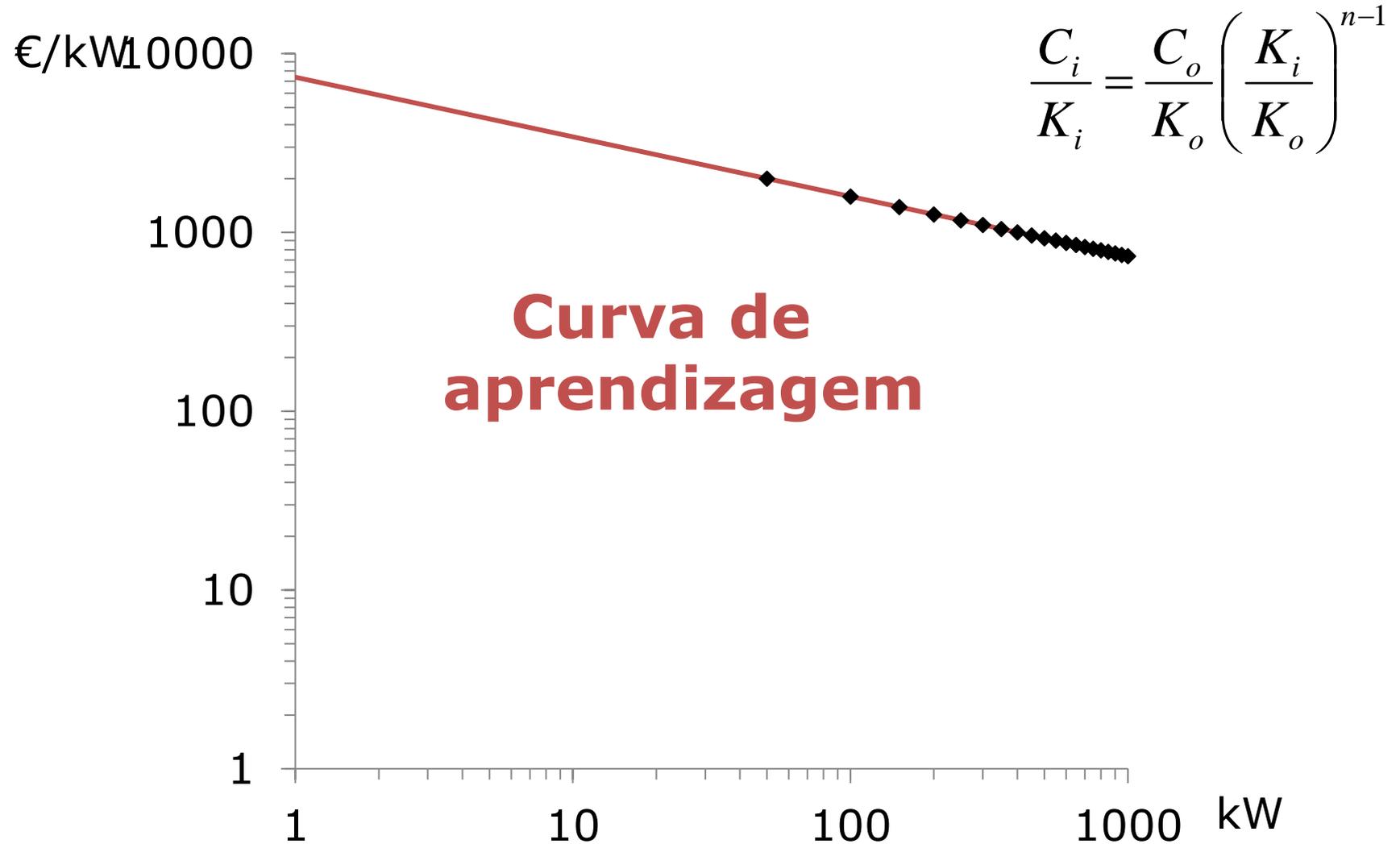
ECONOMIAS DE ESCALA

'fazer mais é mais barato'



ECONOMIAS DE ESCALA

'fazer mais é mais barato'



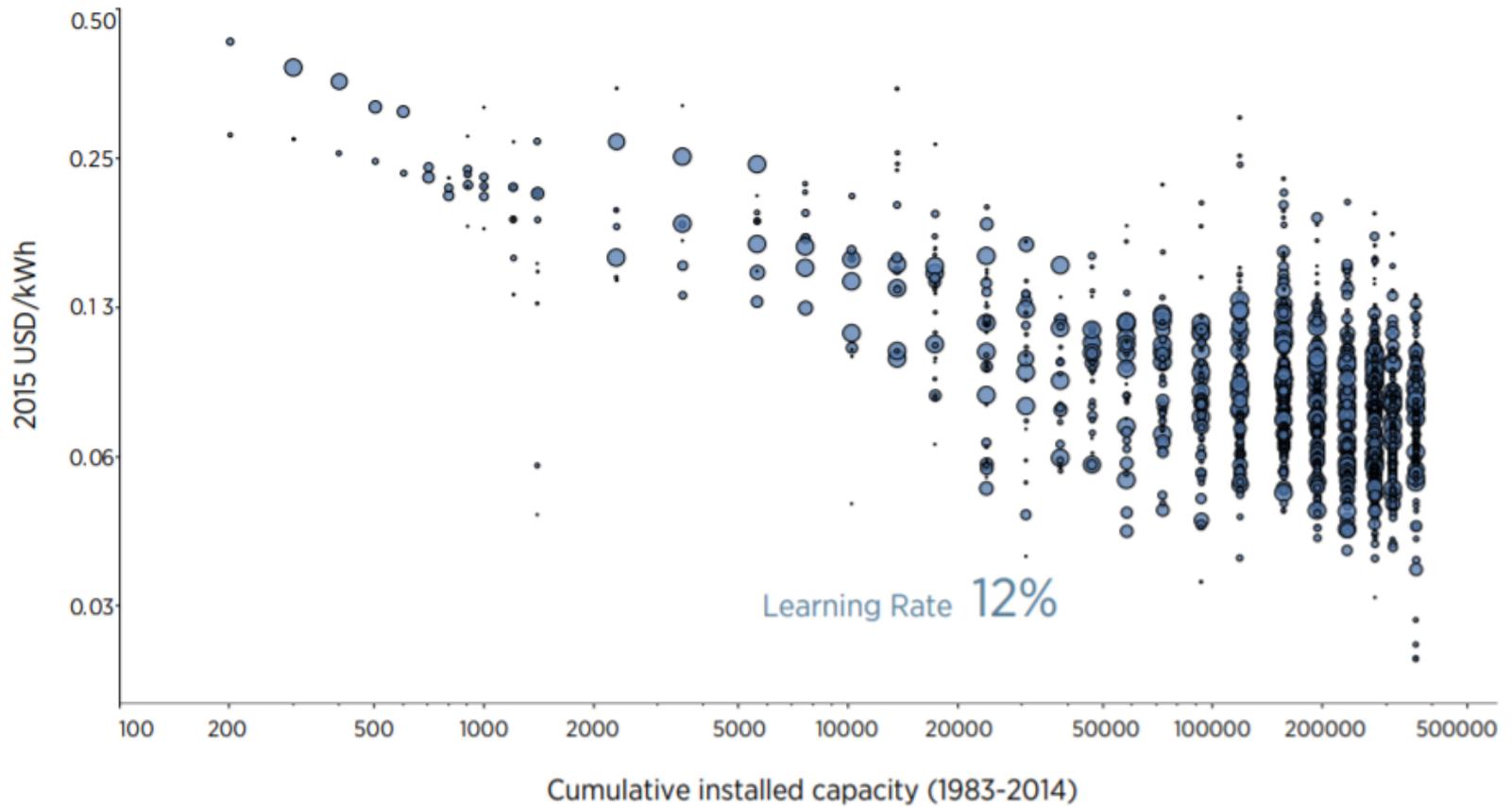
ECONOMIAS DE ESCALA

'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**.

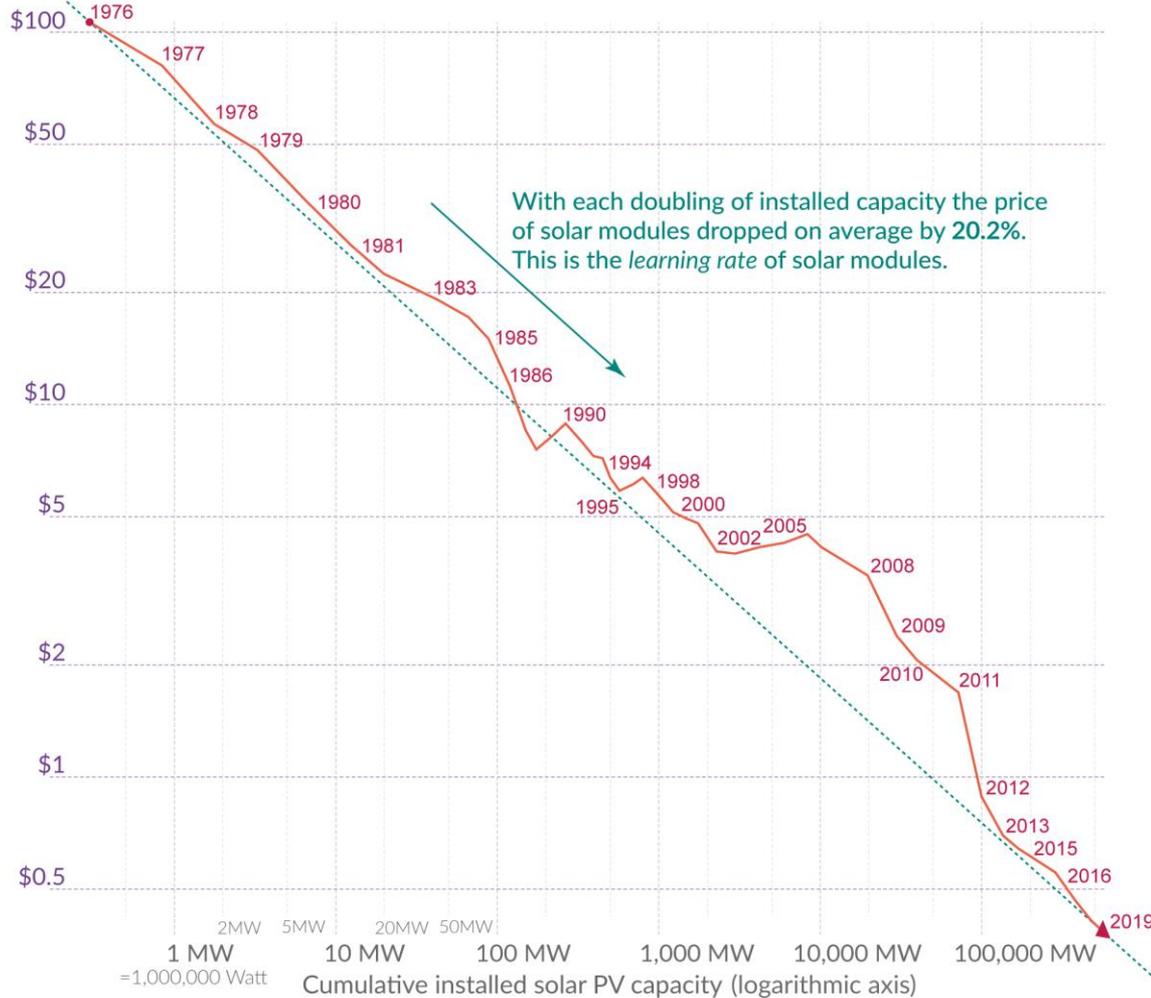
Onshore wind learning curve (1983 - 2014)



The price of solar modules declined by 99.6% since 1976



Price per Watt of solar photovoltaics (PV) modules (logarithmic axis)
 The prices are adjusted for inflation and presented in 2019 US-\$.



Data: Lafond et al. (2017) and IRENA Database; the reported learning rate is an average over several studies reported by de La Tour et al (2013) in Energy. The rate has remained very similar since then.
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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
- ...

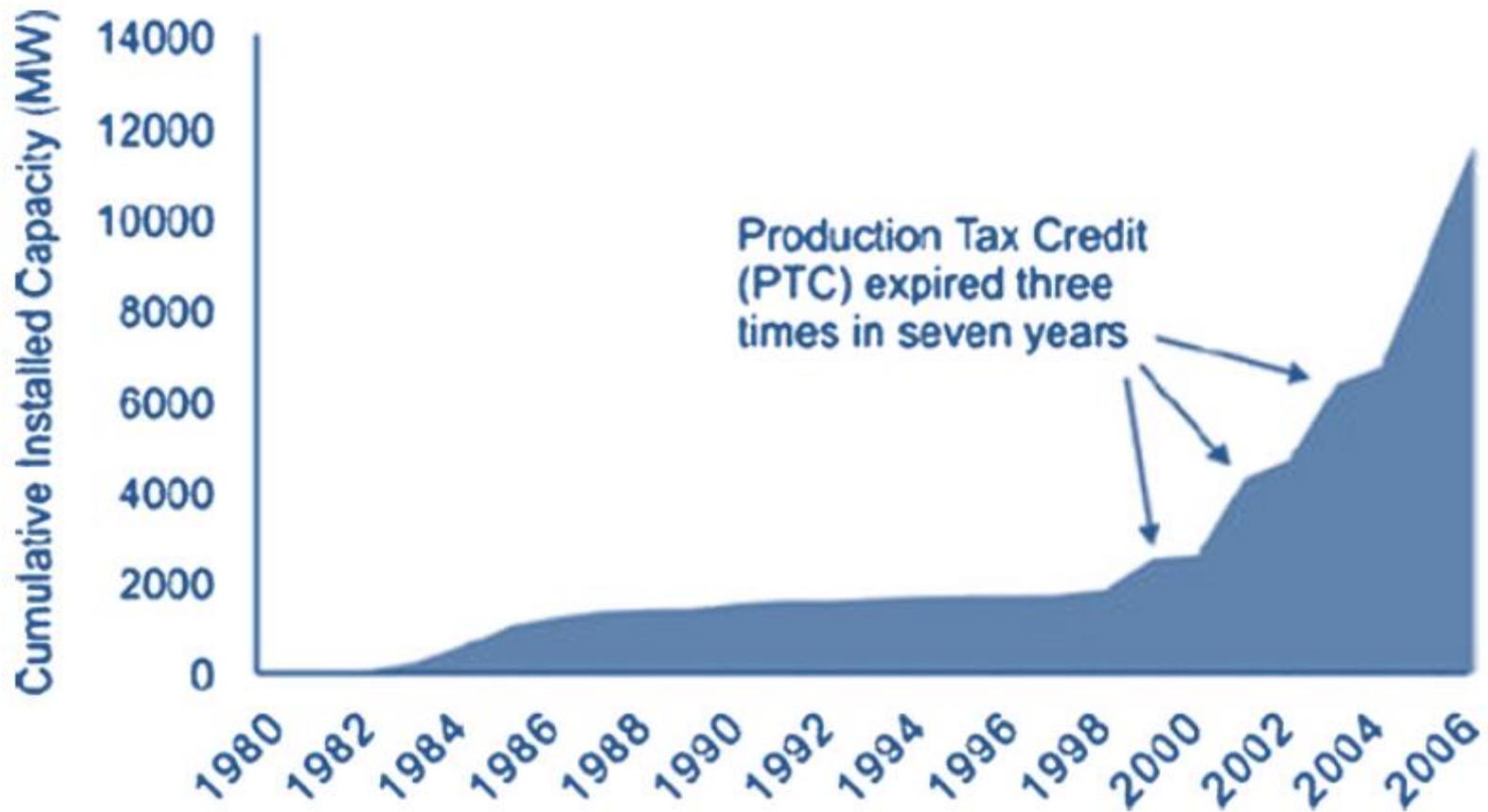
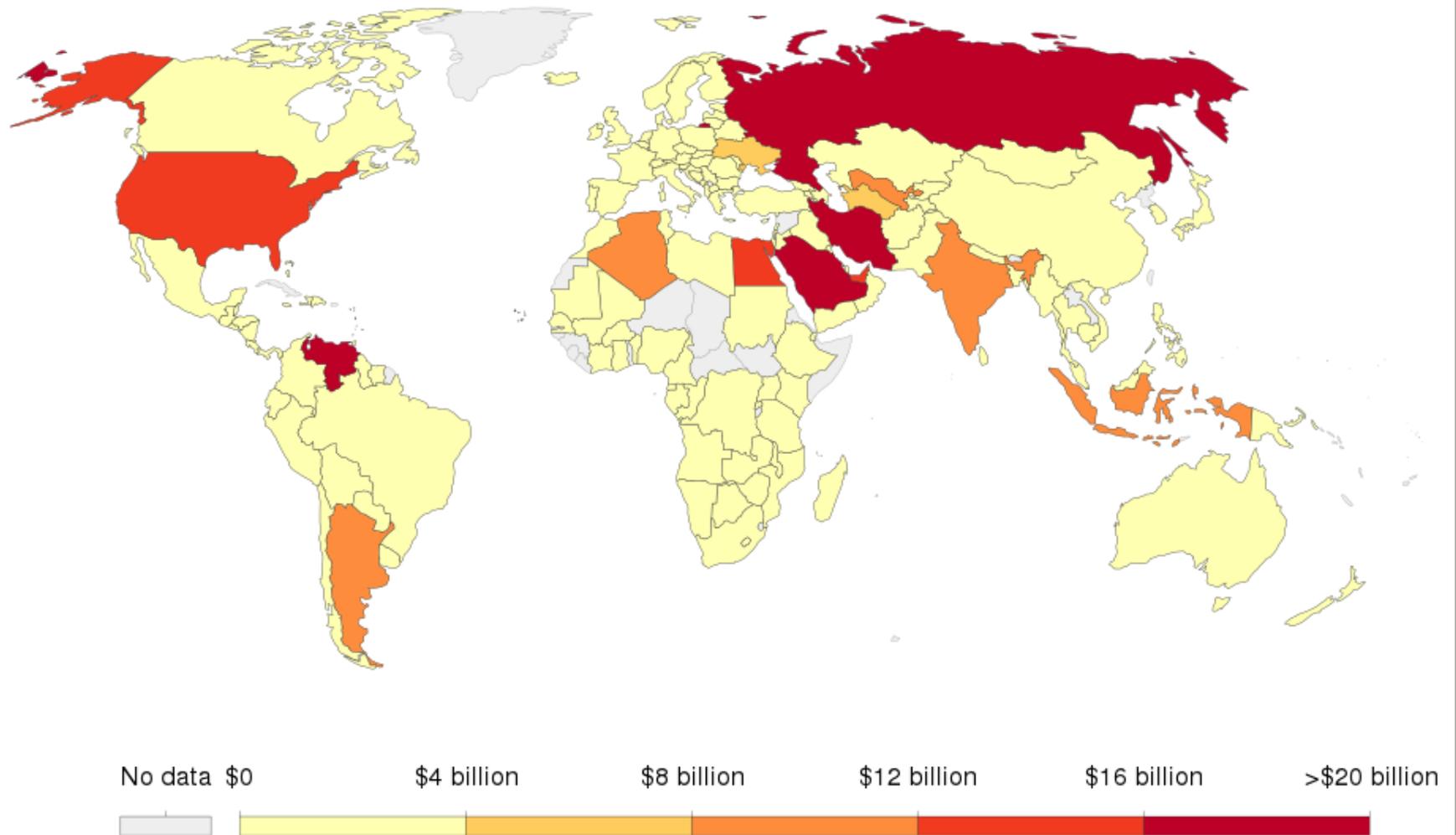


Fig. 1. Cumulative wind energy capacity in the US showing stagnation of industry development at the each expiration of the PTC (taken from EIA, 2008a).

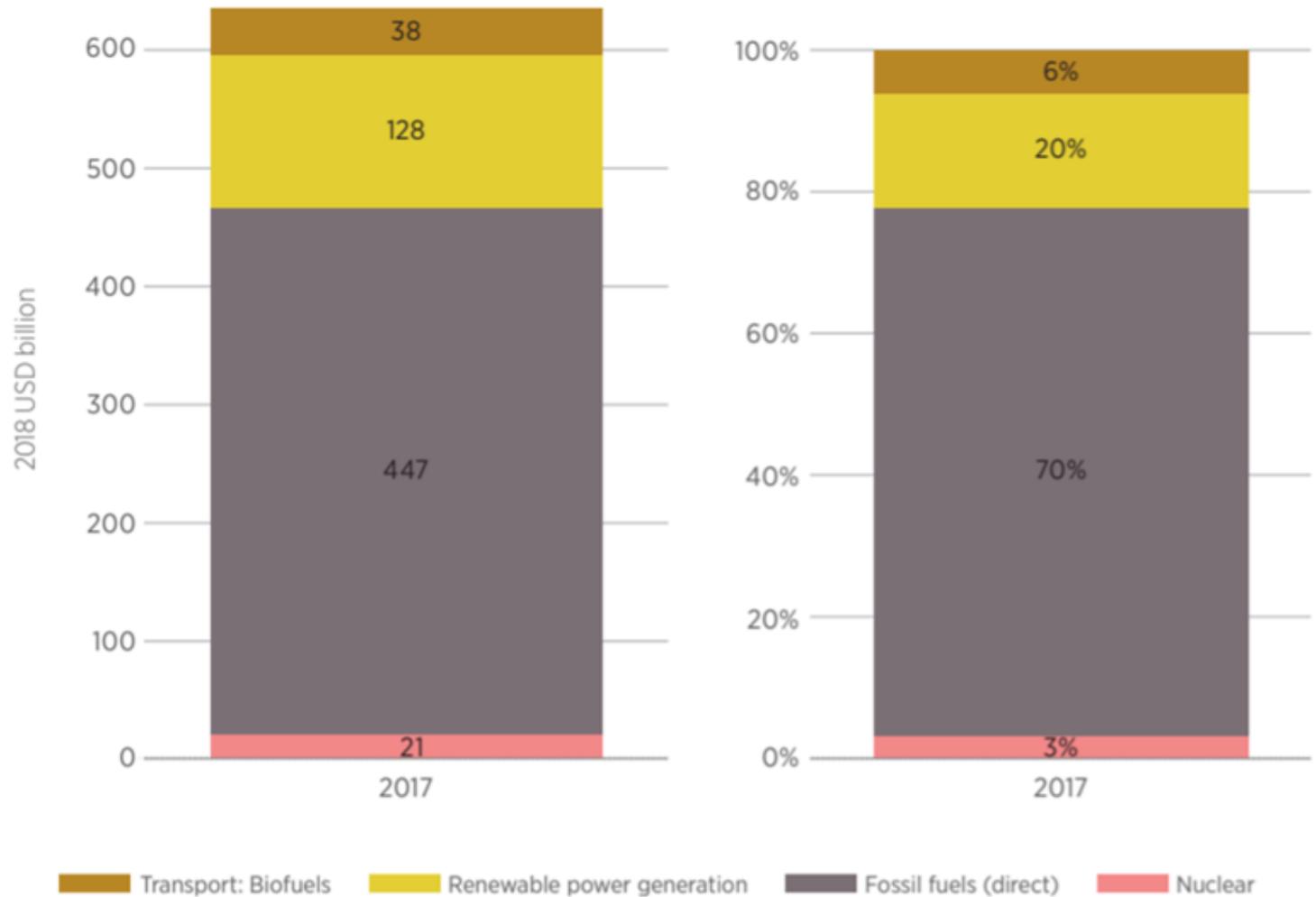
Fossil-fuel subsidies, 2015

Fossil-fuel pre-tax subsidies measured in current US dollars.



Source: UN Statistics Division (2019)

Figure 10: Total energy sector subsidies by fuel/source, 2017



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€/tonCO₂
- 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

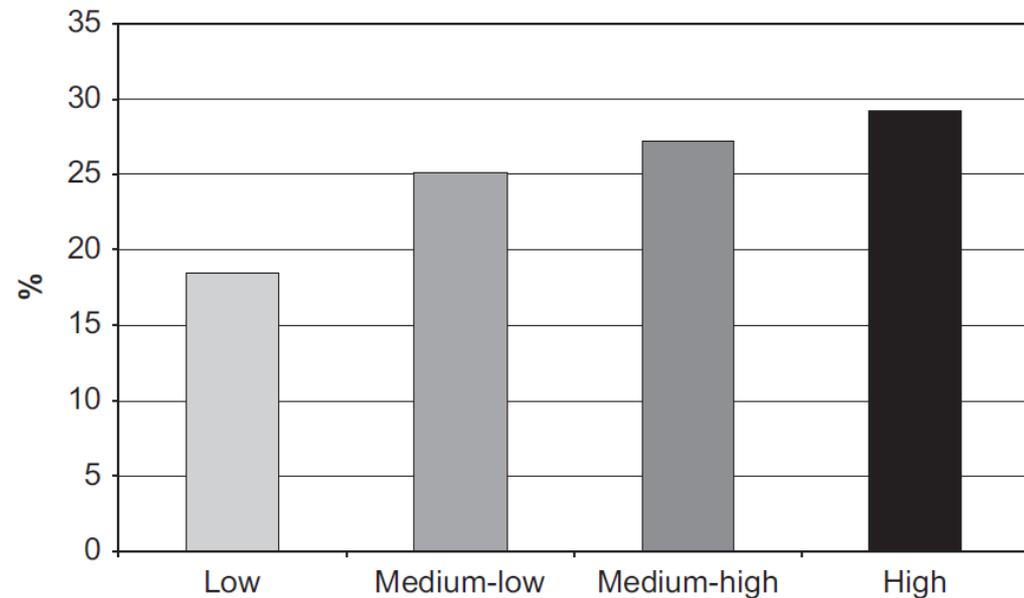


Fig. 9. Proportion of successful PVRP applicants from postal areas with low, medium-low, medium-high and high SES ratings (ABS, 2006a; ADEWHA, 2010).

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