Oslo Centre of Research on Environmentally friendly Energy

Phasing out nuclear power in Europe

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Effects of phasing out nuclear power in Europe

- Mixed picture after Fukushima 2011
  - Phasing out nuclear vs. on hold vs. plans to increase nuclear capacity
  - EU 2030 nuclear capacity about 20 percent below EU 2009 capacity
- Effects of a nuclear phase out by 2030 assuming
  - Profitability is the guiding investment principle
  - Long-run perspective: no bottlenecks
  - Competitive markets
  - EU 2030 energy and climate policy is implemented

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Nuclear policy in EU member states

COUNTRY	PLANNED CAPACITY CHANGES	TOTAL NET CAPACITY INCREASE IN GW (2009-30)*
Belgium	866 MWe phase-out by 2015 5077 MWe phase-out by 2025	-5.62
Bulgaria	Plans to extend current reactors	2.03
Czech Republic	1200 MWe in 2026 1200 MWe in 2028	-1.37
Finland	1720 MWe in 2016 2800 MWe by 2024	4.31
France	1750 MWE in 2016	1.75
Germany	8336 MWe shut down in 2011 12003 MWe phase-out by 2022	-19.38
Hungary	1200 MWe in 2023 1200 MWe in after 2025	1.80
Italy	Nuclear power rejected by referendum in 2011	0
Lithuania	1350 MWe in 2022	0.17
Netherlands	Previous decision on phase-out reversed in 2006	0
Poland	3000 MWe in 2024 3000 MWe in 2035	3.00
Romania	720 MWe in 2019 720 MWe in 2020	1.44
Slovakia	940 MWe in by 2015 1500 MWe in by 2025	0
Slovenia	Considering capacity expansion	0
Spain	Political uncertainty	-7.04
Sweden	Plans to uprate/replace old units	-1.73
Switzerland	1102 MWe by 2022 (net) 2150 MWe by 2034 (net)	-1.10
United Kingdom	16000 MWe by 2030	-1.43

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The impact of lower nuclear capacity

- Short-run effect of less nuclear capacity
  - Higher electricity price; investment incentives
- More RES capacity in the long run
  - Maybe very low prices in some periods; undermine investment incentives?
- Numerical model
  - Quantify net effects; how much RES, how much gas power?
  - Investment, production, prices; the entire energy industry

Nuclear phase out: main research questions

- The impact on production of electricity
- The impact on the electricity technology mix

Numerical model

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LIBEMOD

- Static equilibrium model for energy markets in Europe and global markets
- Application of standard economic theory
- Long run (2030), competitive, deterministic

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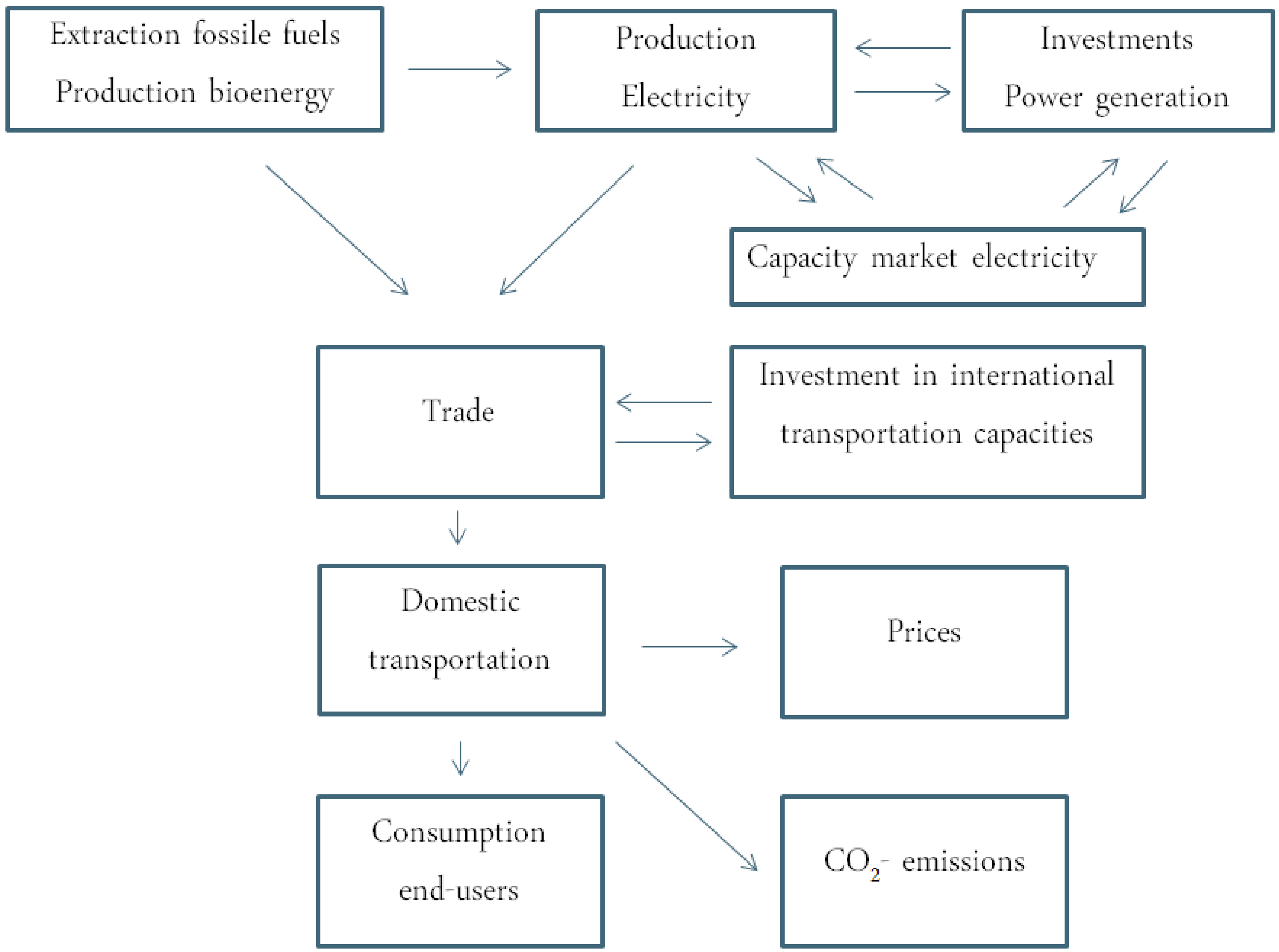
LIBEMOD – basic structure

- Energy goods
  - Coal (3), gas, oil, bio (2), electricity
- Electricity technologies: coal (CCS), gas (CCS), oil, bio, nuclear, hydro, wind, solar
- Agents
  - Producers of energy
  - End users of energy
  - Traders
  - Governments
- Countries – model countries (EU-30) vs. ex. countries/regions
- Markets: World, European
- Determination of ”all” prices and quantites (investment, production, trade and consumption) in European and global energy markets. Emissions of CO2 by country and sector

LIBEMOD – modeling of electricity supply

- Producer maximizes profits subject to technology constraints
- Can sell electricity or maintained power capacity to system operator
- Costs
  - Fuel, operational, start-up, maintenance, investment, grid connection
- Efficiency of thermal power plants
  - Calibrated efficiency distributions for pre-existing plants (country, technology)
  - Assume efficiency for new plants (fuel based technologies)
- Technology constraints
  - Some are common; constraint on annual production of electricity (downtime)
  - Some are technology specific; reservoir hydro

LIBEMOD



Extraction fossile fuels
Production bioenergy
Production
Electricity
Investments
Power generation
Capacity market electricity
Trade
Investment in international
transportation capacities
Domestic
transportation
Prices
Consumption
end-users
CO_2- emissions

Cost of electricity

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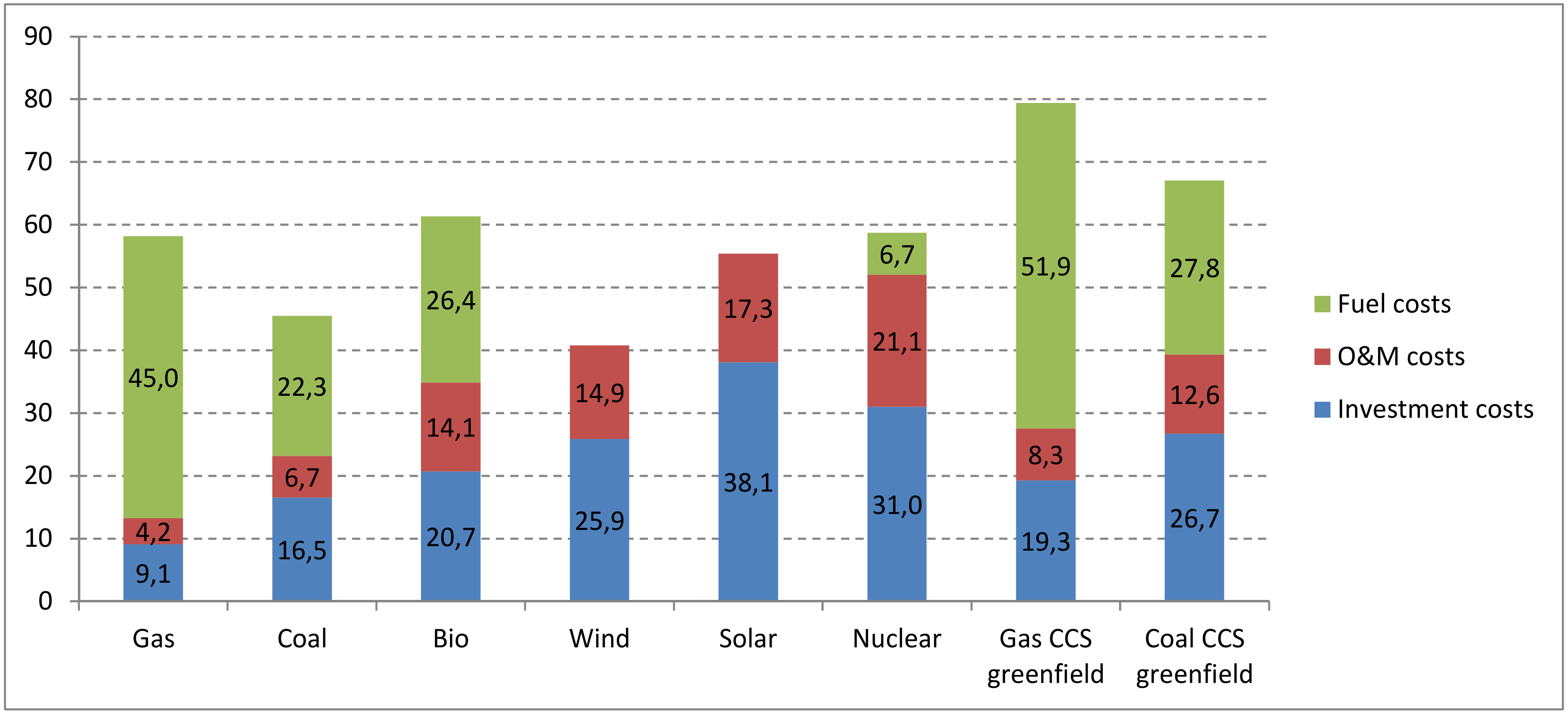
Hypothetical costs of new electricity in 2030 with 2009 input prices (€2009/MWh)



Fuel prices: Gas. coal and biomass prices in EU-30 in 2009. uranium prices from OECD (2011) .
Load hours: 70% for coal. gas. nuclear. CCS and bio. Wind and solar based on good locations in Europe (3500 and 2500 hours)

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Scenarios - 2030

EU 2030 energy and climate policy

- 40 percent GHG emissions reduction relative to 1990
  - GHG emissions in ETS 43 percent lower than in 2005
  - GHG emissions in non-ETS 30 percent lower than in 2005
- Transformed these targets to LIBEMOD
  - LIBEMOD has only emissions of CO_2
- Carbon instruments
  - One ETS CO_2 tax, and one non-ETS CO_2 tax
- Target for renewable energy in final energy demand
  - 27 percent
- Renewable instruments
  - EU-wide renewable subsidy to reach renewable target

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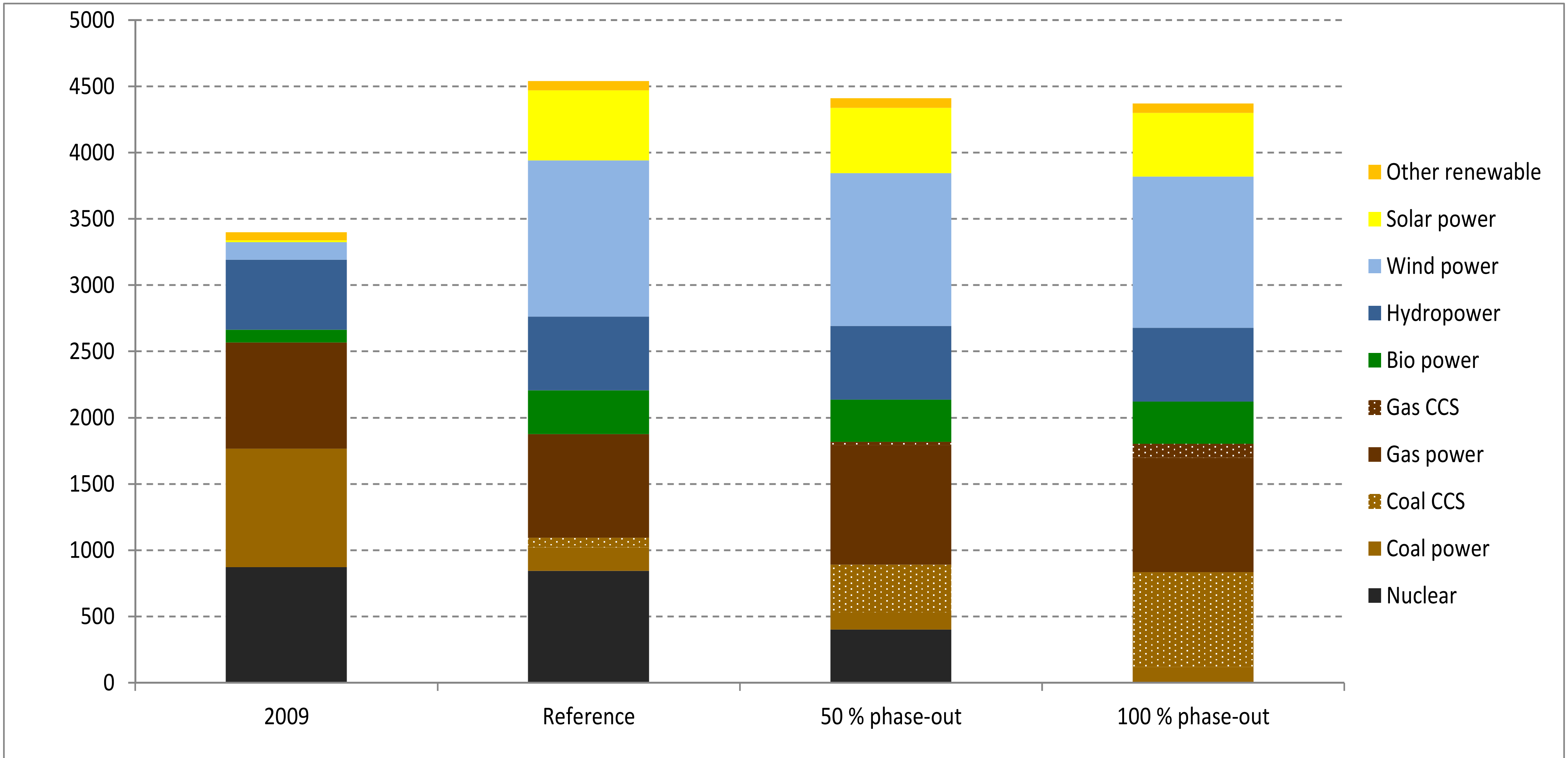
Results for EU-30 in 2030

- Reference: Current plans for nuclear capacity
- 50 % phase out
- 100 % phase out

Power generation in EU-30 in 2030 (TWh)
100 % phase-out: 4 % lower production than in reference



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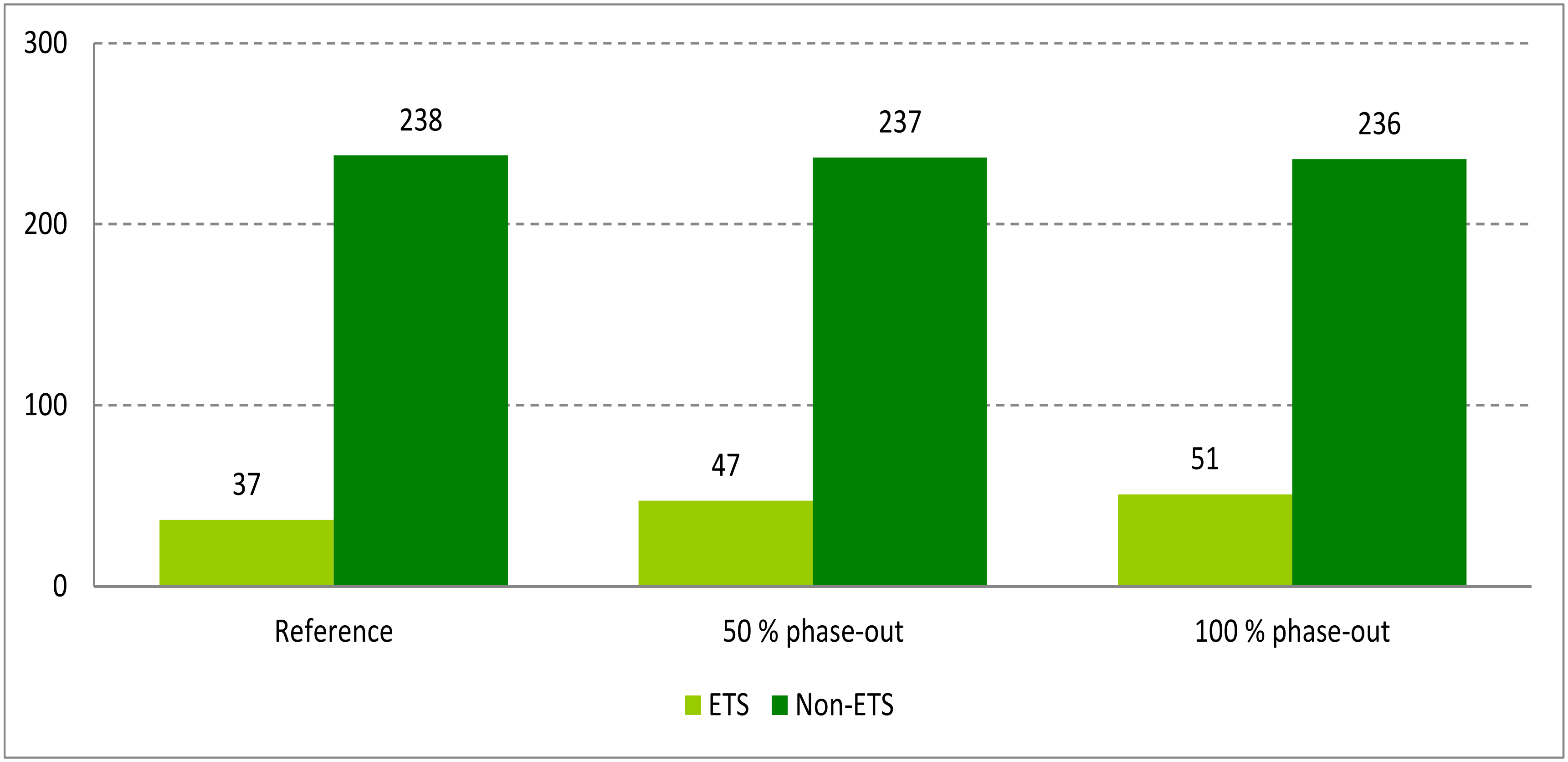
CO_2 price in EU-30 in 2030 (€/tCO_2)



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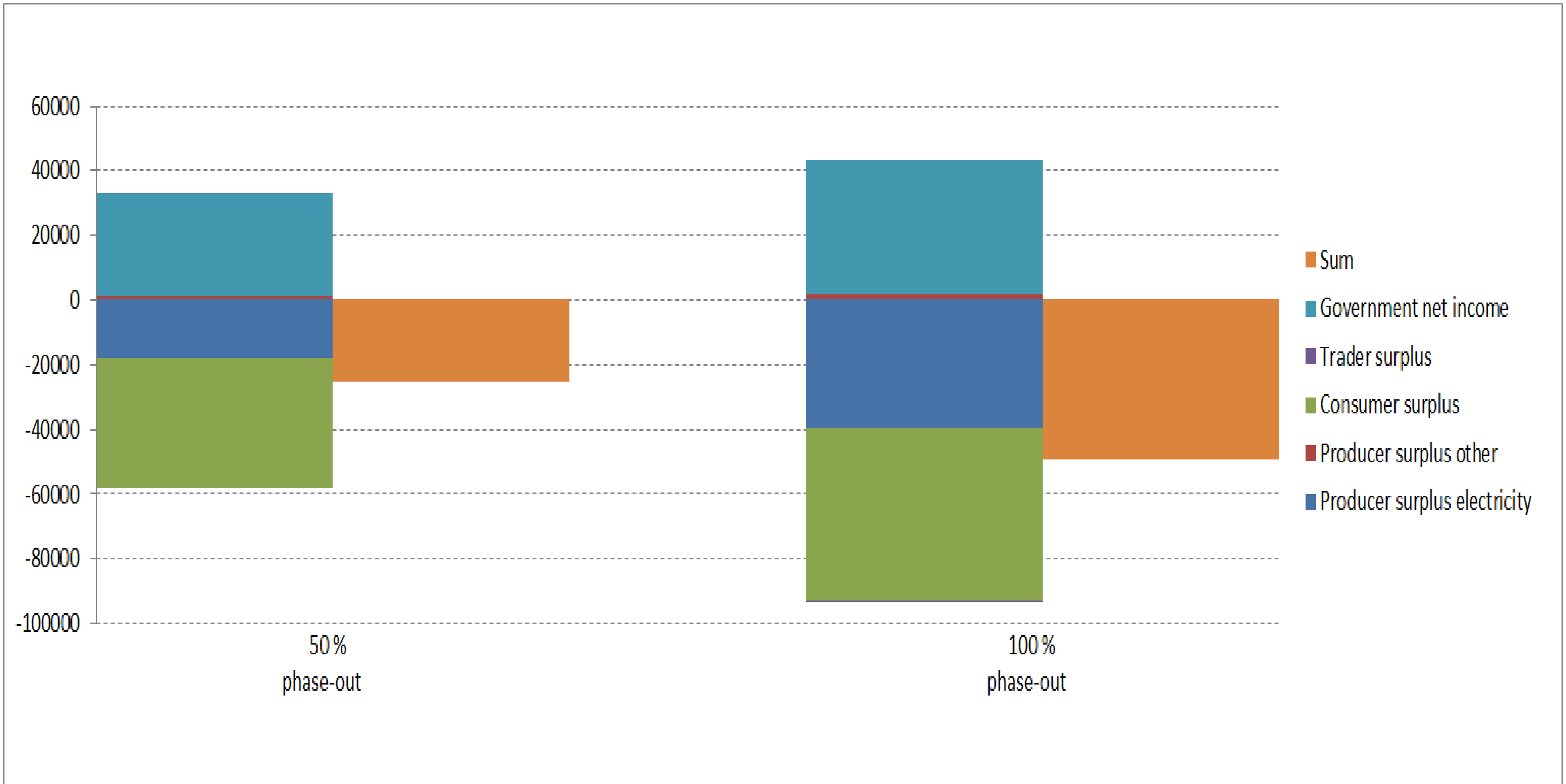
Welfare by scenario relative to reference scenario (Million €2009). EU-30
Annual reduction in 100 % phase-out: 0.4 percent of EU-30 GDP



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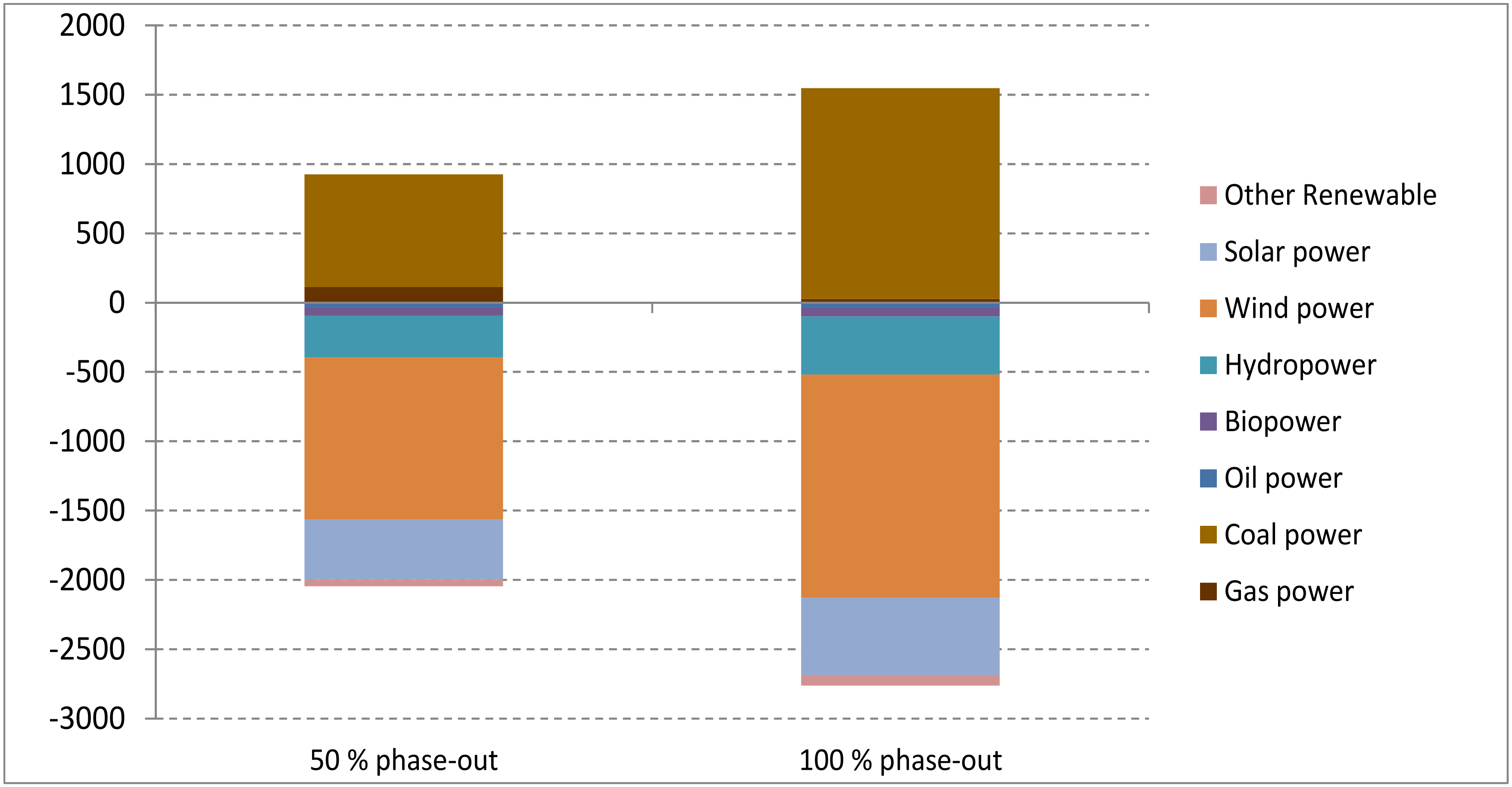
Electricity producer surplus by technology (except for nuclear power) relative to reference scenario (Million €2009). EU-30



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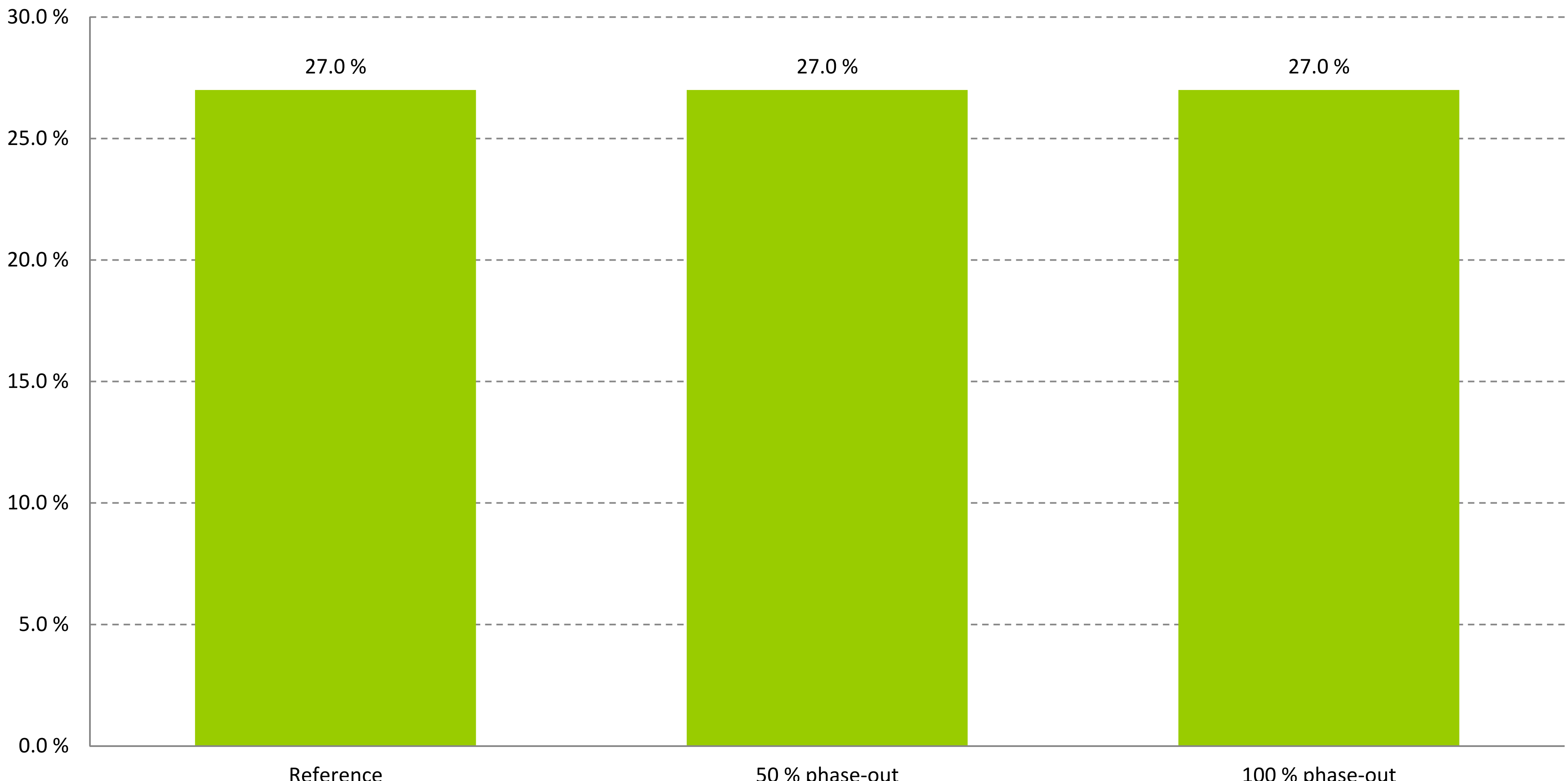
Renewable share in EU 30 in 2030

European Commission proposal: 27 %



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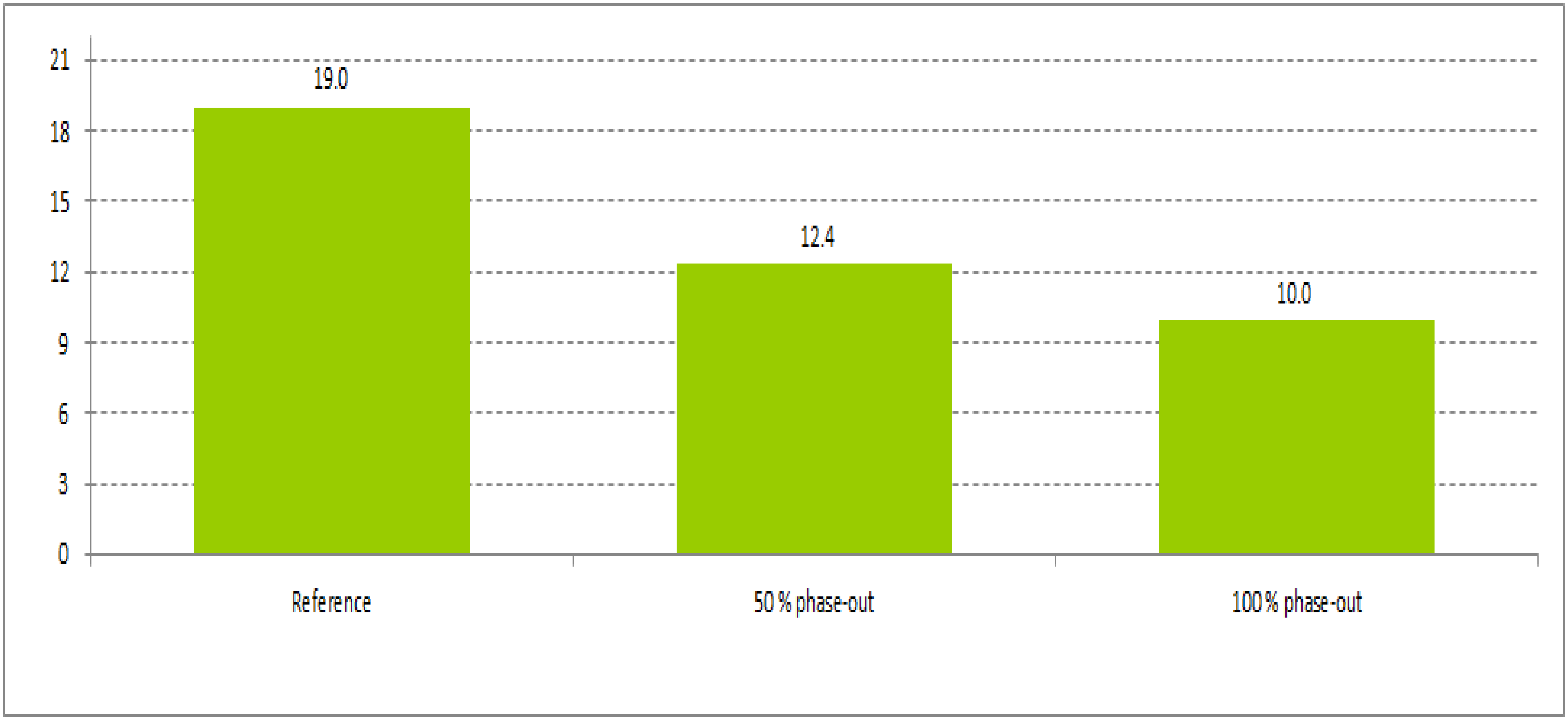
Common Renewable feed in tariff in EU-30 in 2030. (€2009/MWh)



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Wind data

Country	Best *(load hours)*	Potential* 2030 (TWh)	Country	Best *(load hours)*	Potential* 2030 (TWh)
AT	2000	26.7	IE	3400	131.5
BE	2800	43.7	IS	3700	81.1
BG	2500	27.9	IT	2000	58.1
CH	1700**	0.4	LT	3000	74.4
CY	1500**	3.9	LU	2000	3
CZ	2093	51.9	LV	3000	85.3
DE	2500	367.3	MT	2000	0.7
DK	3200	75.2	NL	2800	55.3
EE	2500	67.2	NO	3700	162.1
ES	2500	170.0	PL	3000	364.4
FI	3100	441.1	PT	3000	46.8
FR	2500	452.4	RO	2000	47
GB	3400	440.9	SE	3100	456
GR	3000	44.3	SI	2000	1.9
HU	2000	21.4	SK	2000	13.9

*Sources: Eerens and Visser (2008). EEA (2009). Hoefnagels et al. (2011a)and Storm Weather Centre. *In the model only 10 % of the potential from Hoefnagels et al. (2011a) has been used. Potential if price of electricity is 70 €/MWh. **According to our data sources these numbers should be somewhat lower than 2000 hours. In the LIBEMOD runs we still use 2000 hours to obtain a positive wind power production in the calibration equilibrium.*

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Solar data

Country	Best site *kWh/m2/yr*	Worst site *kWh/m2/yr*	Country	Best site *kWh/m2/yr*	Worst site *kWh/m2/yr*
AT	1386	1245	IE	1220	1089
BE	1143	1134	IS	1182	776
BG	1612	1509	IT	1989	1490
CH	1421	1366	LT	1300	1137
CY	2142	2044	LU	1207	1204
CZ	1216	1153	LV	1313	1165
DE	1272	1079	MT	2095	2078
DK	1287	1090	NL	1289	1090
EE	1248	1165	NO	1191	813
ES	2114	1601	PL	1181	1131
FI	1142	956	PT	1983	1965
FR	1817	1175	RO	1504	1358
GB	1291	1109	SE	1217	999
GR	2065	1516	SI	1568	1386
HU	1420	1254	SK	1285	1169

Source: All data from the NASA Surface meteorology and solar energy database

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National subsidies to new power generation (2009€/MWh)

	Wind power	Solar power	Biopower	Reservoir hydro power	Run-of-river power
Austria	20	20	20	4	4
Belgium	20	20	20	20	20
Bulgaria	20	20	20	20	20
Switzerland	0	20	0	20	20
Cyprus	20	20	20	0	0
Czech Republic	20	20	20	20	20
Germany	20	20	20	20	20
Denmark	20	0	20	0	0
Estonia	15	15	15	15	15
Spain	20	20	20	20	20
Finland	20	0	18	0	0
France	20	20	20	15	15
United Kingdom	20	20	20	20	20
Greece	7	20	20	6	6

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National subsidies to new power generation (2009€/MWh), continued

	Wind power	Solar power	Biopower	Reservoir hydro power	Run-of-river power
Hungary	20	20	20	16	16
Ireland	11	0	20	20	20
Italy	20	20	20	20	20
Lithuania	20	20	20	20	20
Luxembourg	20	20	20	20	20
The Netherlands	20	20	20	20	20
Norway	20	0	0	20	20
Poland	20	20	20	20	20
Portugal	20	0	20	20	20
Romania	20	20	20	20	20
Sweden	20	20	20	20	20
Slovenia	0	20	0	20	20
Slovakia	20	20	20	20	20