European University Institute

ROBERT SCHUMAN CENTRE FOR ADVANCED STUDIES

Loyola de Palacio Chair

Climate Policy Research Unit

The Implicit Carbon Price of Renewable Energy Incentives

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Contribution

Germany

- Claudio Marcantonini, A. Denny Ellerman (EUI) [*Marcantonini, C. and Ellerman, A. D. (2013), The Implicit Carbon Price of Renewable Energy Incentives in Germany, EUI working paper RSCAS 2014/28, submitted to Energy Journal*]

Italy

- Claudio Marcantonini, Vanessa Valero (EUI) with the collaboration of REF-E (Milan)

Outline

I. The European Climate Policy

EU Climate and Energy Policy for 2020

- The European Union (EU) has ambitious climate and energy policy for 2020 with two binding targets

2020 Climate Target

- *Climate target*: 20% CO2 emissions reduction from 1990 levels
- *Justification*: mitigation of global warming
- *Main instrument*: CO2 carbon market (EU ETS)

2020 Renewable Target

- *Renewable target*: 20% energy consumption from renewable energy (RE) sources
- *Main instruments:* renewable energy incentives (REI) at national level
- *Very effective in deploying RE* especially wind and solar within the electricity sector
- *High cost paid by consumers* through surcharges on electricity bills

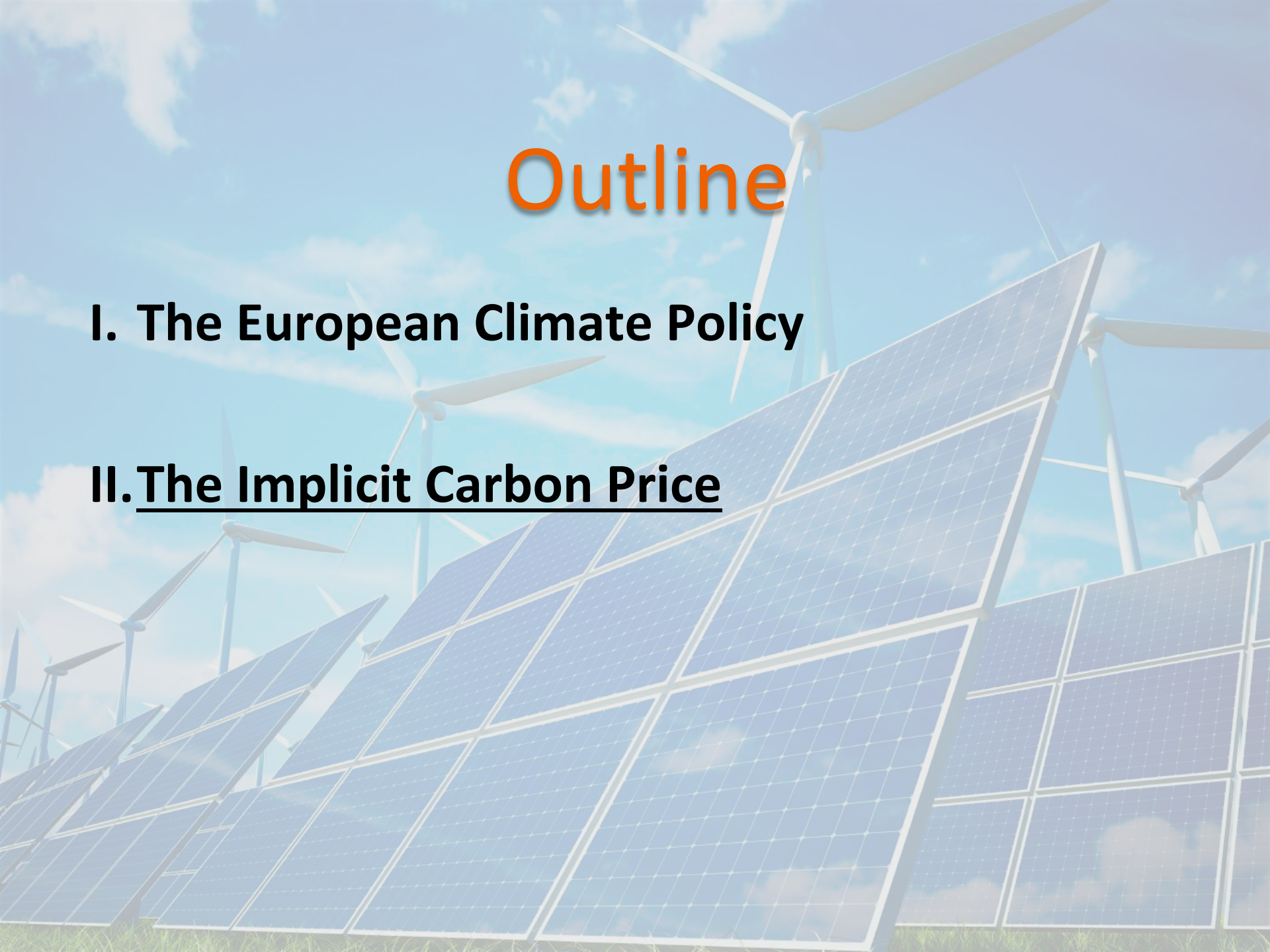
justification?

2020 Renewable Target

- *1st justification*: *"The increased use of energy from renewable sources constitute important parts of the package of measures needed to reduce greenhouse gas" (Directive 2009/28/EC)*

- We look at the renewable energy only from the climate policy point of view

Have REI been efficient climate policy instruments?



Outline

I. The European Climate Policy

II. The Implicit Carbon Price

Implicit Carbon Price

- It is the equivalent carbon price being paid when we think of REI as a climate instrument alone

$$\textit{Implicit carbon price} = \frac{\textit{Net cost of renewables}}{\textit{CO2 emission reduction}}$$

- *Net cost of renewables*: the sum of the costs and savings for consumers resulting from injecting RE into the electric power system
- *CO2 emission reduction*: net change in CO2 emissions between the power system with and without the RE

We analyze…

- What:

Wind

Solar

- Where:

Germany

Italy

- When: years *2006-2012*

CO2 emission reduction

- We use the model developed by Weigt et al.
- The model is a deterministic unit commitment model of the German electricity market for the years 2006-2010
- The model calculates the Total emissions in two scenarios

OBS

No Wind

- *No Wind* differs from *OBS* only on wind energy production

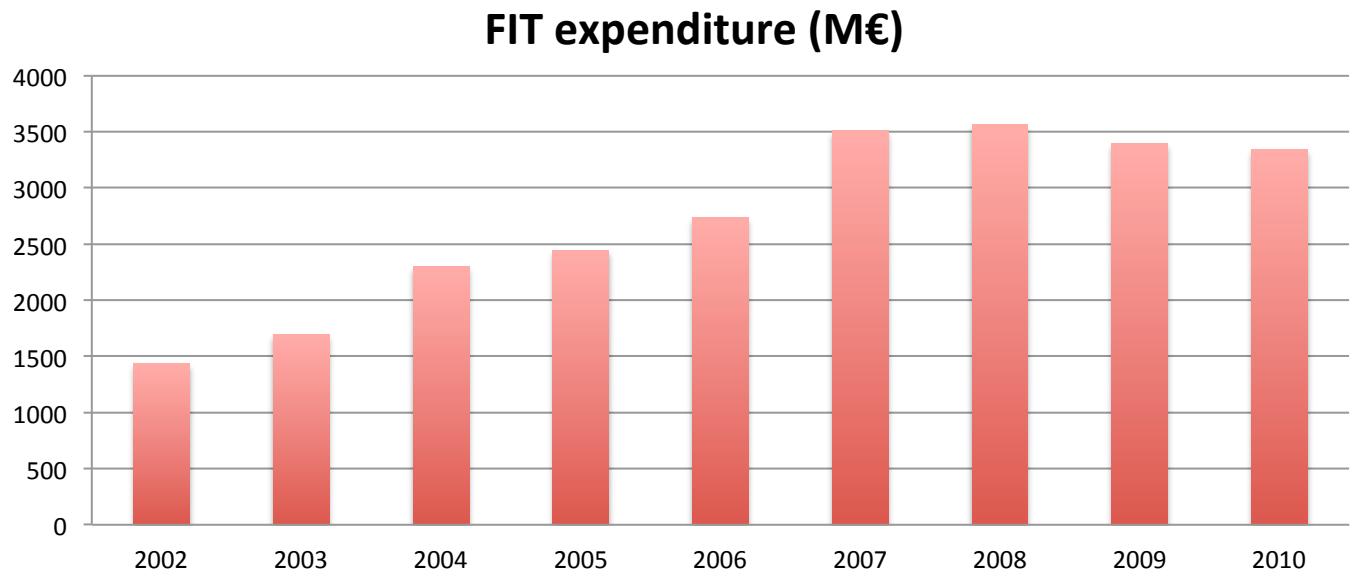
CO2 emission reduction =
Total emissions (*No Wind*) - Total emissions (*OBS*)

Costs of renewable energy

1. Remuneration to generators
   - It depends on the renewable energy incentives
   - No interest in engineering cost of production
   - We equalize the remunerations along the lifetime of the power plants

1. Remuneration

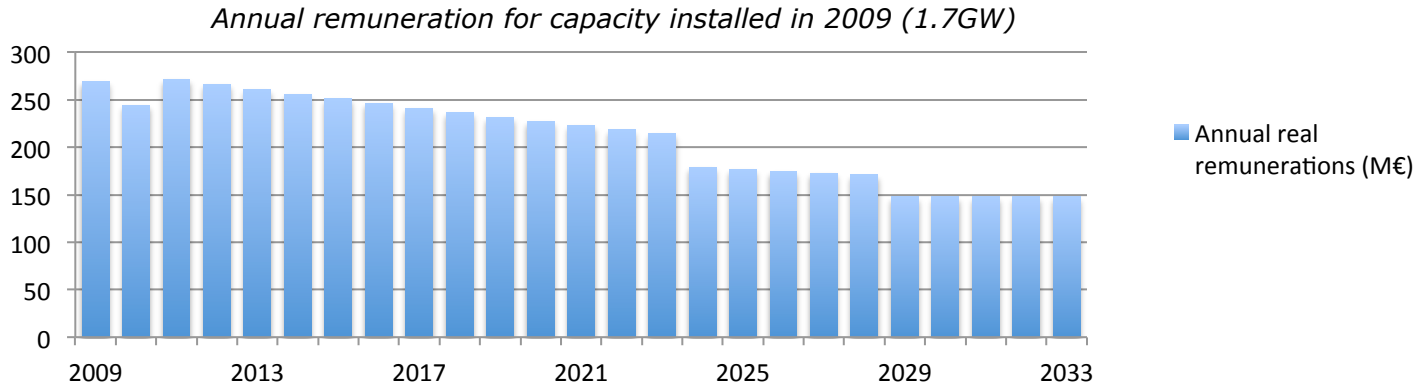
- In Germany, wind energy receives a guaranteed FIT for 20 years



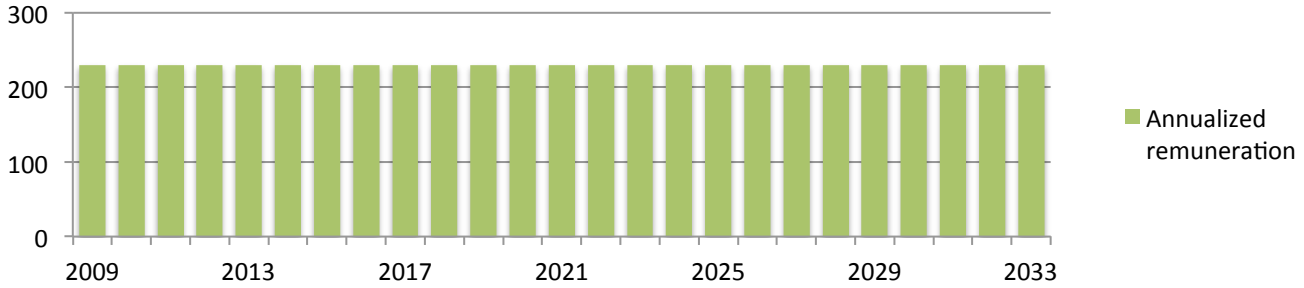
- The FIT are nominal
- The level FIT can be reduced after 5 years

1. Remuneration

1. Determine the real annual remunerations for each vintage of installed capacity for all life-time of the power plants (assumed 25 years)



2. Discount the annual remunerations and redistribute that sum over a 25-year mortgage at 7%



3. The Equalized Remuneration is the sum of the mortgage payments for each capacity in-service

Costs of renewable energy

1. Remuneration to generators
   - It depends on the renewable energy incentives
   - No interest in engineering cost of production
   - We equalized the remunerations along the lifetime of the power plants

2. Additional balancing cost
   - Additional cost for the power system
   - Order of few €/MWh (we consider €2/MWh)

3. Additional cycling cost
   - Additional cost of conventional generations (start-up cost, maintenance cost)
   - Only start-up cost
   - Additional Start-up cost = Start-up cost (*No Wind*) – Start-up cost (*OBS*)

Savings Due to Renewable Energy

1. Fuel cost saving

- A reduction of electricity produced from thermal generation implies a reduction in fuel burnt
- Fuel cost saving = Total Fuel cost (*No Wind*) - Total Fuel cost (*OBS*)

2. Capacity saving

- Economic benefit coming from reducing fossil fuel capacity
- *Capacity credit*: amount of conventional capacity that can be replaced by RE capacity (expressed as a % of the installed RE capacity)
- We assume 7% capacity credit used in year 2015

Outline

I. The Context: the EU Climate and Energy Policy

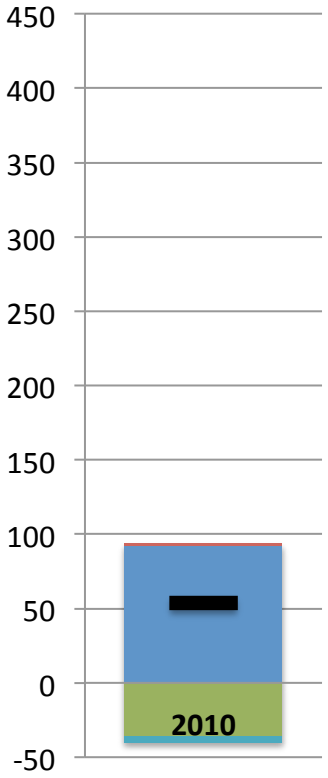
II. The Implicit Carbon Price

III. Results

Germany
Net cost of RE

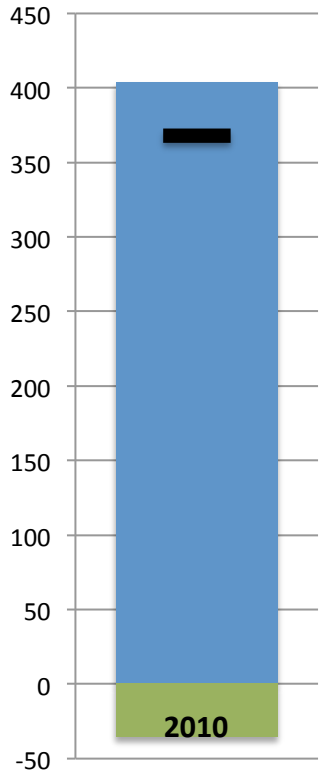
WIND

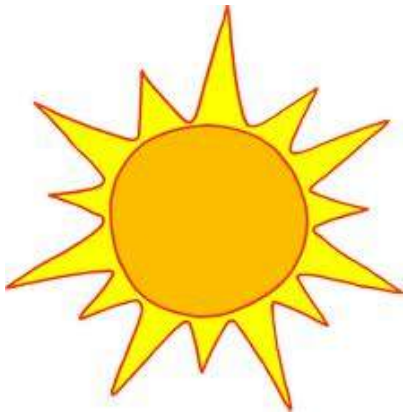
54€/MWh



SOLAR

368€/MWh



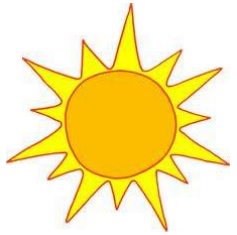


Equalized remuneration | Fuel Cost Saving | Capacity Saving | Additional Balancing Cost | Net cost

Germany
Implicit Carbon Price

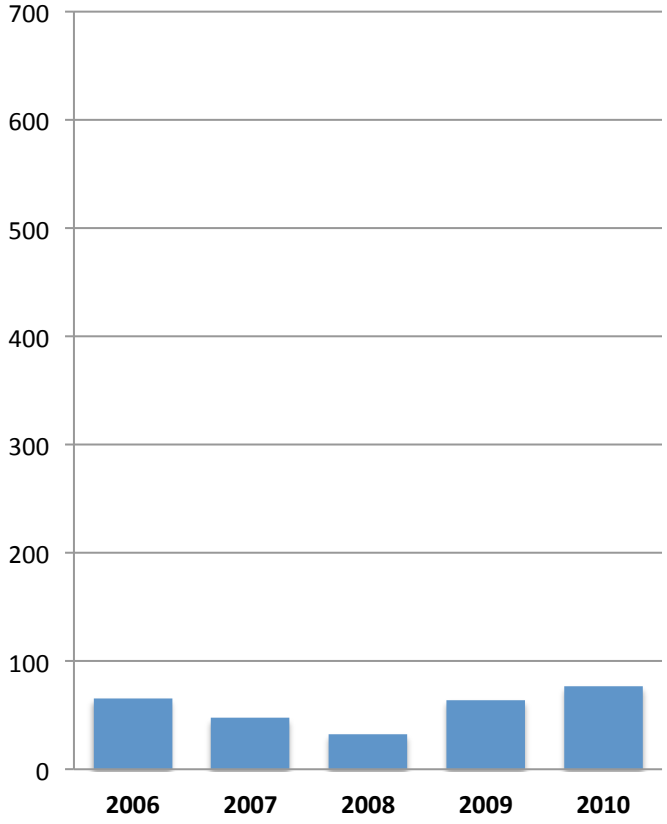
WIND

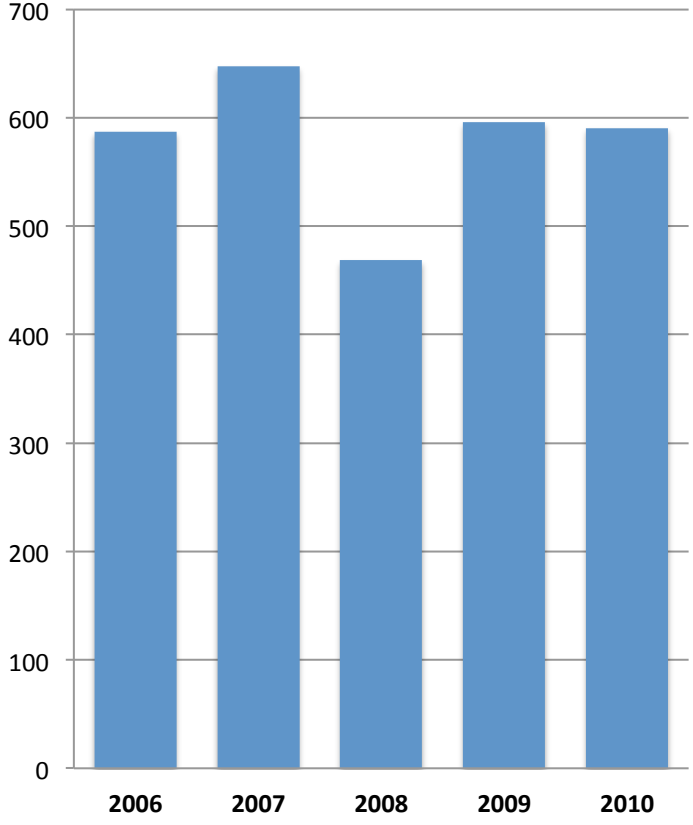
57€/tCO2



SOLAR

552€/tCO2

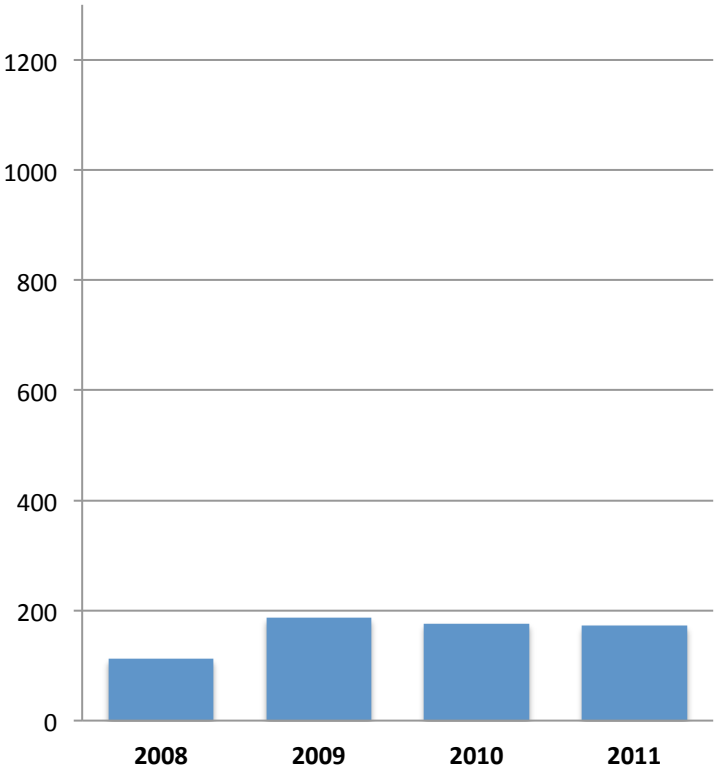




Italy
Implicit carbon price

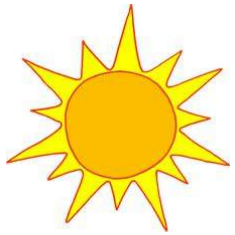
WIND

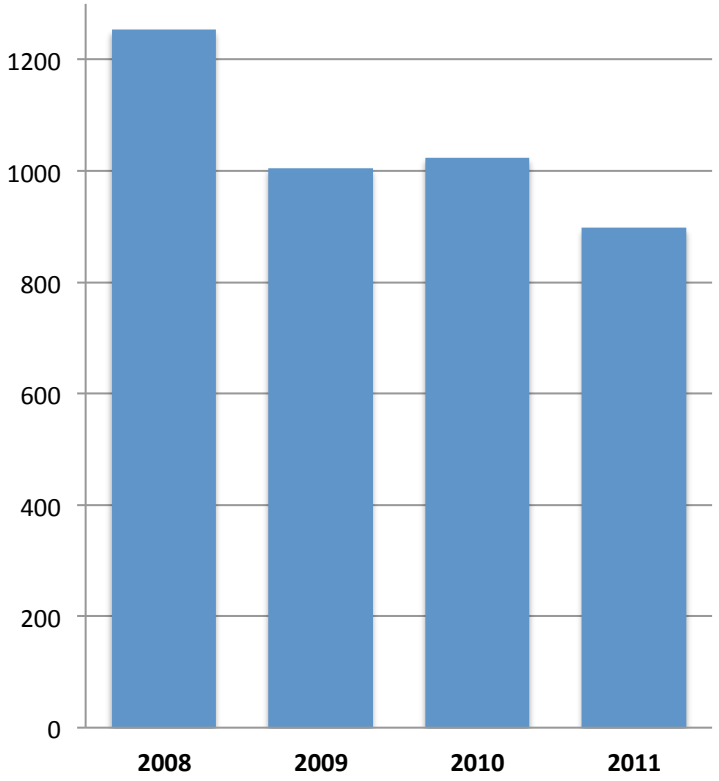
162€/tCO2



SOLAR

956€/tCO2

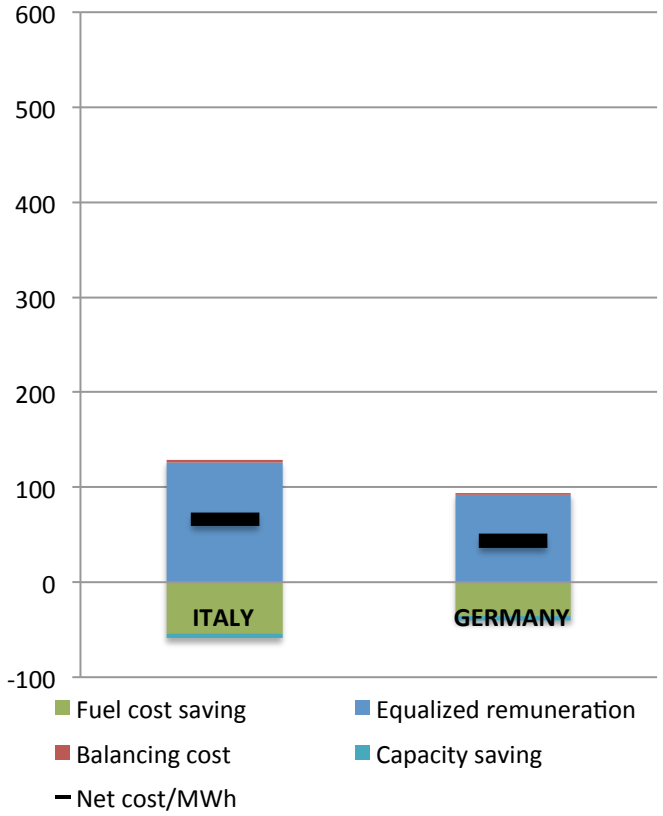


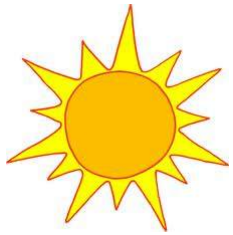


Italy vs. Germany

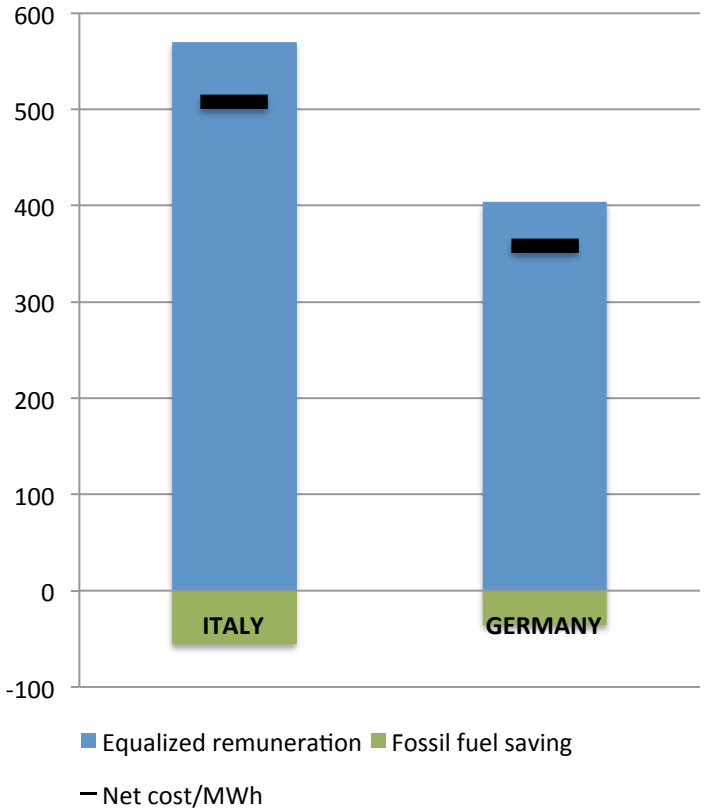
Net cost per MWh in 2010 [€/MWh]

WIND





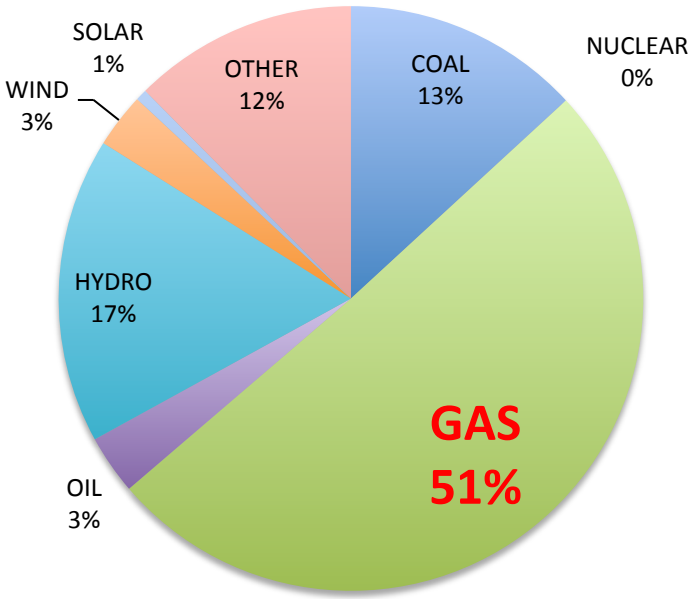
SOLAR



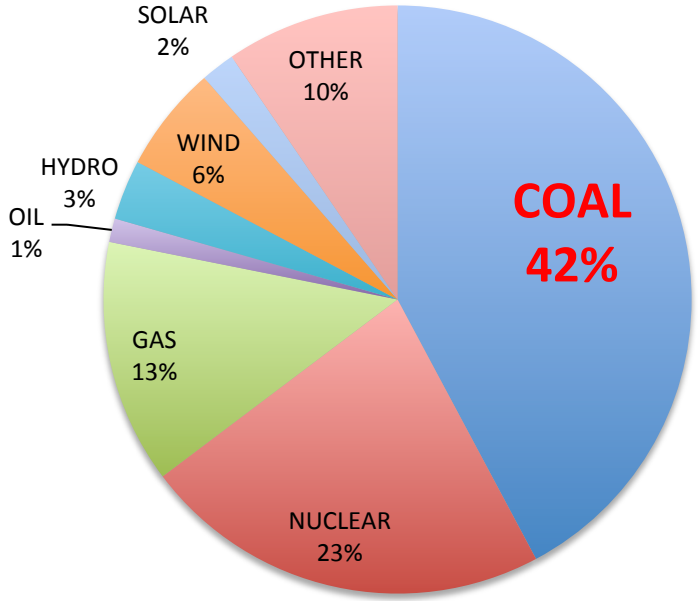
Italy vs. Germany

Electricity Production in 2010

ITALY (302TWh)



GERMANY (624TWh)



1 MWh of wind energy in 2010 displaced 0.4 tCO_2 in Italy and 0.7 tCO_2 in Germany

Conclusions

- Supporting solar energy through RE incentives has been thus far a very expensive way of inducing CO2 emissions reduction
- Supporting wind energy through RE deployment incentives has been less expensive especially for Germany
- Including **Learning Effect**: analysis shows that cost remains of order of tens of €/tCO2 for wind and hundreds €/tCO2 for solar
- Non-climate goals for RE policy non included: security of energy supply, technological development, opportunities for employment and regional development

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Thanks for your attention

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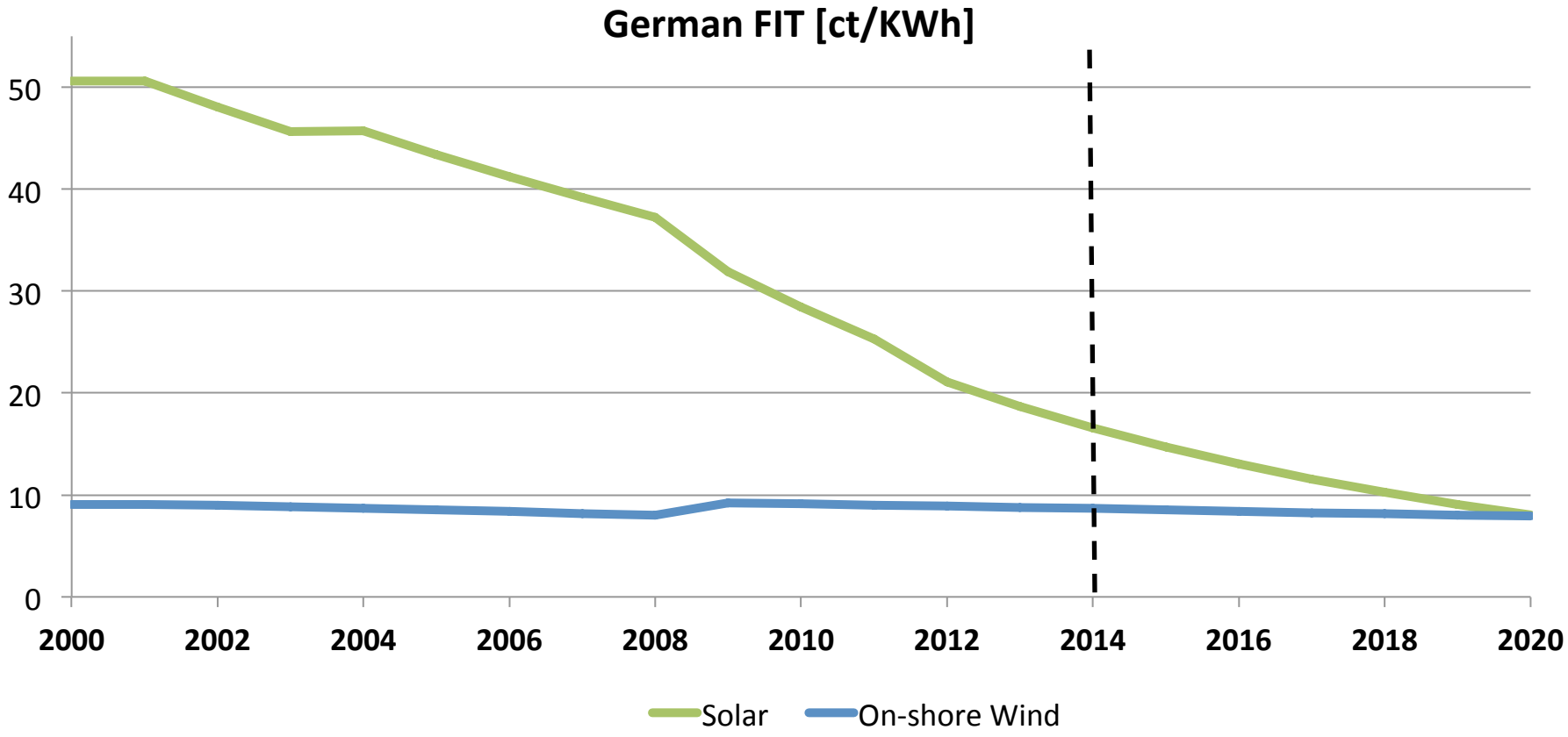
Backup slides

Learning Effect

Learning Effect

- Future costs of wind and solar power plant will be less because of learning-by-doing from today's subsidized deployment

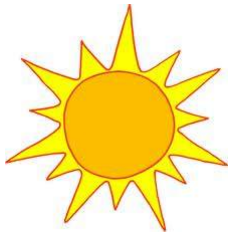
- In these recent years the level of FIT has been reduced



Learning Effect

- Cost reductions in future years can be credited to current and past deployments
- We estimated the revenue of all capacity up to 2020 and redistributed equally per MWh
- Estimation based on the scenario of government or on optimistic assumptions

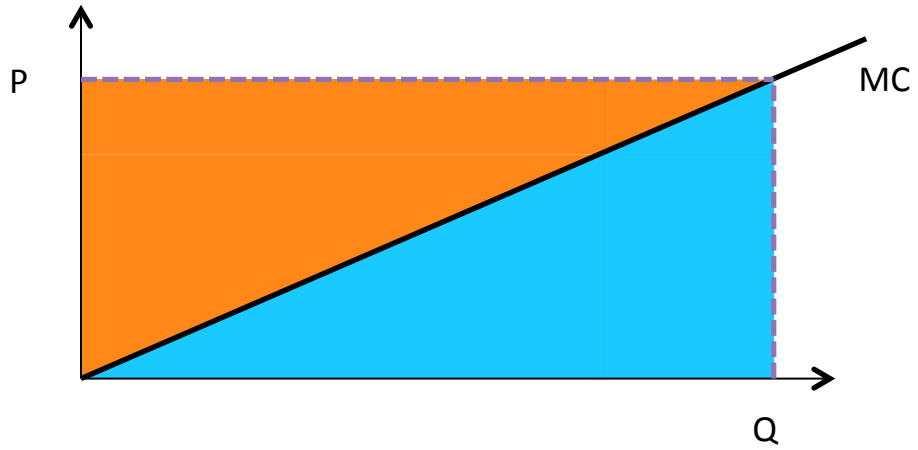
WIND **57**€/tCO2 → **48**€/tCO2



SOLAR **552**€/tCO2 → **306**€/tCO2

Merit order effect

Electricity price *with* renewable injection



P = price w/ RES

P_{NoRES} = price w/o RES

Q = fossil fuel generation w/ RES

Q_{NoRES} = fossil fuel generation w/o RES

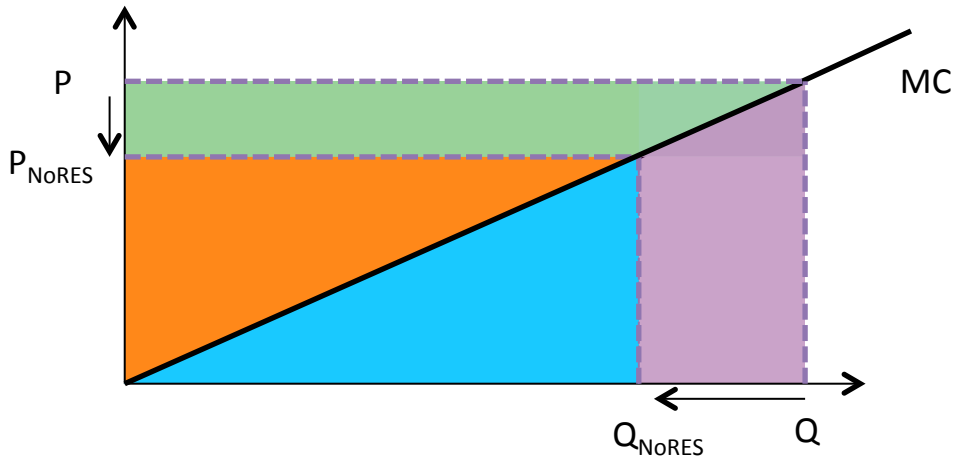
MC = marginal cost of fossil fuel generation

Fossil fuel generation cost

- *Fossil fuel cost*
- *Capital cost*

Merit order effect

Electricity price *without* renewable injection



P = price w/ RES

P_{NoRES} = price w/o RES

Q = fossil fuel generation w/ RES

Q_{NoRES} = fossil fuel generation w/o RES

MC = marginal cost of fossil fuel generation

Fossil fuel generation cost

- *Fuel cost*
- *Capital cost*

Consumer savings

- *Fuel cost saving*
- *Capital cost saving*

Outline

I. The European Climate Policy

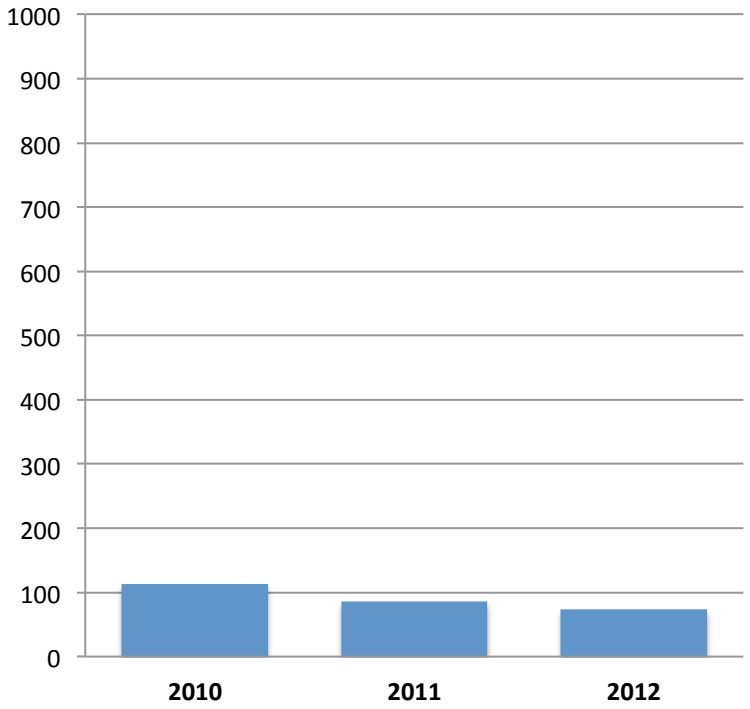
II. The Implicit Carbon Price

III. Results

Spain
Implicit carbon price

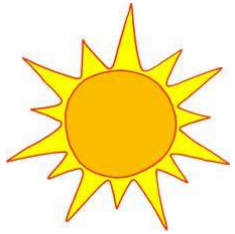
WIND

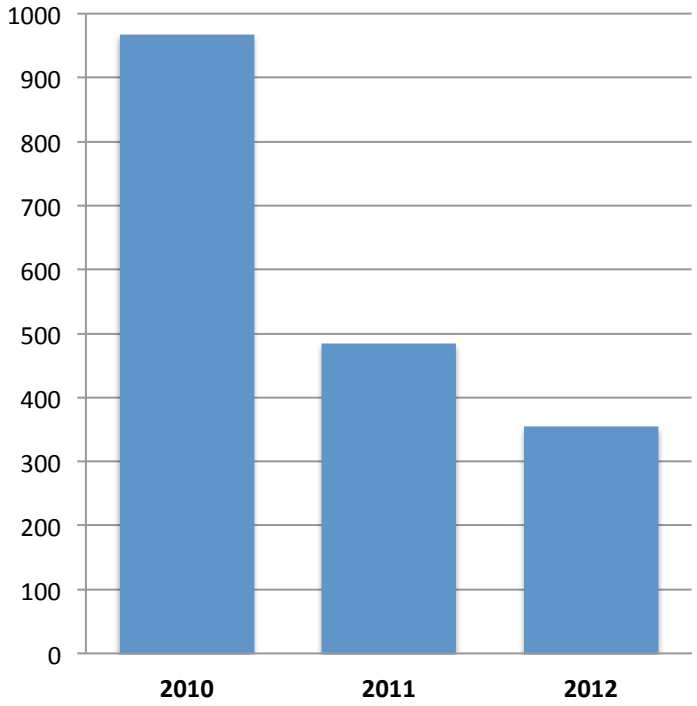
86€/tCO2



SOLAR

539€/tCO2





Source: Julian Barquin Gil, Endesa

Total: 600 TWh; 2010 154 GW
Year: Tecn., Capacity, Penetration
2010: Solar 17GW, 2%;
2010:Wind, 27GW. 7-8%
2011: Wind: 29GW, 6%
2012: Solar: 30GW, 4.6%
2020: Solar 53GW, 7%: 3.5GW and 11% (3.5GW-11%FIT red., 24¢/kWh); Wind 51GW, 13% penetration, (2.5GW, 1.5% FIT red, 8¢/kWh)

Total: 300 TWh, 2010 106 GW
2011: Solar: 12GW, 3.5%; Wind: 7GW, 3.2%
2012 Solar: 16GW, 6%,
2020: Solar: 28GW, 11% (1.8 GW, no FIT from 2013), Wind: 14GW, 7% (: 0.8 GW, 2% FIT reduction annually)

Total: 150 TWh; 2010 101 GW
2010: Gas 24%; Coal 8%
2011: Wind 21GW, 15% (20% capacity)
2012: Solar: 4.5GW, 3%; Wind: 18%; Gas:14%; Coal: 23%

RE in Europe

	Primary production (1 000 toe)		Share of total, 2010 (%)				
	2000	2010	Solar energy	Biomass & waste	Geothermal energy	Hydropower energy	Wind energy
EU-27	96,650	166,647	2.2	67.6	3.5	18.9	7.7

%Share of renewable energy in gross final energy consumption

	2004	2005	2006	2007	2008	2009	2010	2011	
EU (28 countries)	8.1	8.5	9.0	9.7	10.4	11.6	12.5	13.0	
EU (27 countries)	8.1	8.5	9.0	9.7	10.4	11.6	12.5		13