Renewable energy
Market and perspectives

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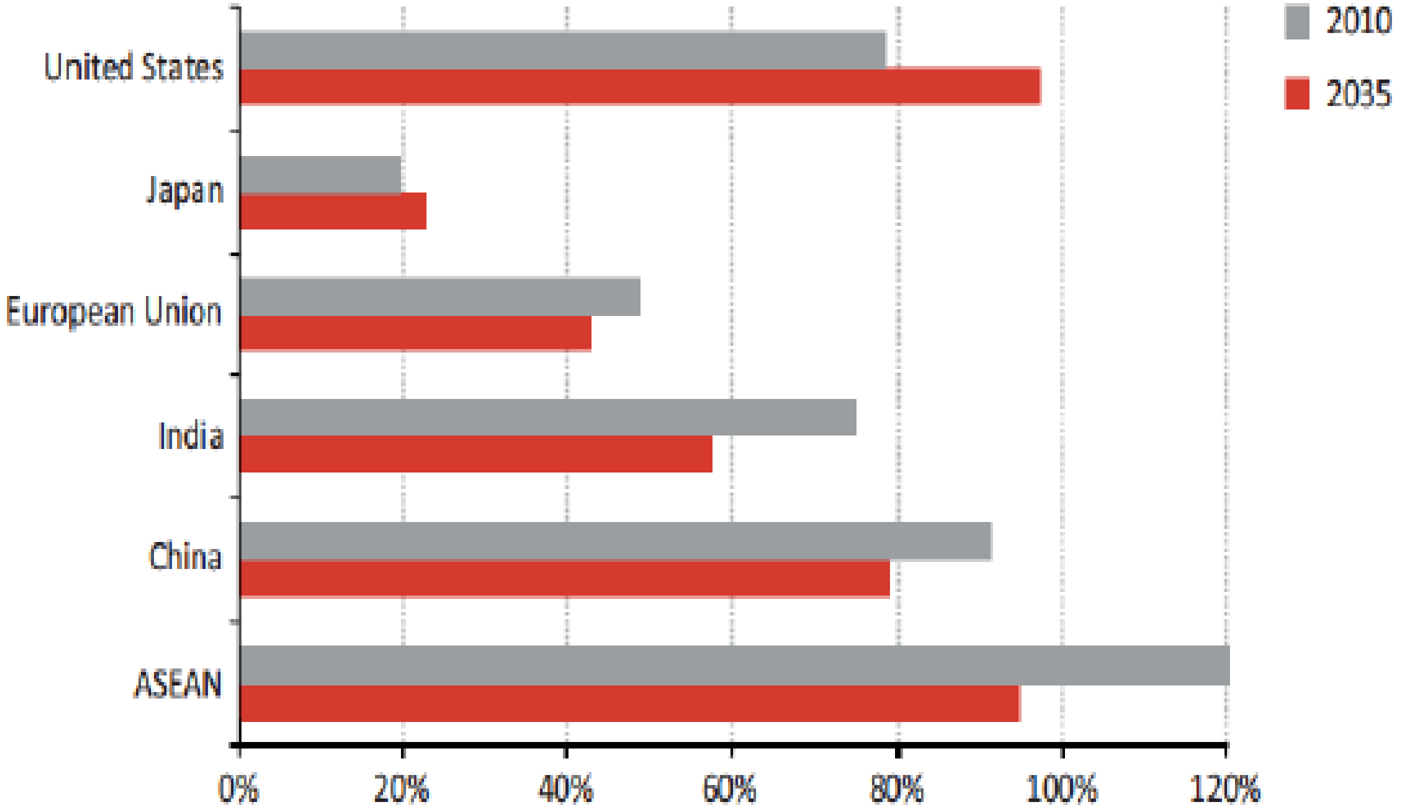
Paris, 17/11/15

The context

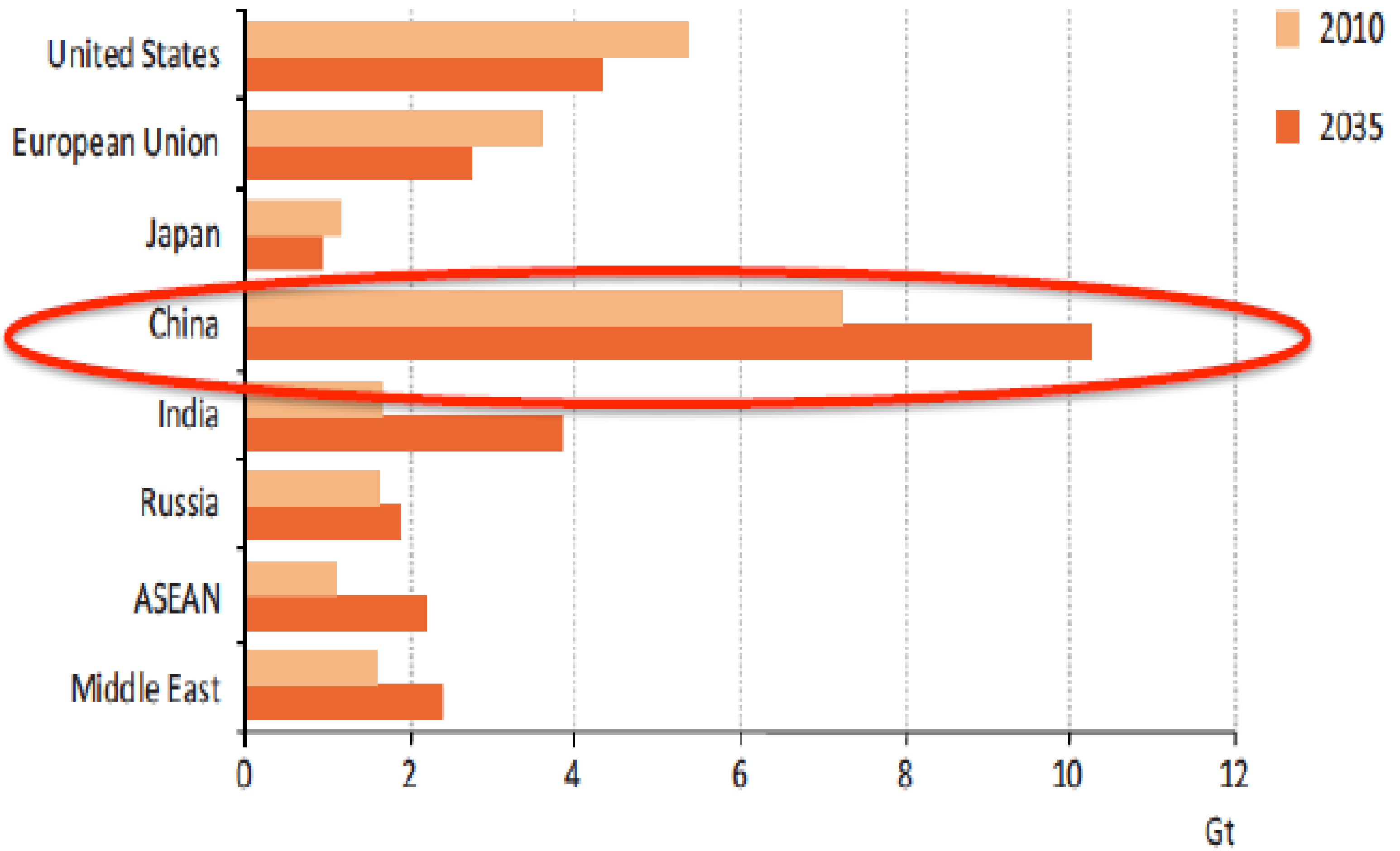
- Increase of energy import dependency
- Instability of fossil fuel prices, scarcity of fossil fuels
- Climate change
- Security aspects

Energy dependency

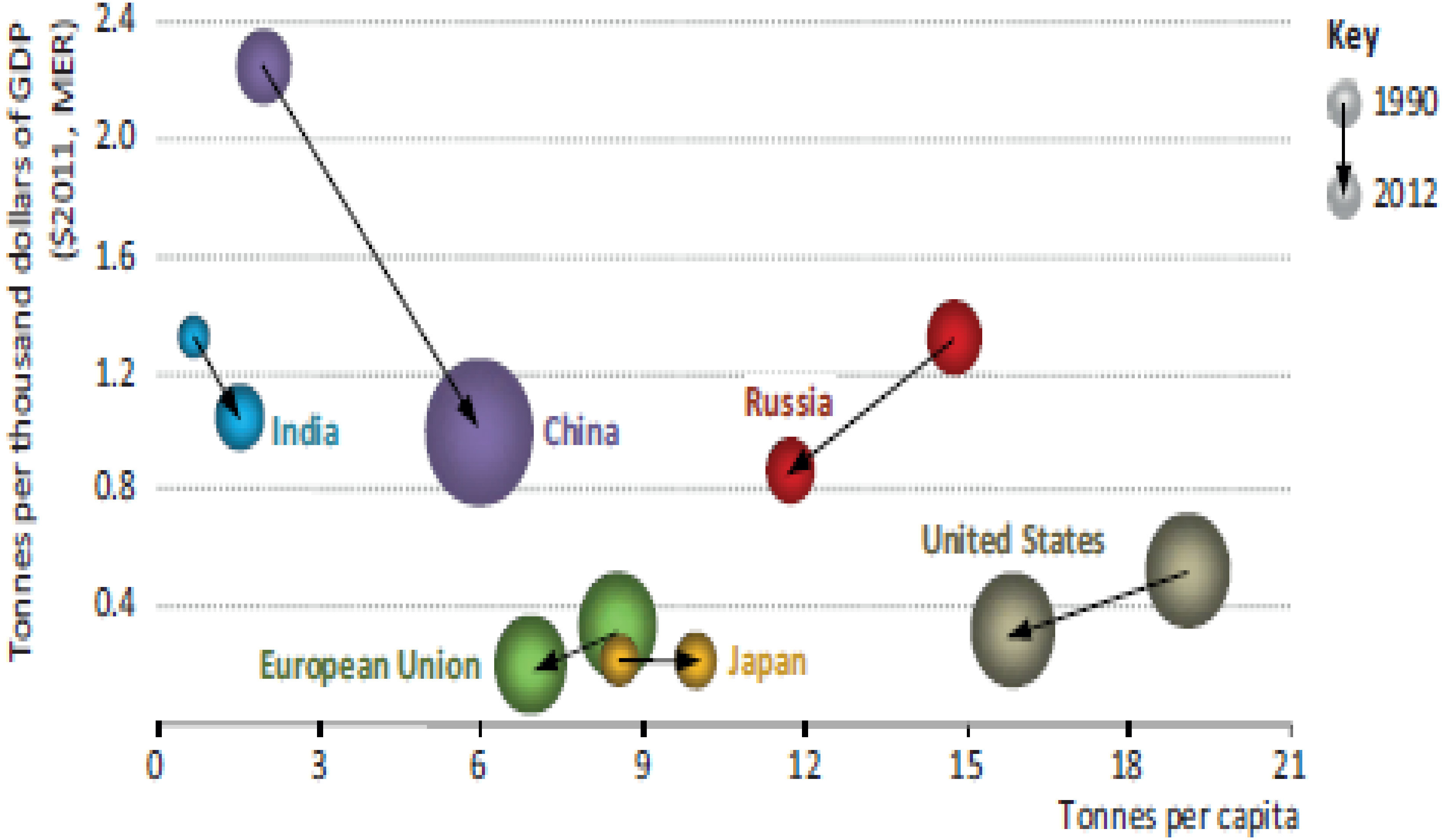


Note: Self-sufficiency is calculated as indigenous energy production (including nuclear power) divided by total primary energy demand.

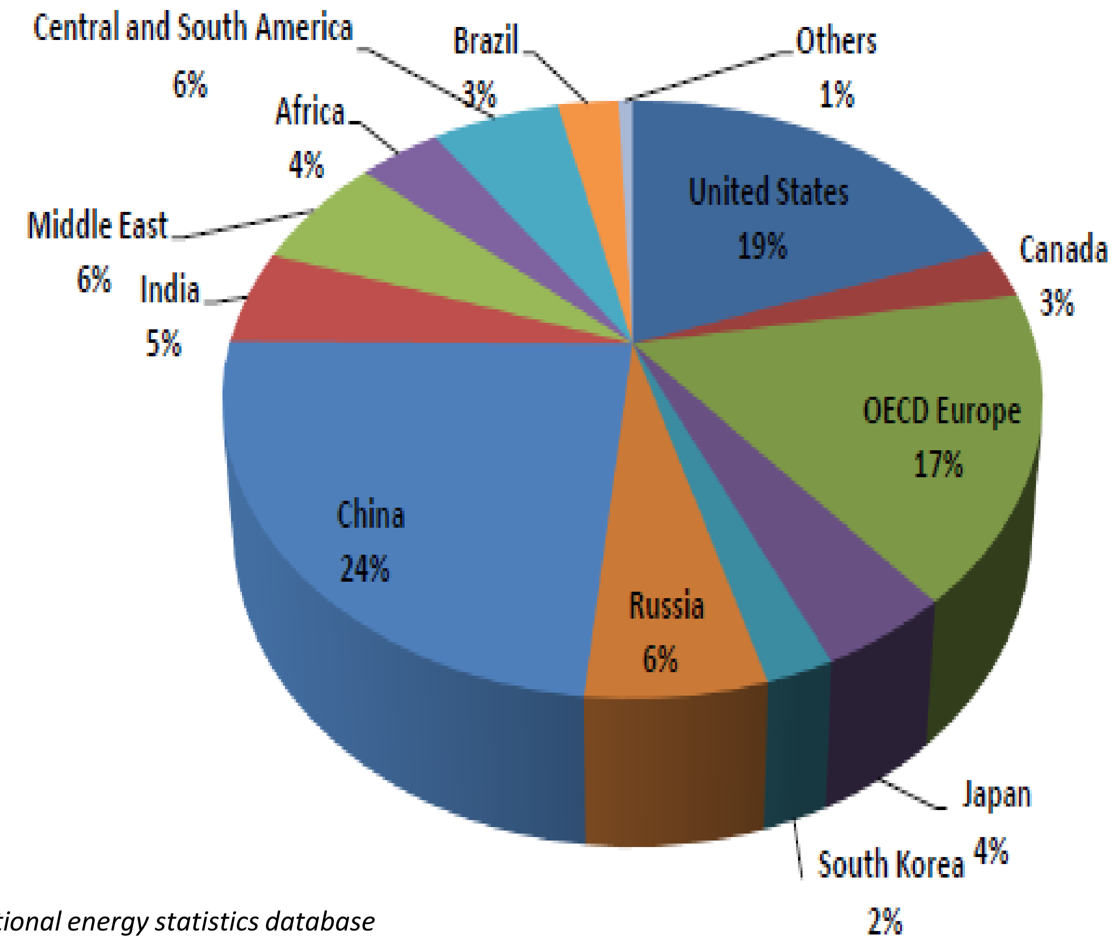
Energy related CO2 emissions in selected countries



Energy related CO2 emissions and CO2 intensity per capita in selected countries



World total primary energy consumption by region – 2012



13 620 Mtoe

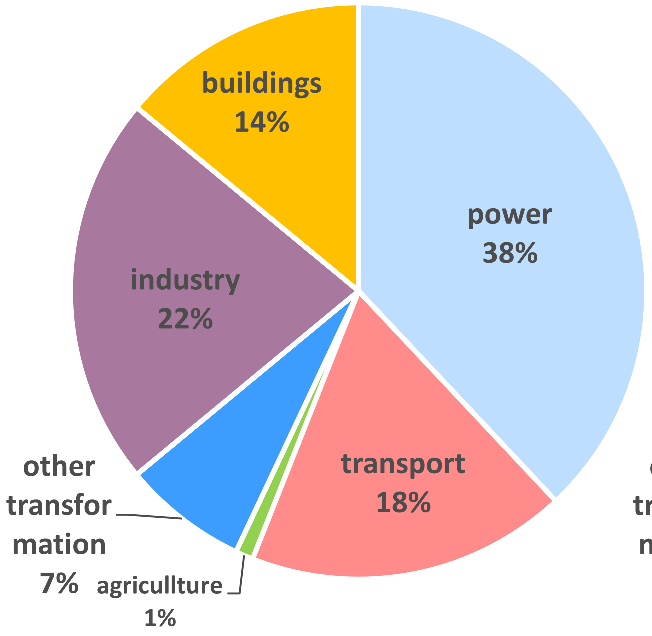
158 000 TWh

Source : International energy statistics database

Primary energy use and CO2 emissions by sector and final energy demand

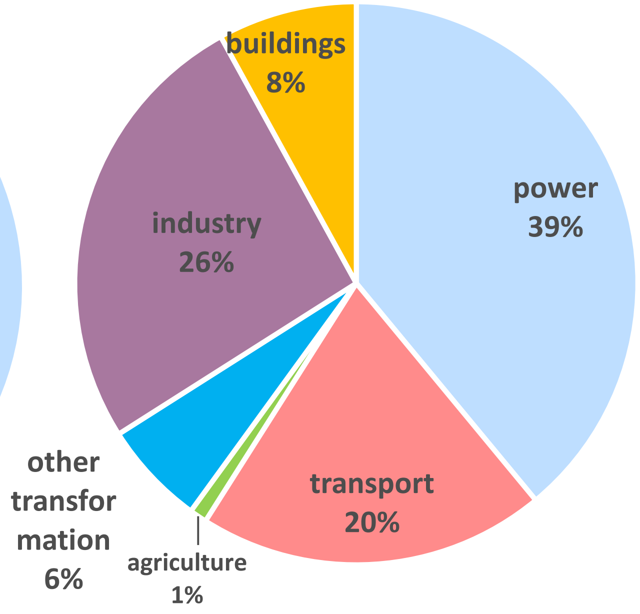
World primary energy use

550 EJ (2011)



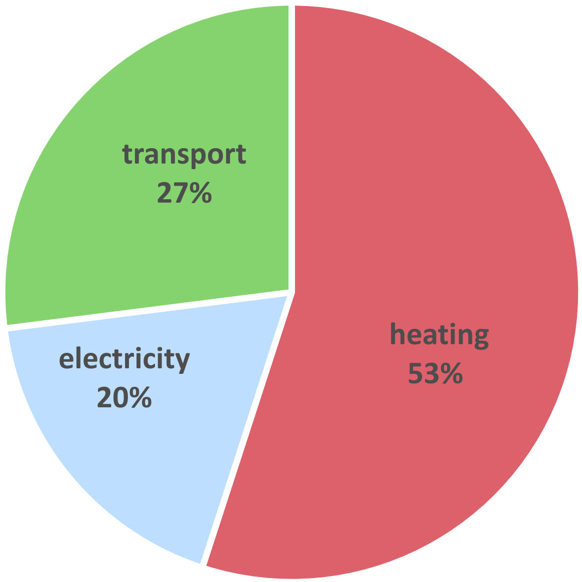
World CO2 emmissions

38 Gt (2011)

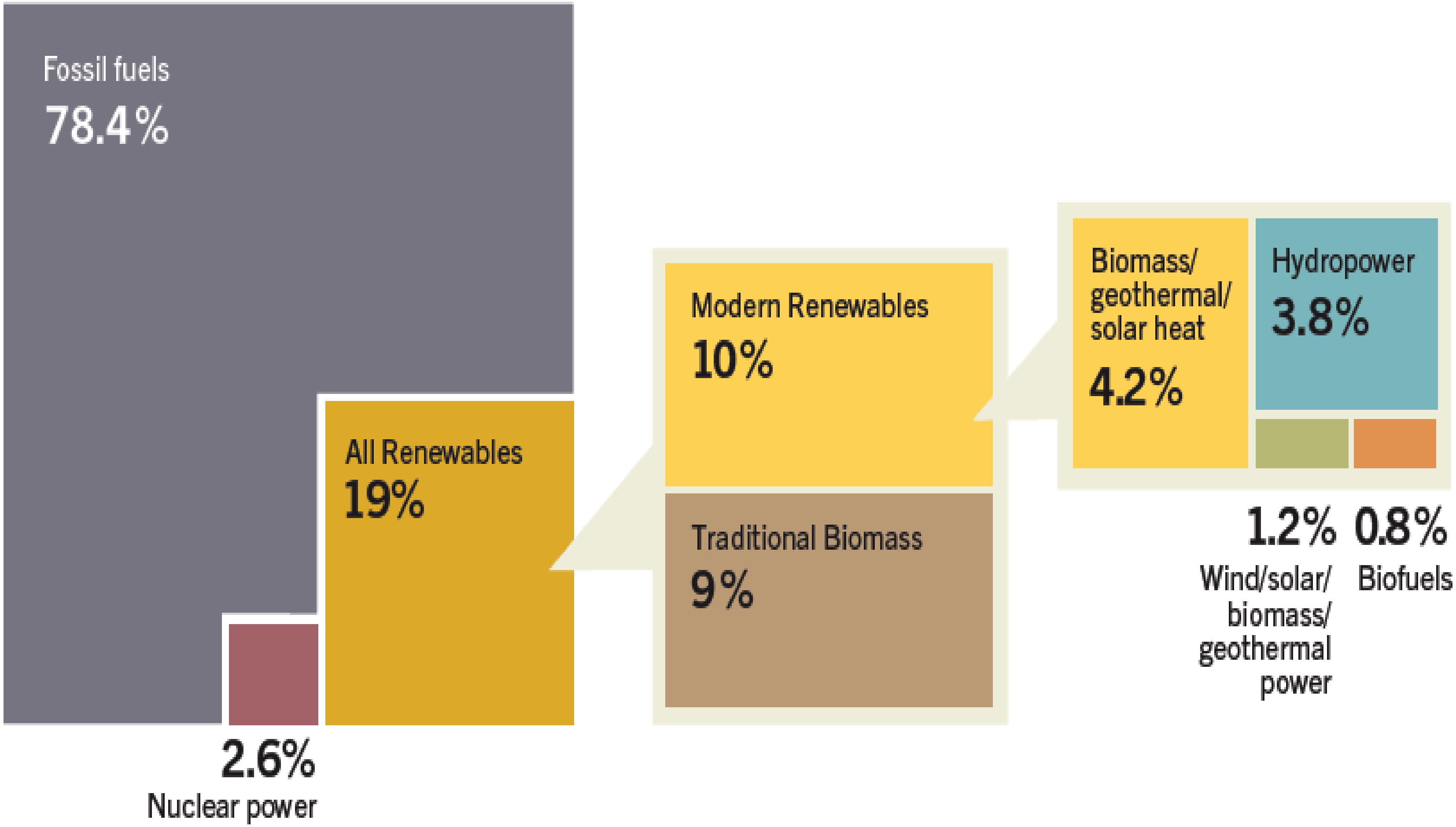


Average final energy demand

380 EJ (2011)

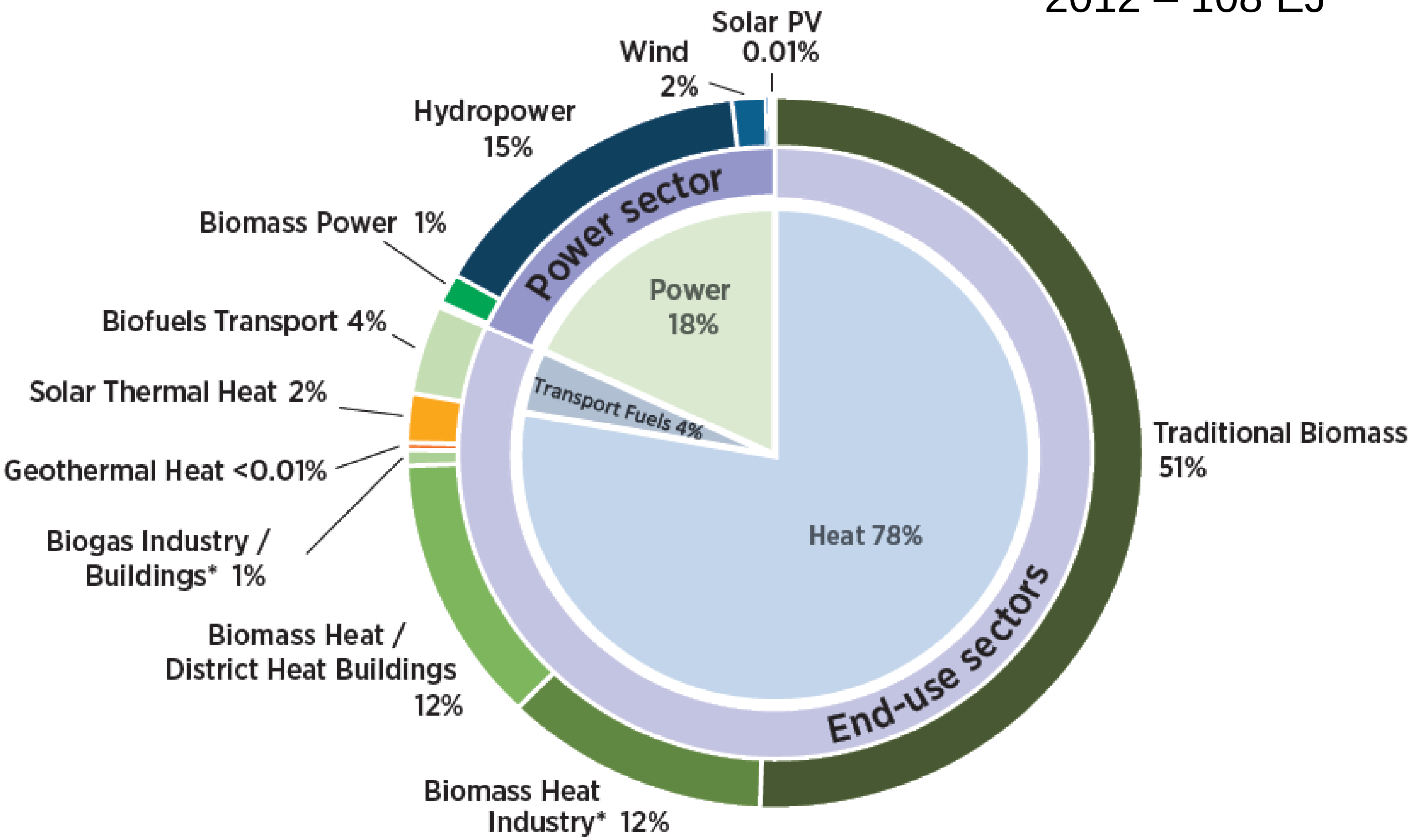


Estimated RE share of global final energy consumption - 2013

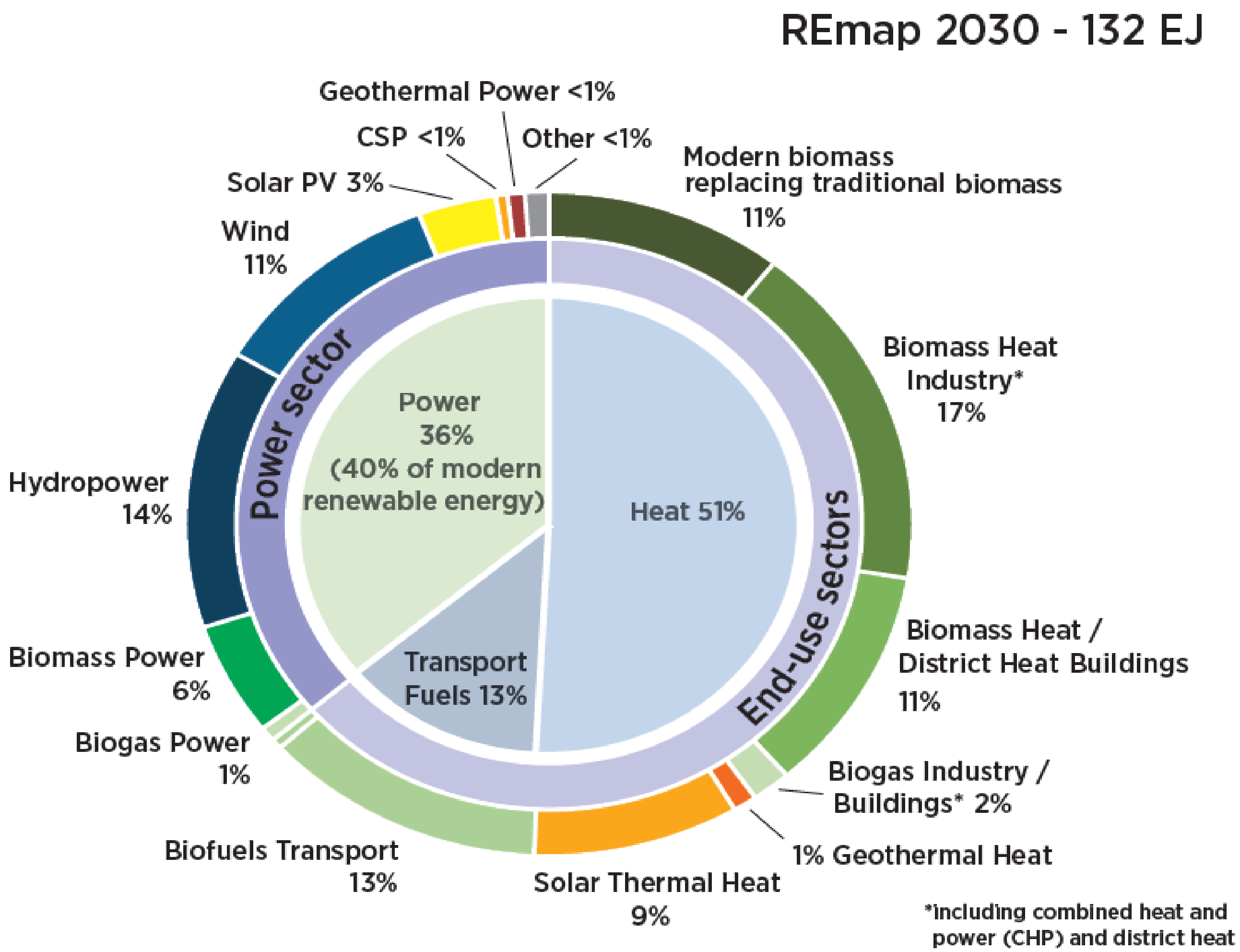


Breakdown of world global Renewable Energy used

2012 – 108 EJ



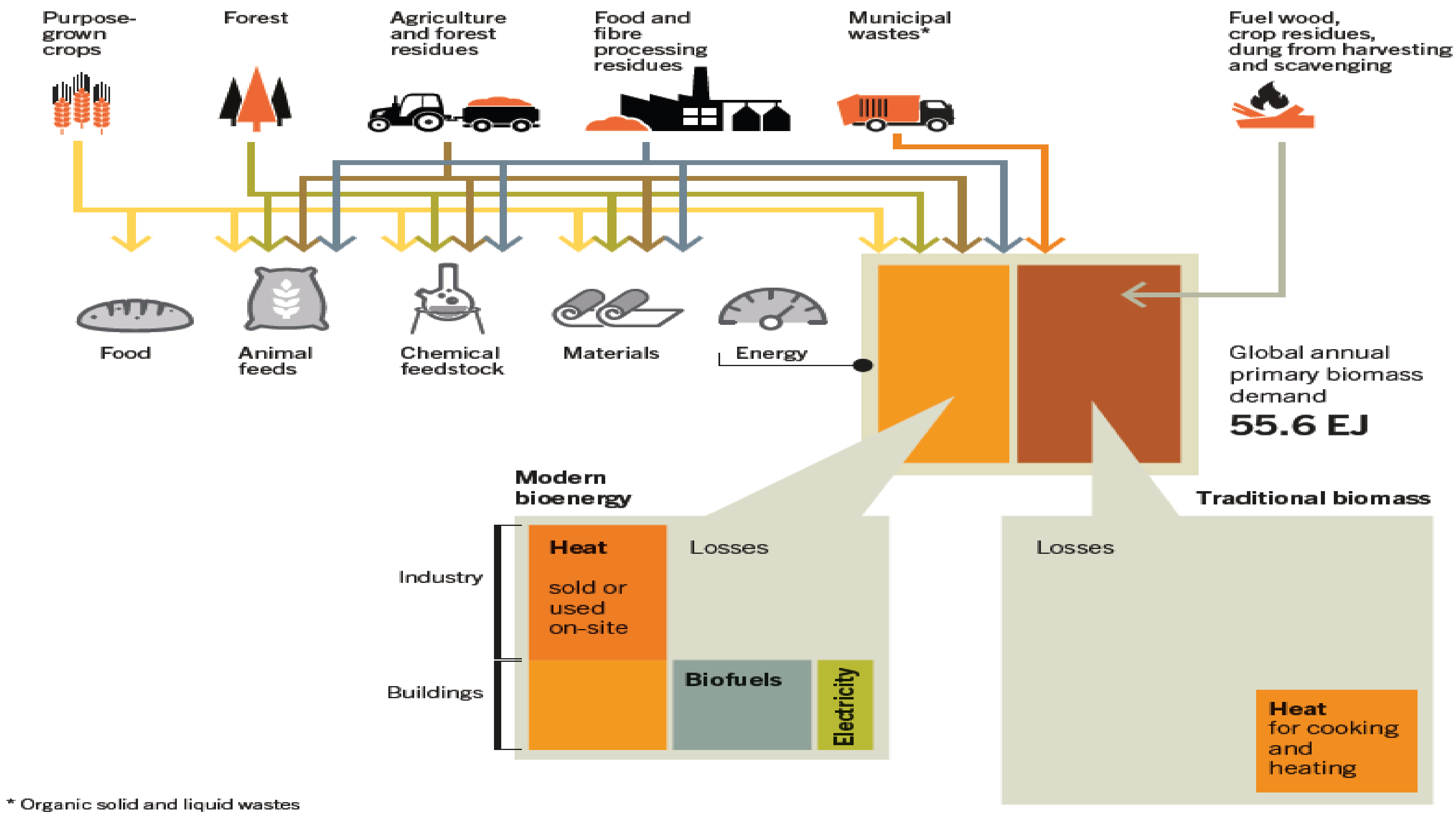
Breakdown of world global Renewable Energy used



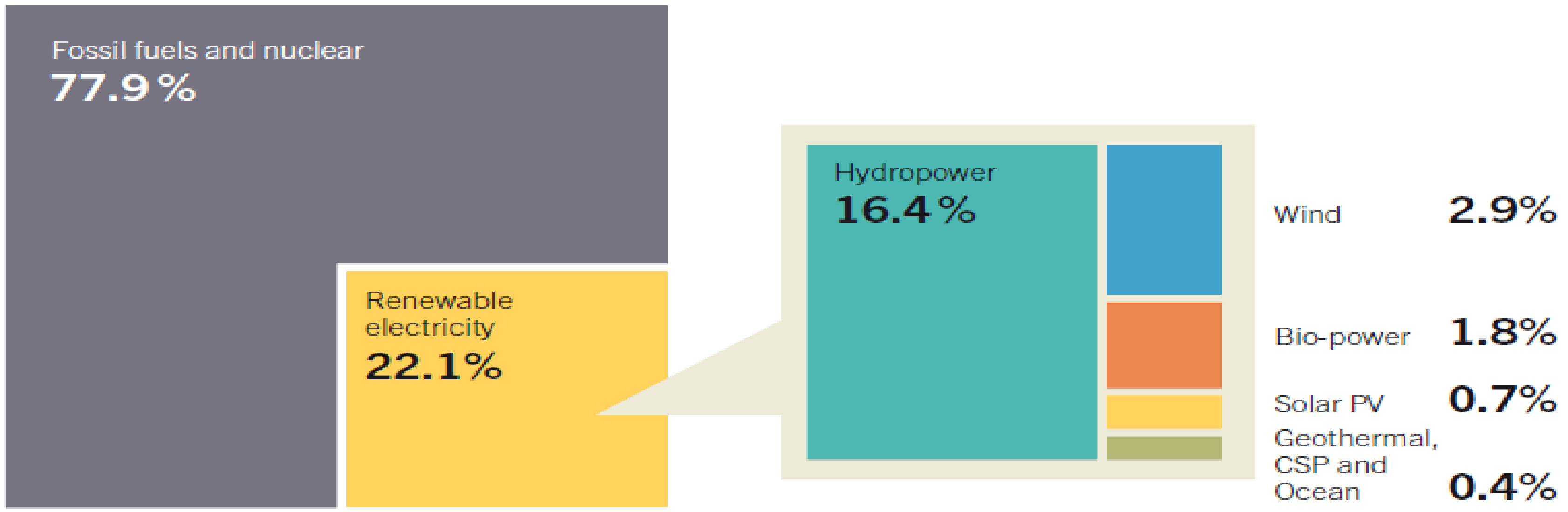
Renewable energy sources and technologies

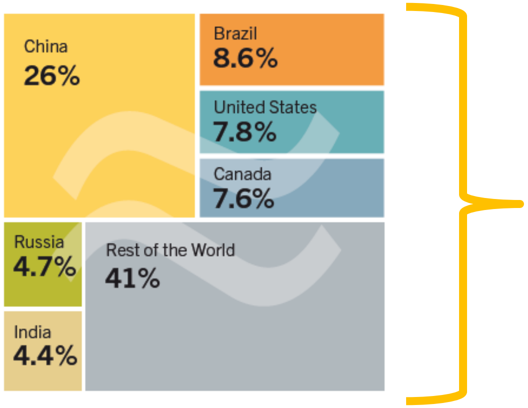
	Electricity	Heating and Cooling	Transport
Wind	Onshore Offshore		
Hydro	Small Hydropower (<10MW) Large Hydropower (>10MW)		
Solar	Photovoltaics (PV) Concentrated Solar Power (CSP)	Solar Thermal	
Ocean	Wave; Tidal; Thermal; Osmotic		
Geothermal	Conventional Geothermal Electricity (hydrothermal); Electricity ORC and Kalina Cycle; Enhanced goethermal systems (EGS); Supercritical fluids	Direct Use Ground Source Heat Pumps	
Bioenergy	Biomass Biogas	Biomass Biogas	Bioethanol Biodiesel Biogas

Biomass resources and energy pathways



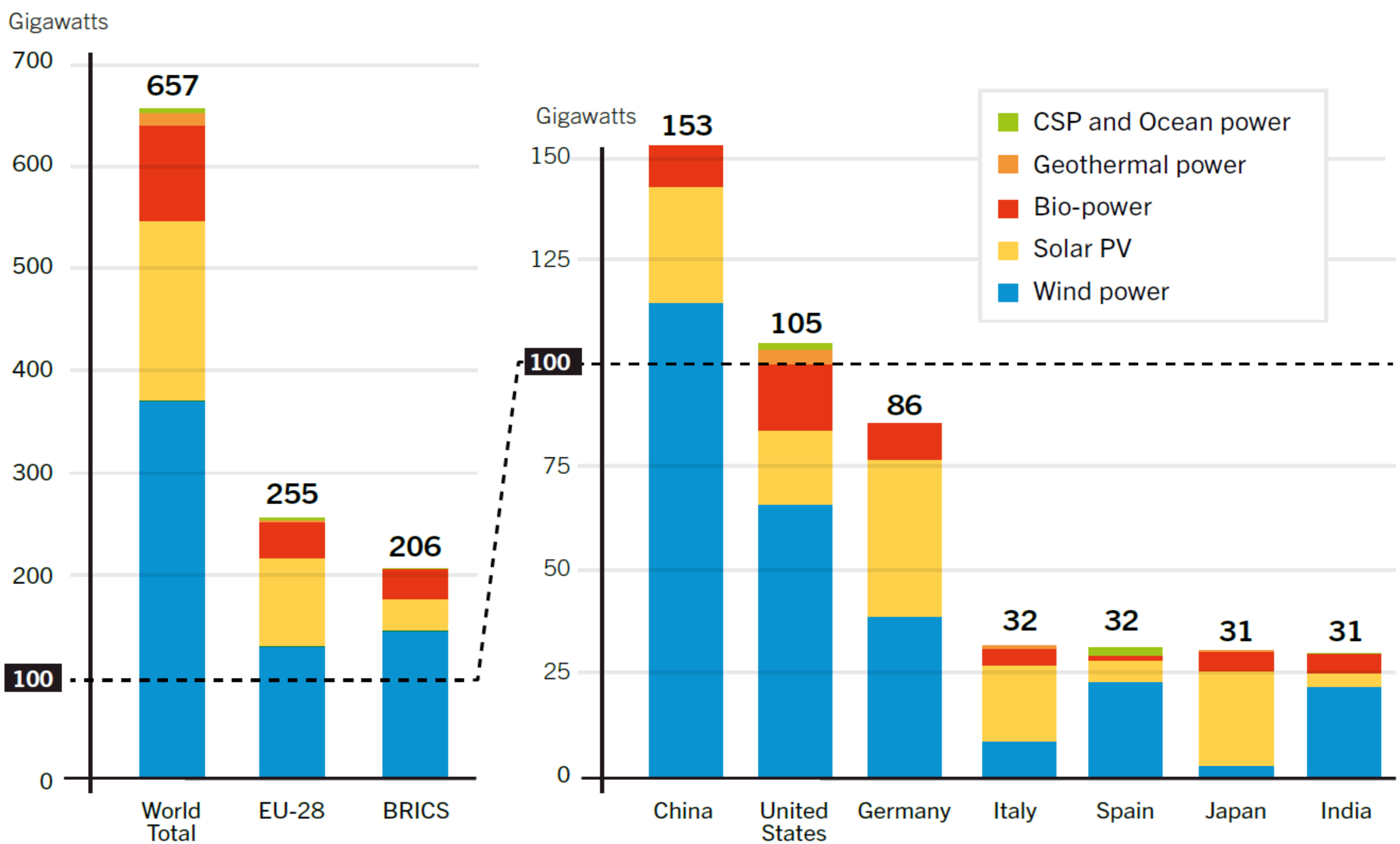
Estimated RE share of global electricity production-2013



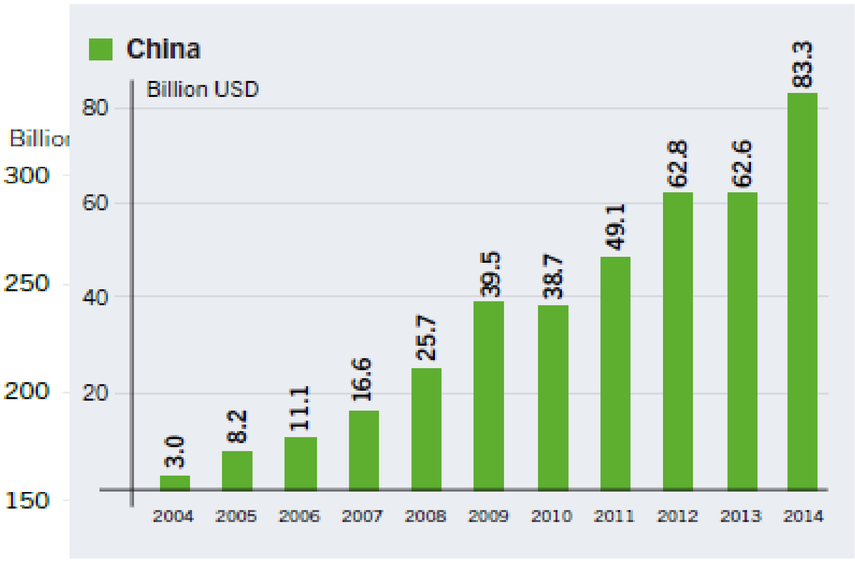


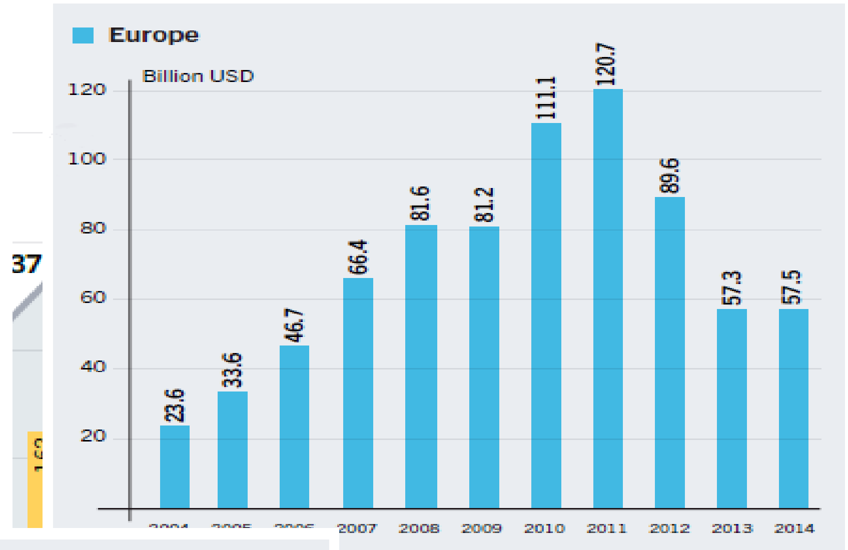
1053 GW Hydro + 657 GW others

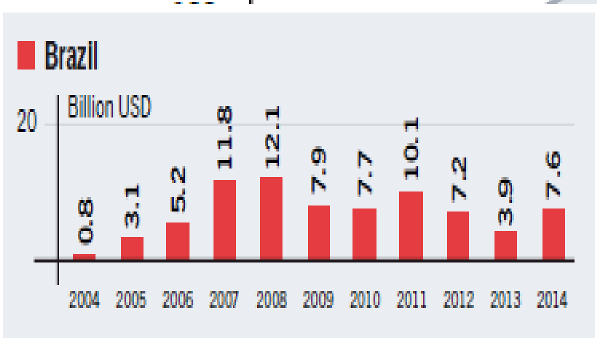
World Renewable power capacities not including hydropower

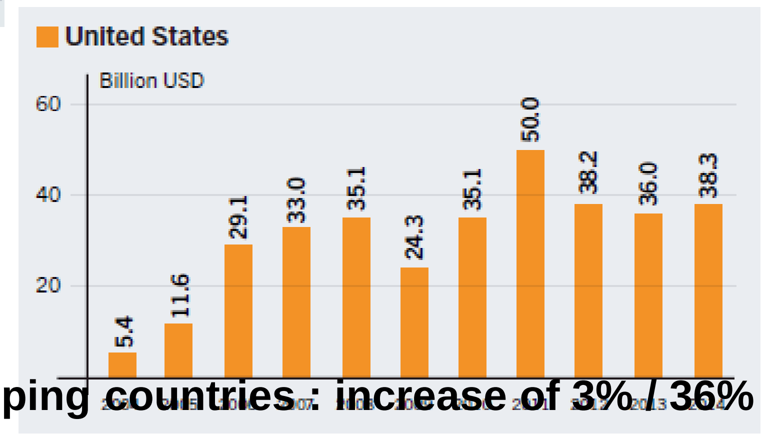


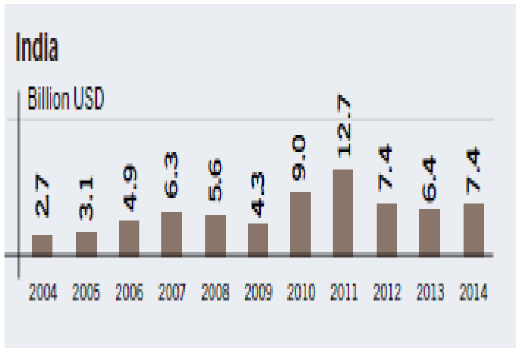
Global new investments in RE technologies





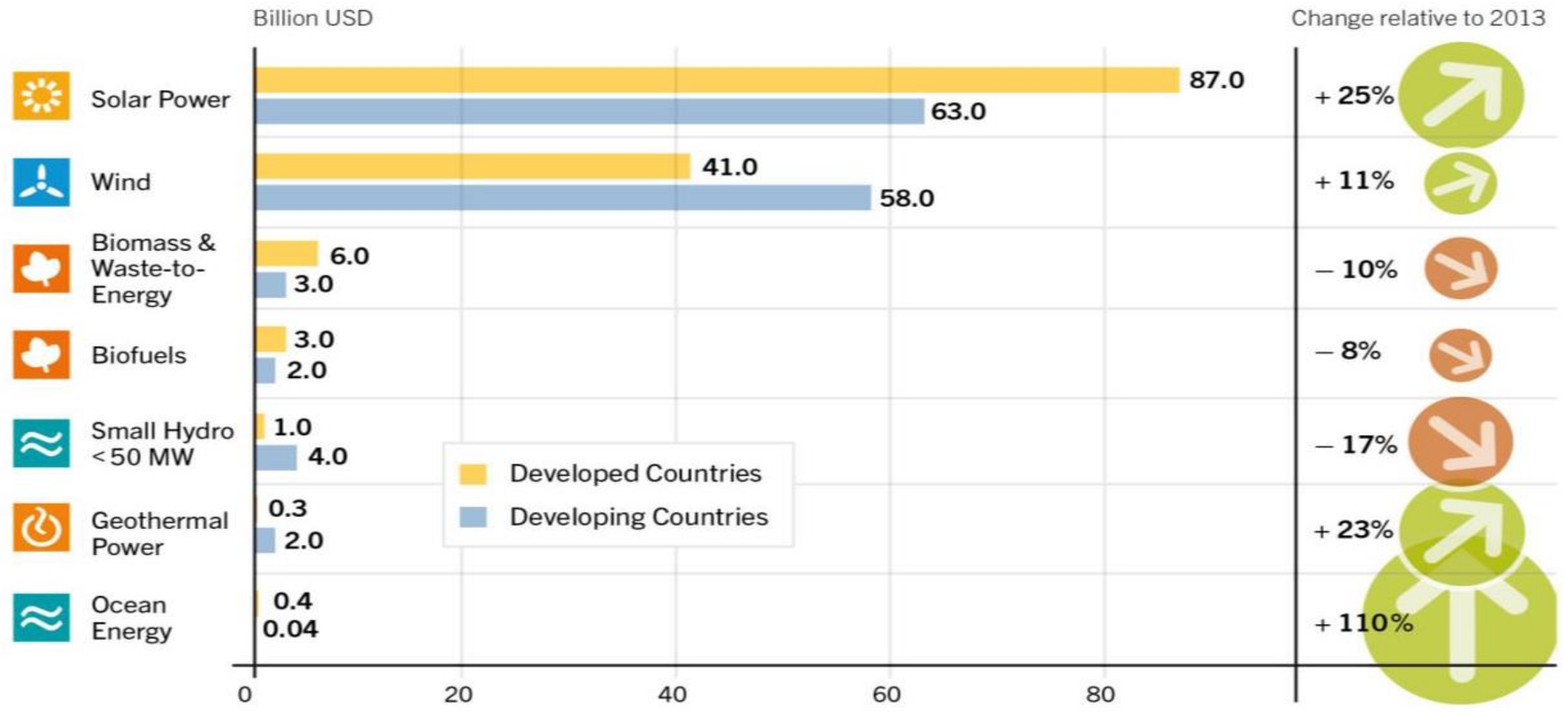






Developed countries/ Developing countries : increase of 3% / 36% compared to 2013

Global new investments in RE by technologies



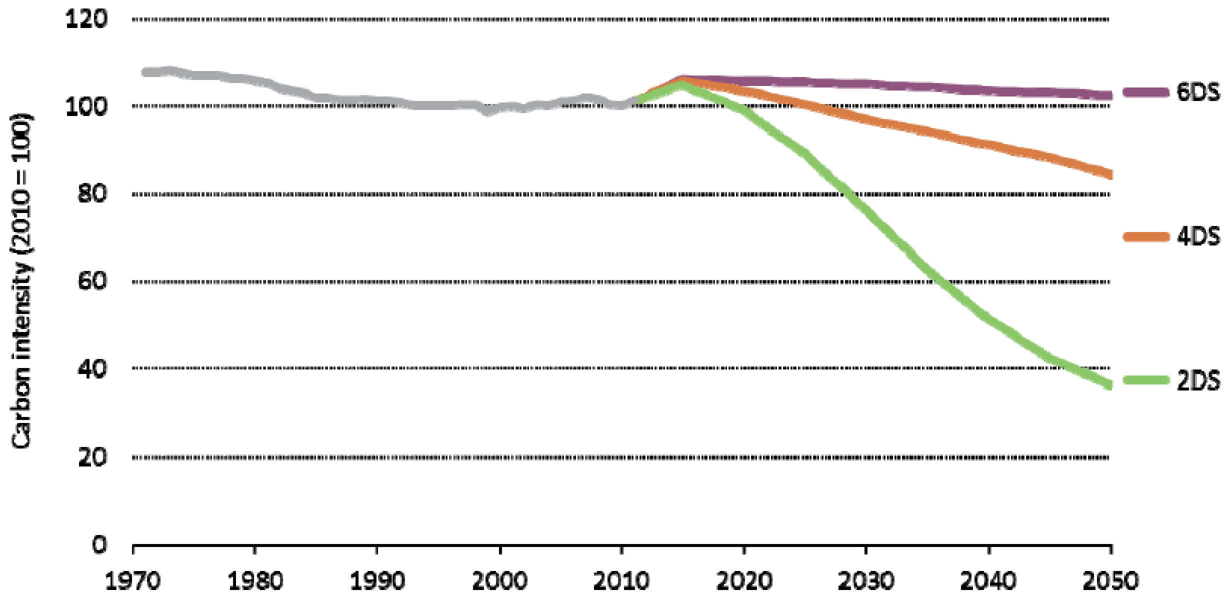
REN21 *Renewables 2015 Global Status Report*

Source: Frankfurt School–UNEP and BNEF

Jobs in Renewable Energy

Scenario IEA

Energy Technology Perspective 2014



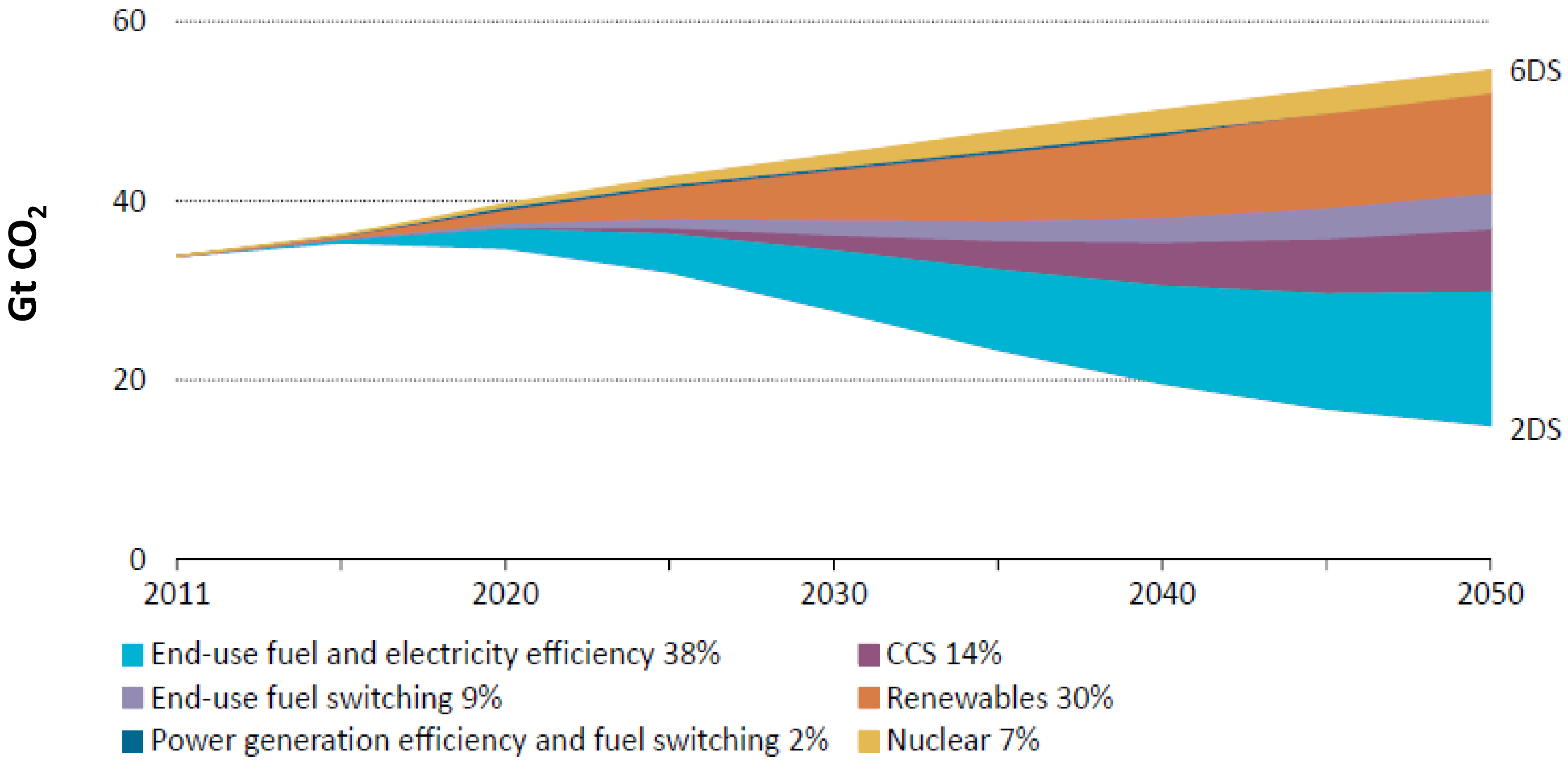
6DS : expresses the current policy. By 2050 energy use grows by more than 2/3

4DS : takes into account the recent decisions to limit CO2 emissions and improve energy efficiency

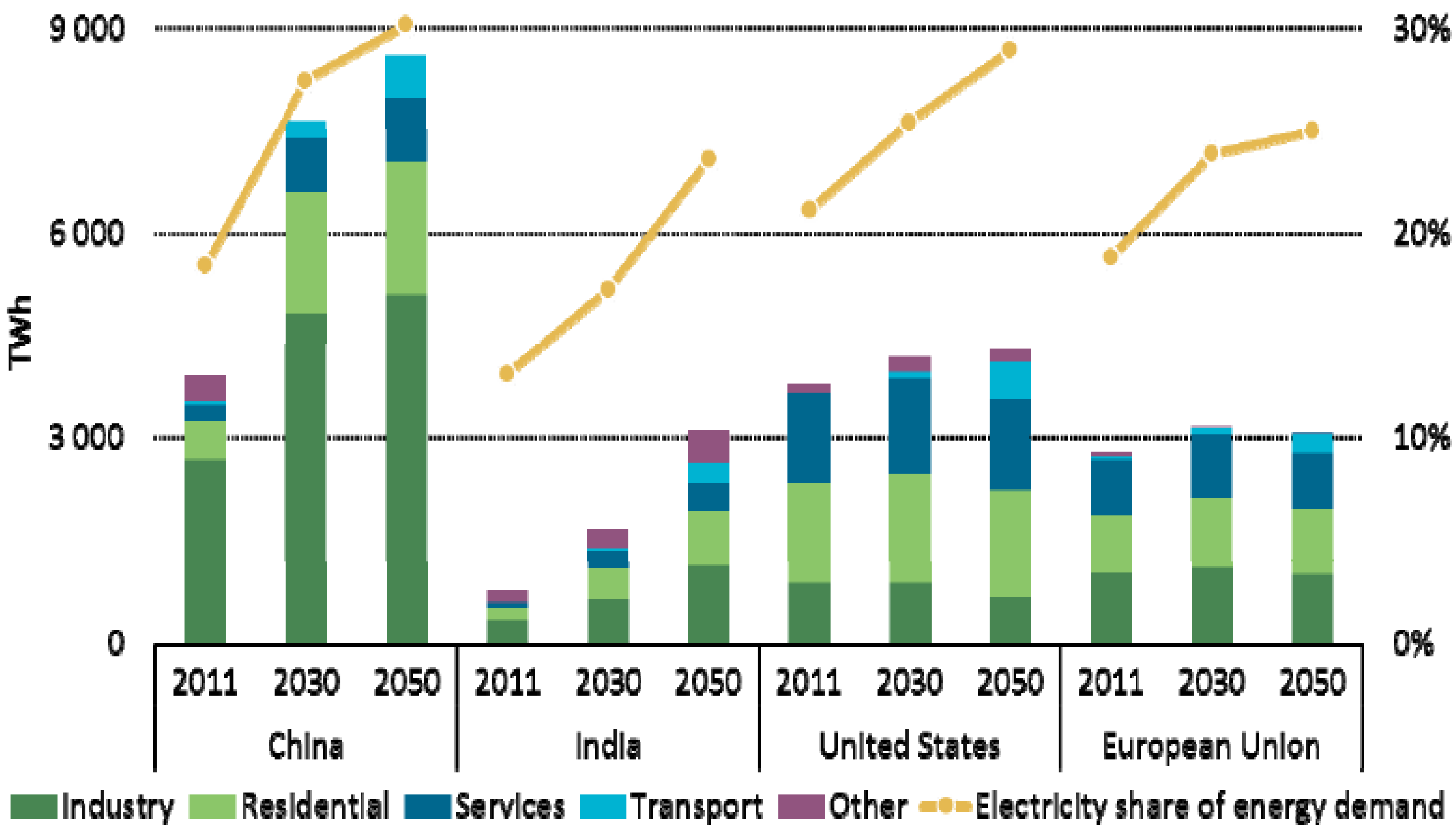
2DS : identifies changes that help ensure a secure and affordable energy system in the long run

Scenario IEA

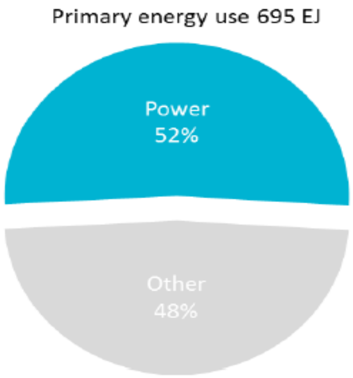
Energy Technology Perspective 2014

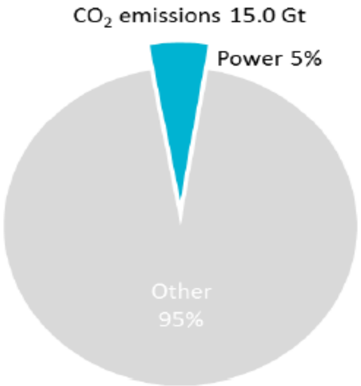


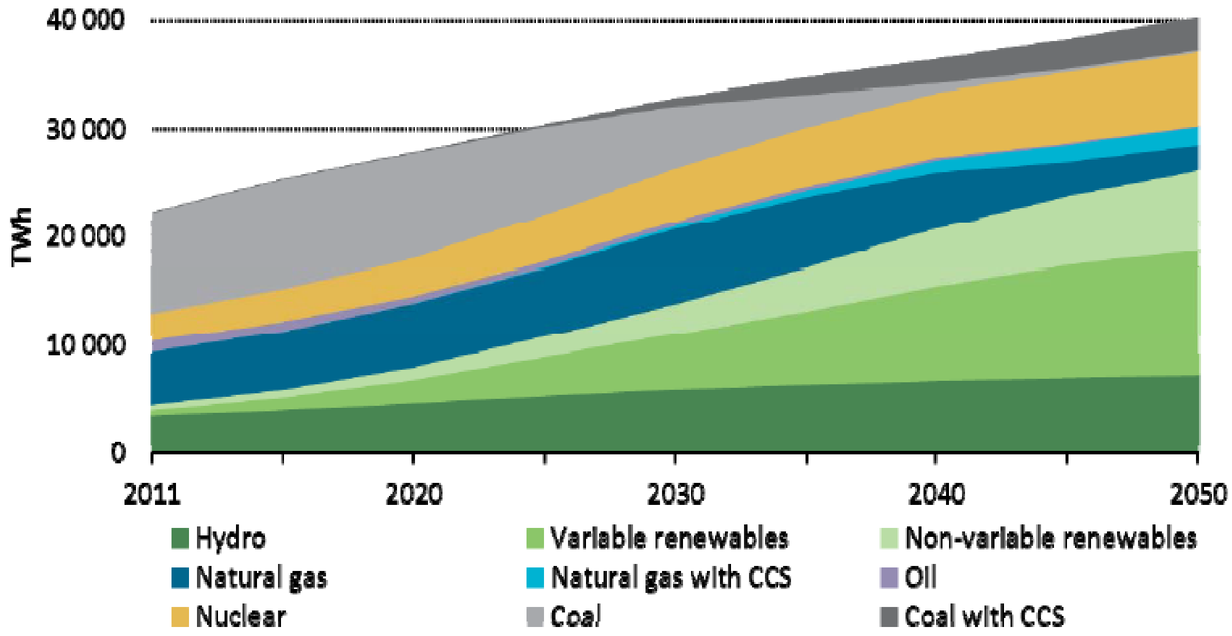
Sectorial electricity demand and share of electricity in final energy demand in 2DS



Electricity generation : a share reversal

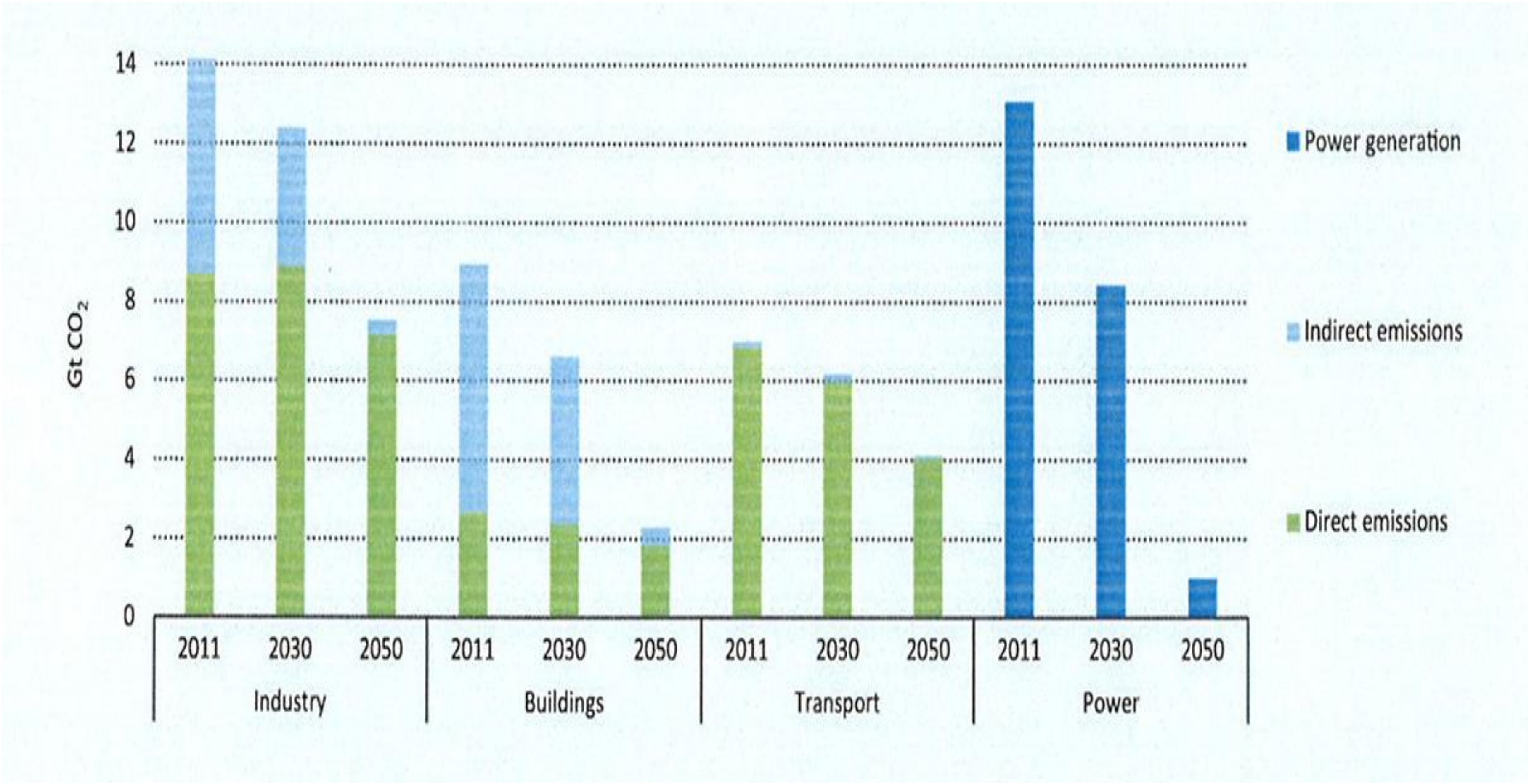




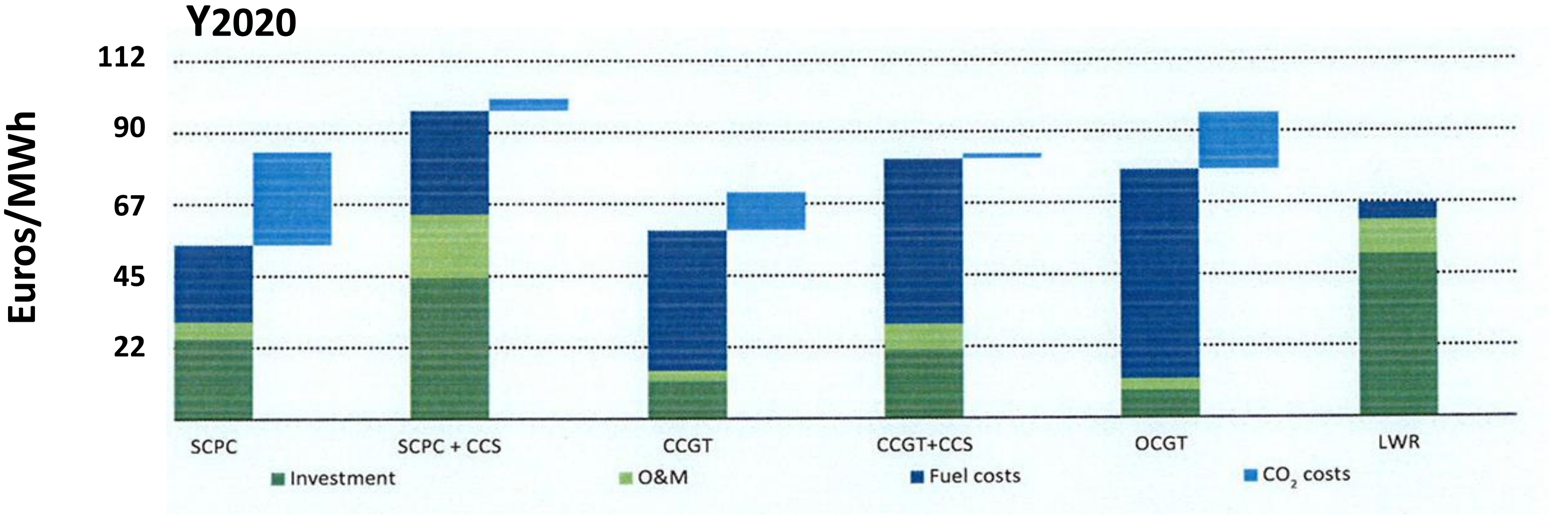


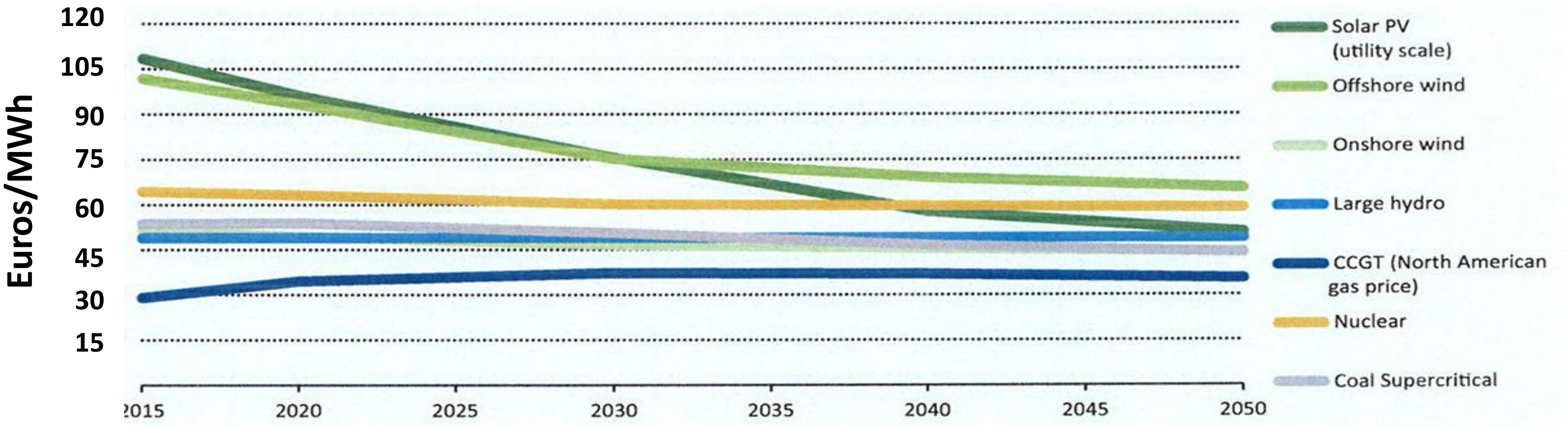
- **Generation today :**
  Fossil fuels : 66%
  Renewables : 22%
- **Generation 2DS 2050:**
  Renewables : 65%
  Fossil fuels : 20%

Additional effect of decarbonizing electricty in 2DS

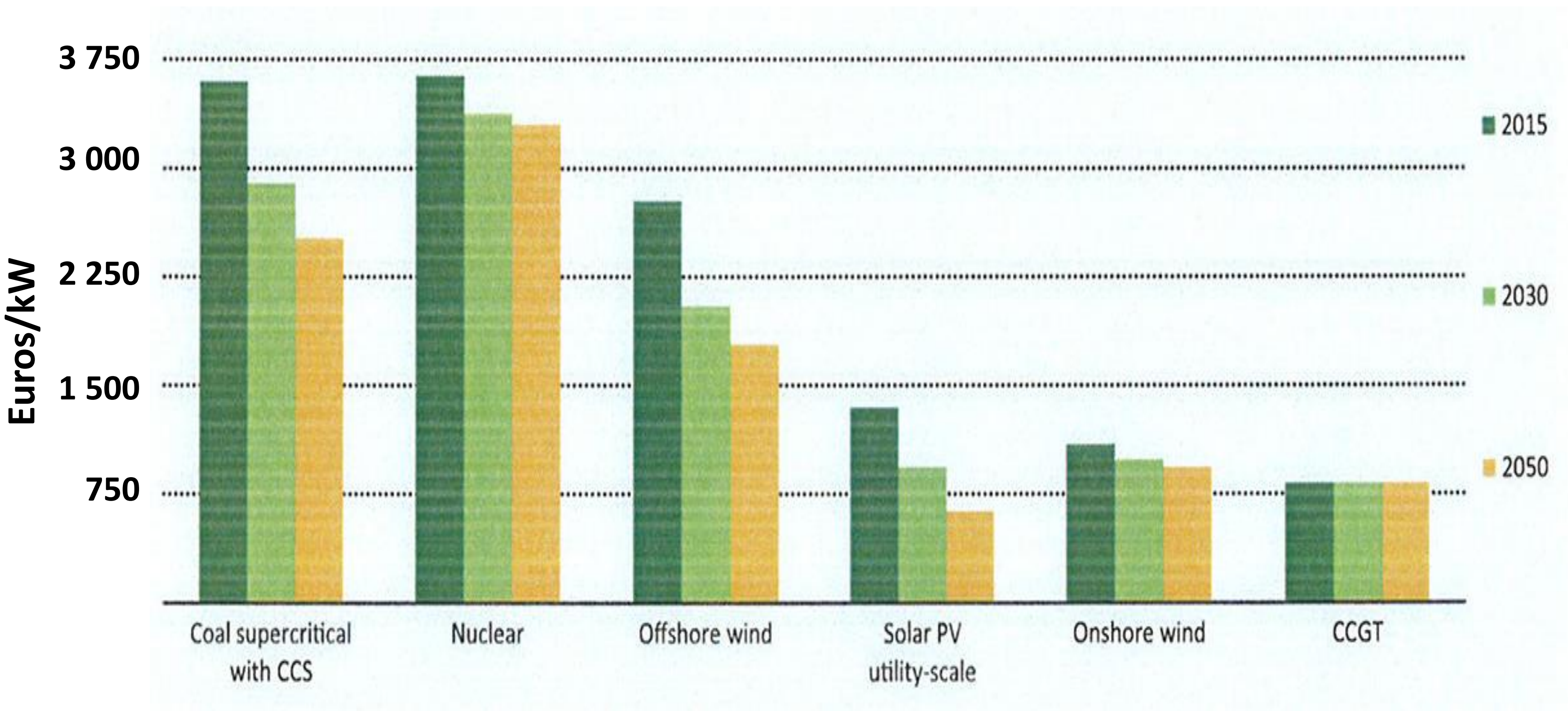


LCOE of power generation technologies





Evolution of the capital costs of power generation technologies



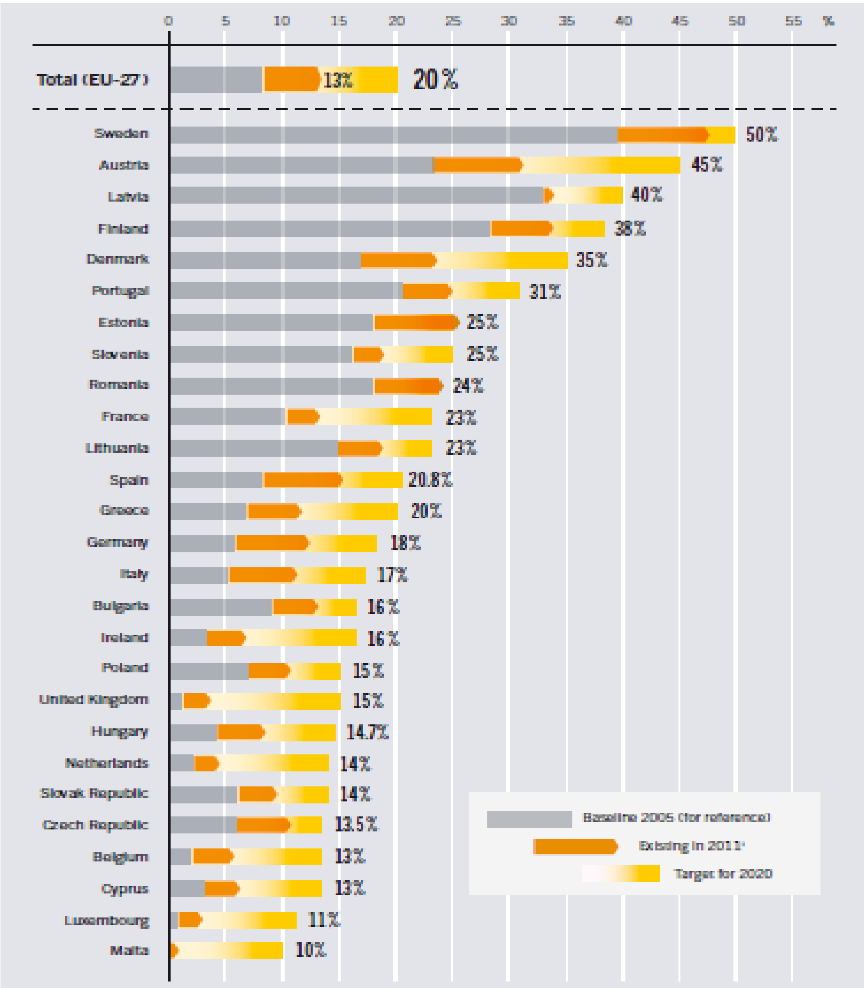
EU climate and energy package

Decision of the European council 8/9 March 2007

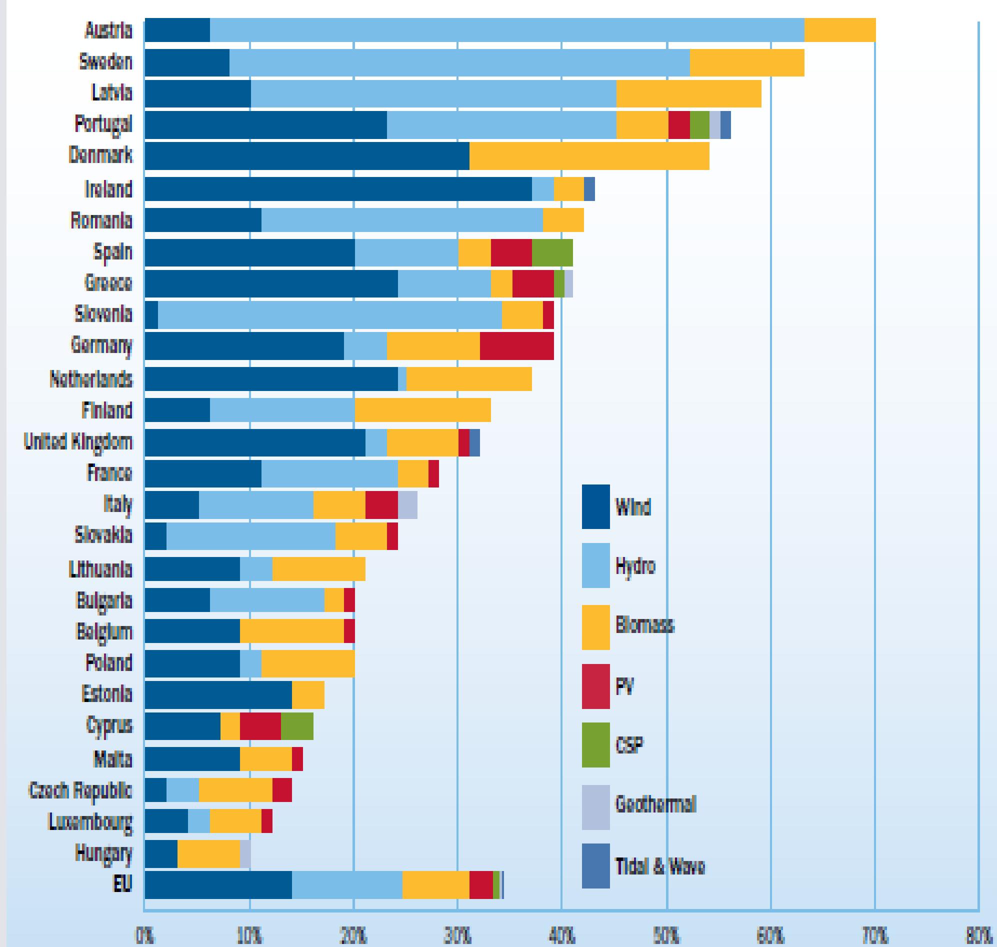
Compulsory targets for the EU at 2020

- **20% Energy consumption reduction comparing to the white book objectives (at present nothing)**
- **20% at least, CO_2 emission reductions**
- **20% contribution of RE in the energy supply of the EU as a binding target, except for biofuels**
- **10% contribution of biofuels for transportation (at present 2,5%)**

RE share of energy consumption by member state in 2020



Final energy



Electricity

Progress as of 2012

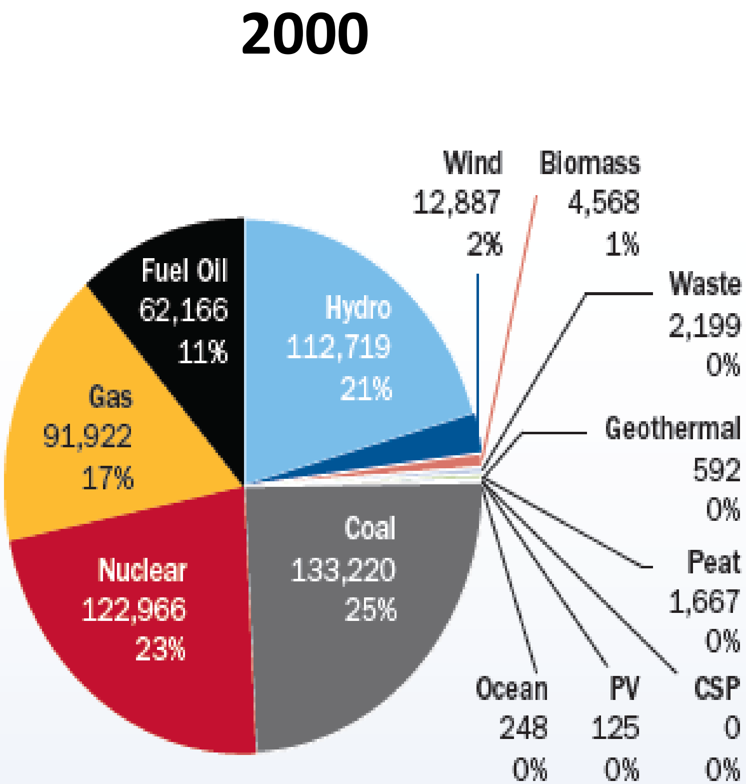
- Greenhouse gas emissions decrease by 18% relative to emissions in 1990 and are expected to reduce further to levels 24% and 32% lower than in 1990 by 2020 and 2030 respectively on the basis of current policies.

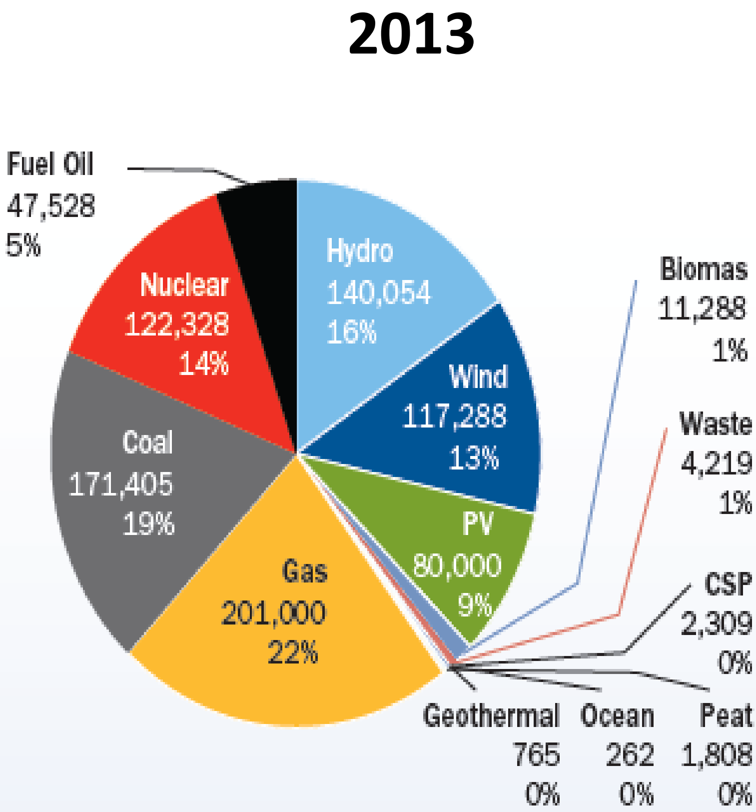
- The share of renewable energy has increased to 13% in 2012 as a proportion of final energy consumed and is expected to rise to 21% in 2020 and 24% in 2030.

- The EU installed about 42% of the world's renewable electricity (excluding hydro) at the end of 2012.

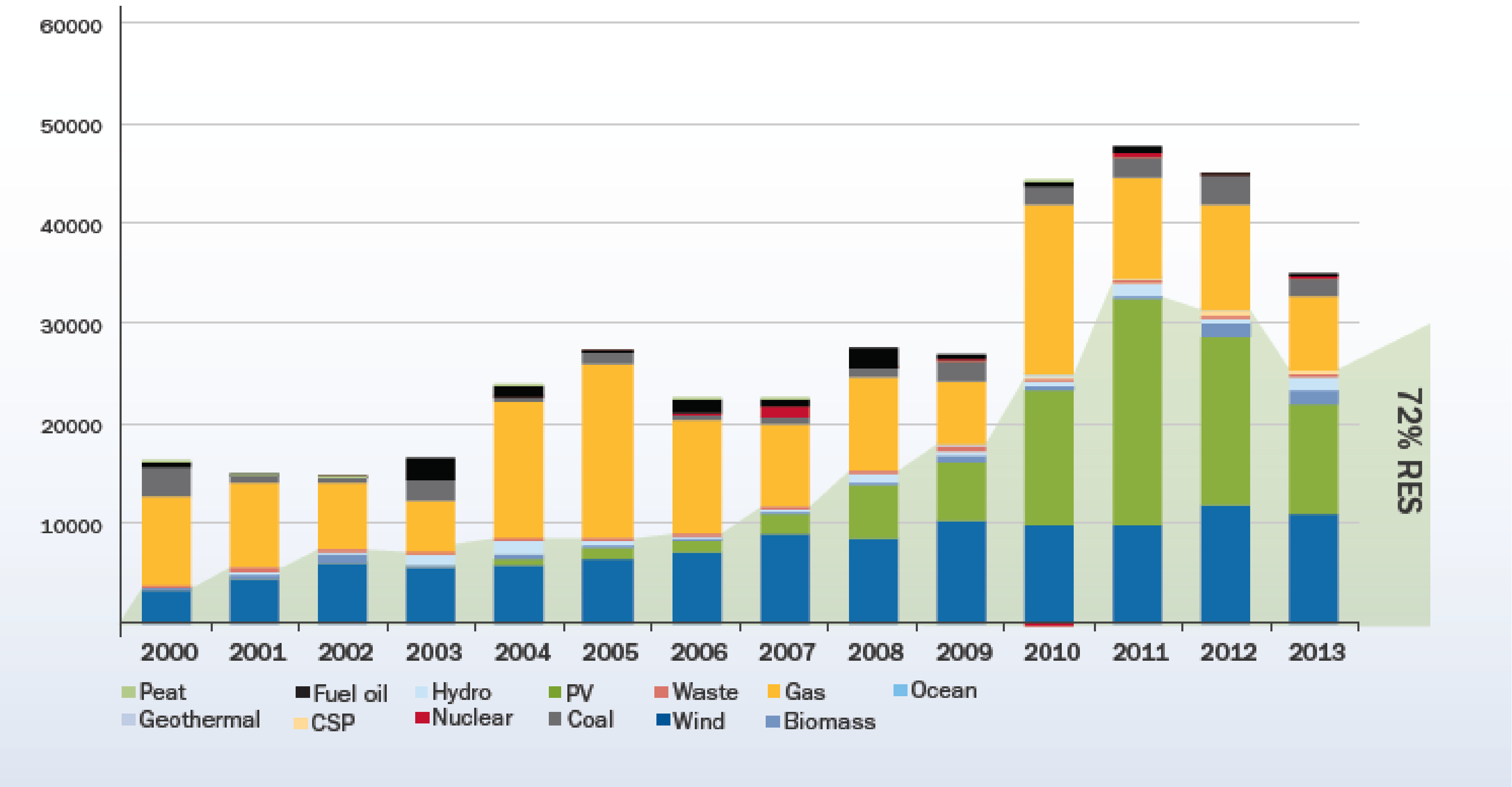
- The carbon intensity of the EU economy fell by 28% between 1995 and 2010.

EU power capacity mix





Installed power generating capacity per year in MW



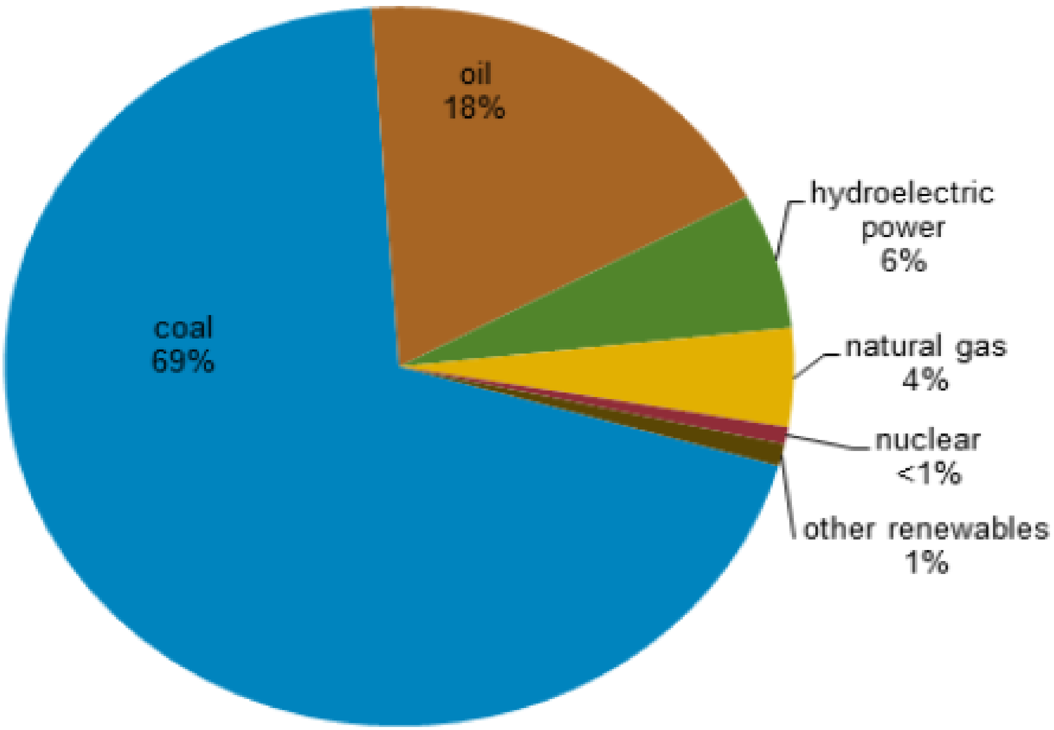
New policy framework from 2020 to 2030

- New reduction target for domestic GHG emissions of 40% compared to 1990 as the centre piece of the EU's energy and climate policy for 2030.
- A greater share of renewable energy in the EU of at least 27%. The share of renewable energy in the electricity sector would increase from 21% today to at least 45% in 2030.
- In terms of energy consumption reduction, a shortfall against the 20% target is predicted. Once the review has been carried out, the Commission will consider whether it is necessary to propose amendments to the Energy Efficiency Directive.

  However, a greenhouse gas emissions reduction target of 40% would require an increased level of energy savings of approximately 25% in 2030.

Total primary energy consumption in China (2011)

- **China is the largest consumer of primary energy in the world with a growth of about 7% per year.**



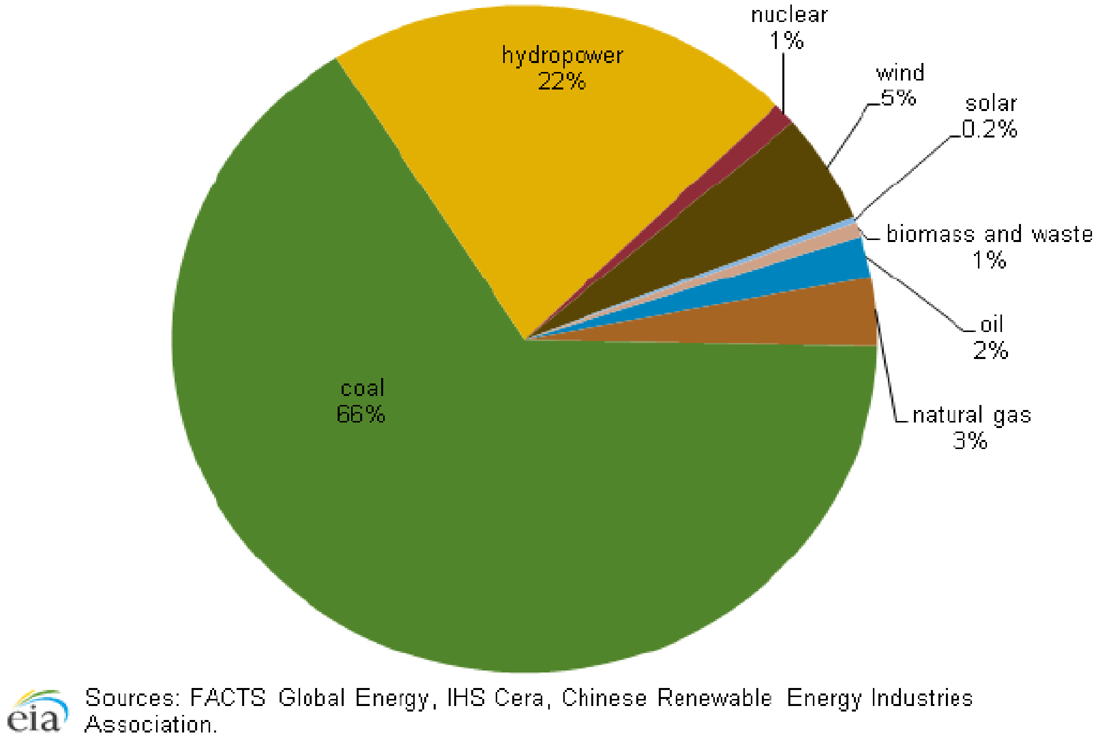
Note: Numbers may not add due to rounding.
Source: U.S. Energy Information Administration *International Energy Statistics*.

China's installed electricity capacity (2012)

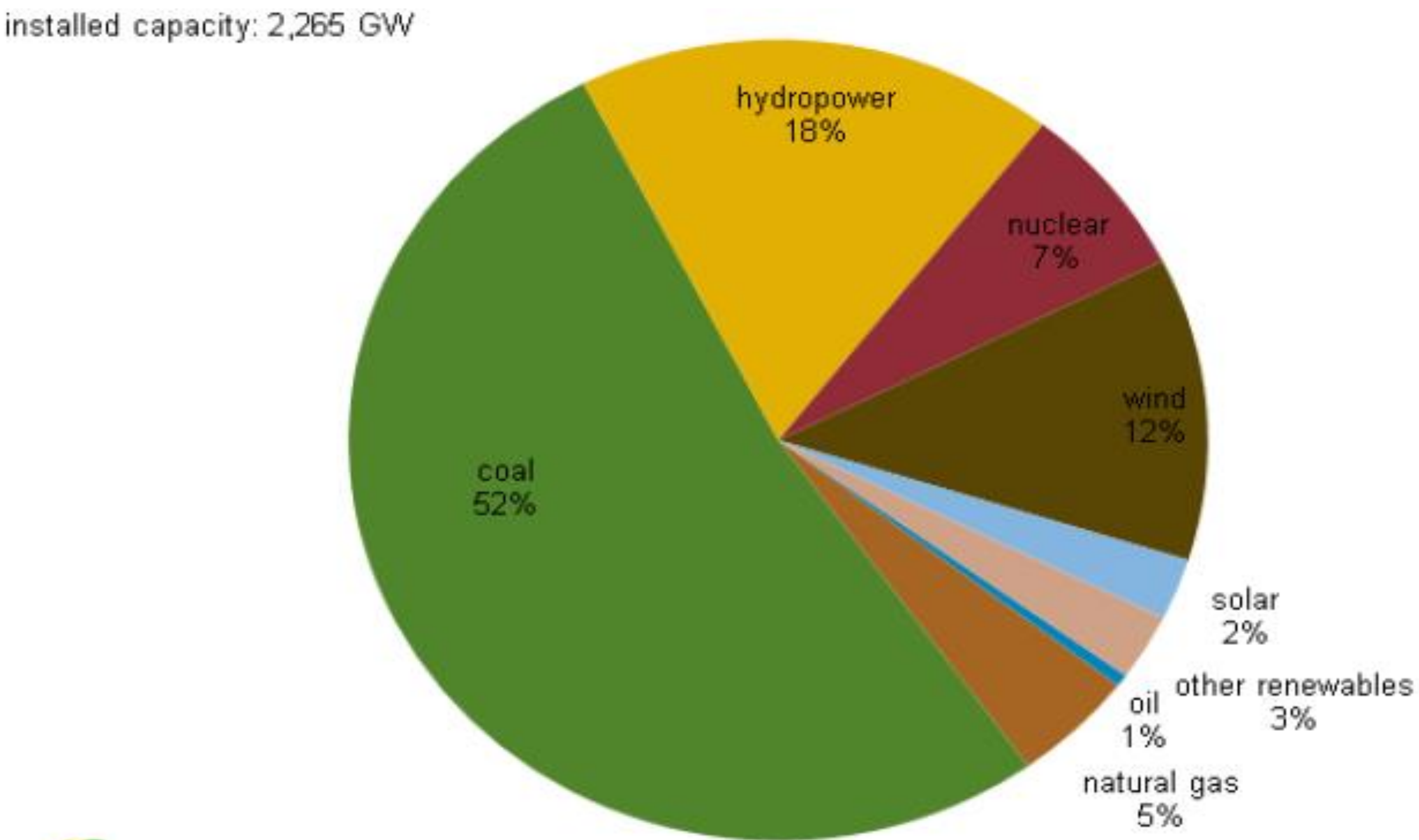
- **China is the world largest power generator with an installed capacity of about 1 000 GW and a production of about 4 480 TWh (2011).**

- **7 300 TWh in 2020**
- **11 600 TWh in 2040**

- **75% for industry needs, at present**



Forecast of China's installed electricity capacity (2040)



Source: EIA, *International Energy Outlook*, 2013.

Air pollution in big cities

USA CO_2 per capita 16.4 tons

2013: China CO_2 per capita 7.2 tons

EU CO_2 per capita 6.8 tons

Less than 1% of China's 500 largest cities met the air quality standards recommended by WHO (PM2.5 <25 µg/m3)

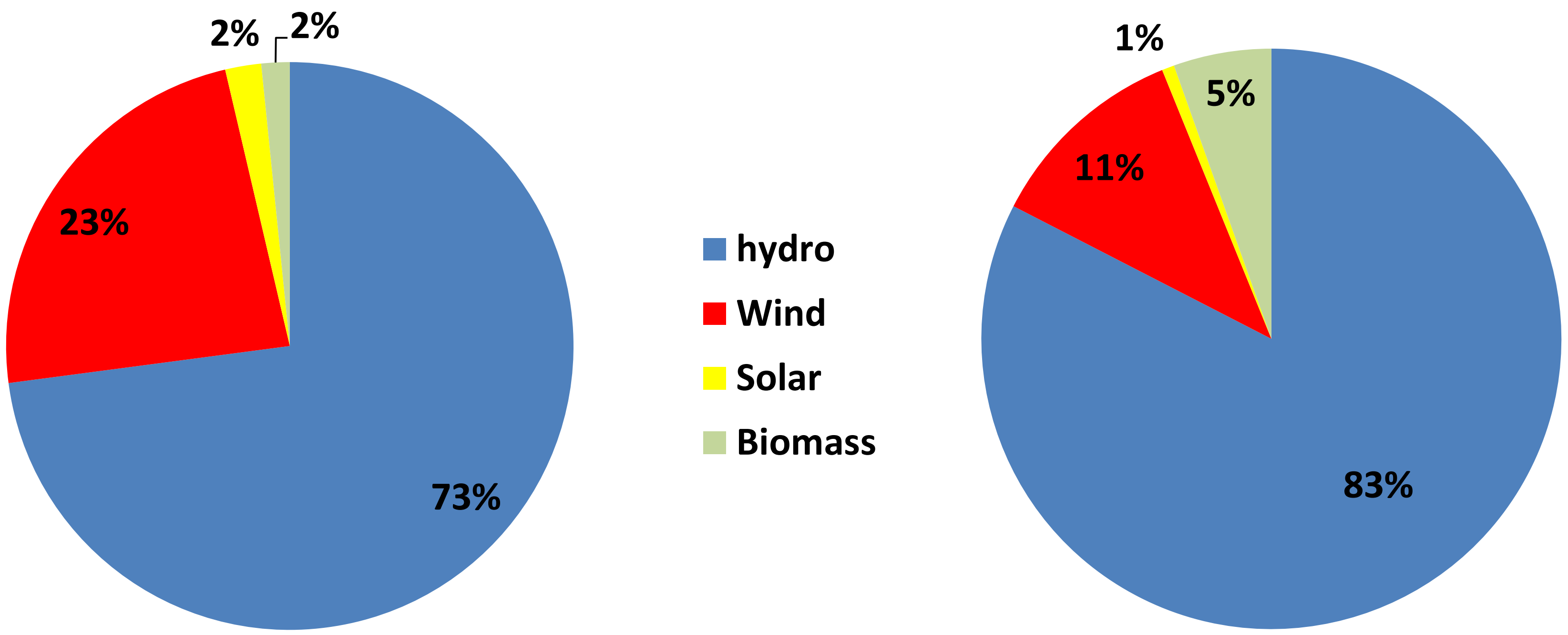
Very fast improvement is needed in energy mix and energy efficiency

China : one of the leader in the RE production

- **In parallel, China became the world's leading producer of renewable electricity.**

Capacity installed: 340 TW

Power generation : 830 TWh



Figures : 2012

Chinese Objectives in terms of energy production and environmental impacts

12th Five-Year Plan (2011-2015)

- Non energy fossil will reach 11,4% of total primary energy consumption
  290 GW hydro - 40 GW nuclear –
  100 GW wind – 21 GW solar
  400 millions m2 of solar heat collection
- Energy consumption (by unit of GDP) will decrease by 16% from 2010
- CO2 emission (by unit of GDP) will decrease by 17% from 2010

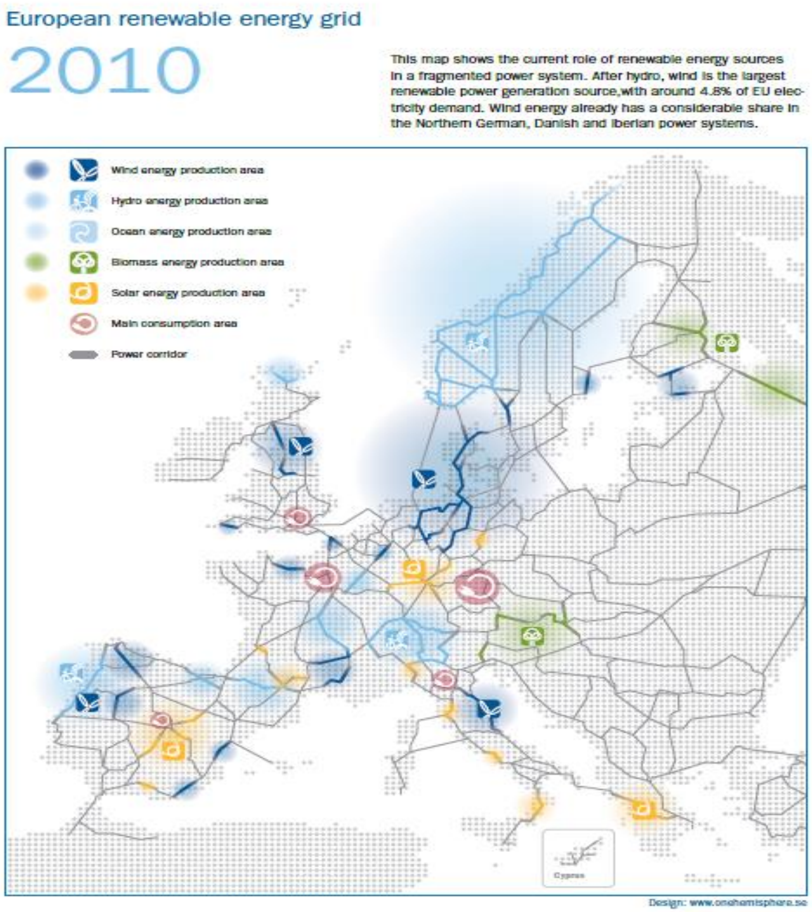
Commitment by 2017

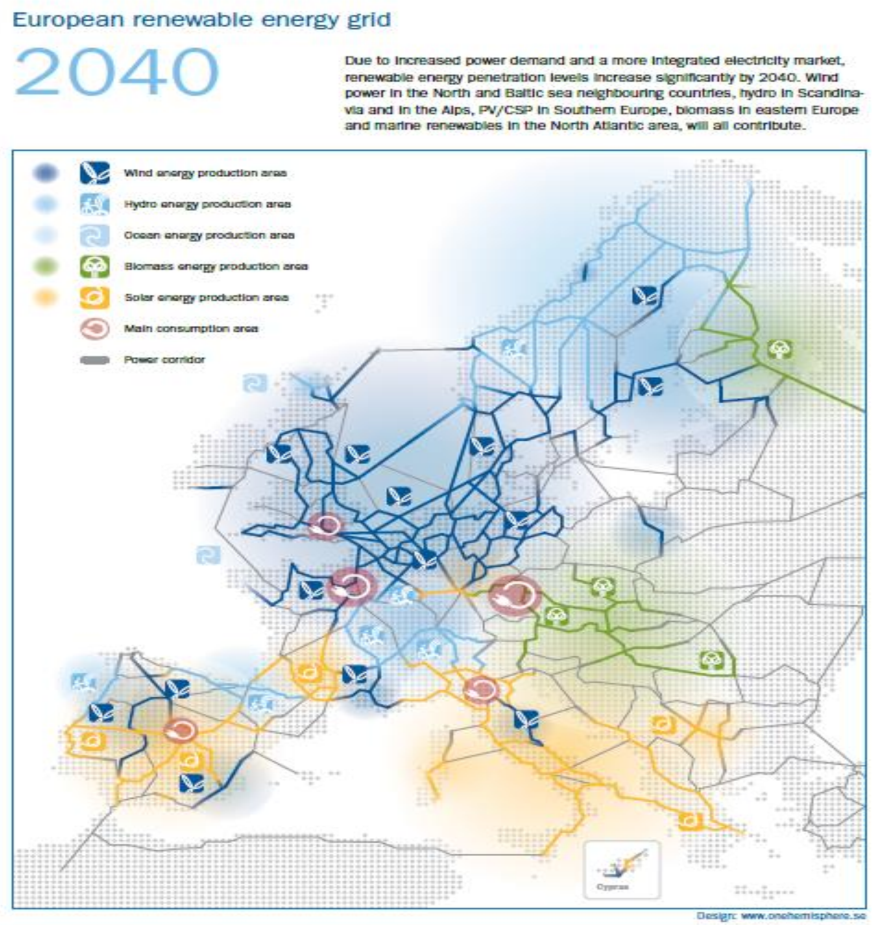
- Cap coal use below 65% of the total primary energy consumption

Commitment by 2020

- Non energy fossil will account for 15% of total primary energy consumption
- CO2 emission (by unit of GDP) will be 40-45% lower than in 2005
- Coal share in the energy mix must fall at 63% in 2020 and 55% in 2040

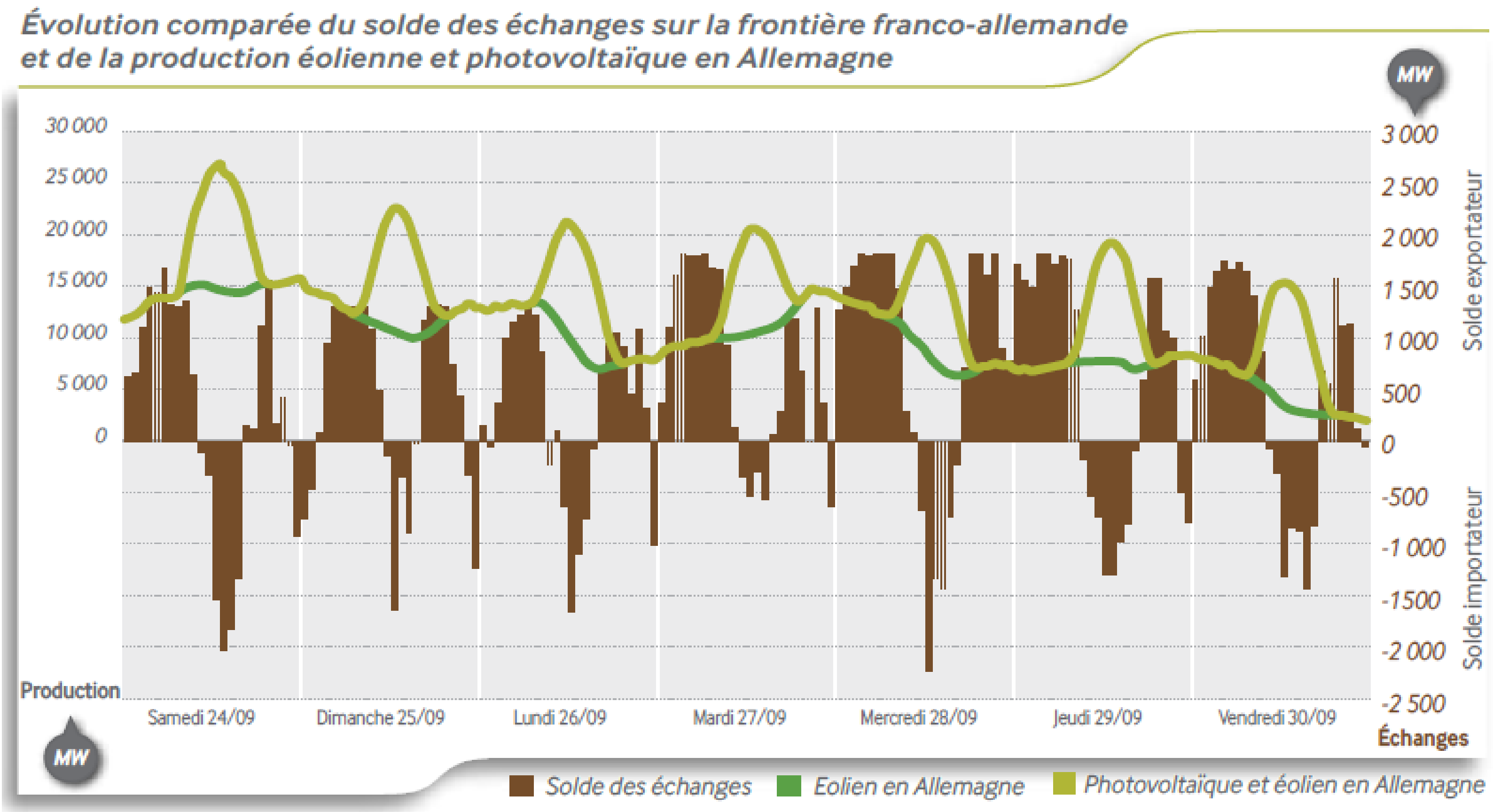
Future power system with high penetration of RE



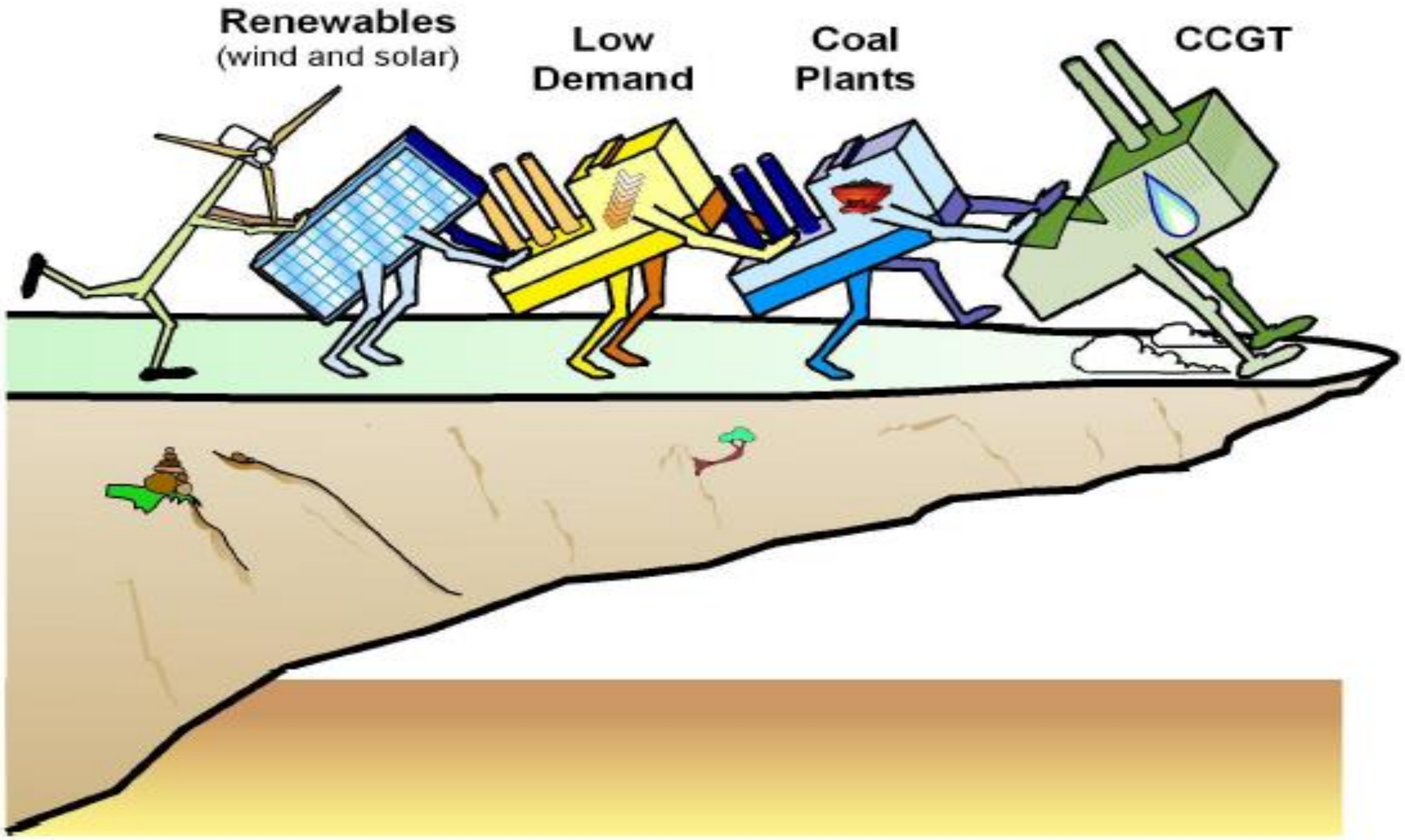


The importance of interconnections

The technology choice of the neighbour countries has an impact on your network



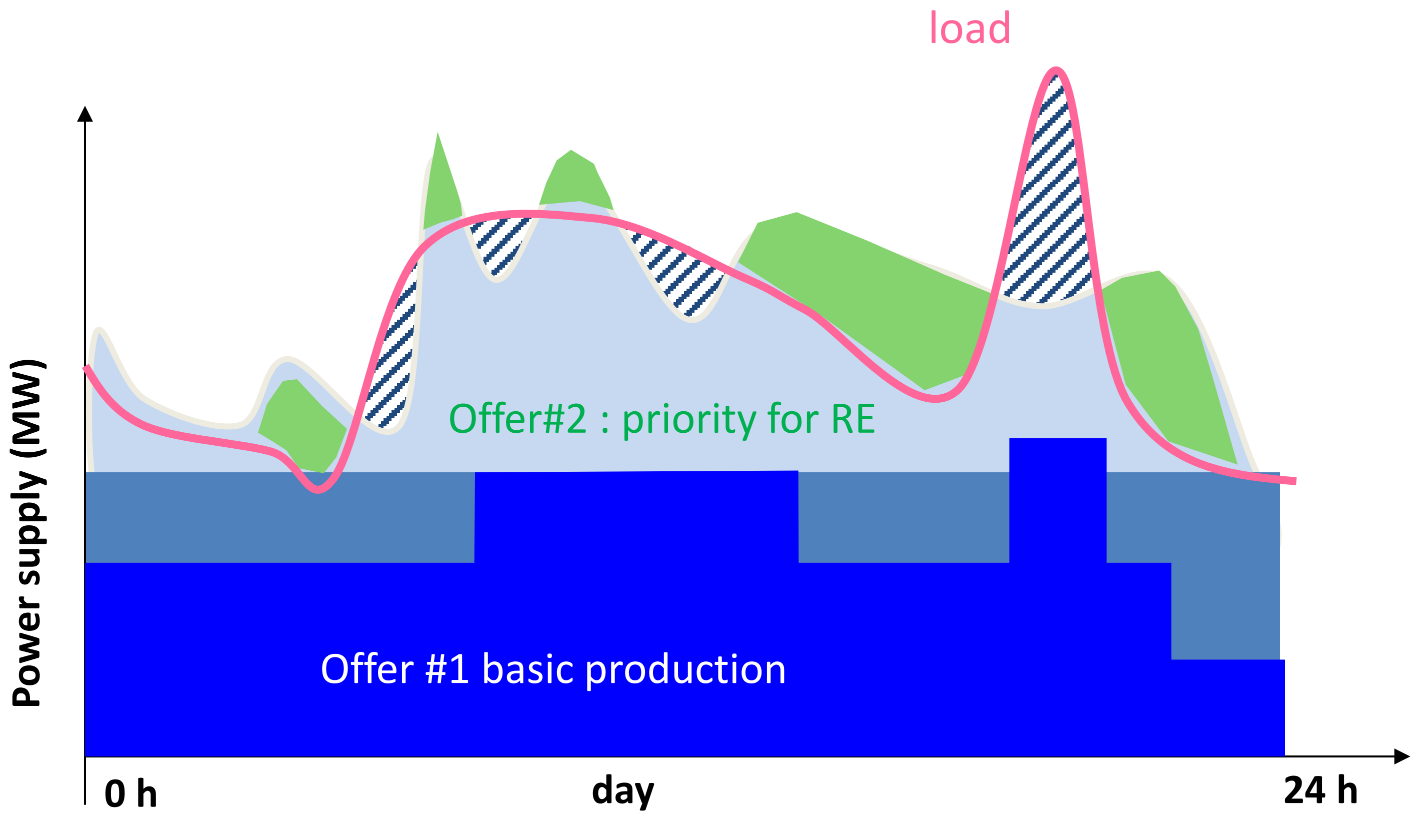
The Merit Order effect as of 2012 in EU



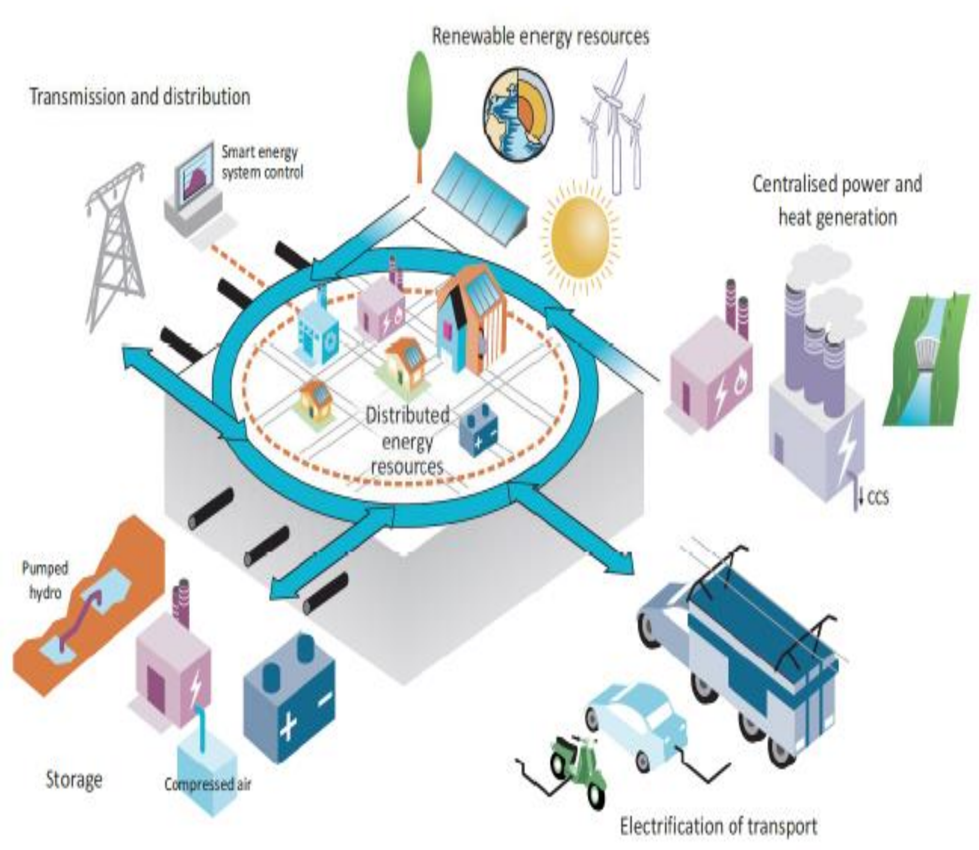
Source: IHS CERA. 20509-15

Make the consumption flexible

- Control the load profile
- Allow the development of shaving capacities

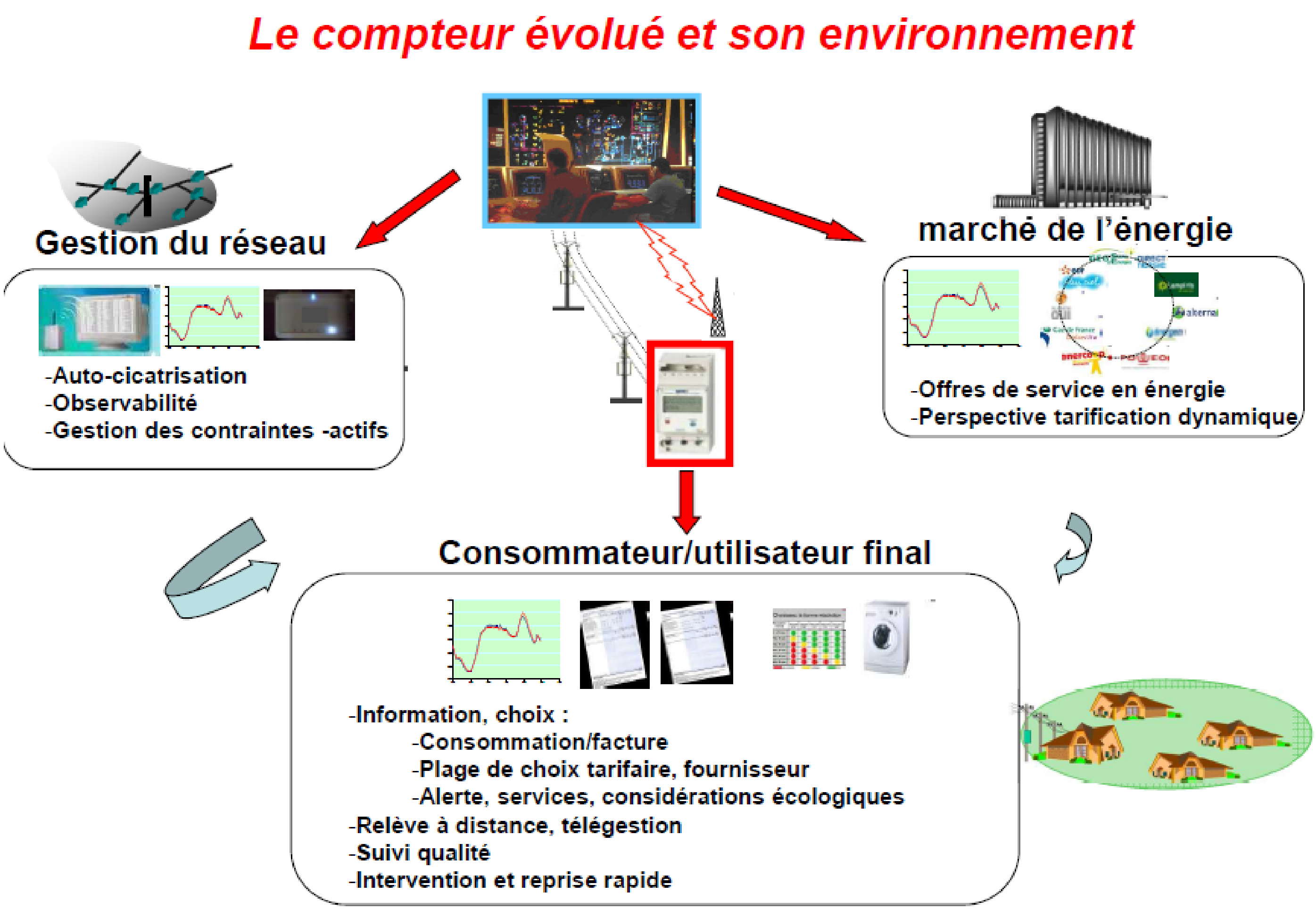


Smart distribution grid concept



- Faciliter l'injection d'EnR
  - *Participation des Enr aux services systèmes*
  - *Limiter l'impact de l'intermittence (prévision, stockage)*
  - *Réseaux inter-continentaux*
  - *Adapter la demande à l'offre : pilotage de la demande*
- Favoriser la MDE / MDP
  - *Limiter les pertes sur le réseau / favoriser l'efficacité énergétique du réseau*
  - *Faciliter le déploiement chez les consommateurs (interopérabilité, confidentialité des données)*
  - *Impliquer les consommateurs (information, appropriation des nouvelles techno, aspect sociologique)*
- Anticiper l'évolution des réseaux et des usages et tester de nouveaux modèles d'affaires
  - *Effacer plutôt que produire : métier d'agrégateur*
  - *Agréger les productions renouvelables*
  - *Faciliter la communication entre les différentes échelles du réseau*
  - *Synergie avec opérateurs Internet*
  - *Intégrer les nouveaux usages (VE…)*

Smart meter

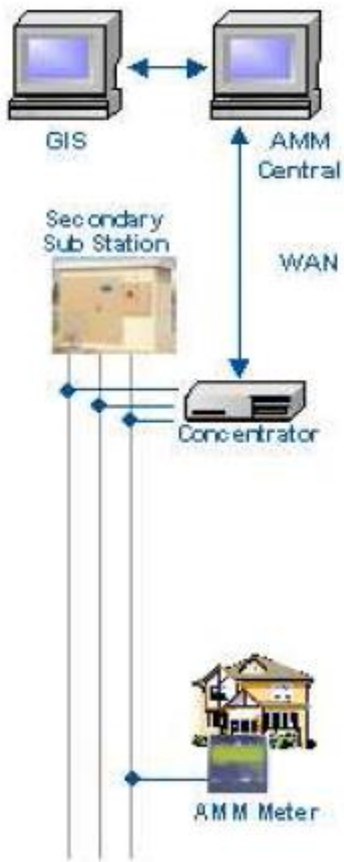

Le compteur évolué et son environnement
Gestion du réseau
-Auto-cicatrisation
-Observabilité
-Gestion des contraintes -actifs
marché de l'énergie
-Offres de service en énergie
-Perspective tarification dynamique
Consommateur/utilisateur final
-Information, choix :
-Consommation/facture
-Plage de choix tarifaire, fournisseur
-Alerte, services, considérations écologiques
-Relève à distance, télégestion
-Suivi qualité
-Intervention et reprise rapide

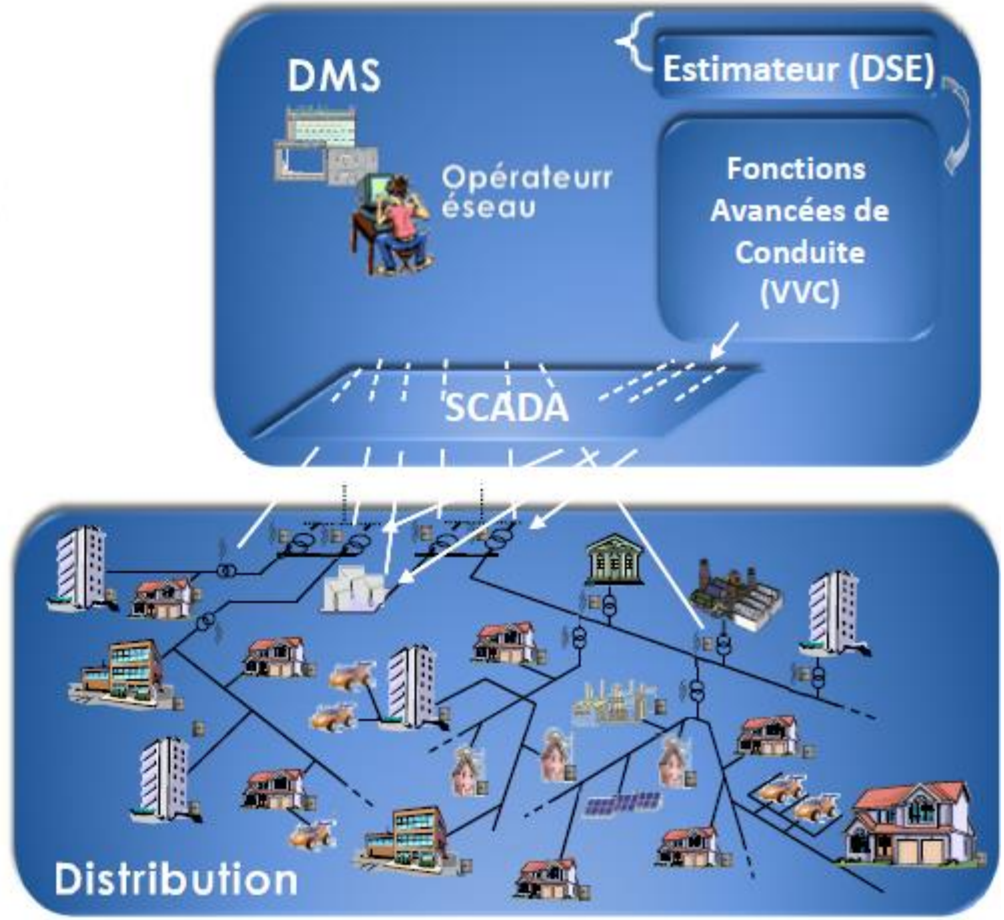
Grid Observability

Linky

Projet ERDF

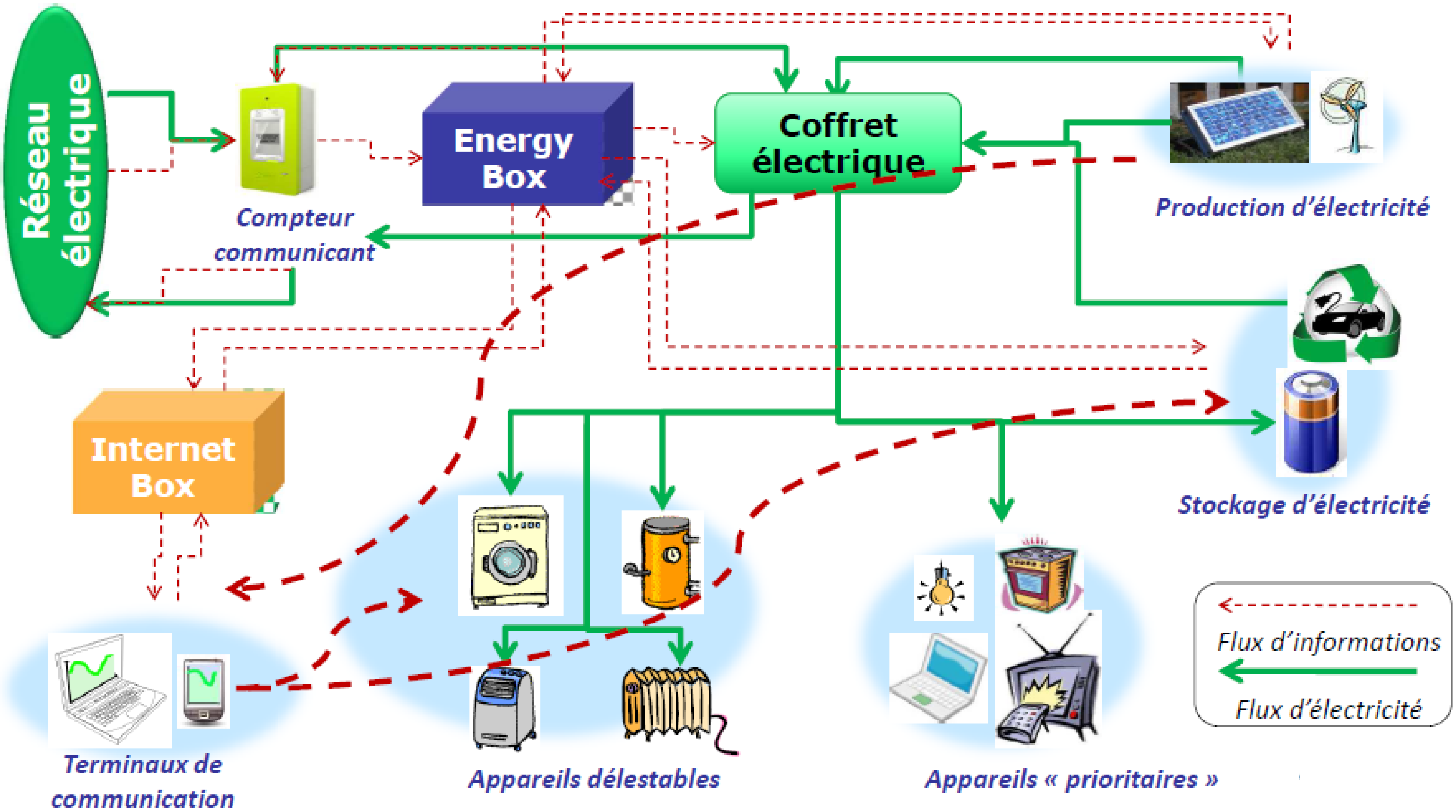
Compteur intelligent



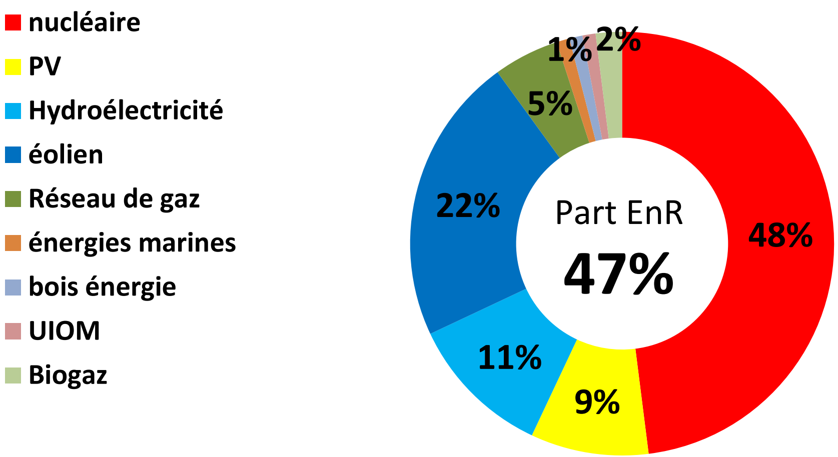


AMM : advanced metering management VVC : voltage/VAR control DMS : distribution Management system

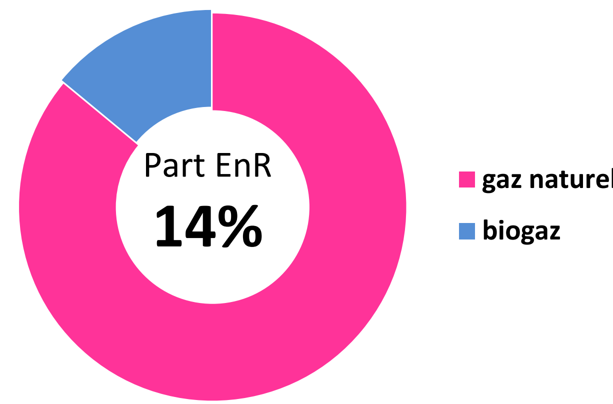
Energy box as energy manager



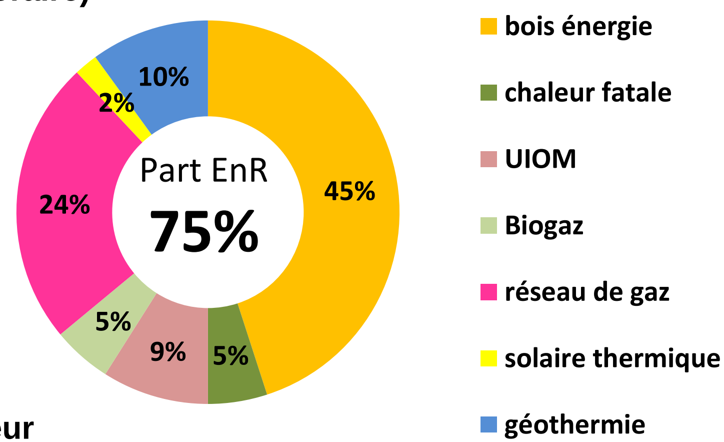
France : mix énergétique 2030



Mix électrique (équilibré au pas horaire)

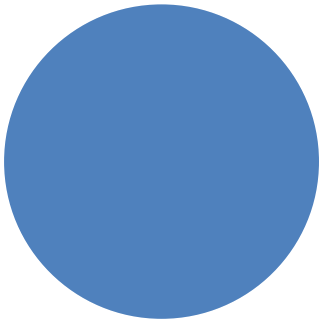


Mix du réseau de gaz



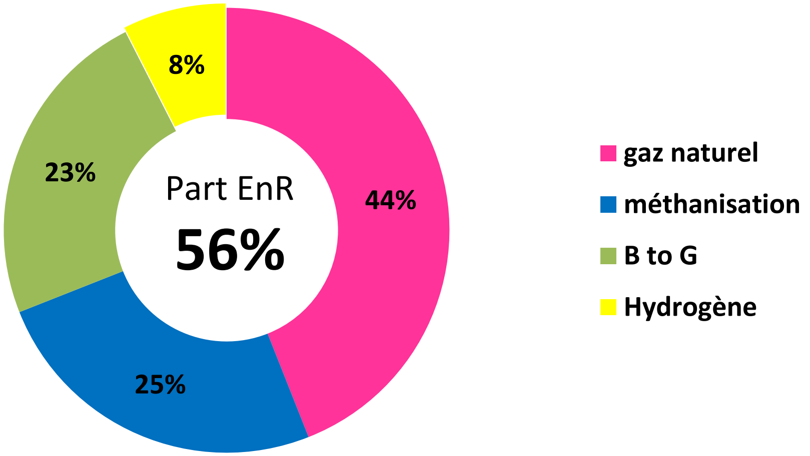
Mix du réseau de chaleur

France : mix énergétique 2050

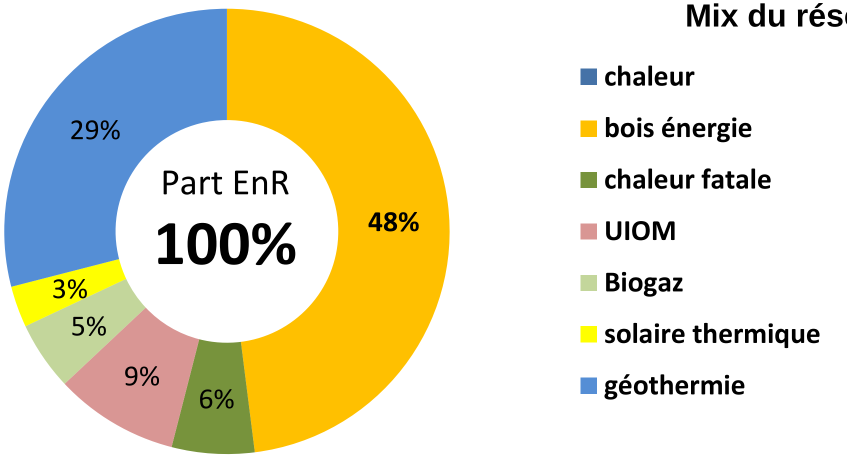


Pas de mix modélisé en 2050

Mix électrique



Mix du réseau de gaz

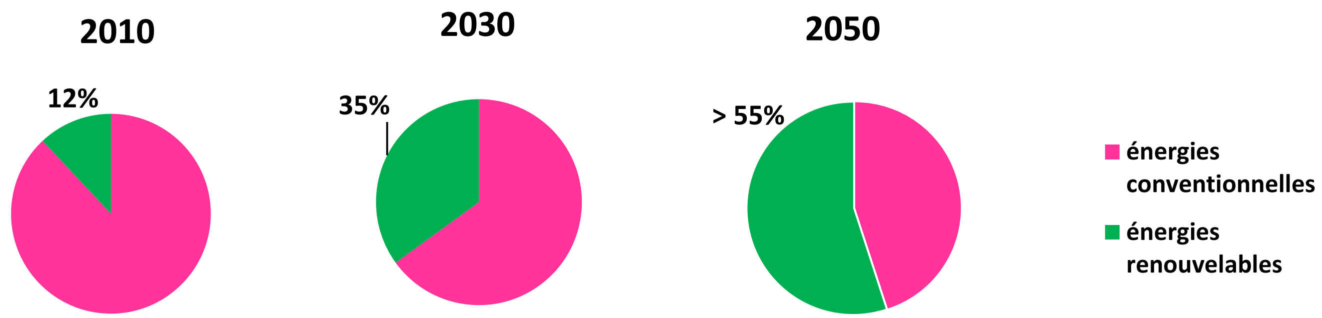


Mix du réseau de chaleur

Ademe :Bilan des scenarios 2030-2050

- Réduction de 50% de la demande d'énergie à l'horizon 2050
- Une part croissante et maitrisée des énergies renouvelables

Bilan en énergie



151 MTep | 123 MTep (-18%) | 82 MTep (- 46%)

Bilan en GES

1990 : **525** Mt CO_2 eq

2030 : **313** Mt CO_2 eq (- 40%)

2050 : **131** Mt CO_2 eq (- 75%)

Climate policy scenario

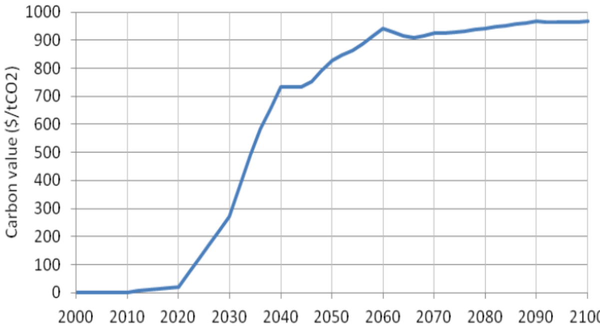


Figure L-1: Carbon value in the climate policy scenario (exogenous assumption).

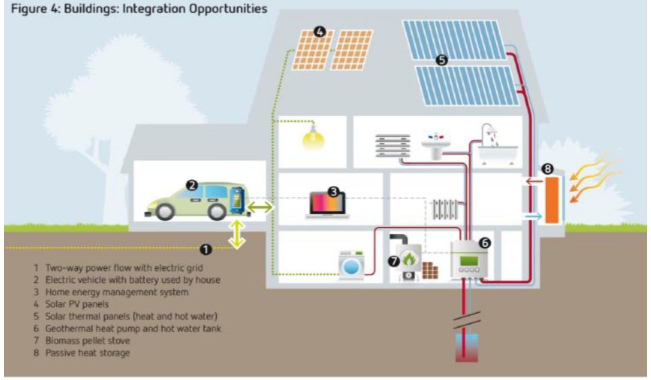
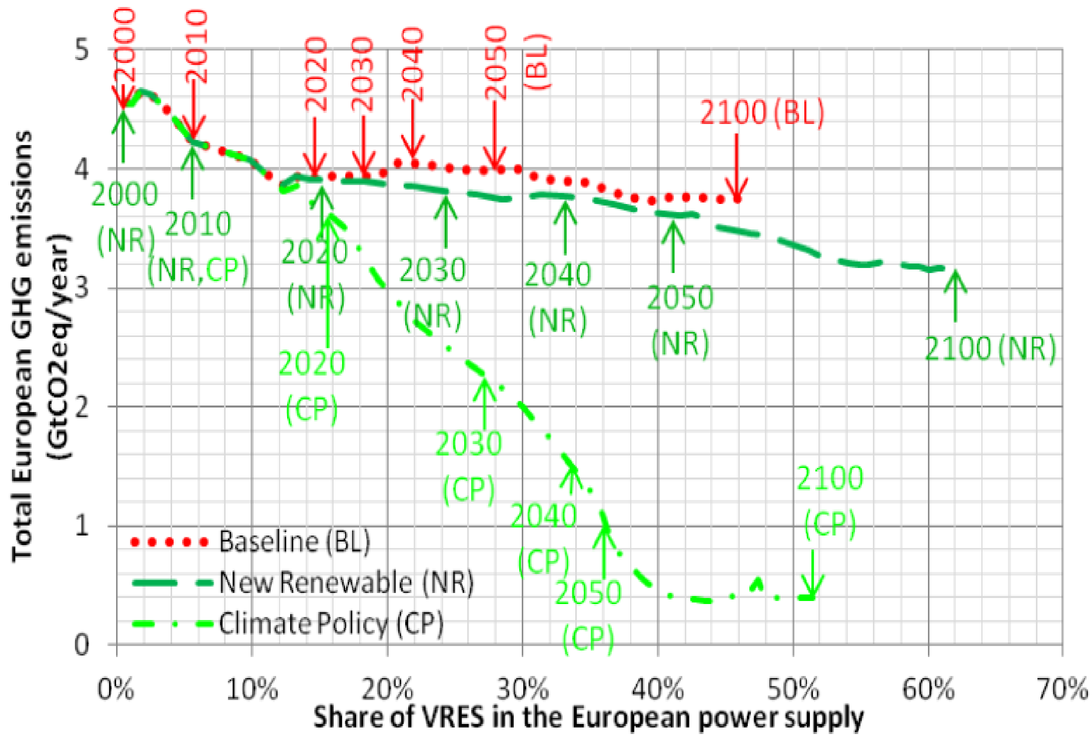


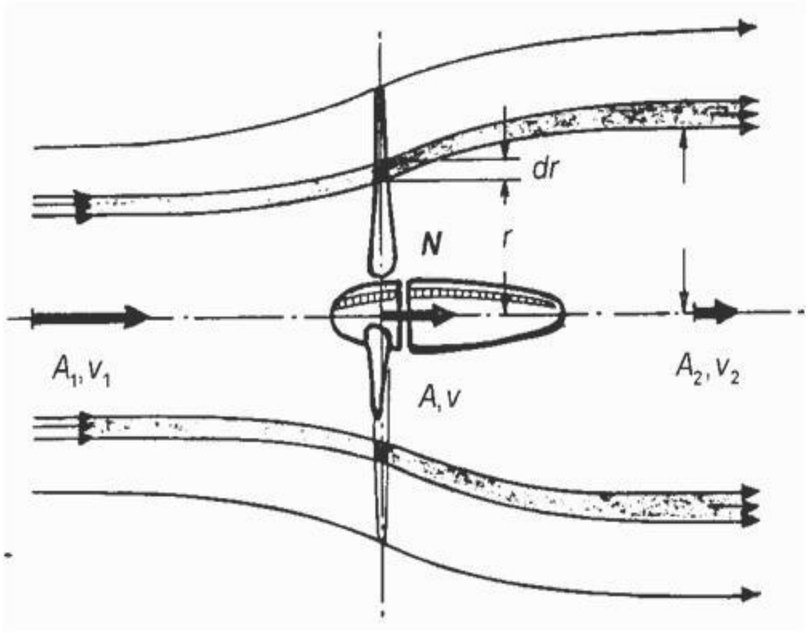
Figure 4: Buildings: Integration Opportunities

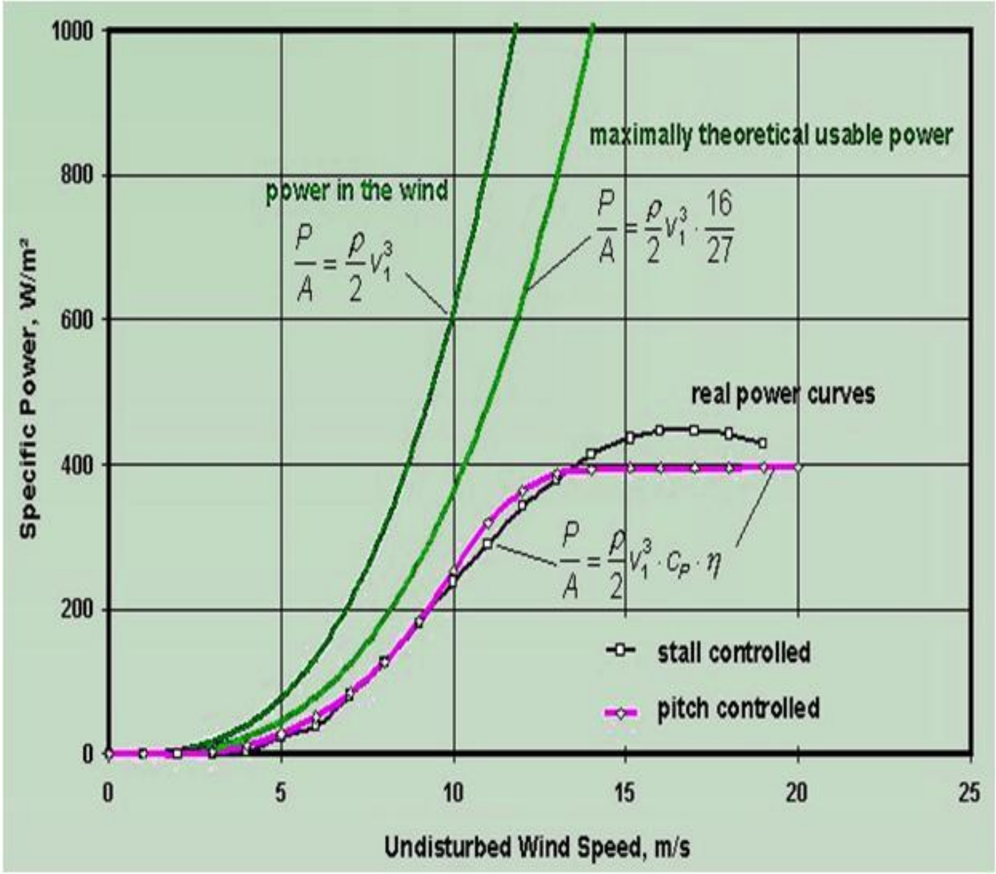


BL : no specific energy policy
NR : low investment cost for RE technologies
CP : evolution of the CO2 value

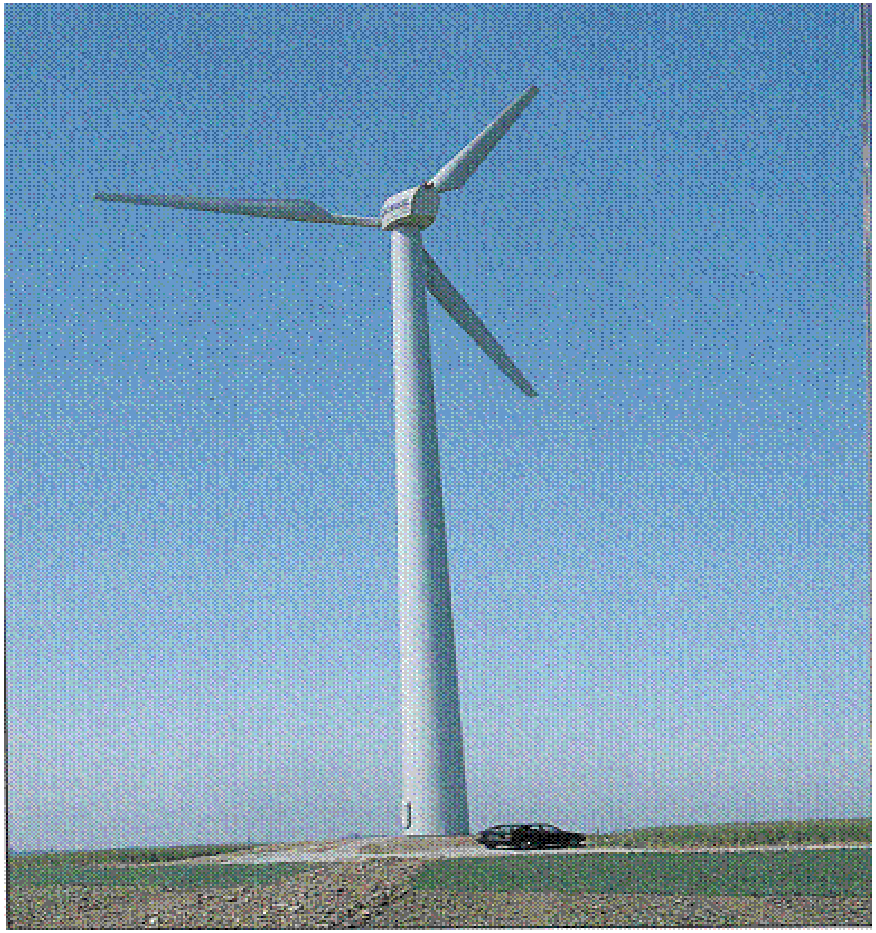
Wind

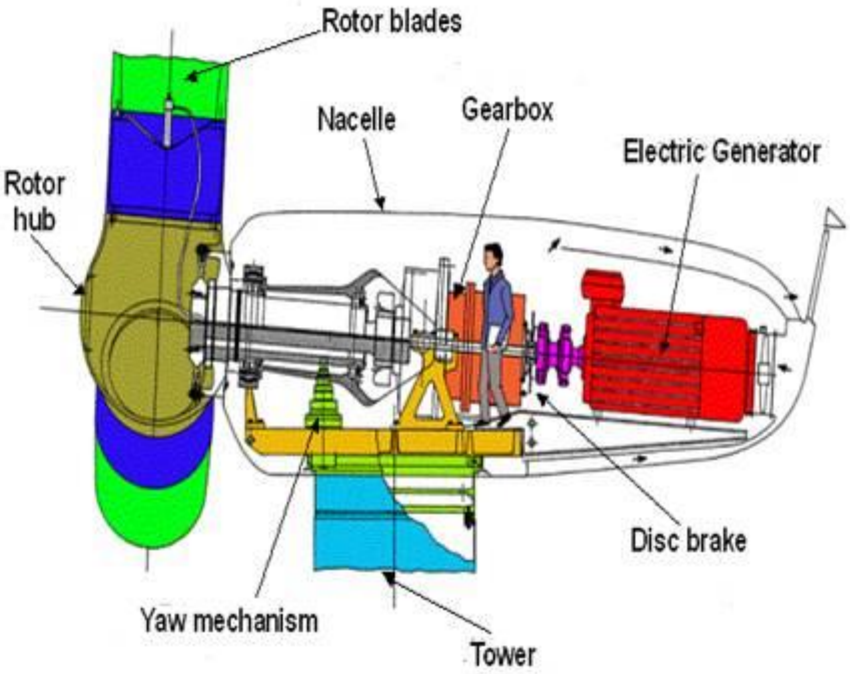
Power density of a wind turbine



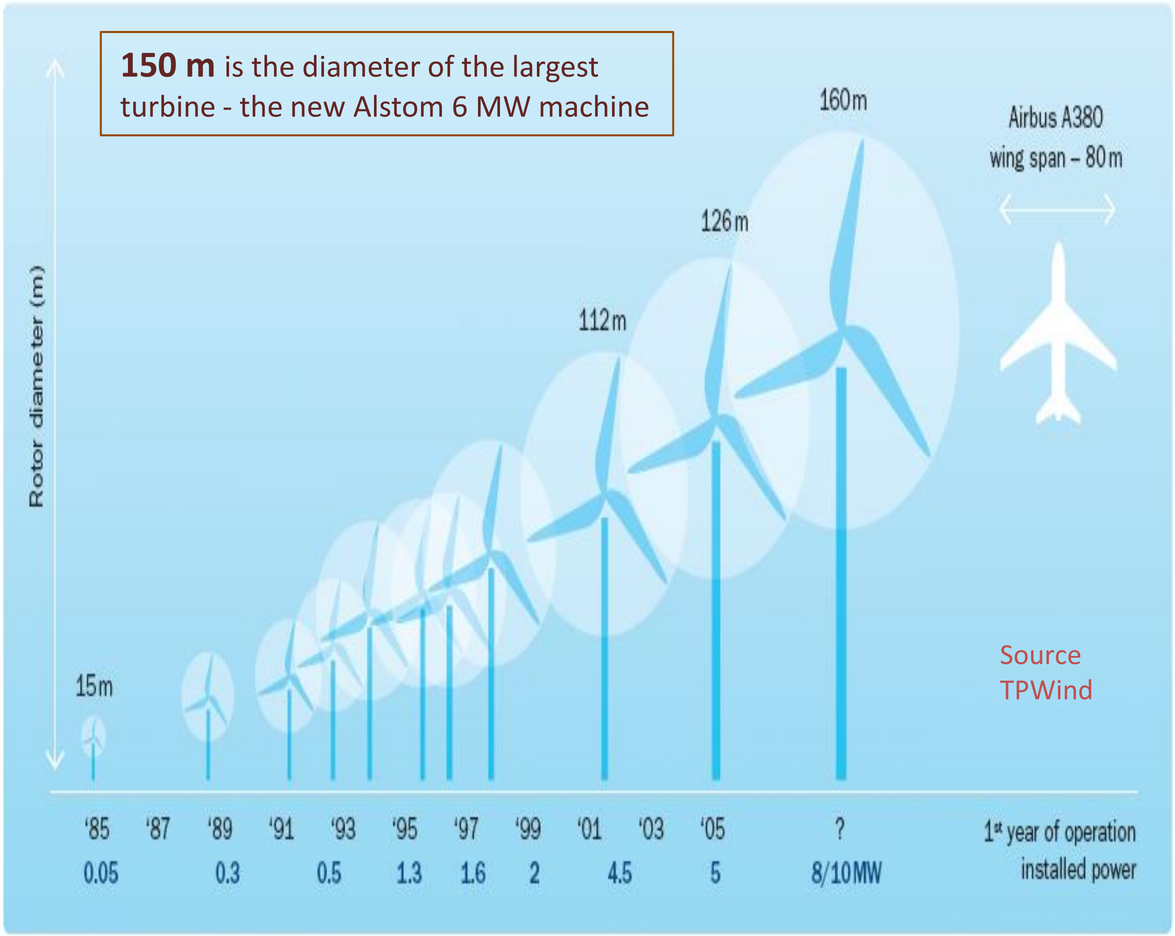


Turbines

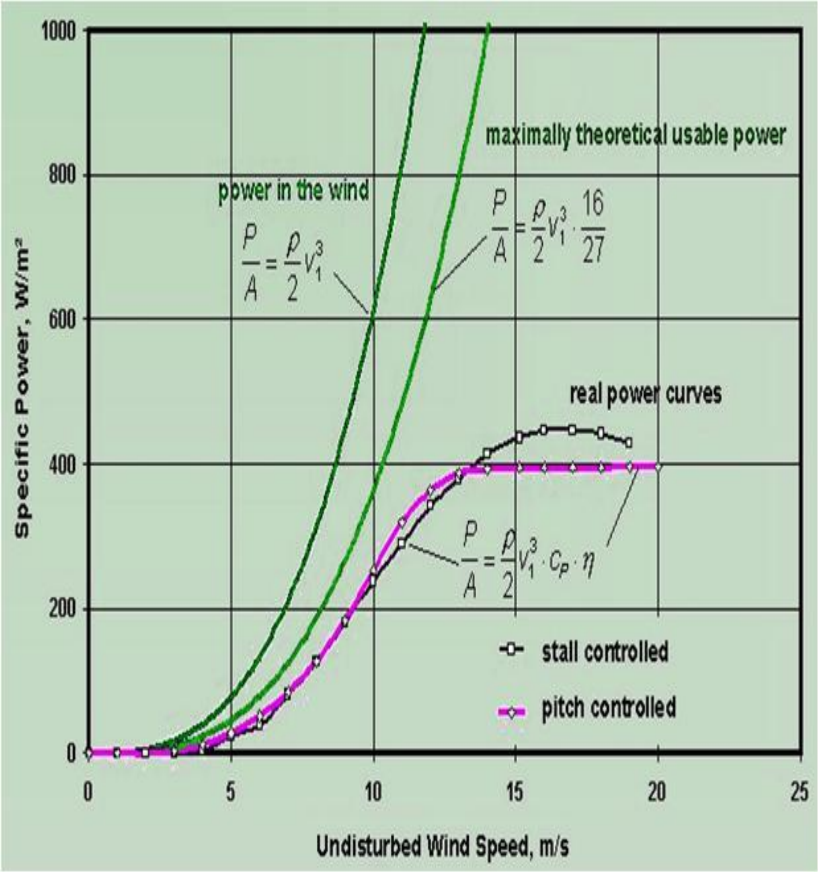



Rotor blades
Nacelle
Gearbox
Electric Generator
Rotor
hub
Disc brake
Yaw mechanism
Tower

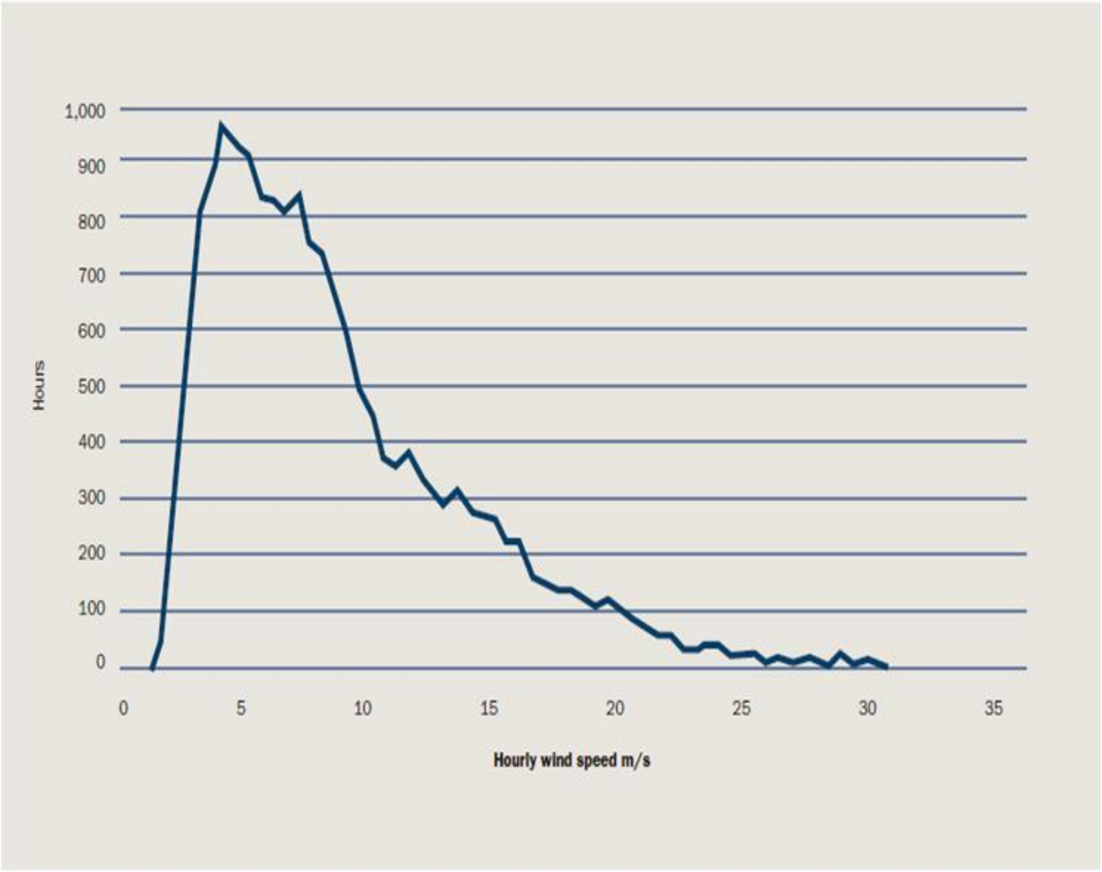
Evolution of the wind turbine size



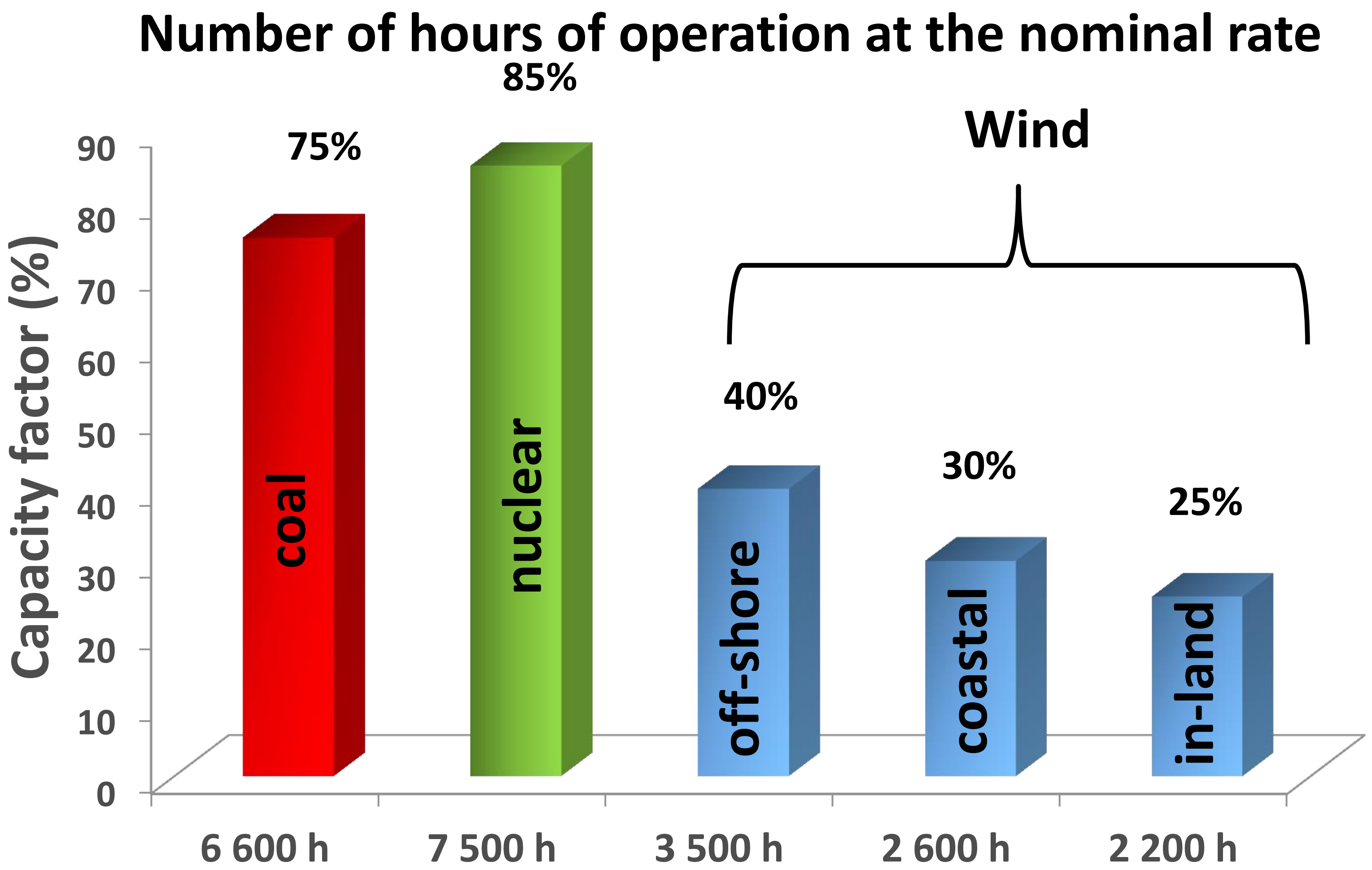
Frequency of wind speed – capacity factor



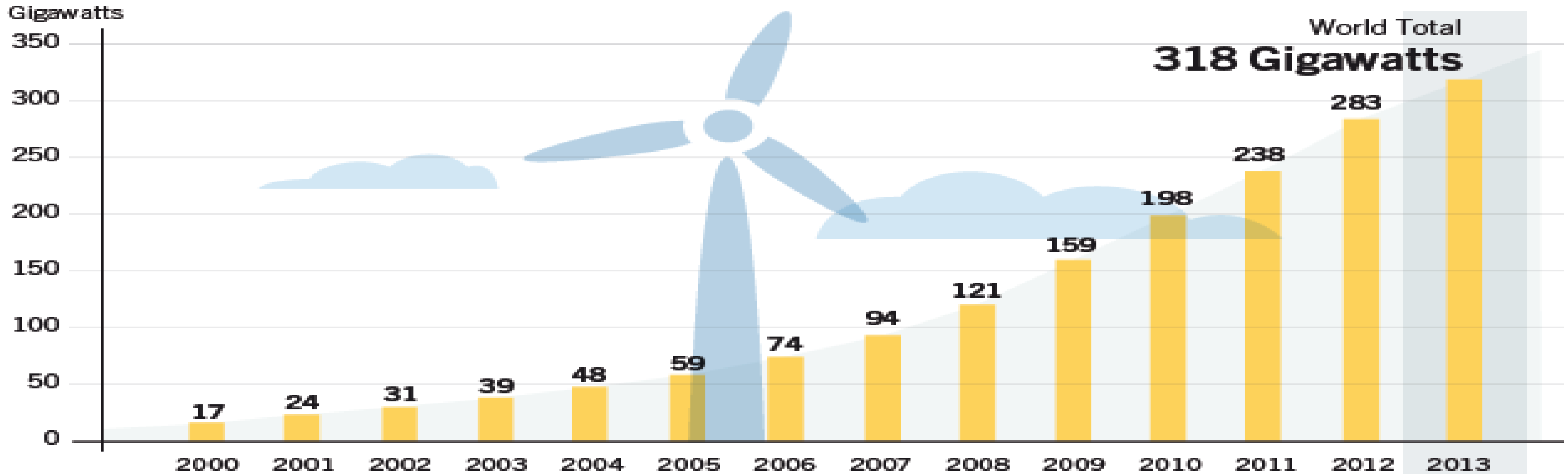
Typical wind farm site

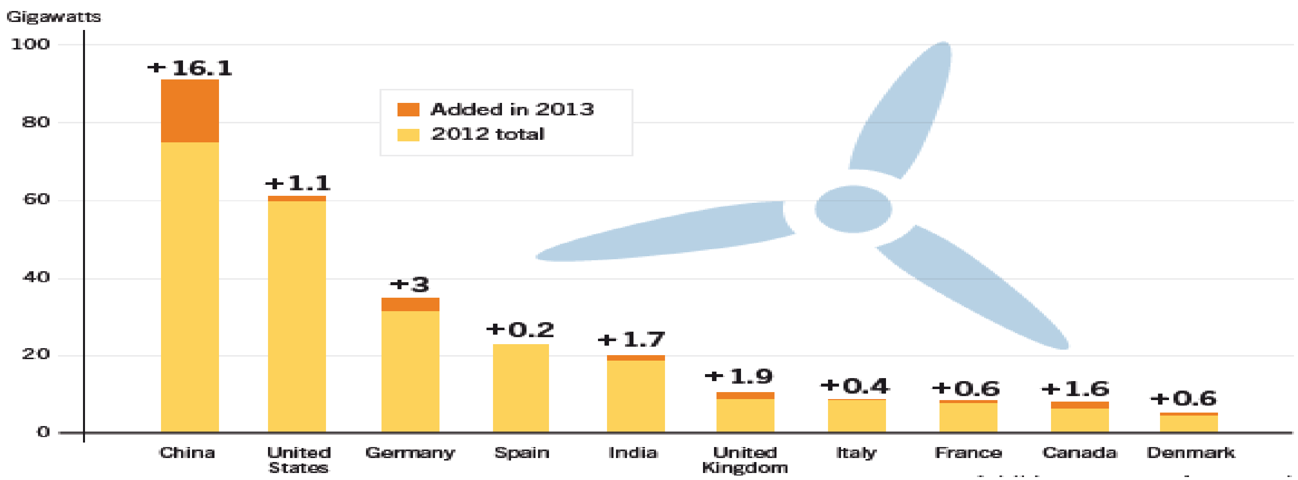


Capacity factor



Global wind power installed capacity (GW)

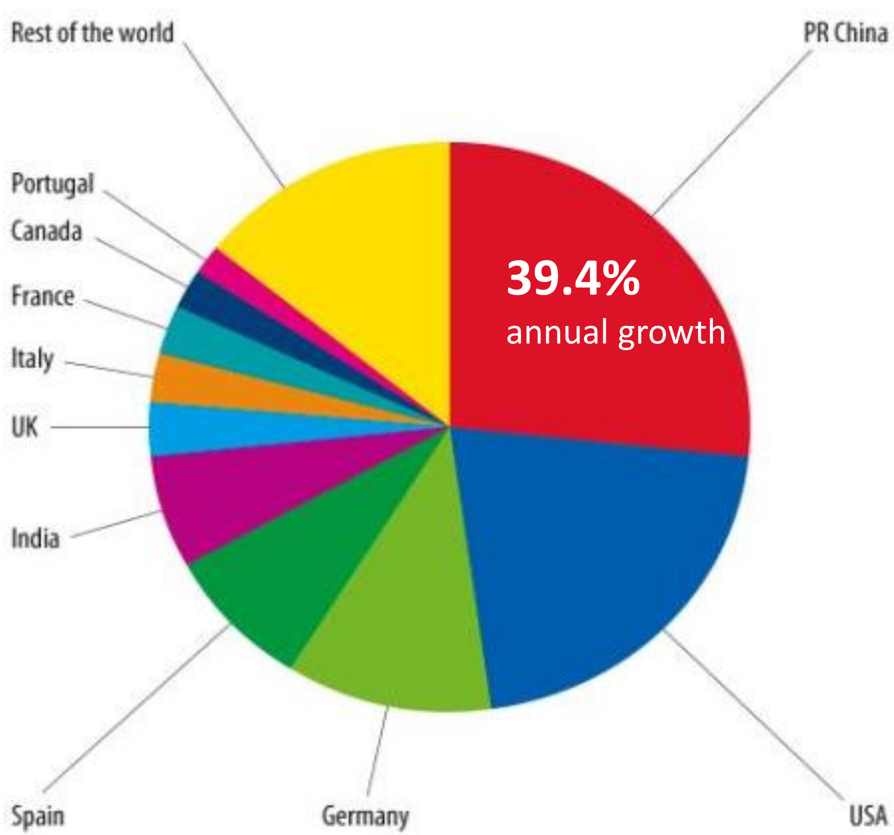


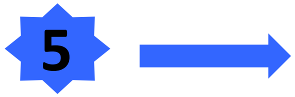


240 000
wind turbines

Cumulative wind power installations (GW) and market share in the EU

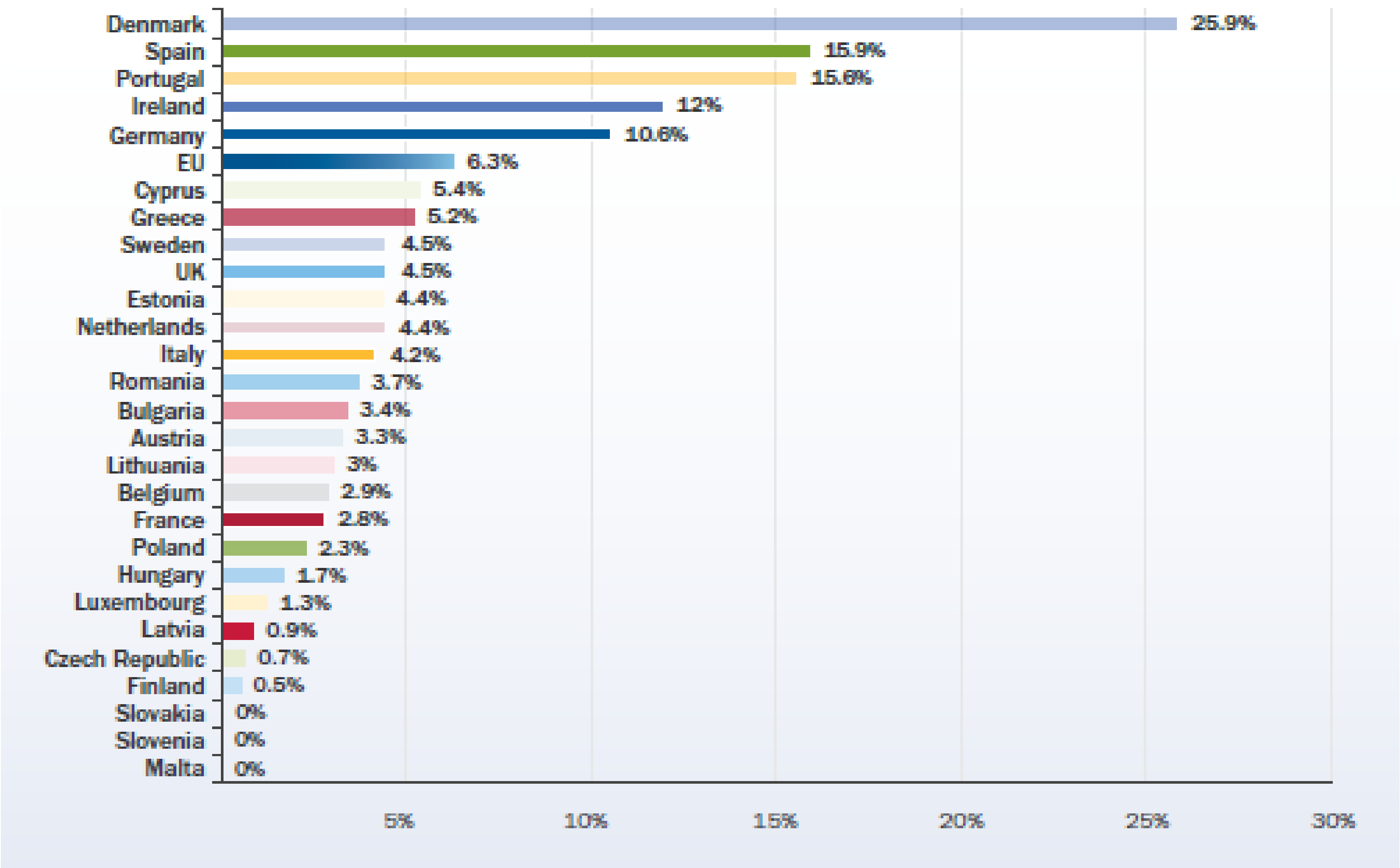
Top 10 Cumulative Capacity (December 2012)





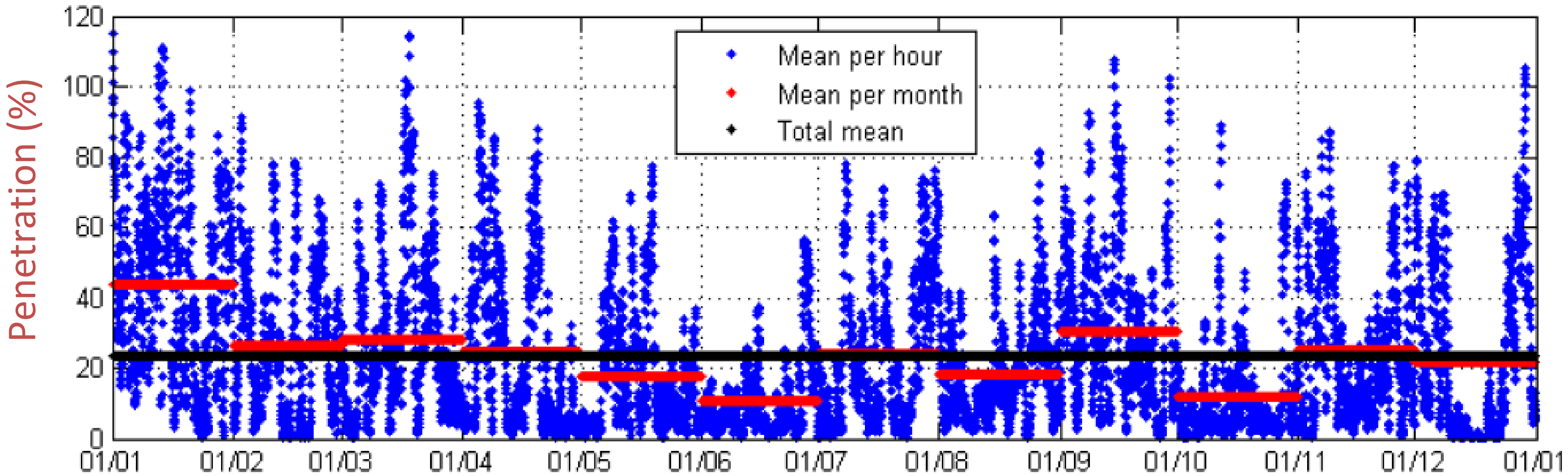
Germany	31,308
Spain	22,796
UK	8,445
Italy	8,144
France	7,564
Portugal	4,525
Denmark	4,162
Sweden	3,745
Poland	2,497
Netherlands	2,391
Turkey	2,312
Romania	1,905
Greece	1,749
Ireland	1,738
Austria	1,378
Rest of Europe [(3)]	4,922
Total Europe	109,581

Wind share of total electricity consumption



Examples of high penetration (Denmark)

Hourly wind power in percent of hourly consumption in Denmark (DK1 area) in 2007



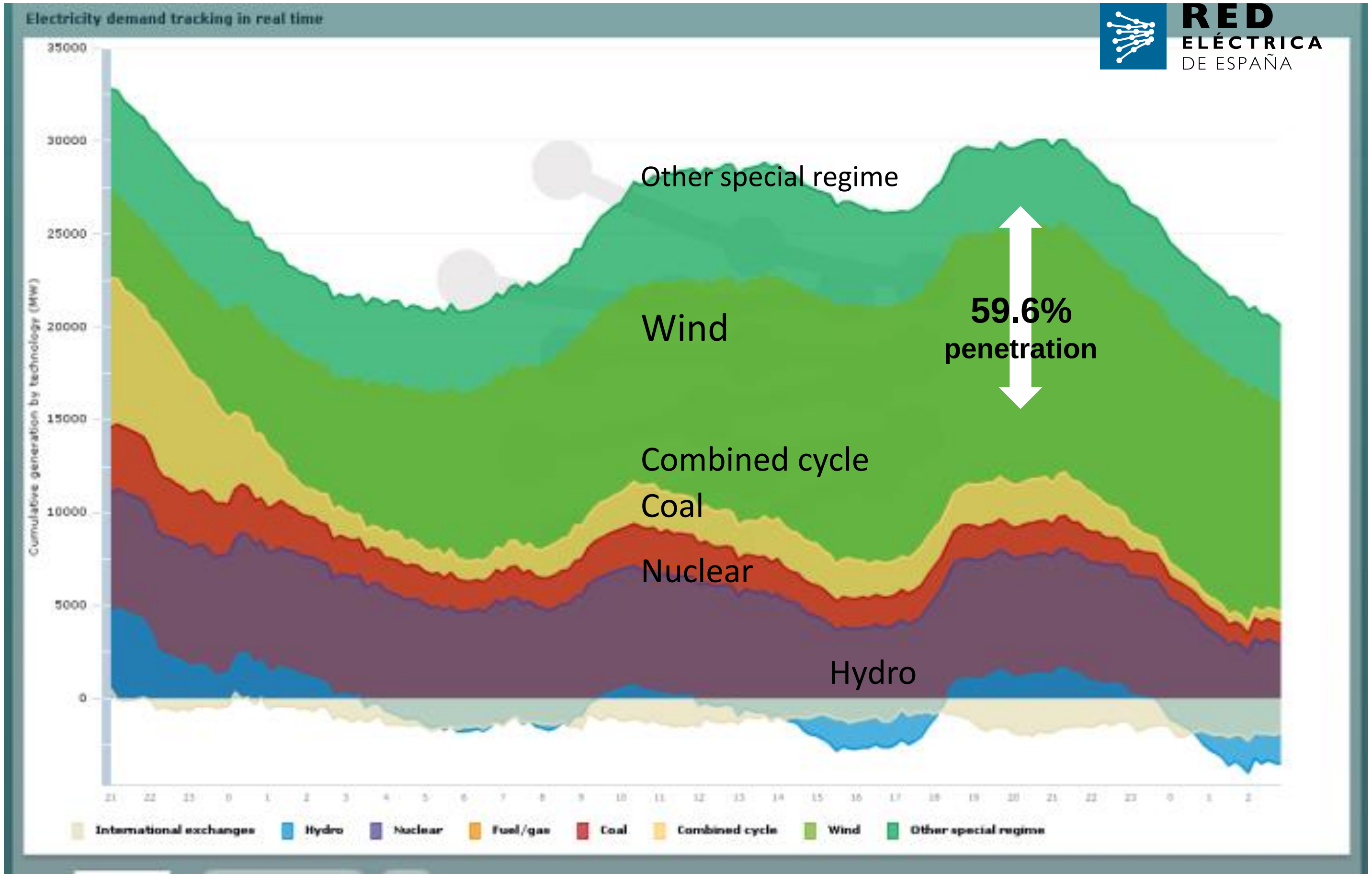
Source: Mines ParisTech

30% of Denmark's electricity consumption was covered by wind energy in 2011.

Targets: 50% of its electricity from wind by 2020 and 100% from renewable energy by 2050.

Examples of high penetration (Spain)

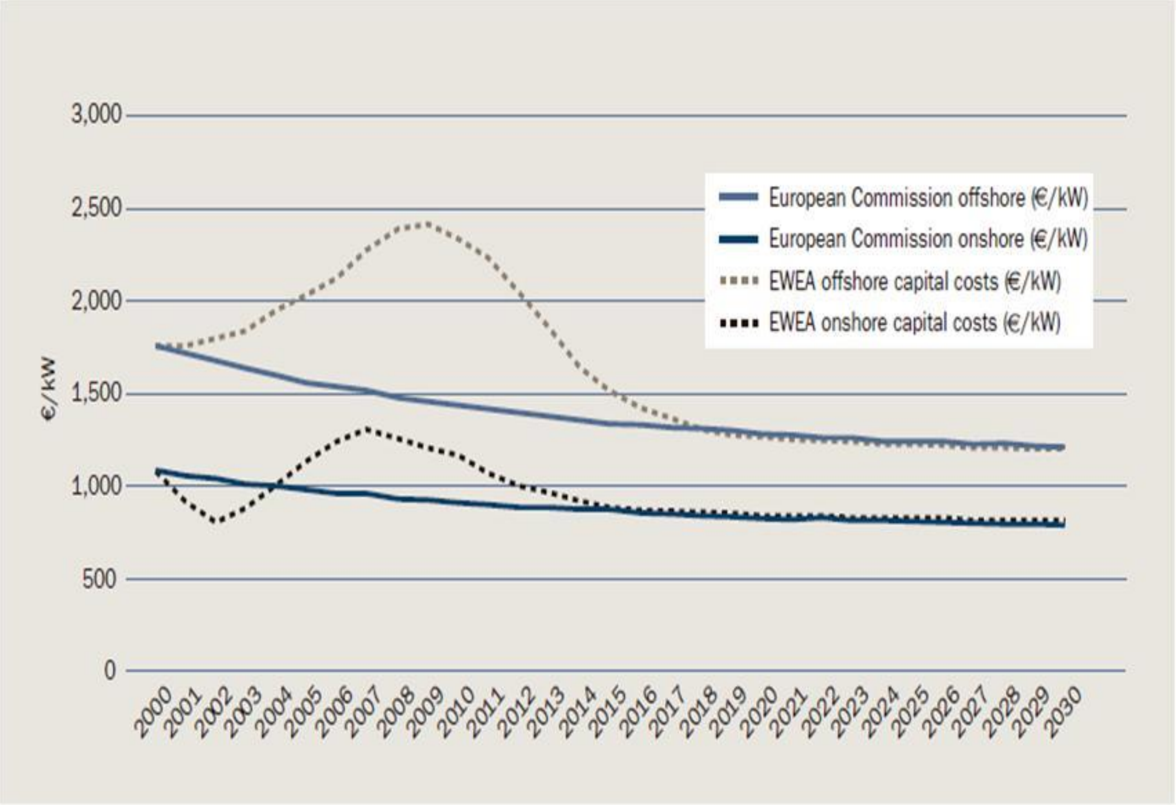
Daily profile of wind generation in Spain (11/6/2011)



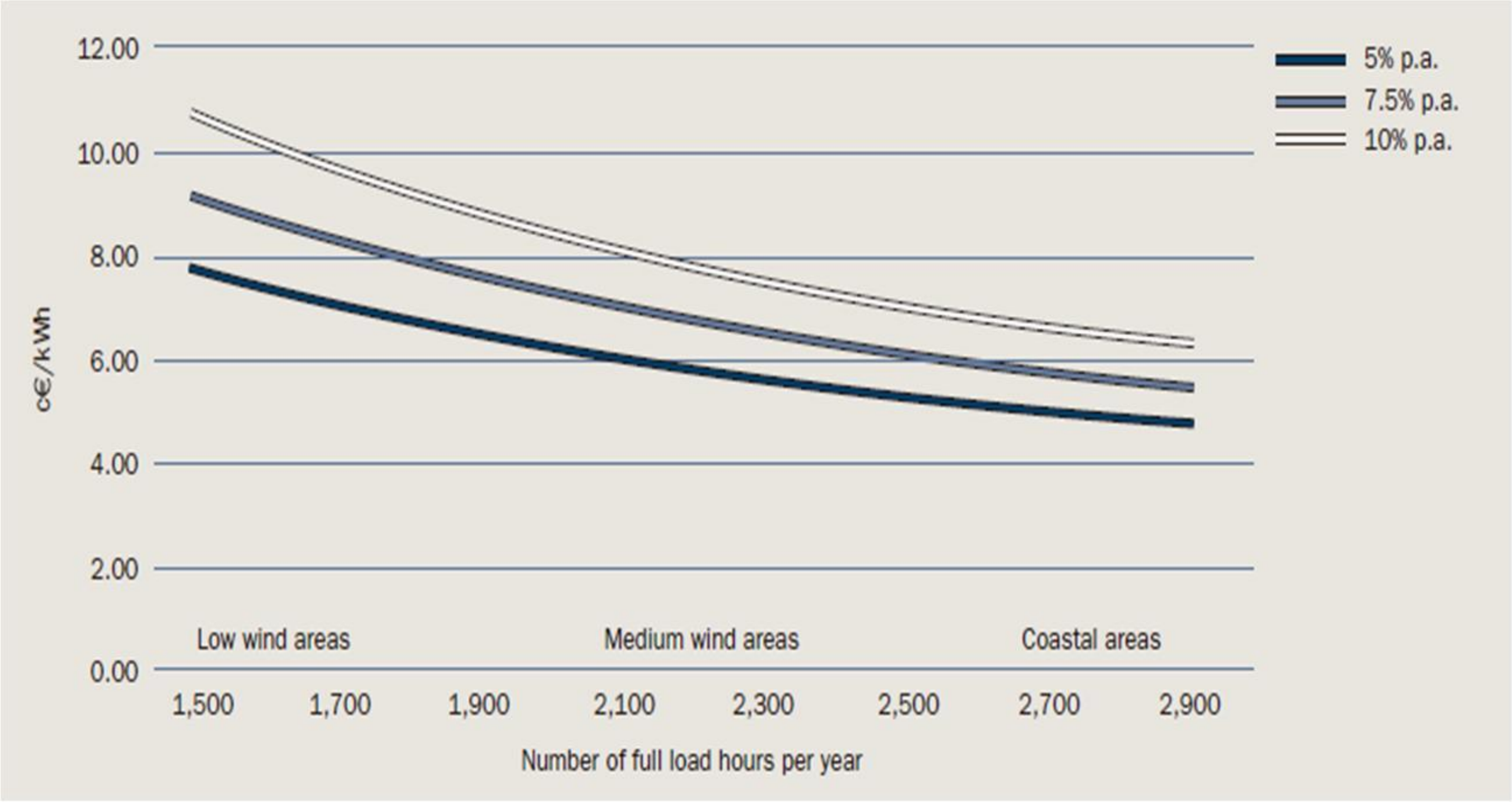
Investment costs

	INVESTMENT (€1,000/MW)	SHARE OF TOTAL COST %
Turbine (ex works)	928	75.6
Grid connection	109	8.9
Foundation	80	6.5
Land rent	48	3.9
Electric installation	18	1.5
Consultancy	15	1.2
Financial costs	15	1.2
Road construction	11	0.9
Control systems	4	0.3
TOTAL	**1,227**	**100**

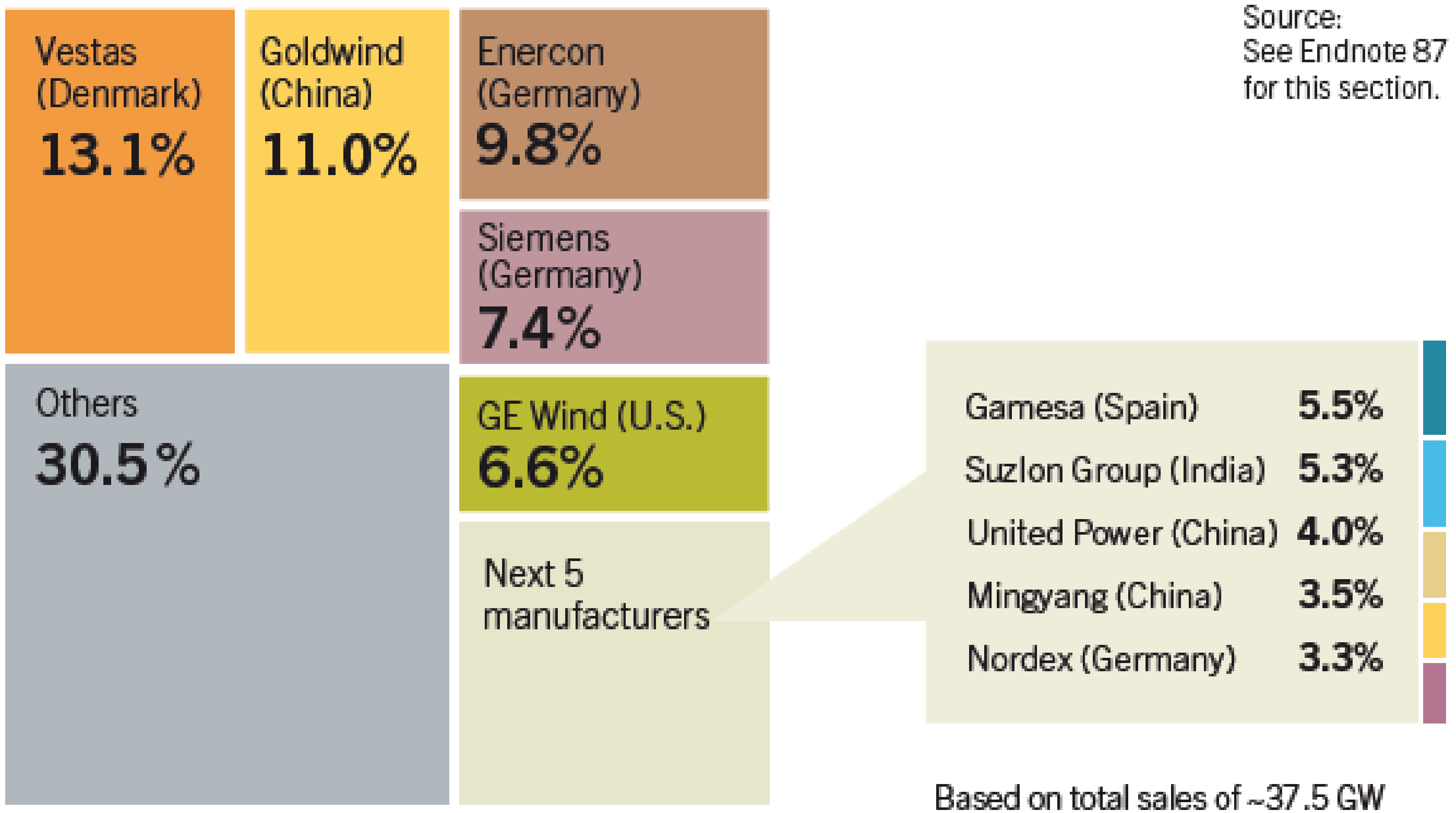
Note: Calculated by the author based on selected data for European wind turbine installations



Cost of wind power
as a function of wind speed and discount rate

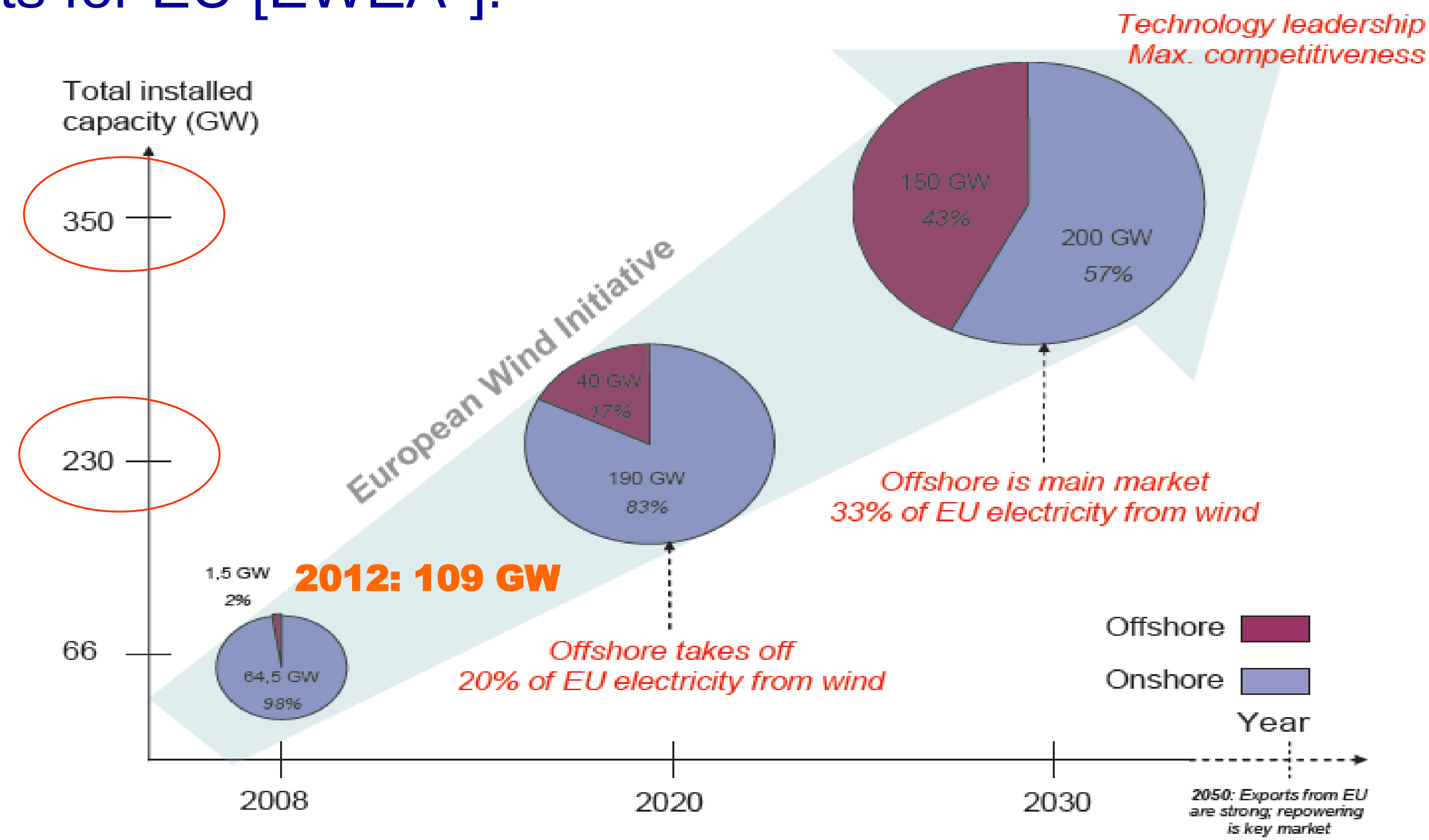


Market share of the top 10 Wind Turbine manufacturers in 2013



Wind Energy : What is the future?

Targets for EU [EWEA*]:



(*) EWEA : European Wind Energy Association

Area used for 20% wind in 2030

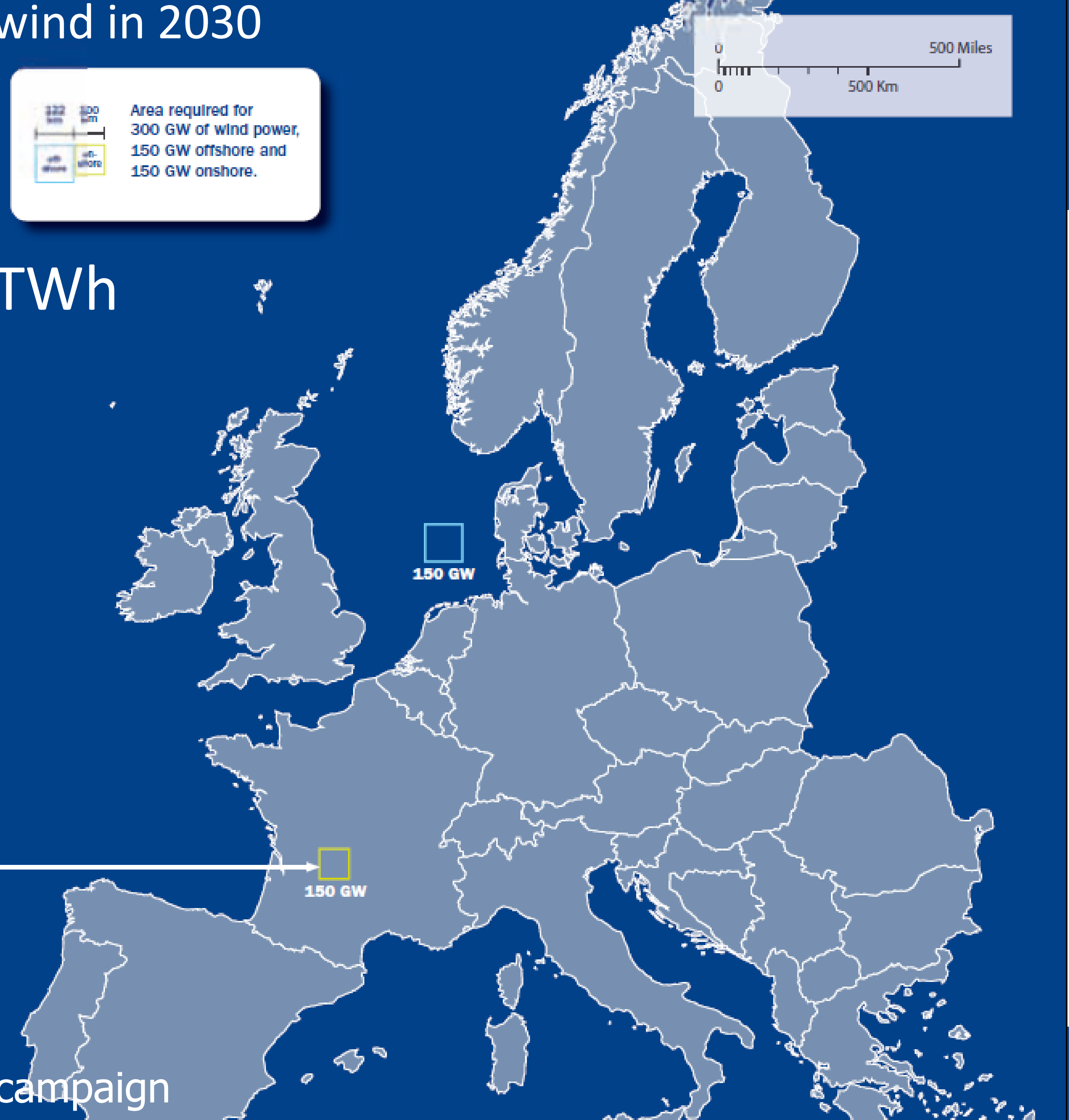
300 GW = 965 TWh

122×122 km^2

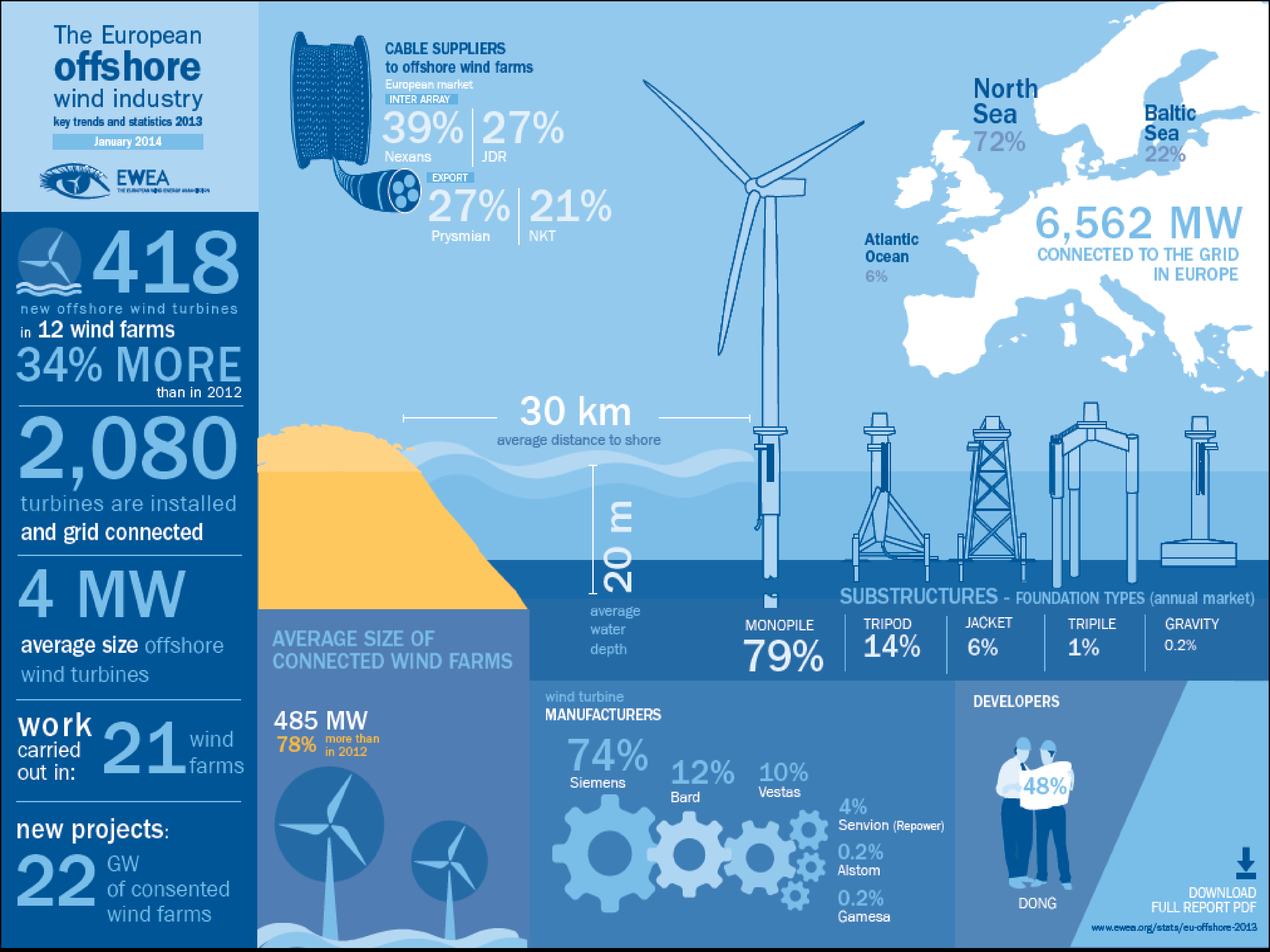
Offshore

100×100 km^2

onshore



Source: EWEA no fuel campaign


The European
offshore
wind industry
key trends and statistics 2013
January 2014
EWEA
418
new offshore wind turbines
in 12 wind farms
34% MORE
than in 2012
2,080
turbines are installed
and grid connected
4 MW
average size offshore
wind turbines
work carried out in: 21 wind farms
new projects:
22 GW
of consented
wind farms
CABLE SUPPLIERS
to offshore wind farms
European market
INTER ARRAY
39% Nexans
27% JDR
EXPORT
27% Prysmian
21% NKT
North Sea 72%
Baltic Sea 22%
Atlantic Ocean 6%
6,562 MW
CONNECTED TO THE GRID IN EUROPE
30 km
average distance to shore
20 m
average water depth
SUBSTRUCTURES - FOUNDATION TYPES (annual market)
MONOPILE 79%
TRIPOD 14%
JACKET 6%
TRIPILE 1%
GRAVITY 0.2%
AVERAGE SIZE OF CONNECTED WIND FARMS
485 MW
78% more than in 2012
wind turbine
MANUFACTURERS
74% Siemens
12% Bard
10% Vestas
4% Senvion (Repower)
0.2% Alstom
0.2% Gamesa
DEVELOPERS
48%
DONG
DOWNLOAD
FULL REPORT PDF
www.ewea.org/stats/eu-offshore-2013

Key figures

- Capacity factor: 25 % - 40%
- Ratio power / swept area: ~ 400 W/m2
- Life time of turbine : ~20 years
- Investment cost : 1 200 – 2 300 €/kW
- Energy payback time : ~ 6 months

670 000 The number of people employed worldwide by the wind industry in 2011

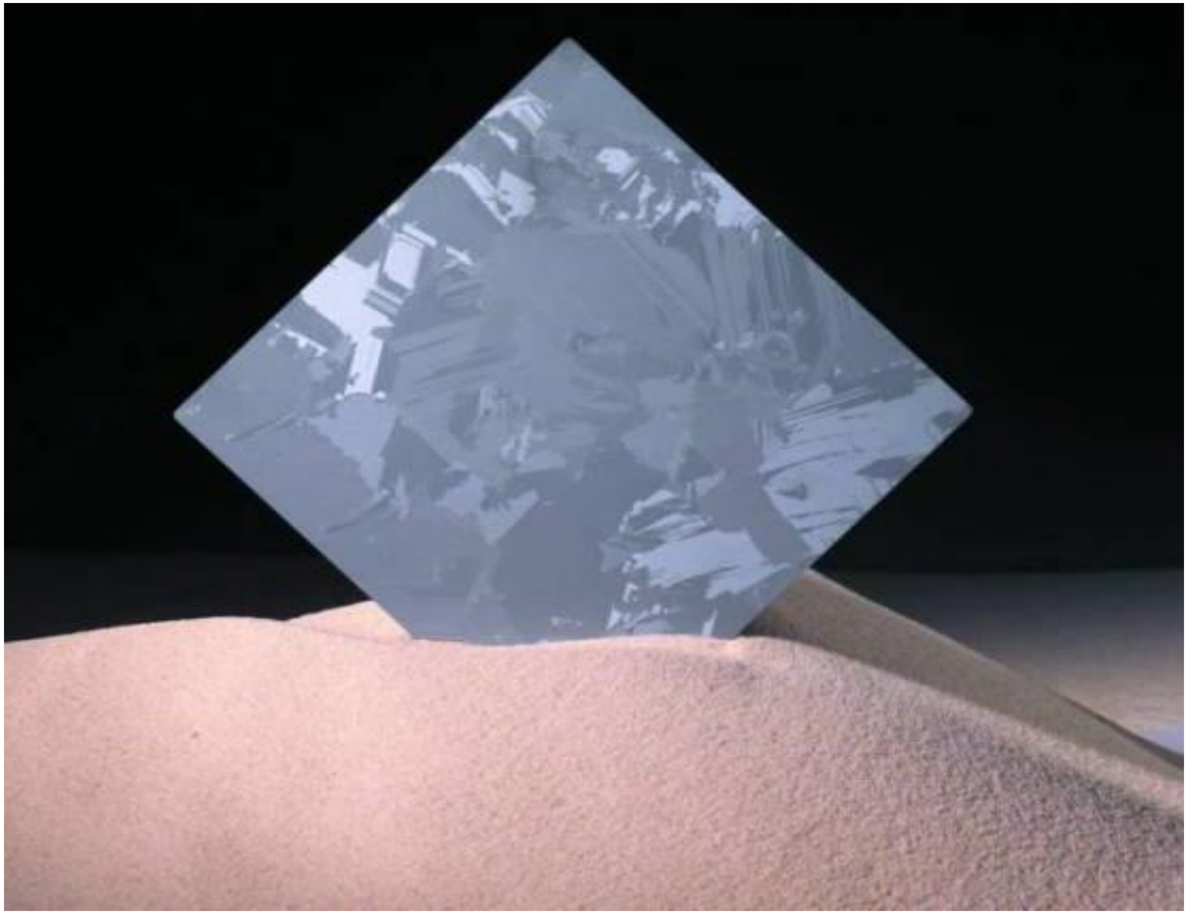
5,7 billion Euro worth of wind industry products and services exported by EU in 2011

2.5% The percentage of world's electricity supplied by wind power. 8-12% by 2020

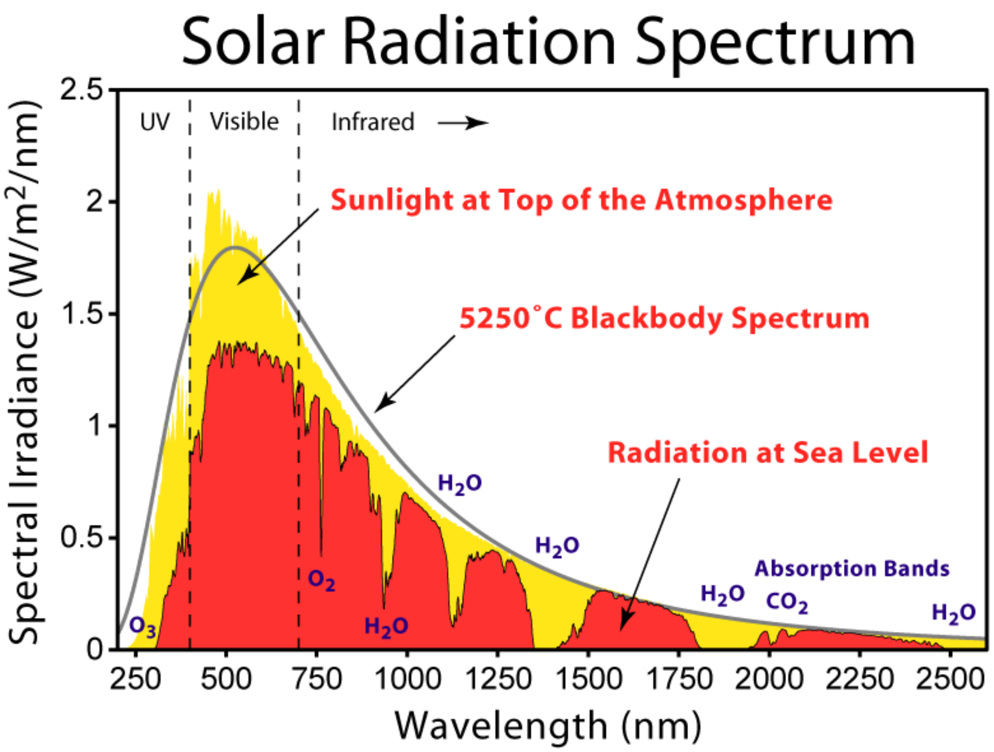
5,500 The number of average EU households that one 6 MW offshore turbine can power

126 Mt of avoided CO_2 emissions in 2010 by the 84 GW wind power in EU =30% of EU cars

Photovoltaics



Spectral distribution of solar irradiation



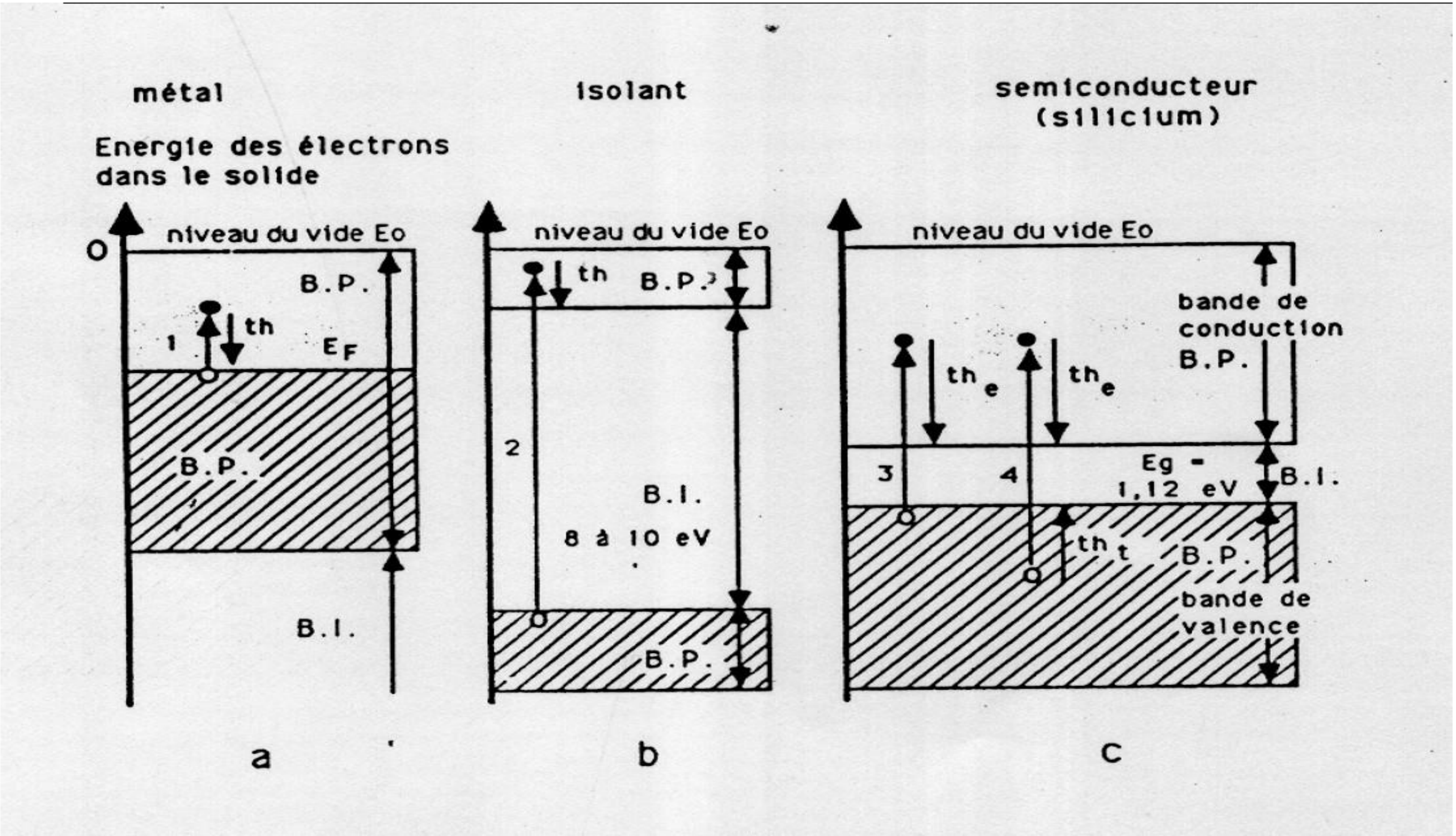
Spectral distribution of a black body at 5 520 K

- ☐ IR : 0,8 < l < 10 µm
- ☐ Visible : 0,4 < l < 0,8 µm
- ☐ UV : 0,12 < l < 0,4 µm
- ☐ Extreme UV : 0,01 < l < 0,12 µm
- ☐ X rays: 10^{-4} < l < 0,01 µm
- ☐ Gamma rays < 10^{-4} µm

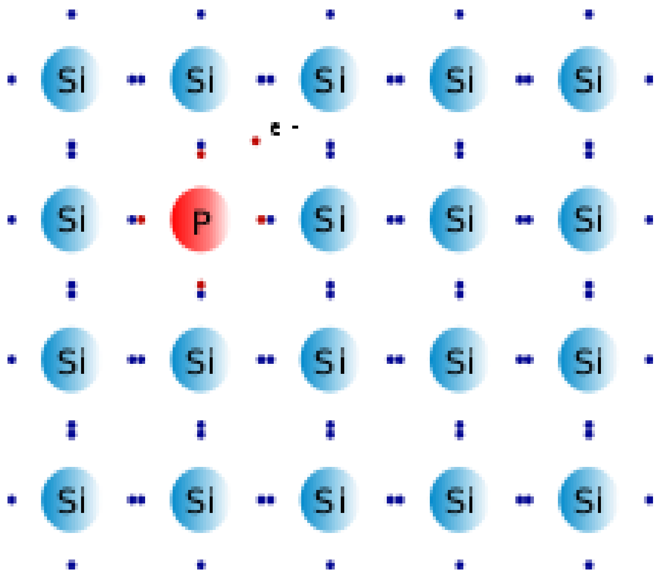
Energy distribution:

- ☐ 98% between 0,3 et 4 µm
- ☐ 8% in UV
- ☐ 48% in visible
- ☐ 42% in near IR

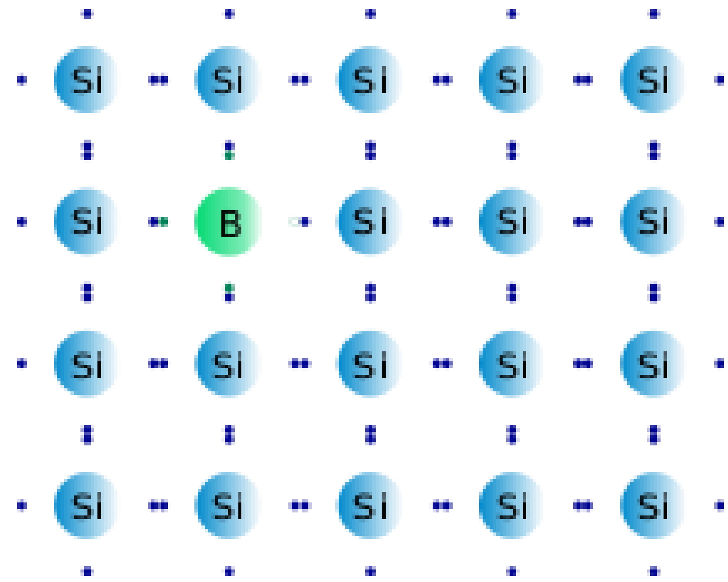
Energy diagram for different materials



Doping

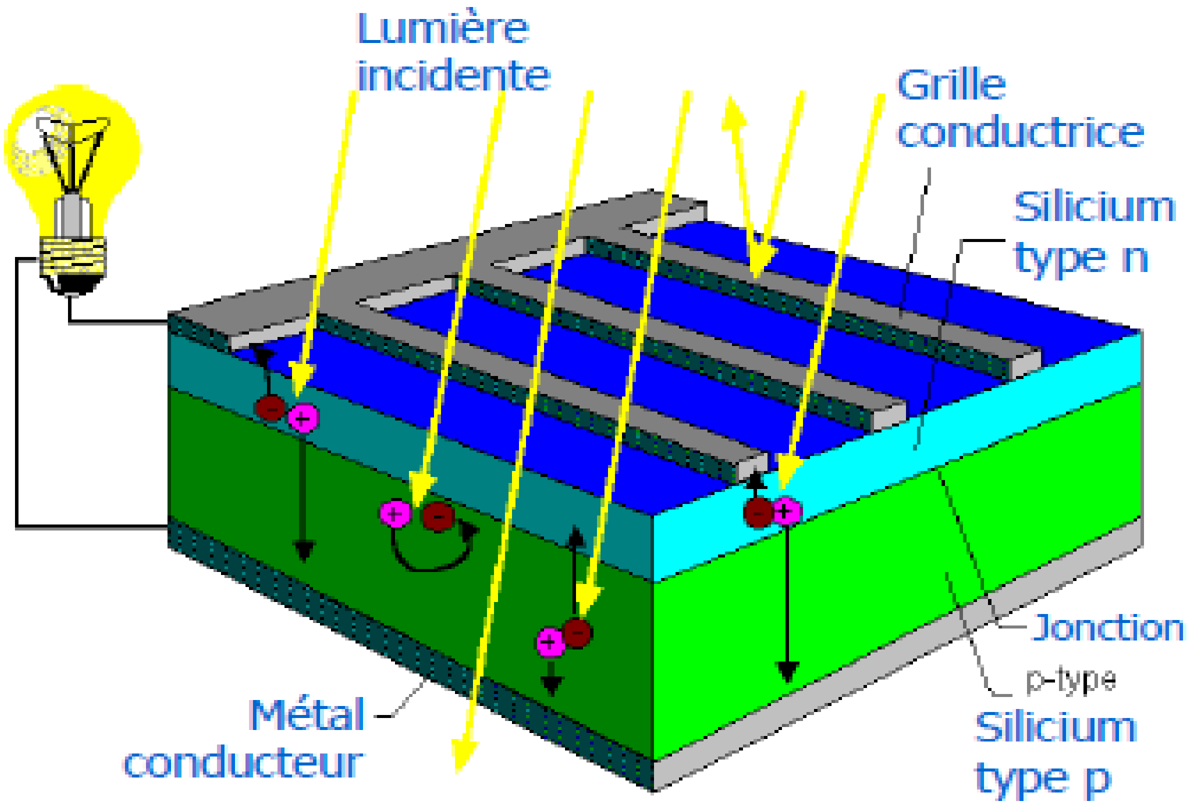


N type Si



P type Si

Operation of a solar cell

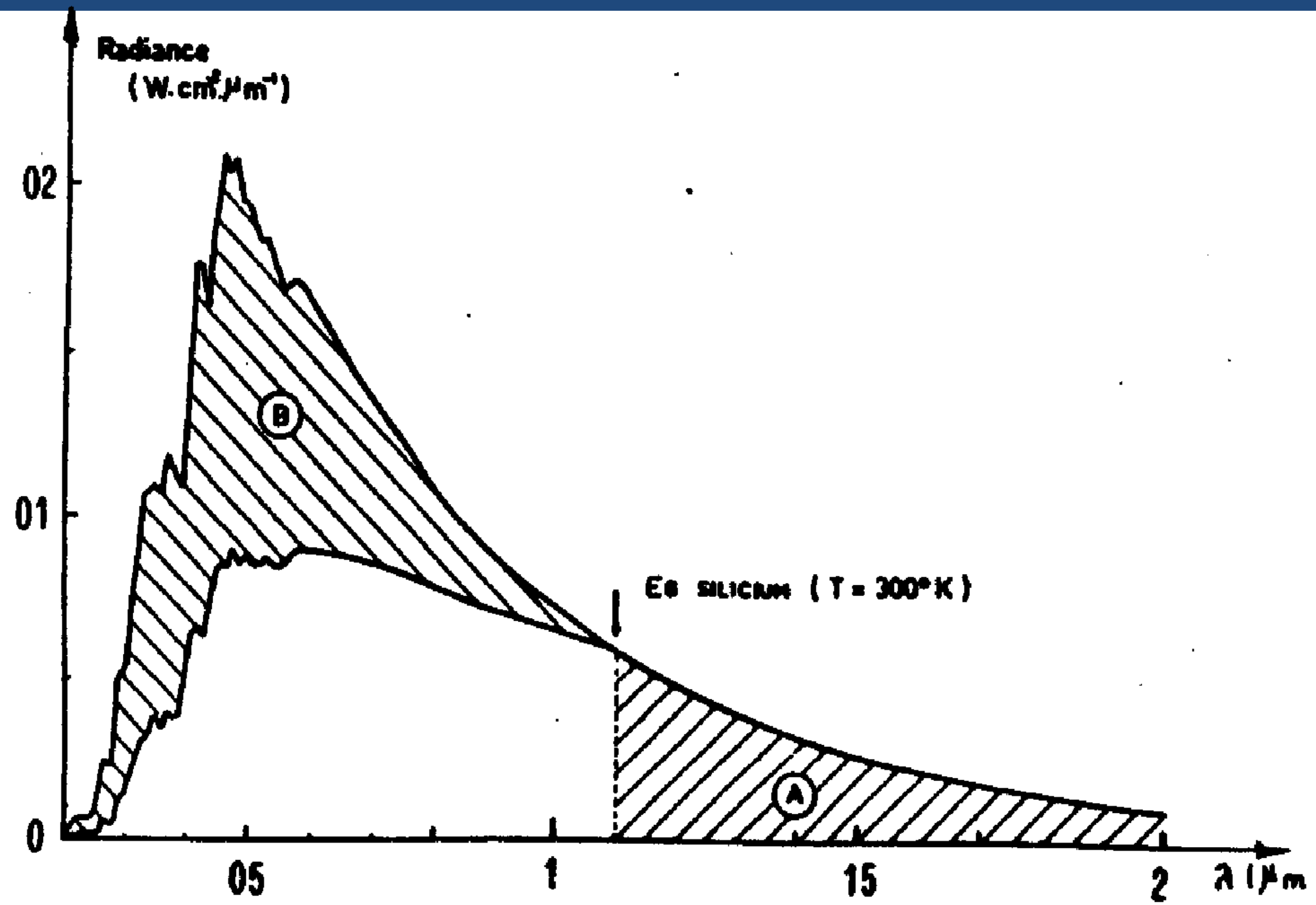


Gap energy of selected materials

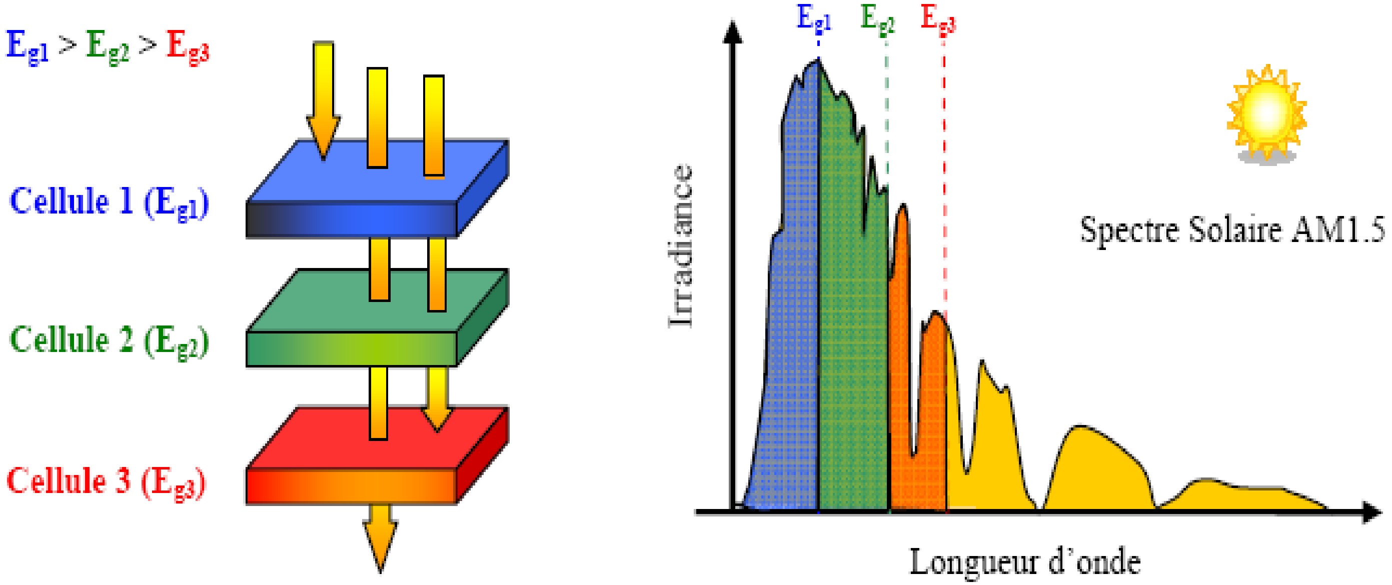
Tableau 3.31 Principales propriétés physiques des semiconducteurs usuels.

	Ge	Si	GaAs	InP	CdS	CdTe
Atomes/cm^3	$4,42 \cdot 10^{22}$	$5,02 \cdot 10^{22}$	$2,21 \cdot 10^{22}$	$1,99 \cdot 10^{22}$	$2,02 \cdot 10^{22}$	$1,48 \cdot 10^{22}$
Masse moléculaire	72,60	28,08	144,63	145,79	144,46	240
Structure cristalline	diamant	diamant	Zn blende	Zn blende	Wurtzite	Zn blende
Constante de réseau [Å]	5,6575	5,4309	5,6534	5,8688	4,16/6,76	6,477
Indice d'ionicité	0	0	0,31	0,42	0,69	0,68
Densité [g/cm^3]	5,327	2,328	5,316	4,790	4,820	5,860
Gap à 300 K [eV]	0,67	1,12	1,43	1,29	2,42	1,44
Indice de réfraction n	4,00	3,42	3,30	3,37	2,53	2,75
Const. diélectr. rel.	16	11,8	11,5	12,1	11,6	10,9
Champ de claq. [V/cm]	10^5	$3 \cdot 10^5$	$4 \cdot 10^5$			

Notion of spectral response



Spectral response

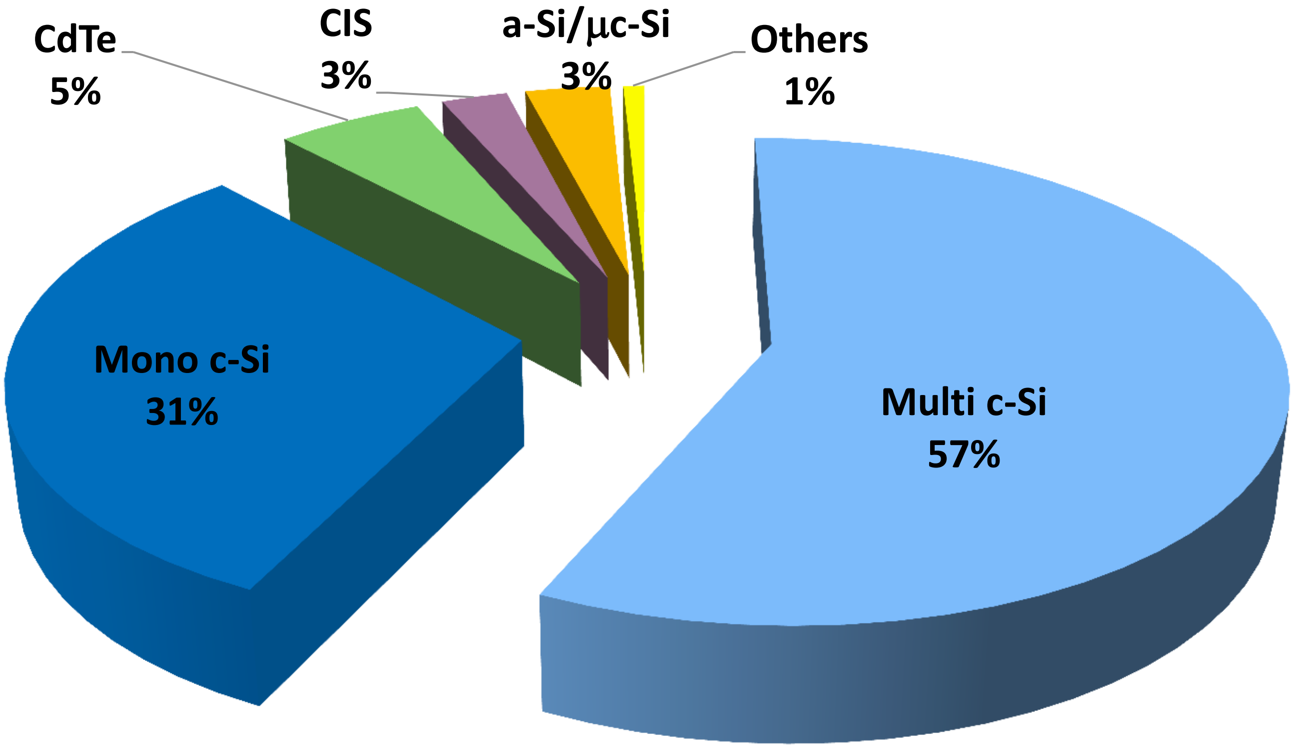


Heterojunction cell response

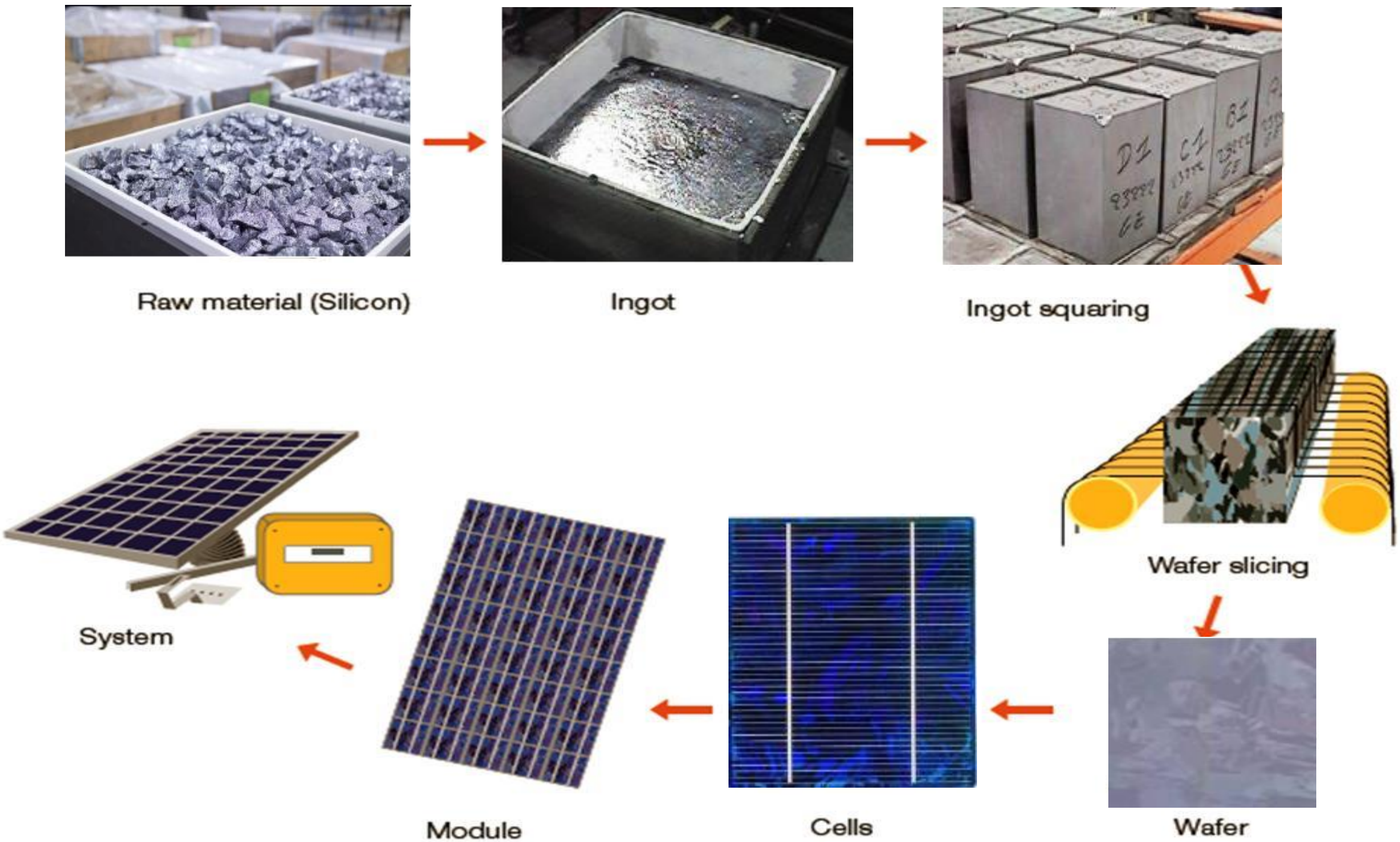
Association of semi-conductor materials

GaAs, AlGaAs, InGaAs ….efficiency up to 40%

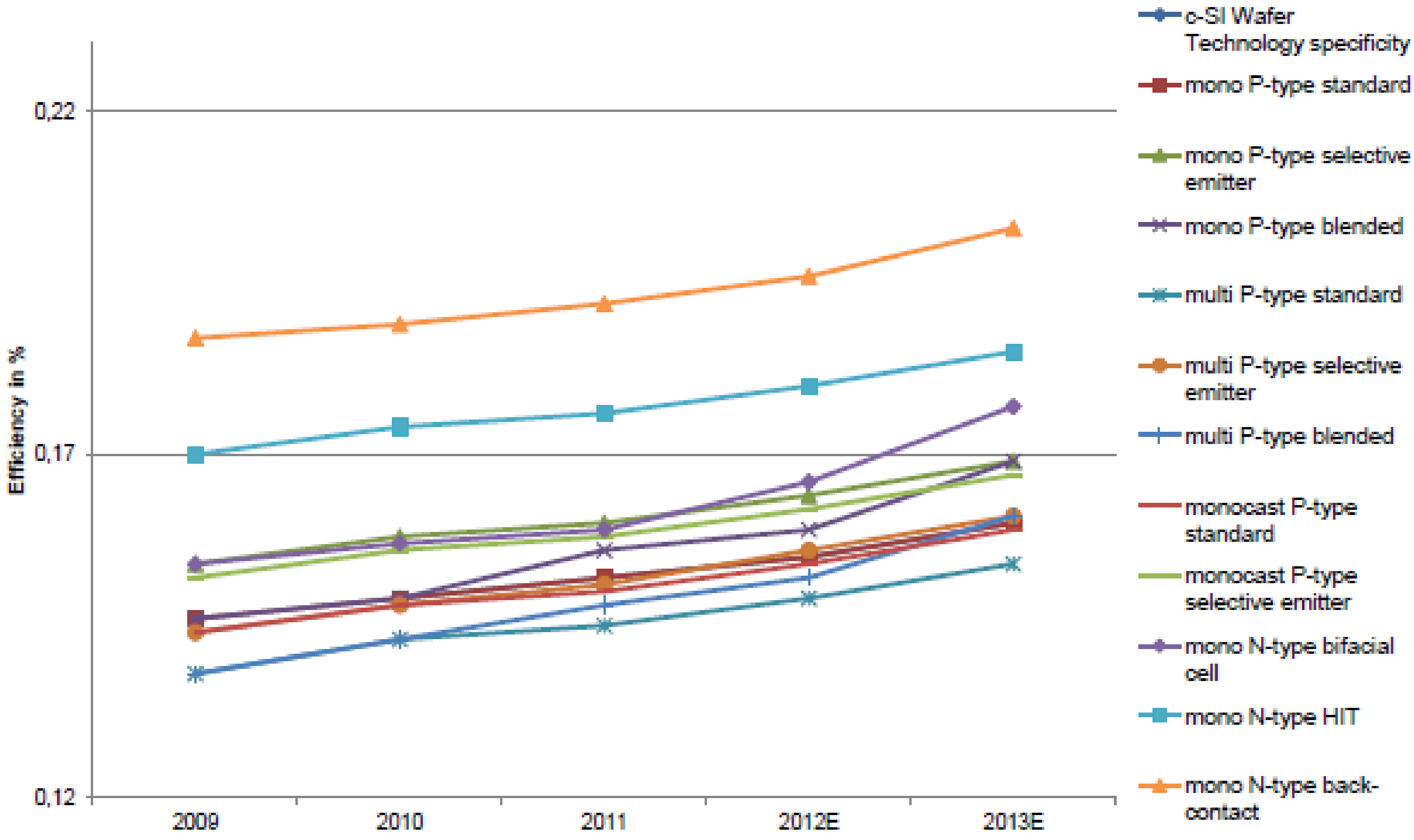
Distribution of the world PV production among technologies - 2012



Production process : The PV value chain

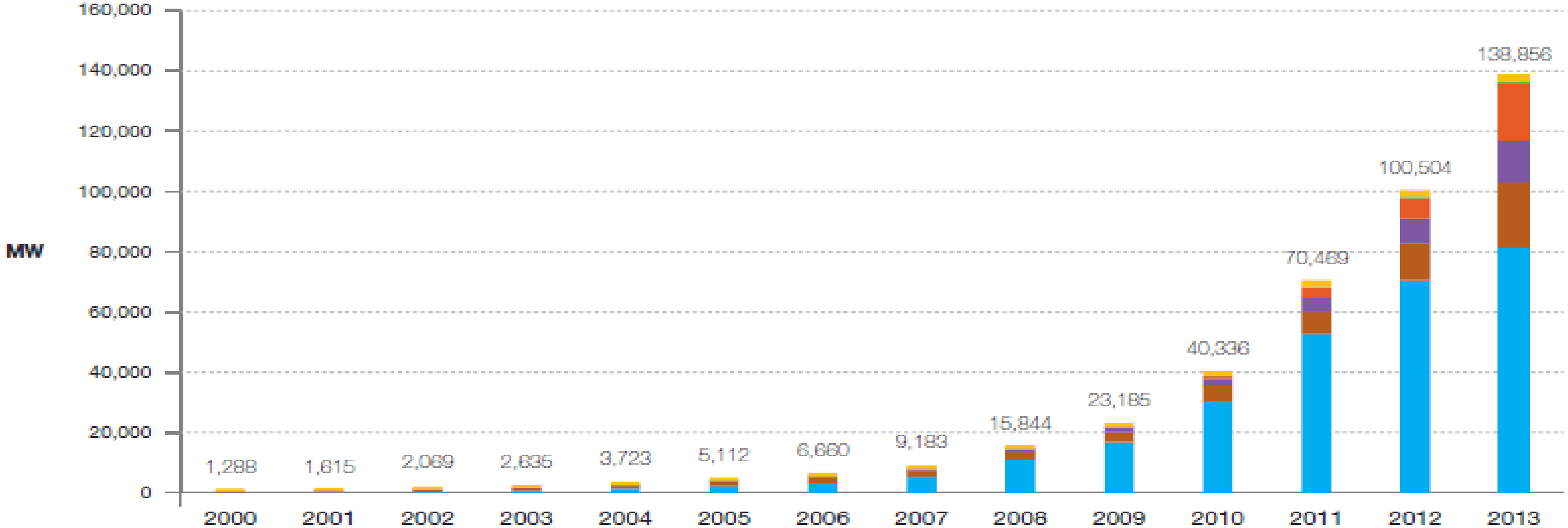


Module efficiency road map



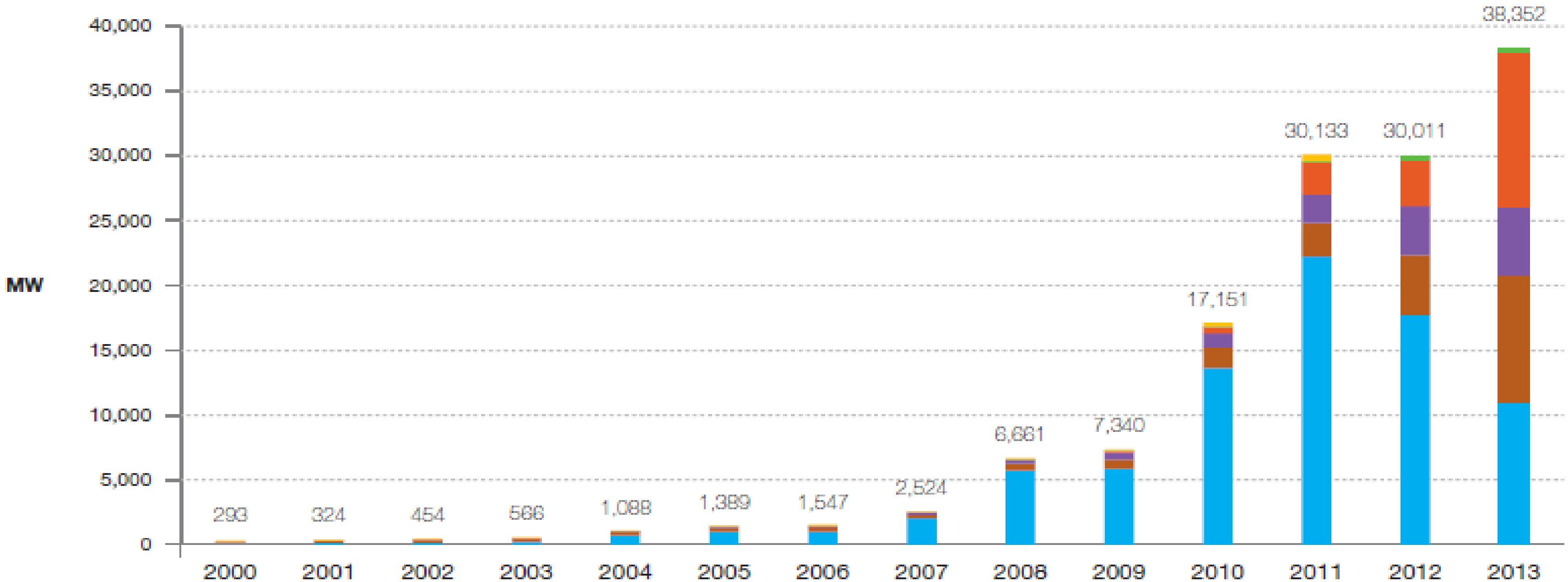
Source: BNEF 2011

World PV global cumulative installed capacity



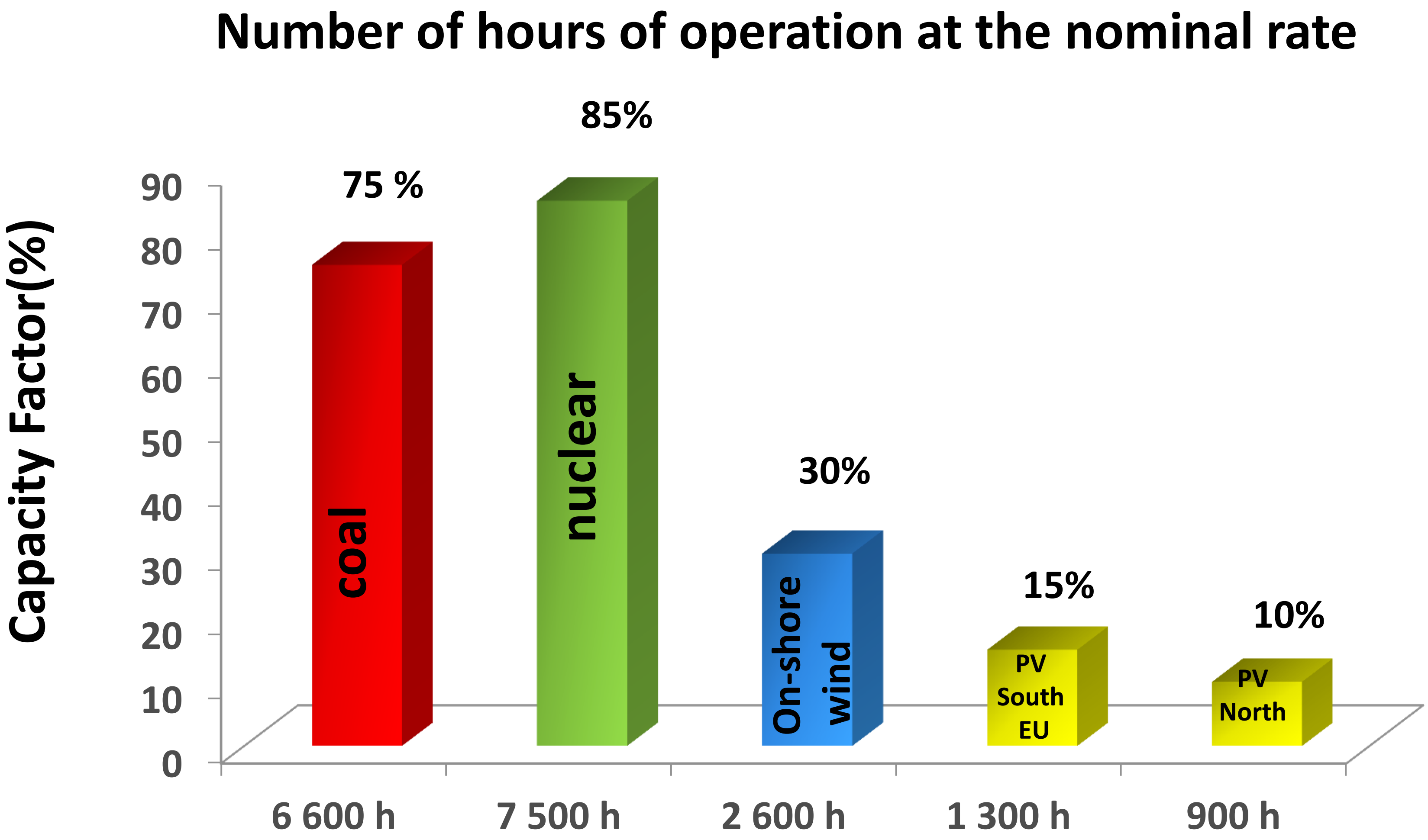
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
RoW	751	807	887	964	993	1,003	1,108	1,150	1,226	1,306	1,590	2,098	2,098	2,098
MEA	n/a	n/a	n/a	n/a	1	1	1	2	3	25	80	205	570	953
China	19	24	42	52	62	70	80	100	140	300	800	3,300	6,800	18,600
Americas	21	24	54	102	163	246	355	522	828	1,328	2,410	4,590	8,365	13,727
APAC	368	496	686	916	1,198	1,502	1,827	2,098	2,628	3,373	4,951	7,513	12,159	21,992
Europe	129	265	399	601	1,306	2,291	3,289	5,312	11,020	16,854	30,505	52,764	70,513	81,488
Total	**1,288**	**1,615**	**2,069**	**2,635**	**3,723**	**5,112**	**6,660**	**9,183**	**15,844**	**23,185**	**40,336**	**70,469**	**100,504**	**138,856**

World global annual PV installations

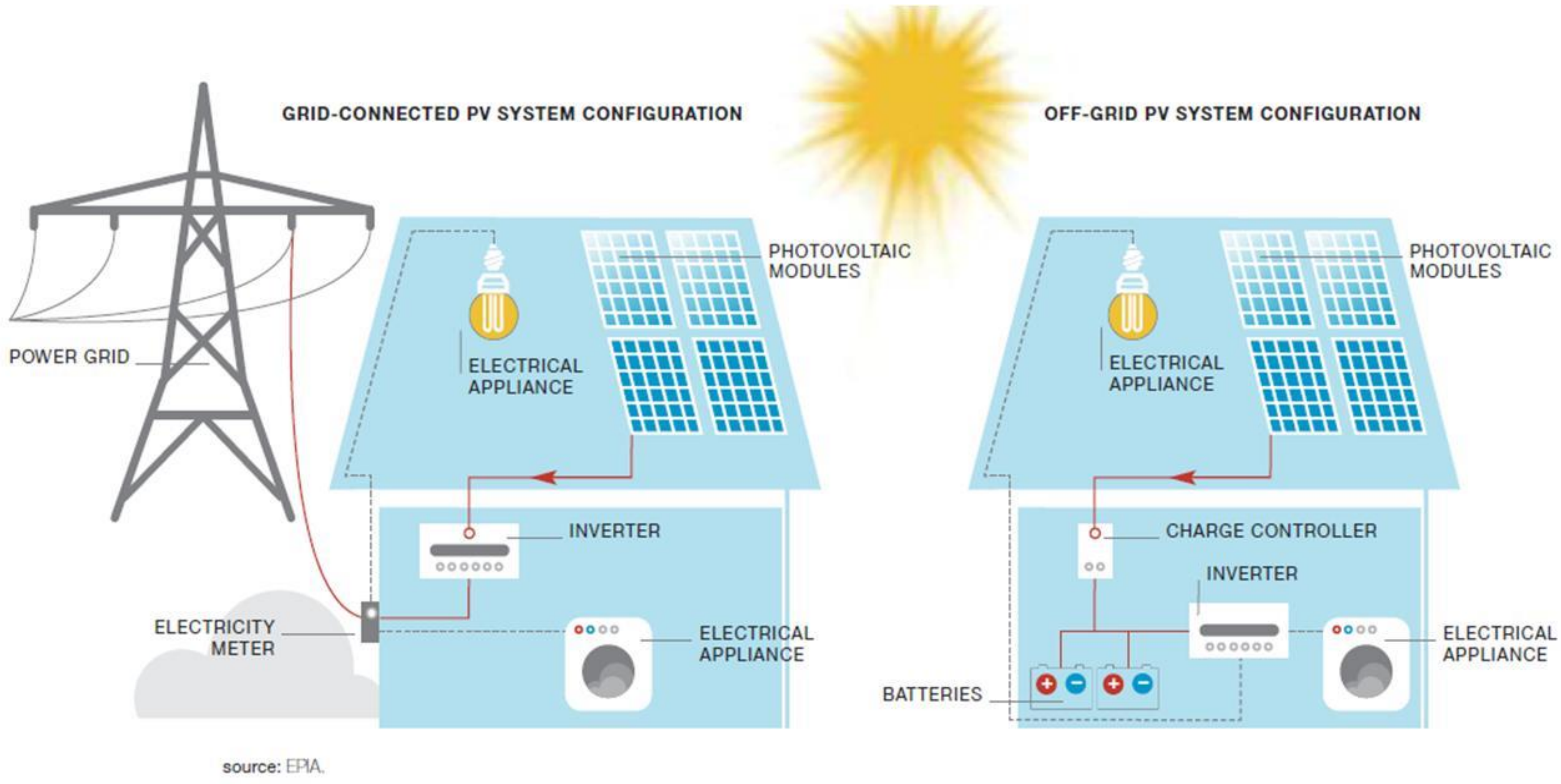


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
RoW	88	56	80	77	29	10	105	42	76	80	284	508	n/a	n/a
MEA	n/a	n/a	n/a	n/a	1	0	0	1	1	22	55	125	365	383
China	19	5	19	10	10	8	10	20	40	160	500	2,500	3,500	11,800*
Americas	2	3	30	48	61	82	110	166	306	500	1,082	2,181	3,774	5,362
APAC	126	128	190	230	282	304	325	271	530	745	1,578	2,562	4,646	9,833
Europe	58	133	134	202	705	985	997	2,023	5,708	5,833	13,651	22,259	17,726	10,975
Total	**293**	**324**	**454**	**566**	**1,088**	**1,389**	**1,547**	**2,524**	**6,661**	**7,340**	**17,151**	**30,133**	**30,011**	**38,352**

Capacity Factor

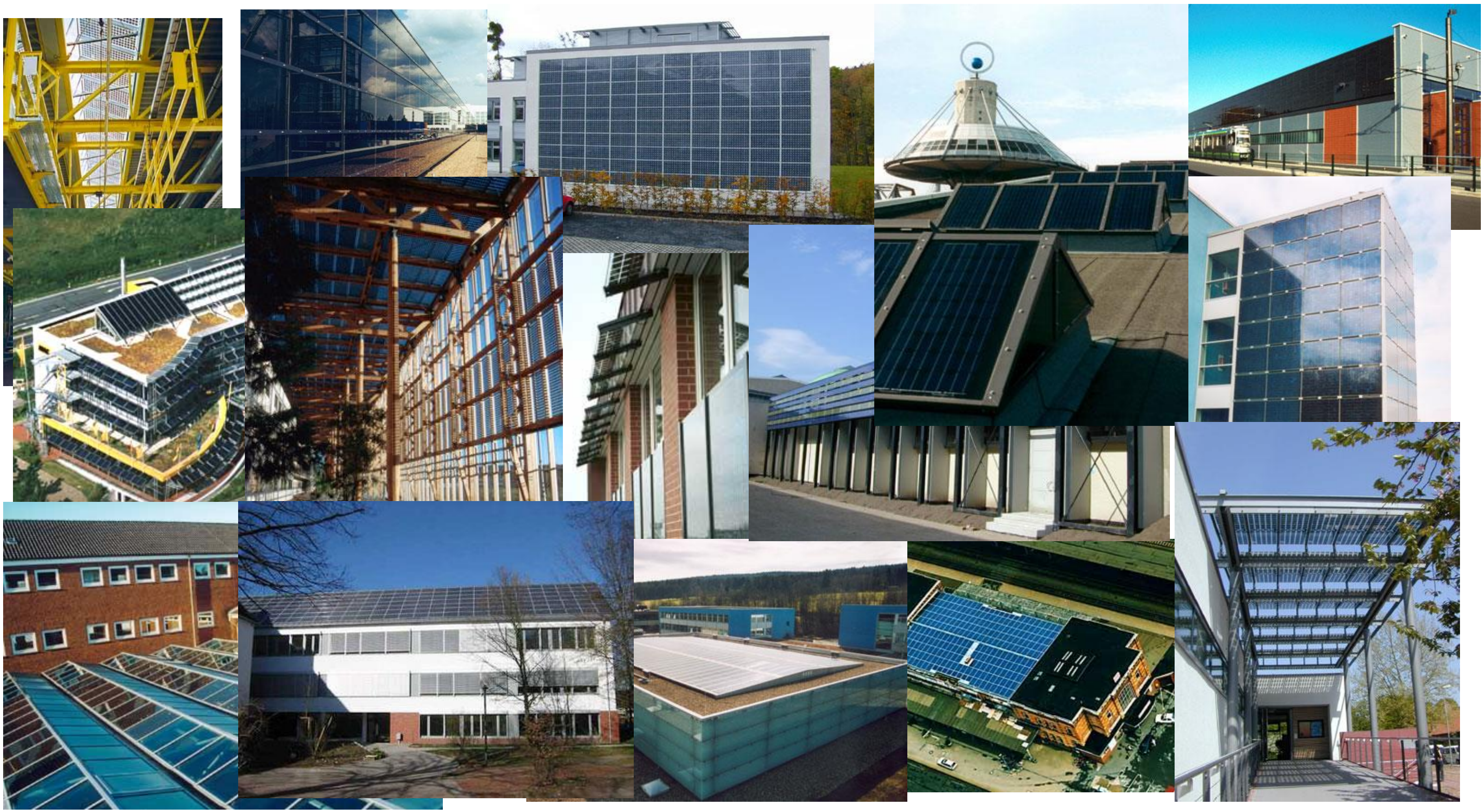


Different configurations of PV systems



Stand alone systems

Building integrated systems

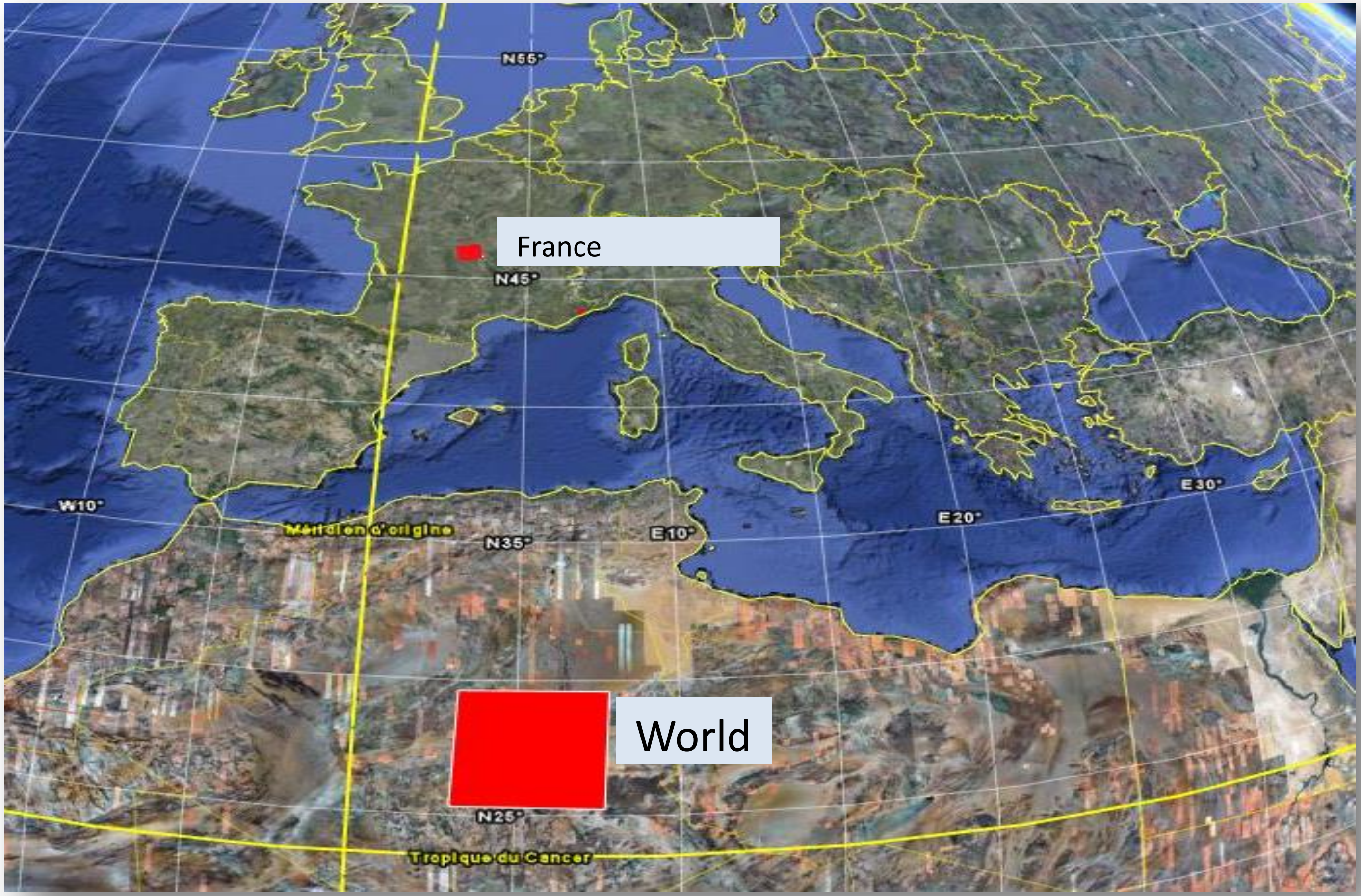


Multi Megawatts power plants

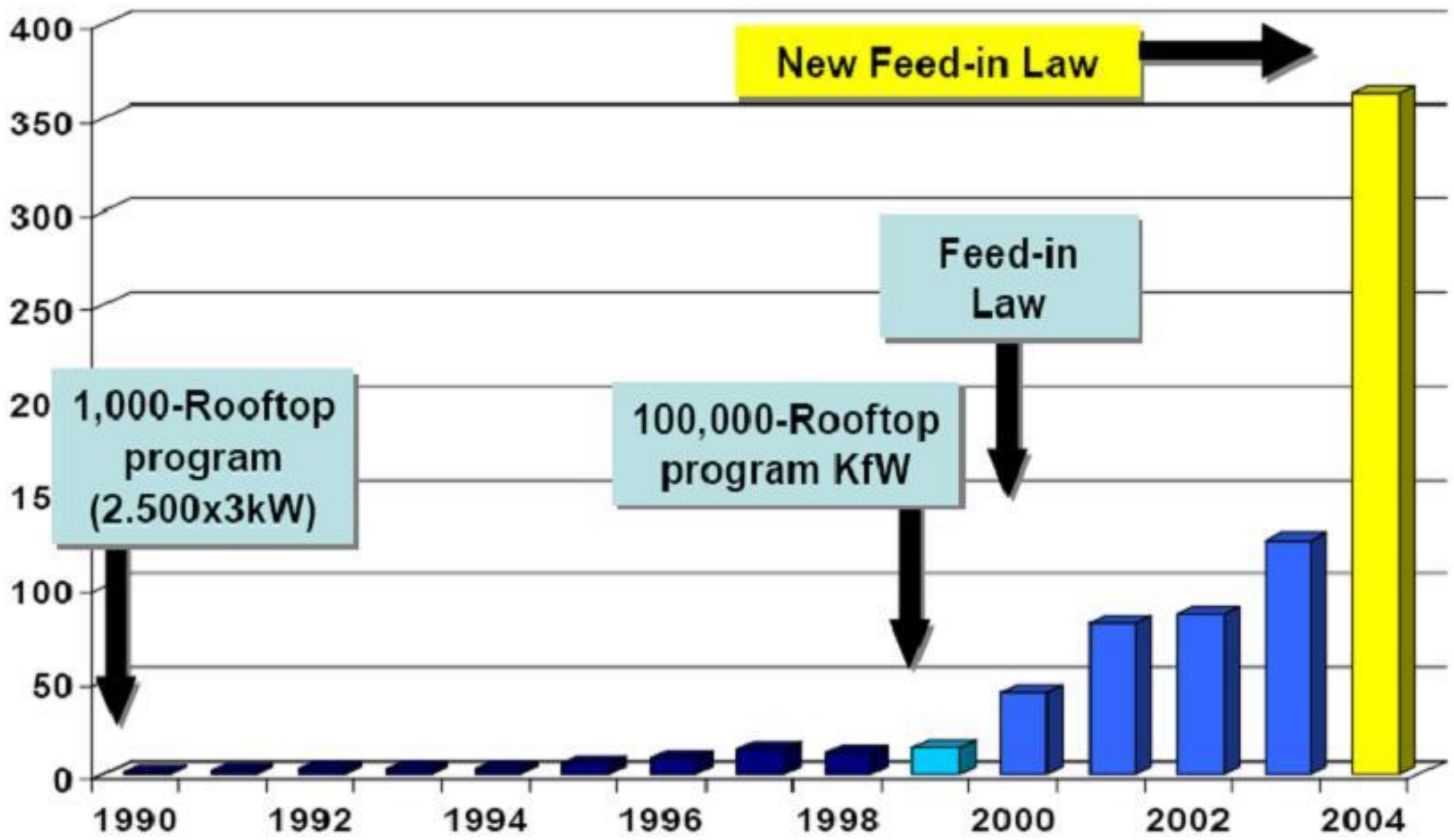
Key figures

- Efficiency of a Si-C PV module : ~13-20 %
- Efficiency of the whole system : ~10 – 17 %
- Ratio installed area / power : ~8m^2/kW (roof top)
  : ~20m^2/kW (power plant)
- Lifetime of a generator : ~30 years degradation < 10%
- Investment cost : 2 200 – 4 000 €/kW roof top
  1 500 – 2 500 €/kW PV plant
- Capacity factor : 900 – 1 500 h/an
- Energy payback time : 2-5 years

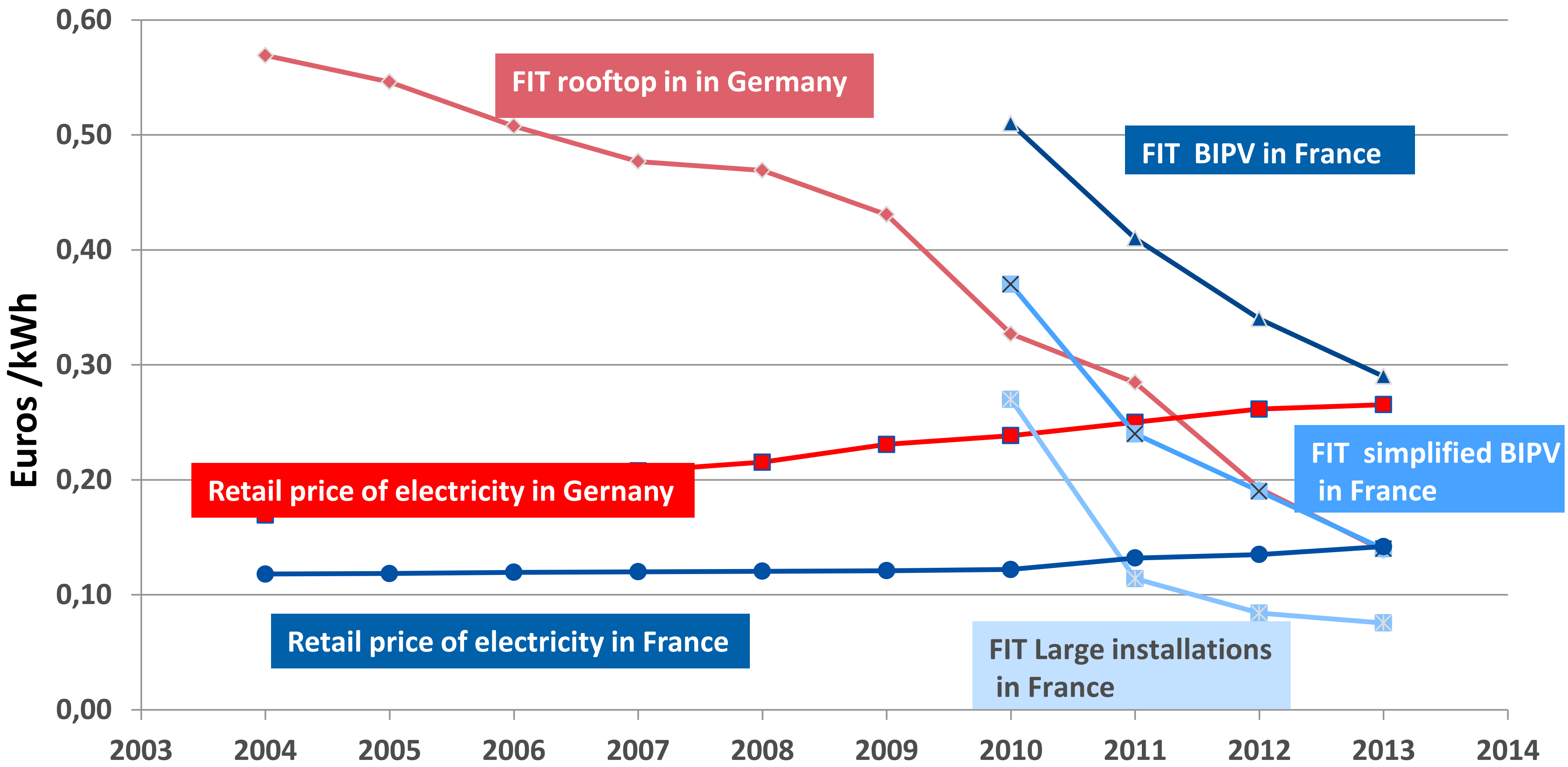
Necessary PV area to supply the french and the world electricity needs



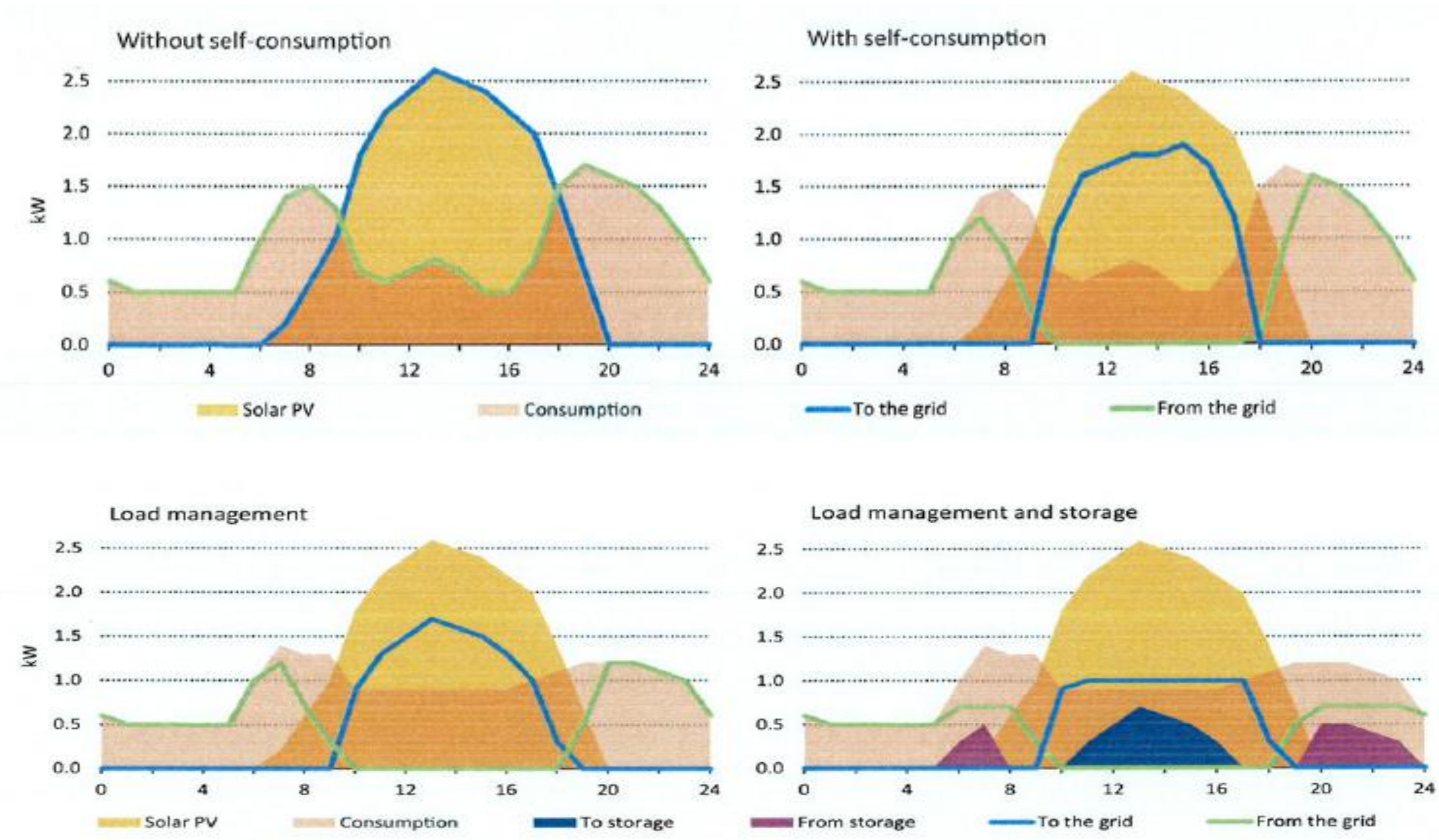
Influence of the support programme: the case of Germany



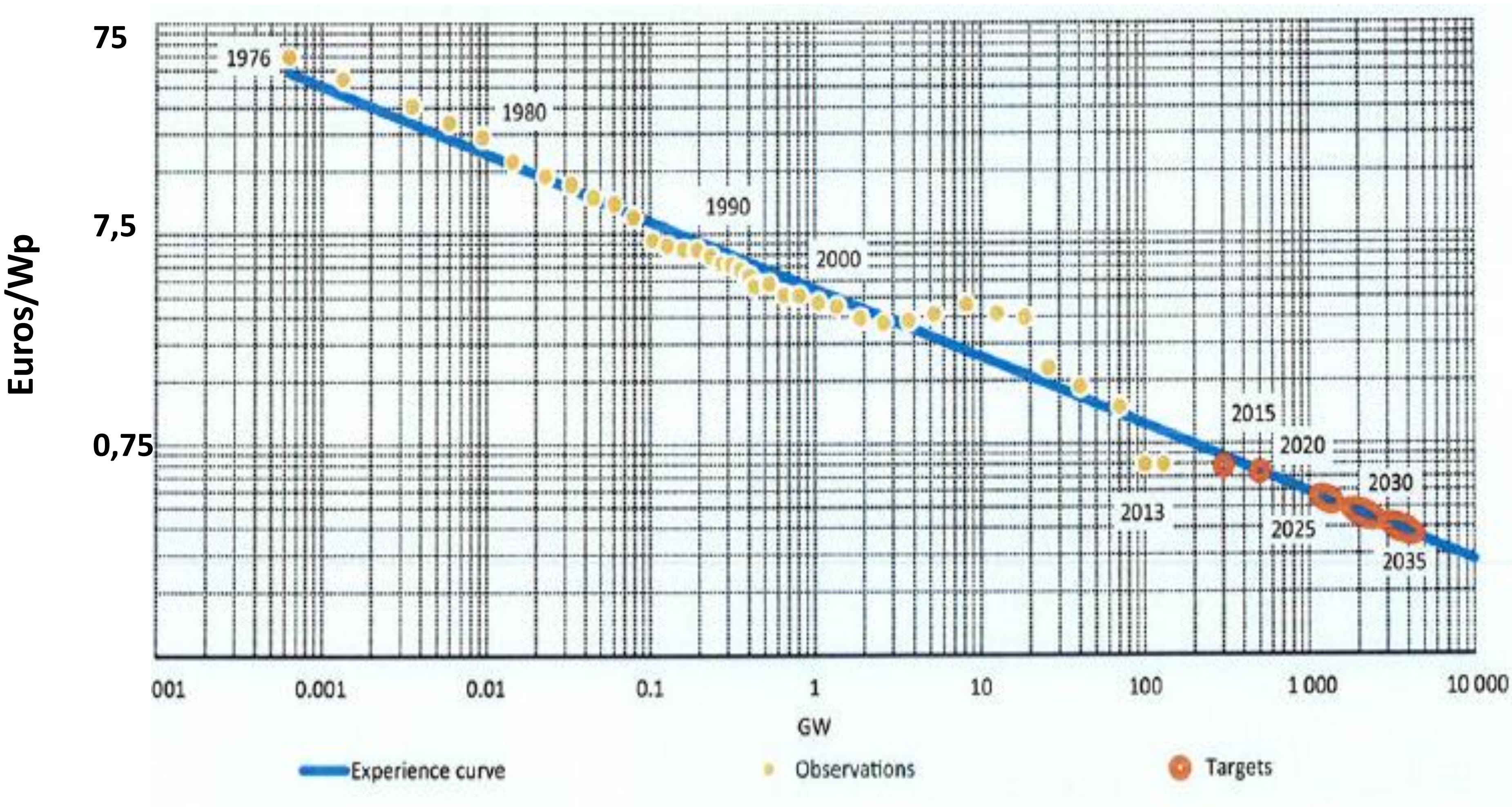
Comparison : french and german situations



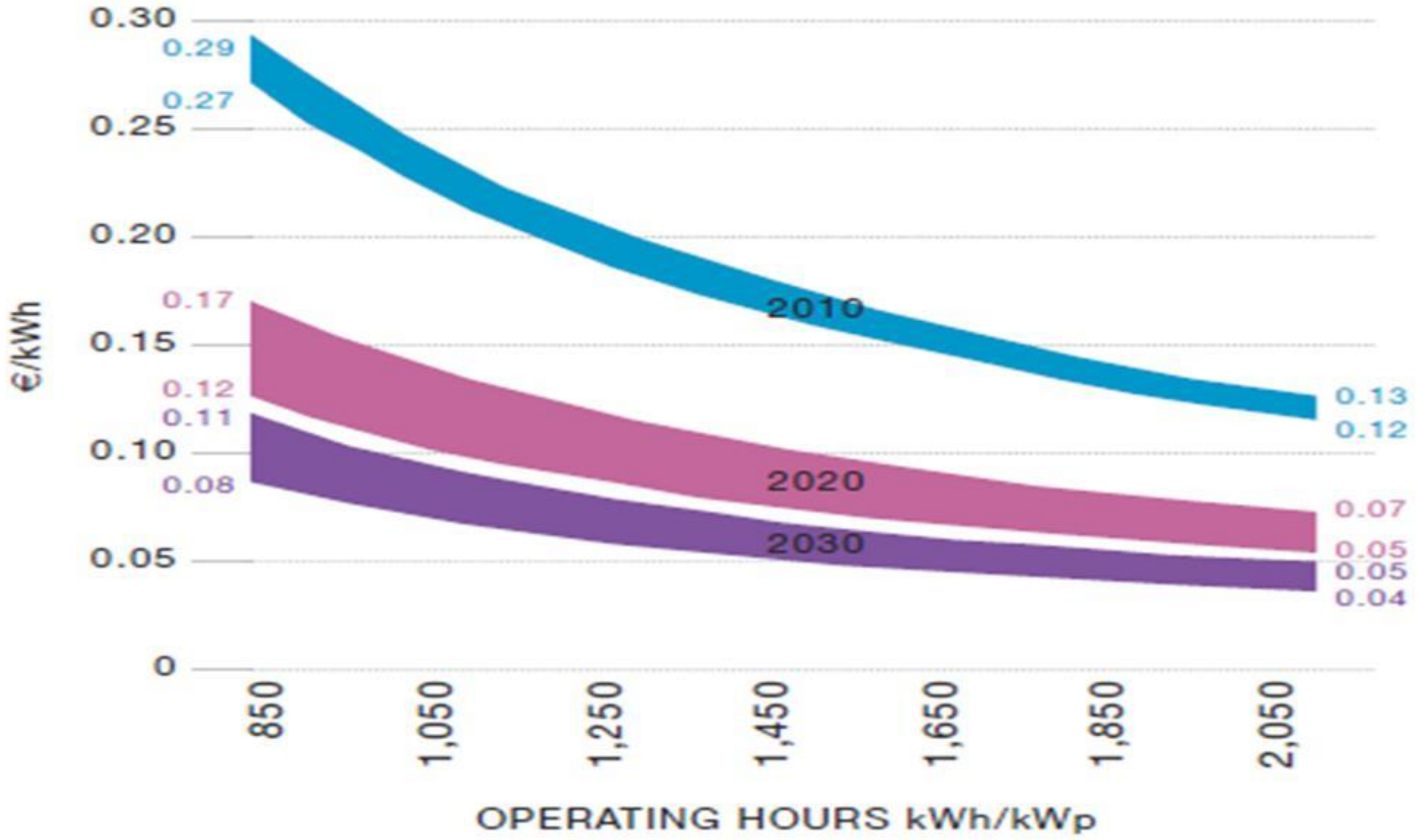
Increasing self-consumption with load management



Experience curve for PV modules and extension to 2035

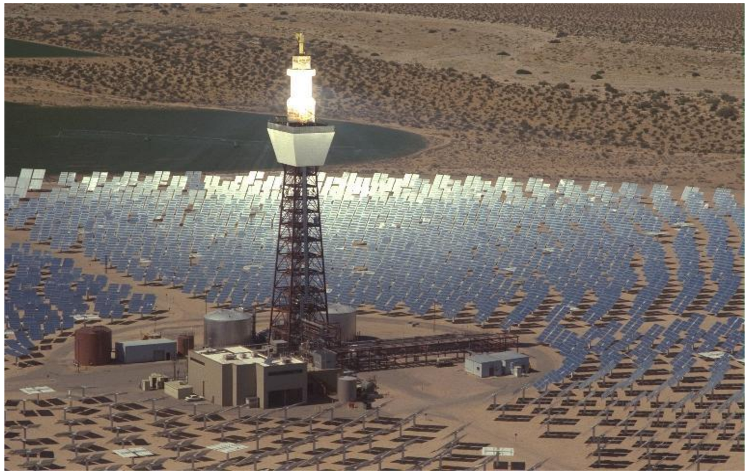


Levelized cost of electricity for PV

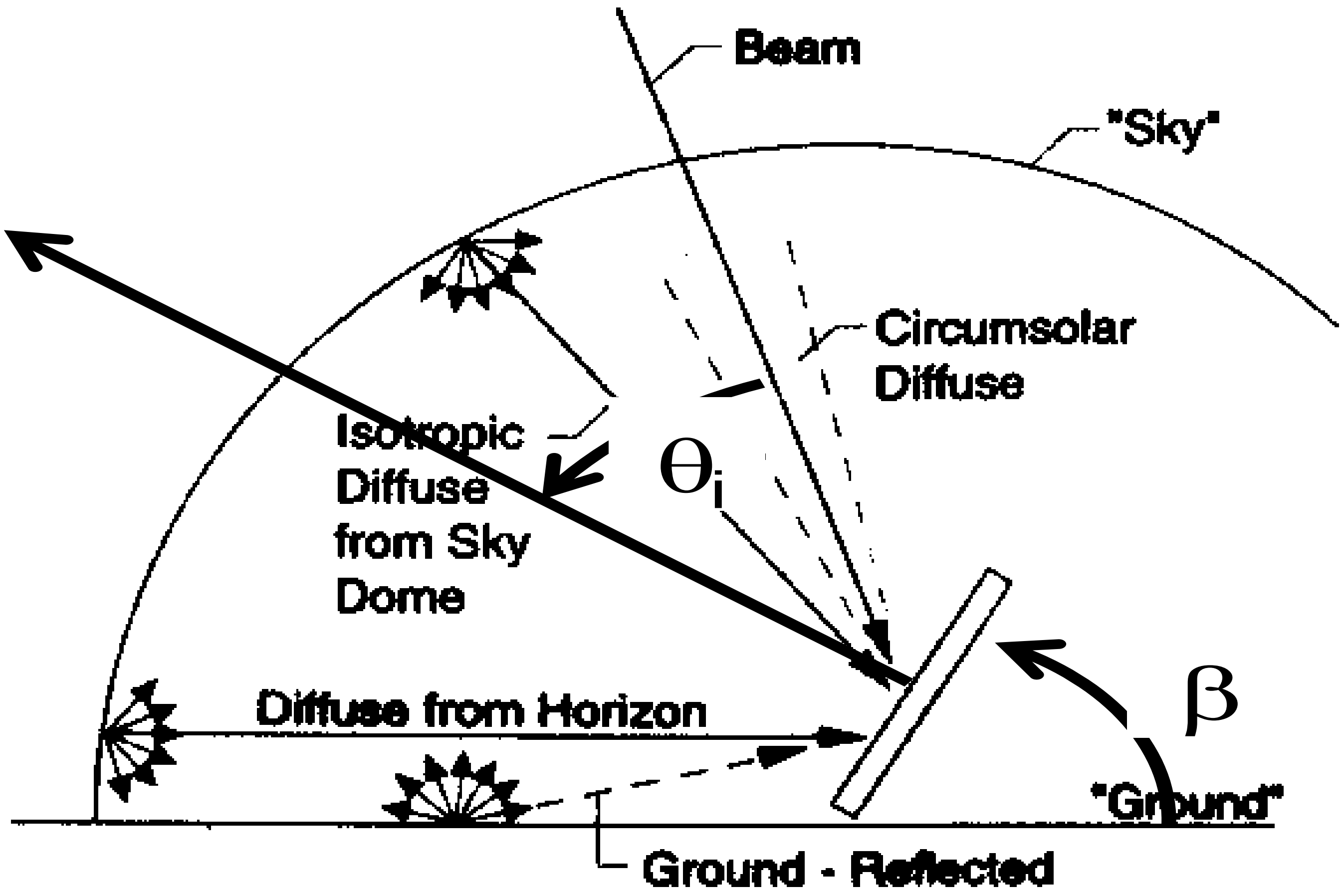


source: Greenpeace/EPIA Solar generation VI 2010.

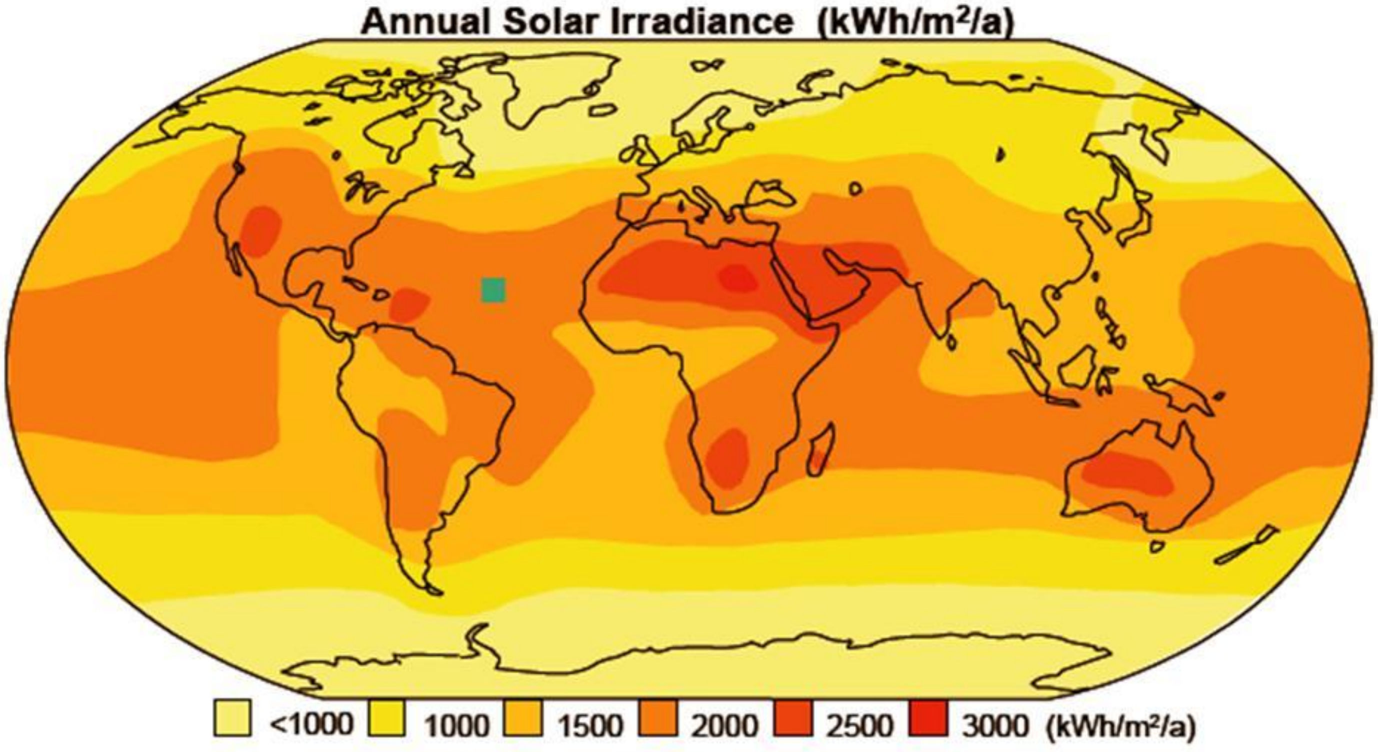
Solar thermal



Different components of solar irradiation

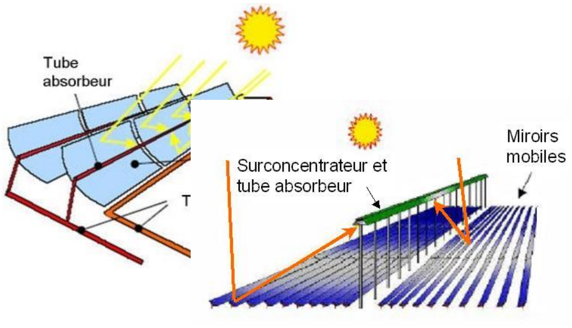


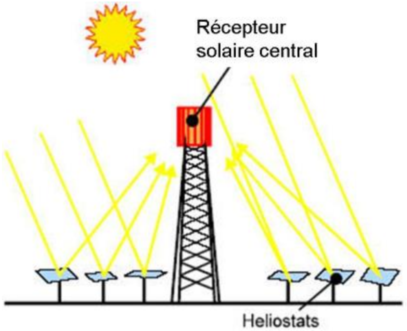
Solar potential for CSP applications

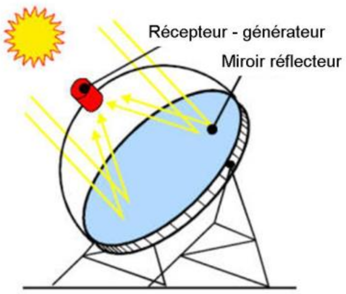


Source: Krieth & Krieger, Principles of Solar Engineering, Mc Graw Hill, 1978

Solar concentrating systems







Concentration < 100

T_{HTF} < 500 °C

0 - 100 MW_th

Concentration > 500

T_{HTF} > 600 °C

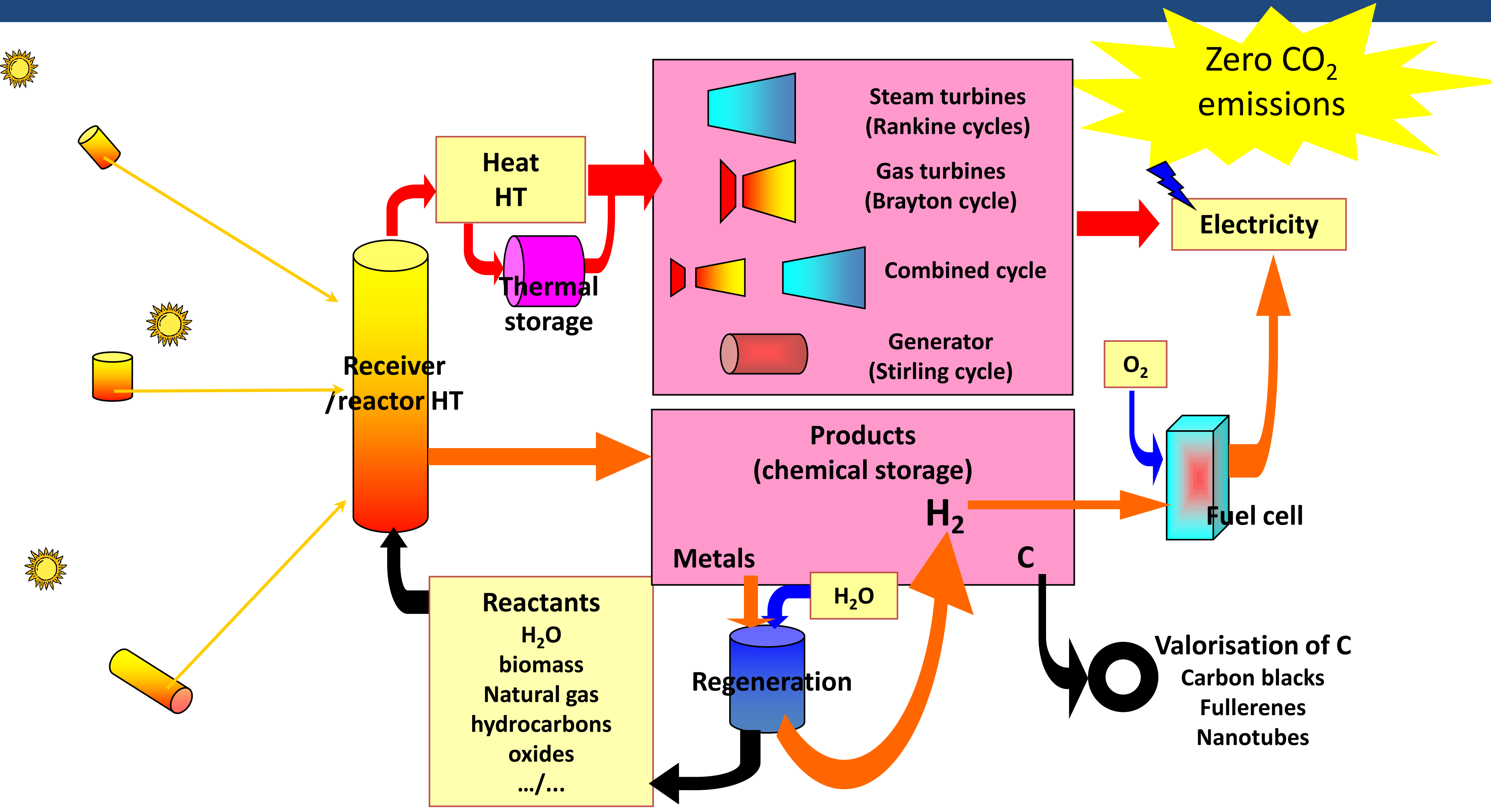
0 - 100 MW_th

Concentration > 5000

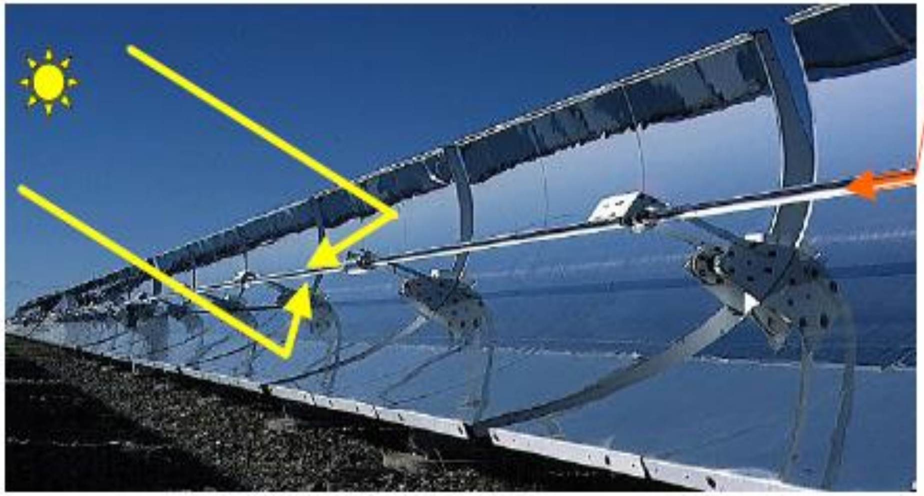
T_{HTF} > 600 °C

0 - 100 kW_th

Solar concentrating technologies



Trough collectors



Heat transfer fluid

- **Natural oil**
- **Synthetic oil**
  Medium pressure
- **Water/steam**
  High pressure

Advantages :

modular system – high power level (>100 MW)
simple construction, one tracking axis, integrated receptors
not high installation and operation costs (ground station)

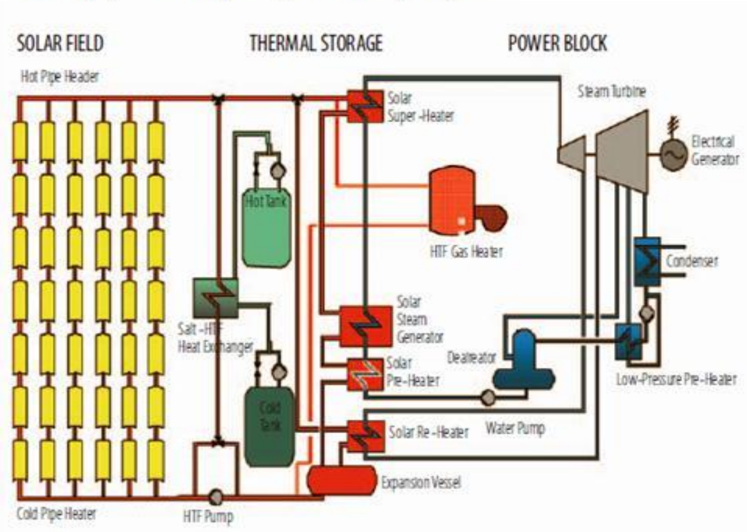
Inconvenients :

Low concentration level (20-100)). Moderate temperatures (250 – 400°C)
Modest efficiencies for the whole cycle.

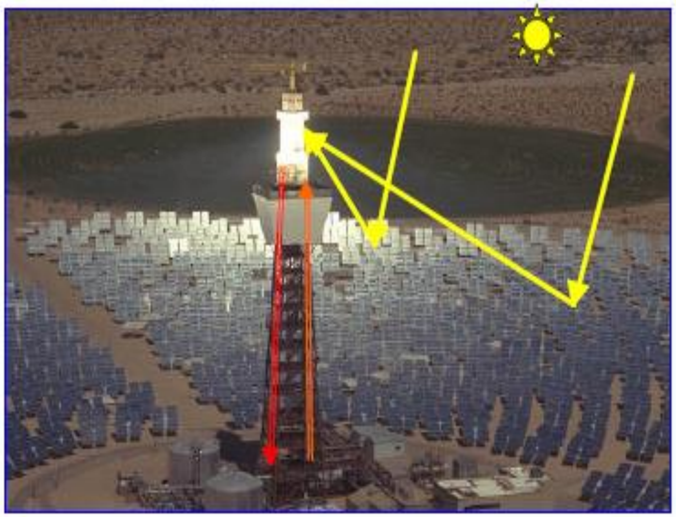
Parabolic trough power plant with molten salt energy storage

ANDASOLPower Plant (Spain 2006)
50 MWe Rankine cycle
Annual equivalent full load : 3 600
Solar field : 200 ha
Storage : molten salts, 7,5 h reserve
Annual electricty production : 179 GWh

Plant Description
AndaSol project solar field, storage and steam cycle operation



Solar Tower



Heat transfer fluid

Moltensalts

Water/steam
High pressure

Air at 1 atm

Pressured air

Advantages :

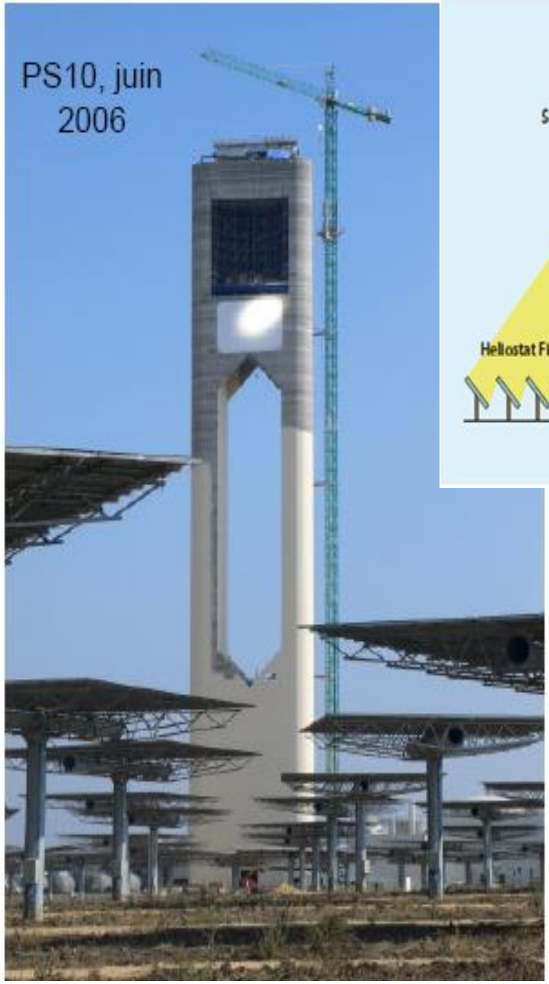
- high concentration level (200-1 000)– high temperature (300K)(>100 MW).
- higher efficiencies for the whole cycle.
- compact recepteurs.
- Less thermal losses.

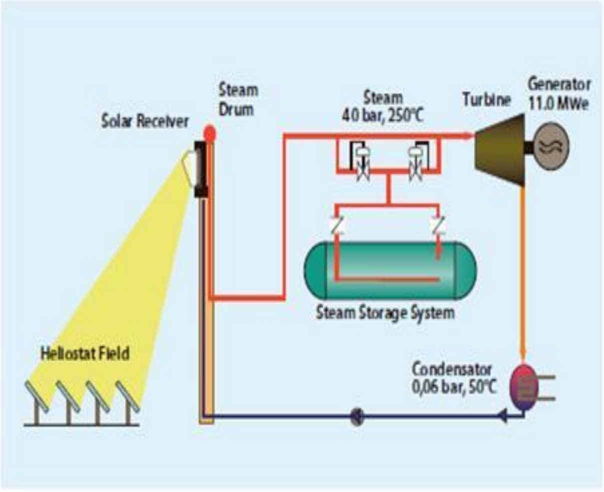
Inconvenients :

- high investment cost (2 axis tracking systems, central receiver, Moderate temperatures (250 – 400°C)
- Low specific power of the basic unit (<500 MWth)

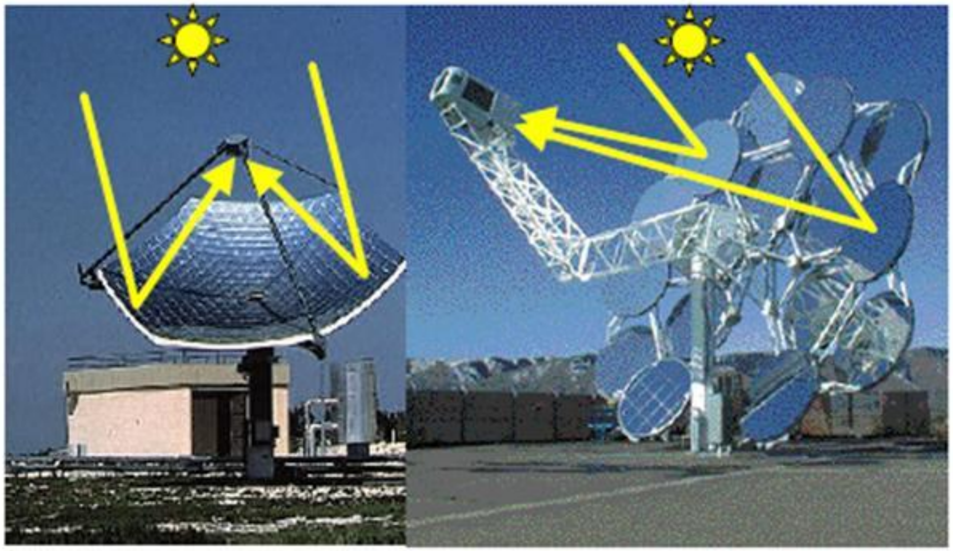
Solar tower with water/steam as a heat transfer fluid

PS 10 Power Plant (Spain 2006)
11 MWe Rankine cycle
Technology : saturated water/steam
Solar field : 75 500 m2
Storage : pressurized water, 20MWh 50mn@50%rate
Annual electricity production : 23 GWh





Dishes (Parabolic collectors)



Heat transfer fluid

*** Synthetic oil**

T < 400°C Ex: VP-1

Medium pressure (10 – 15 bars)

*** Gaz : water/steam, air, helium, hydrogen**

T > 400°C

High pressure (> 60 bars)

*** Liquid metal : sodium**

Advantages :

high level of concentration (500-1200) – very high temperature(>600 °C)

Stirling cyle (He or H2) or Brayton cycle : high efficiency for power rate < 50 kW

Modular

Inconvenients :

Low power units (< 100 kW) – Low collector area (< 100 m2)

high specific costs (> 10 000 €/kW).

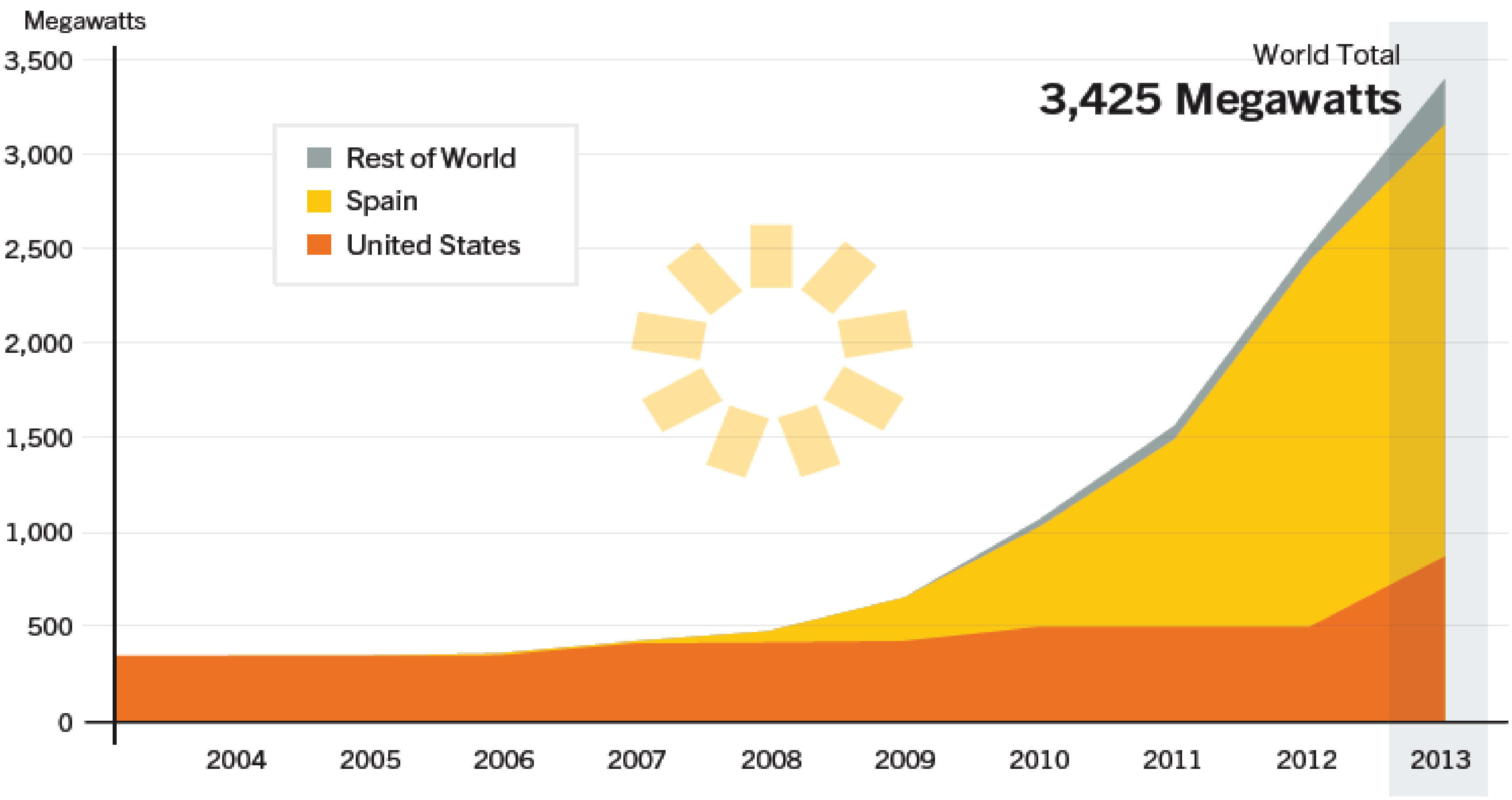
Costs and performances



Technology	Parabolic trough	Tower	Dish-Stirling
Thermal efficiency	70 %	73 %	75 %
Power (MW_{th})	1 - 300	10 - 100	< 0,1
Concentration ratio	80 - 500	700 - 1200	6000-10000
Working temperature	250 – 400 °C	450 – 1000 °C	600 – 1200 °C
Cost of collectors (€/m^2)	210 - 250	140 - 220	~1000
Capital cost (€/W_e)	2,8 – 3,5	3 - 4	7 - 14
Annual solar-to-electricity conversion efficiency (%)	14%	15%	17%

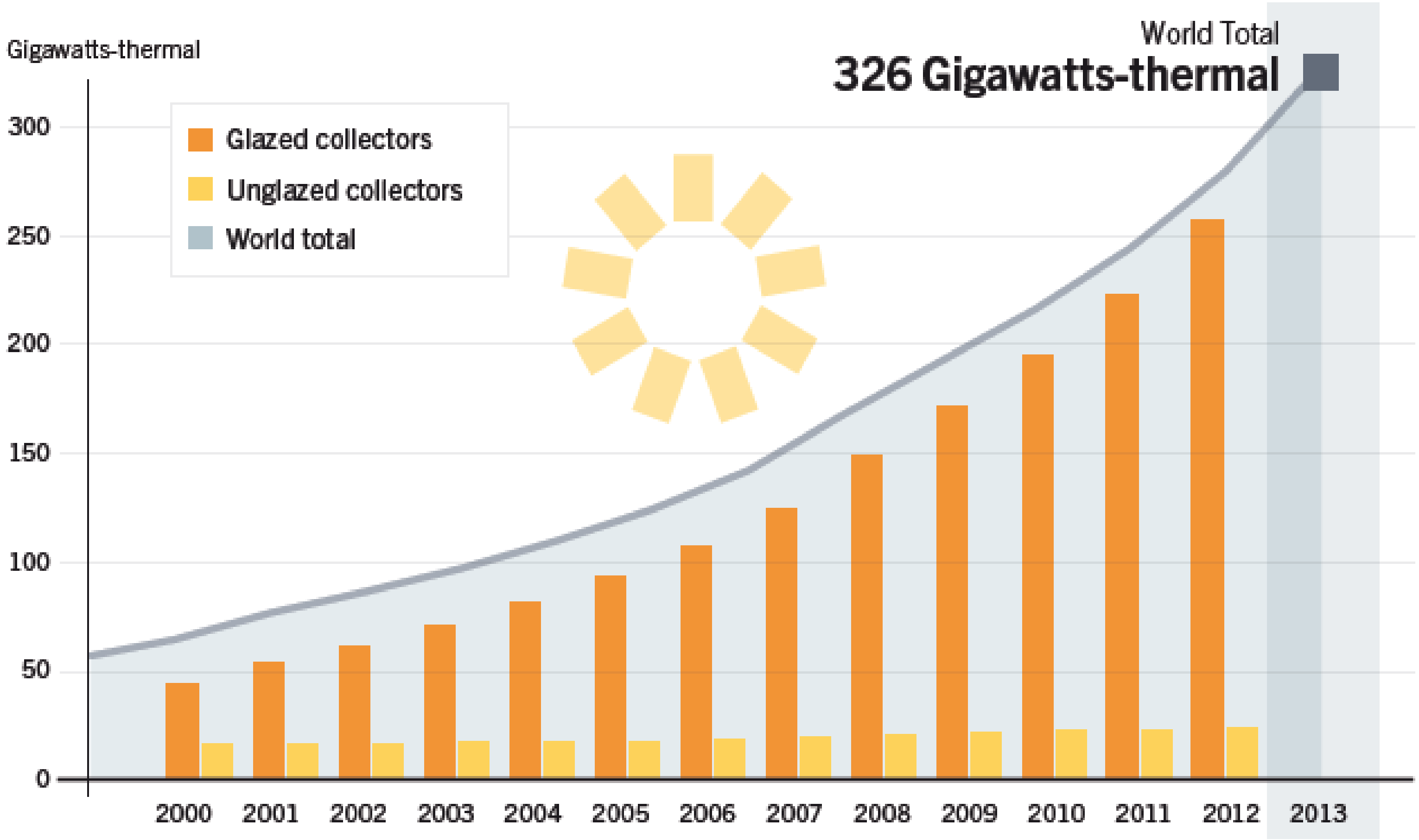
Annual cost of solar thermal electricity: 0.15 – 0.20 €/kWh_e

World market is taking off

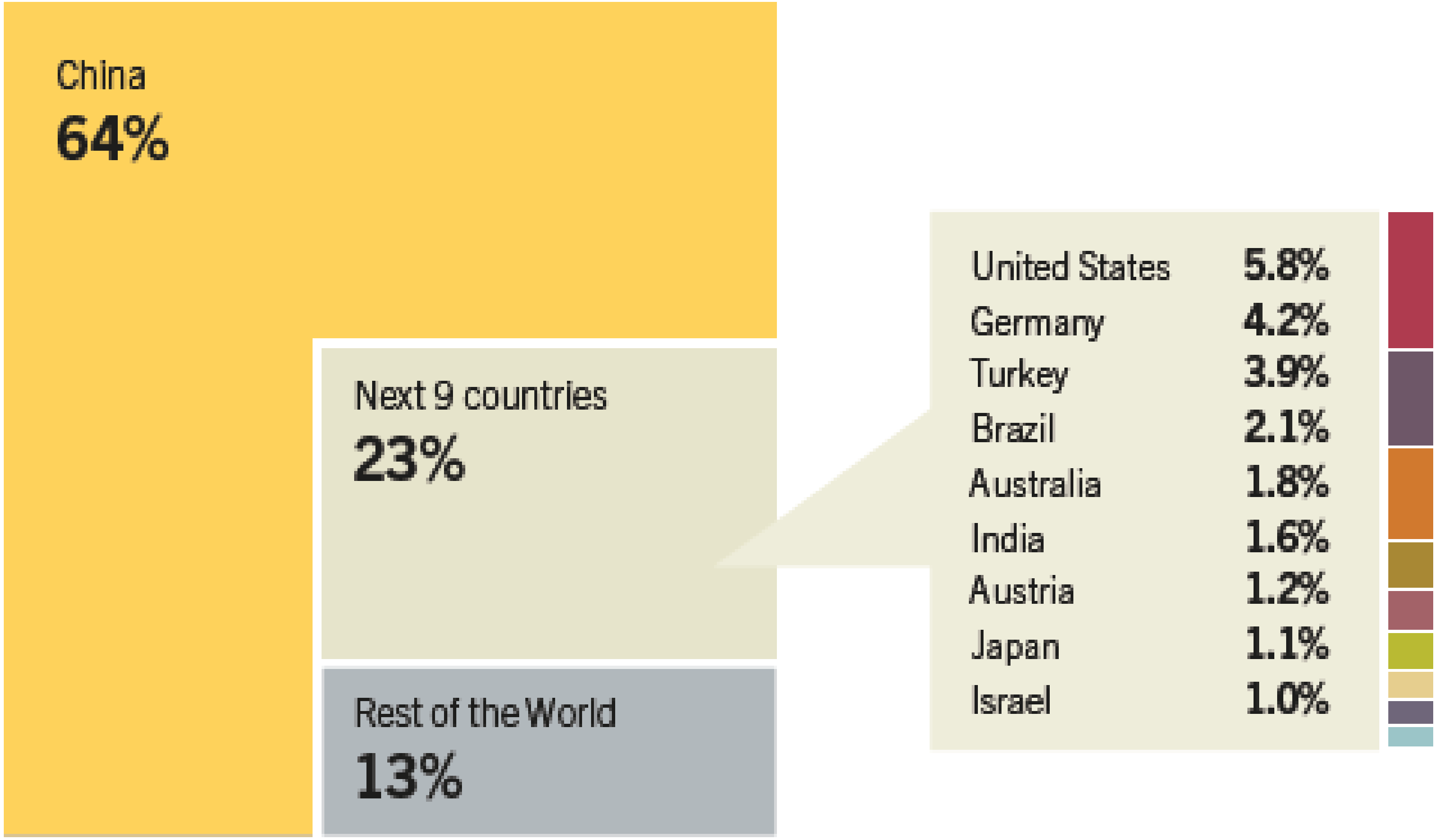


Solar thermal heating and cooling

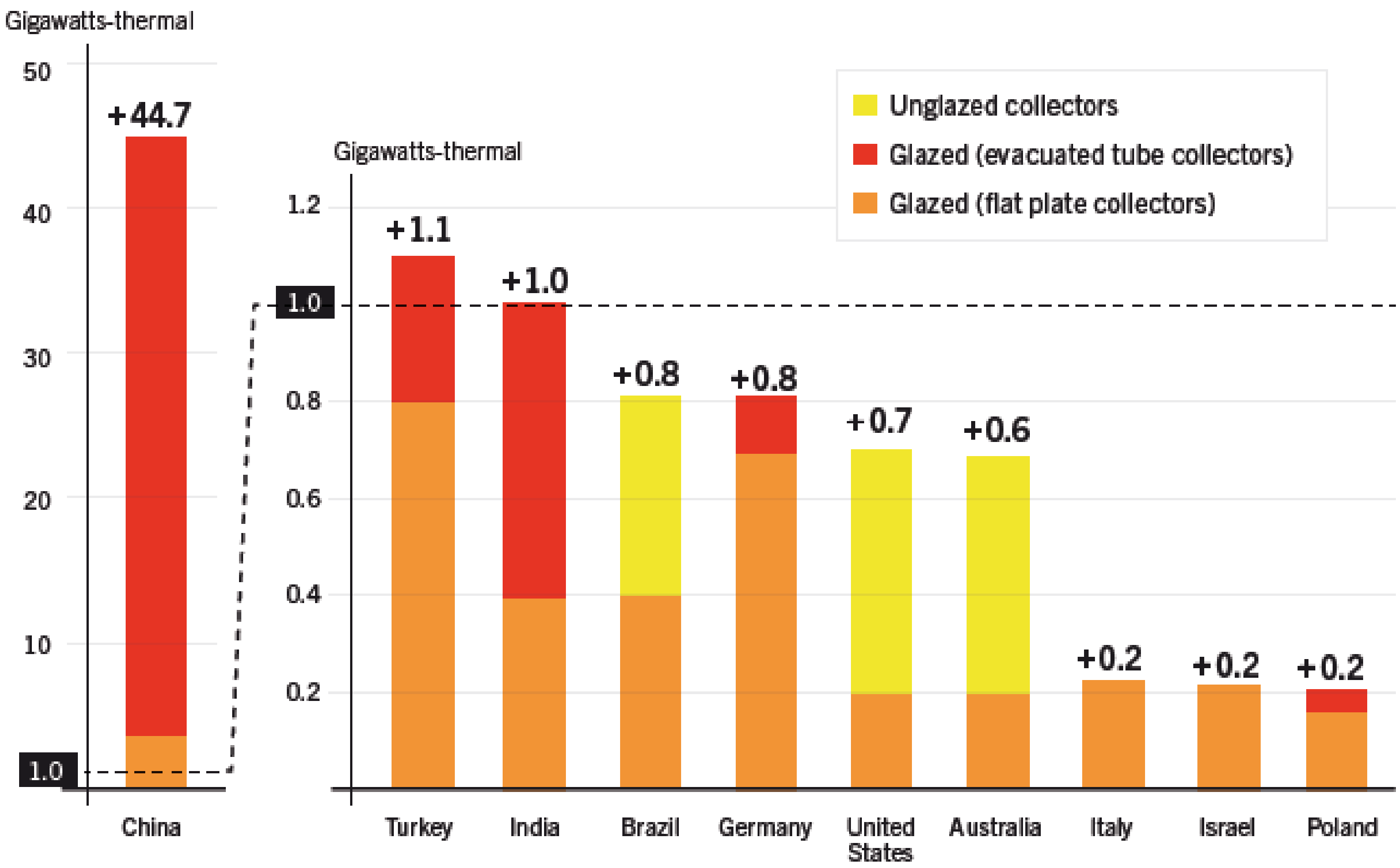
Solar water heating collectors global capacity



Solar water heating collectors top 10 countries



Capacity added in 2012 in the top 10 countries



Environmental Impact of Renewable Energy and Energy Investments

Environmental Impacts

- GreenHouse Gas Emissions
- Direct impacts on eco-systems
- Use of natural resources
- Impacts on human health
- Different pollutions (vision, odor, noise, light, electromagnetism)

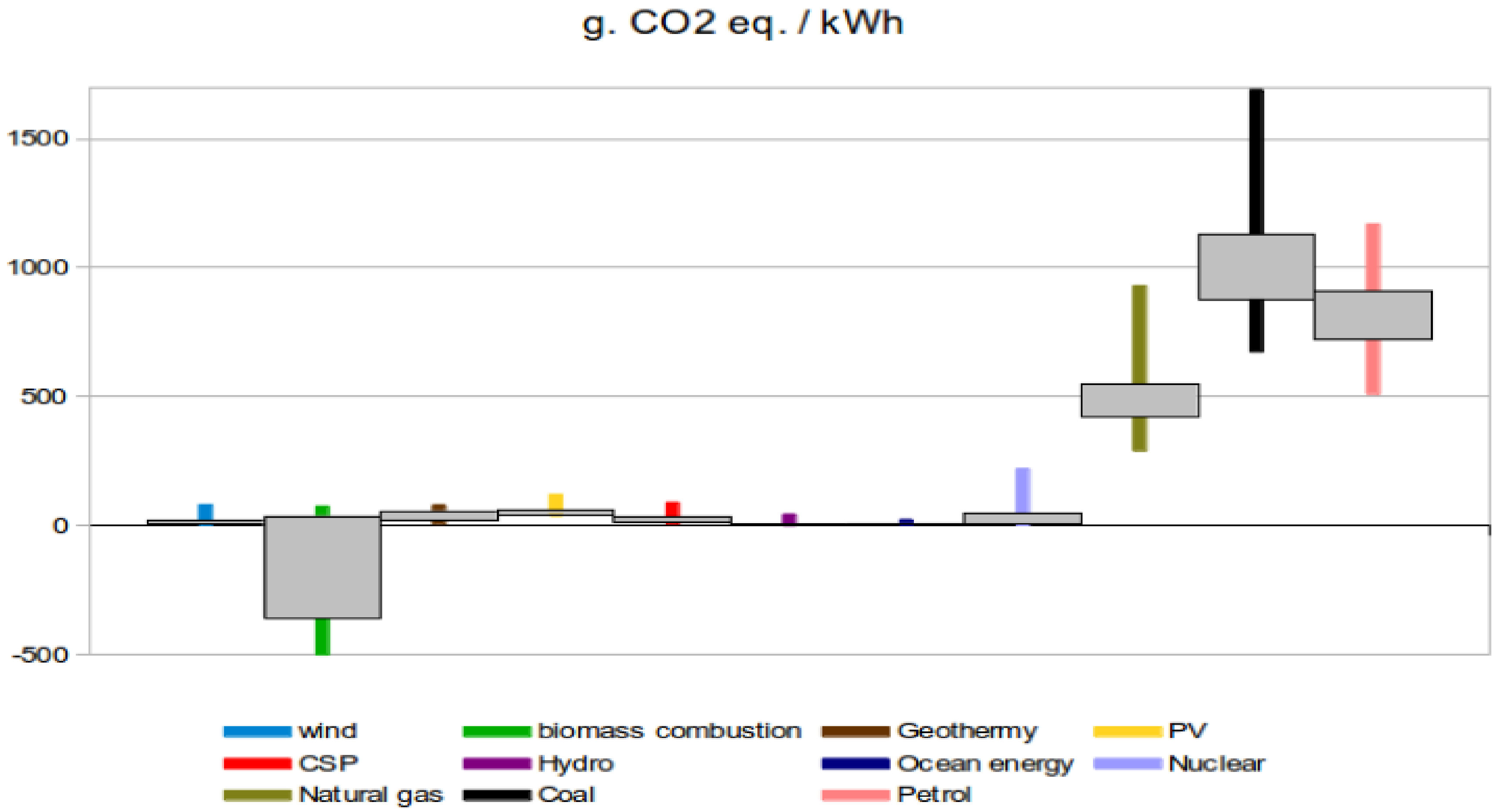
Most environmental impacts are too different in nature to enable proper comparisons.

Only 2 indicators can be considered transversal.

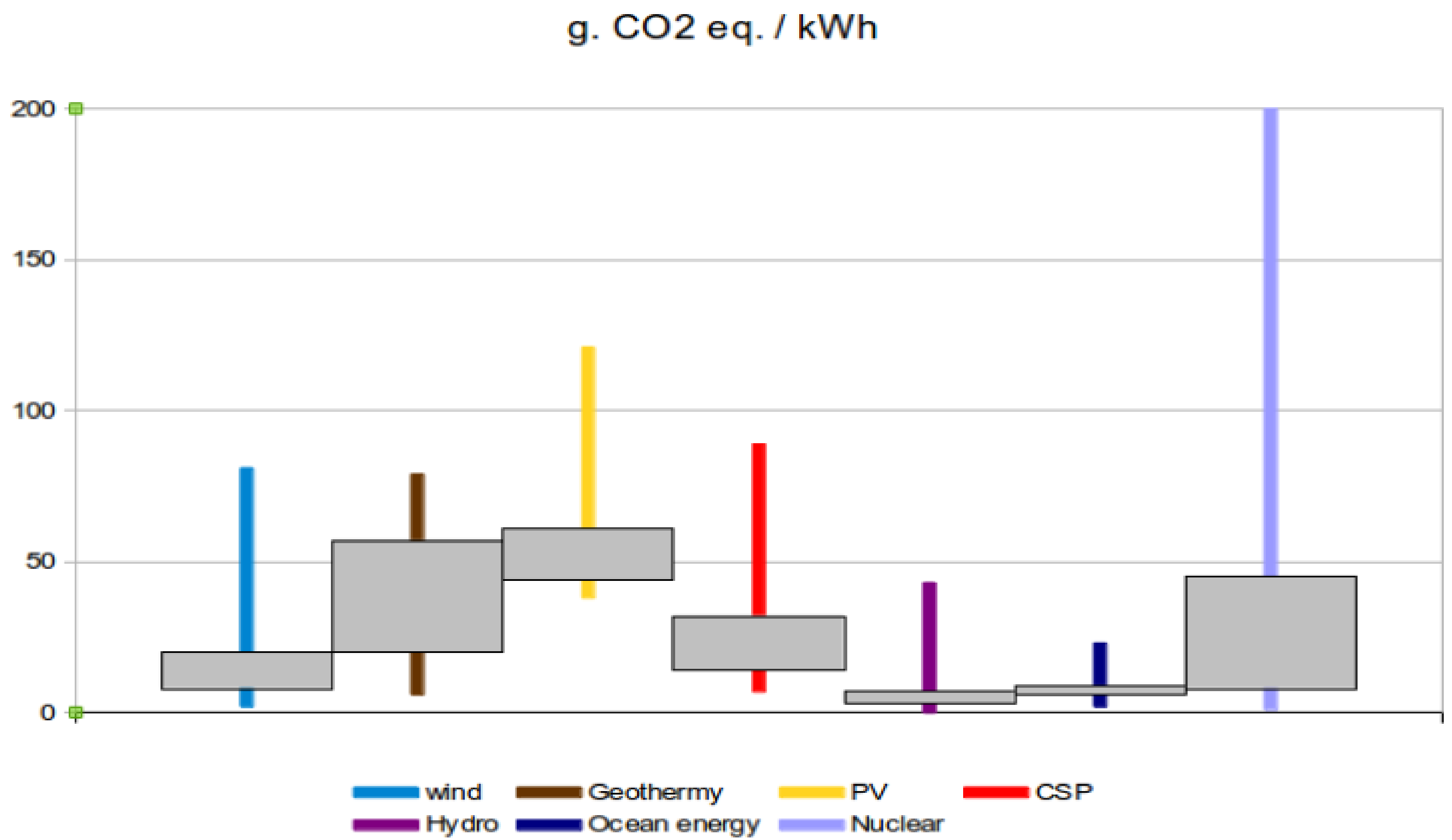
– GHG emissions, Energy Investment

Results are based on LCA.

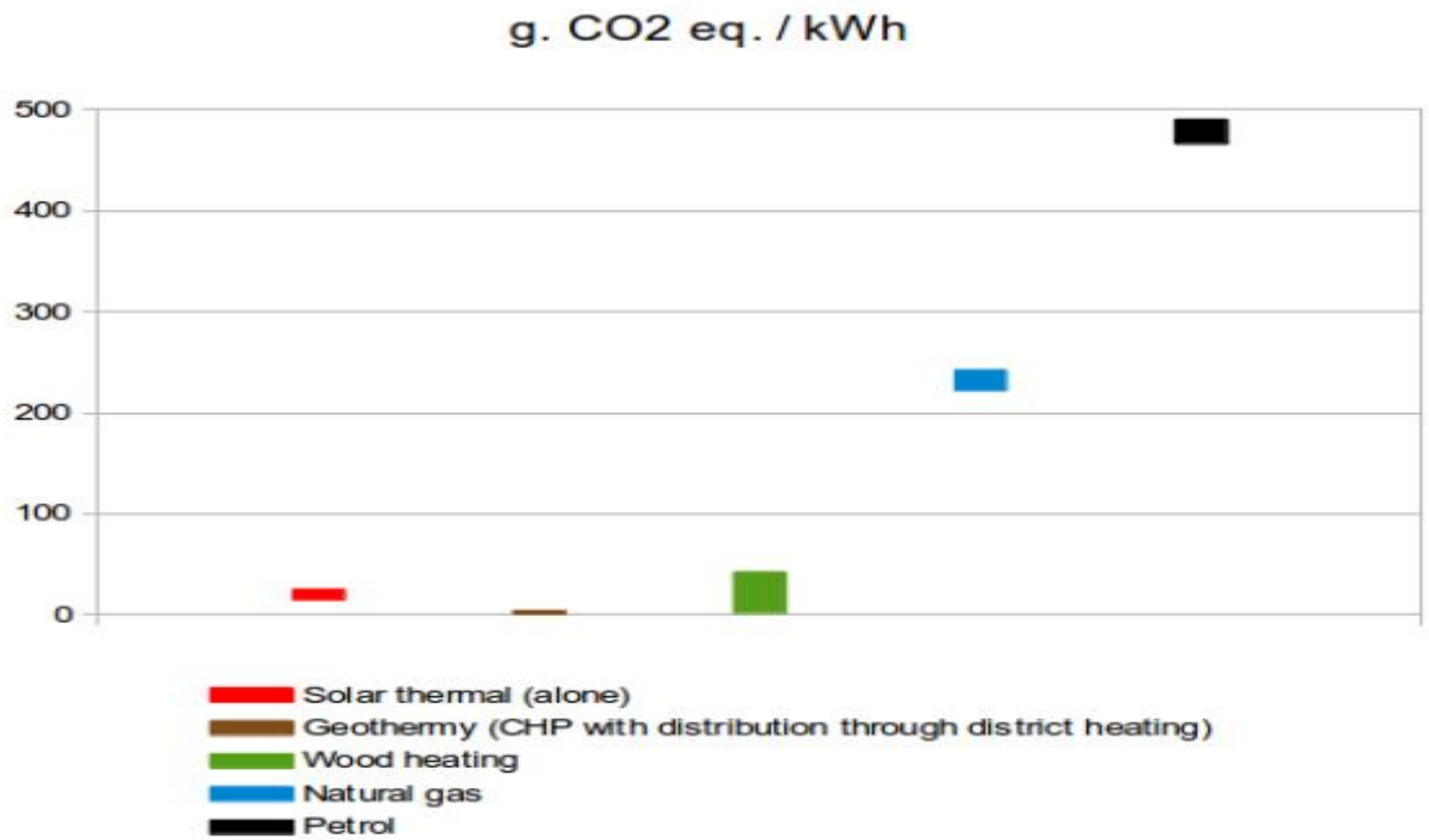
GHG emissions in power generation



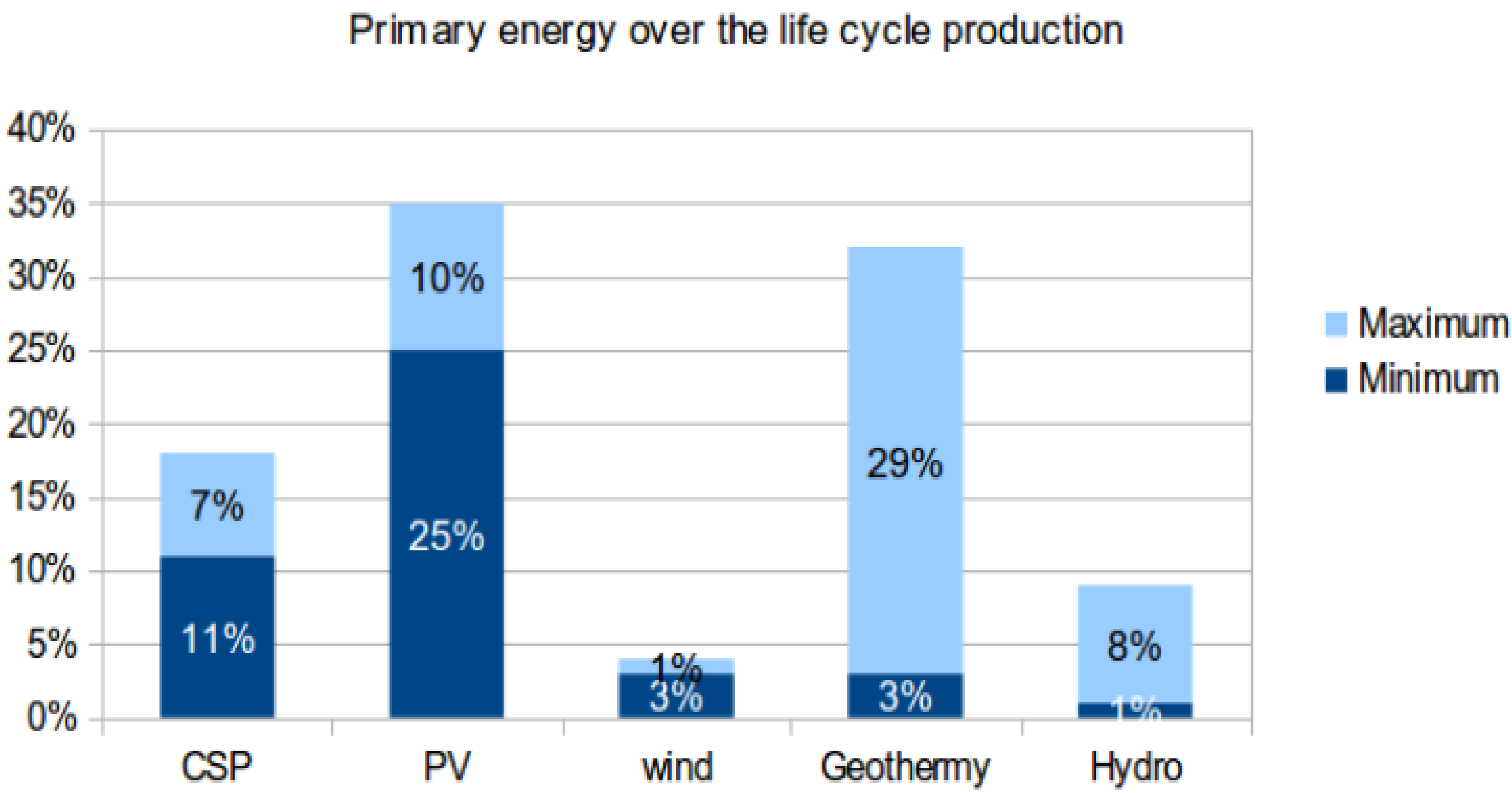
GHG emissions in power generation



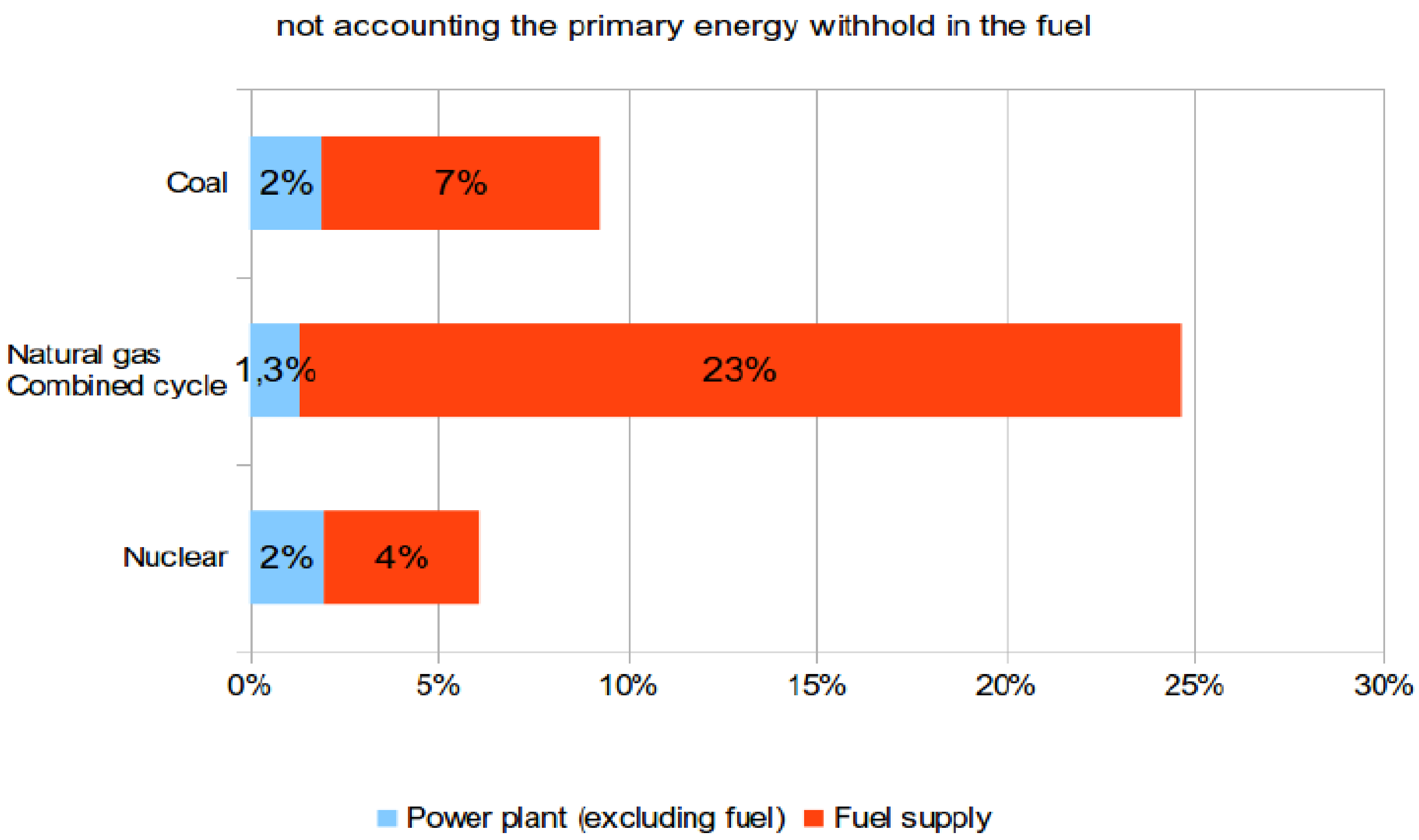
GHG emissions in heat generation



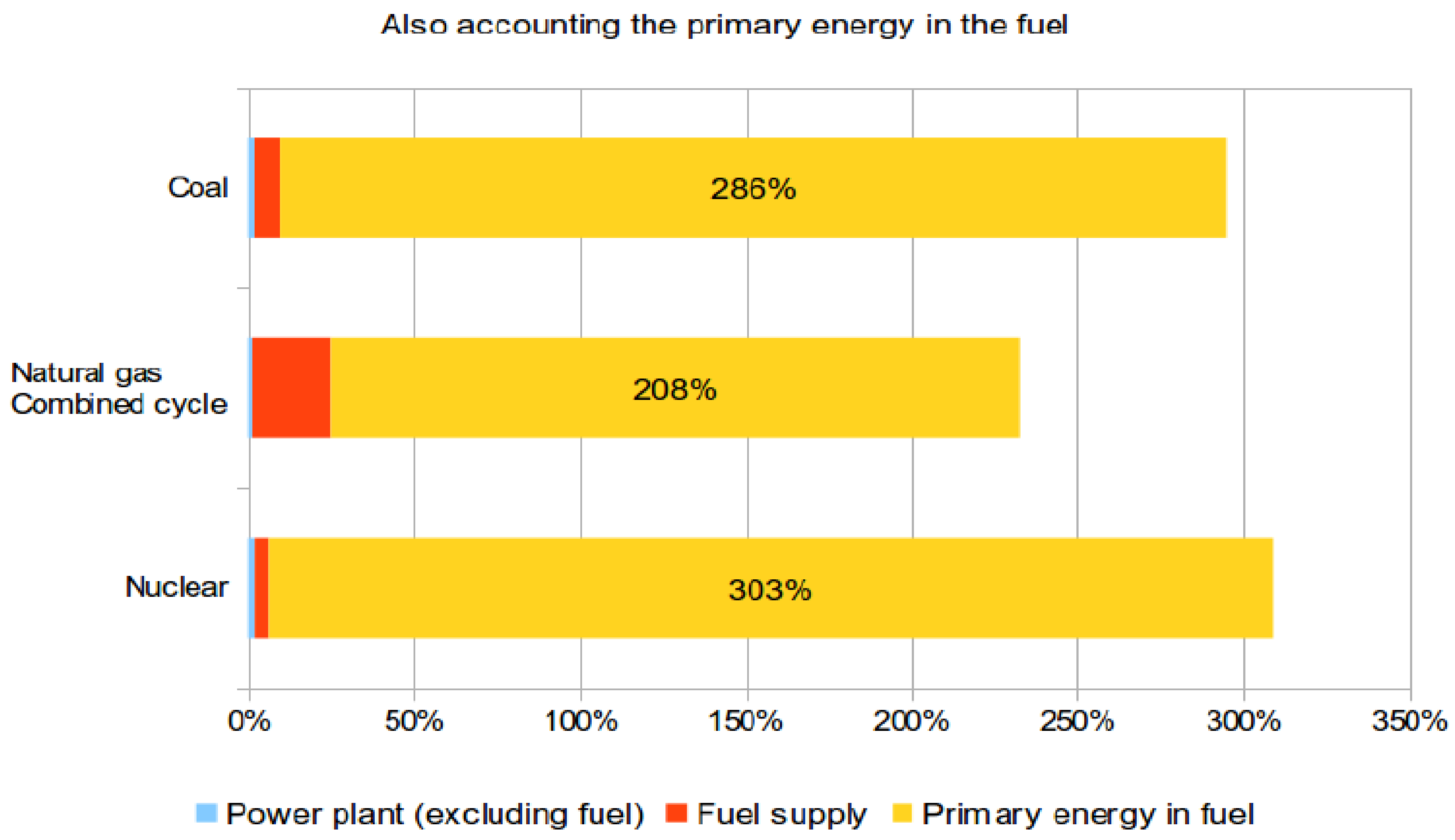
Energy Investment Cost
Power generation – RE technologies



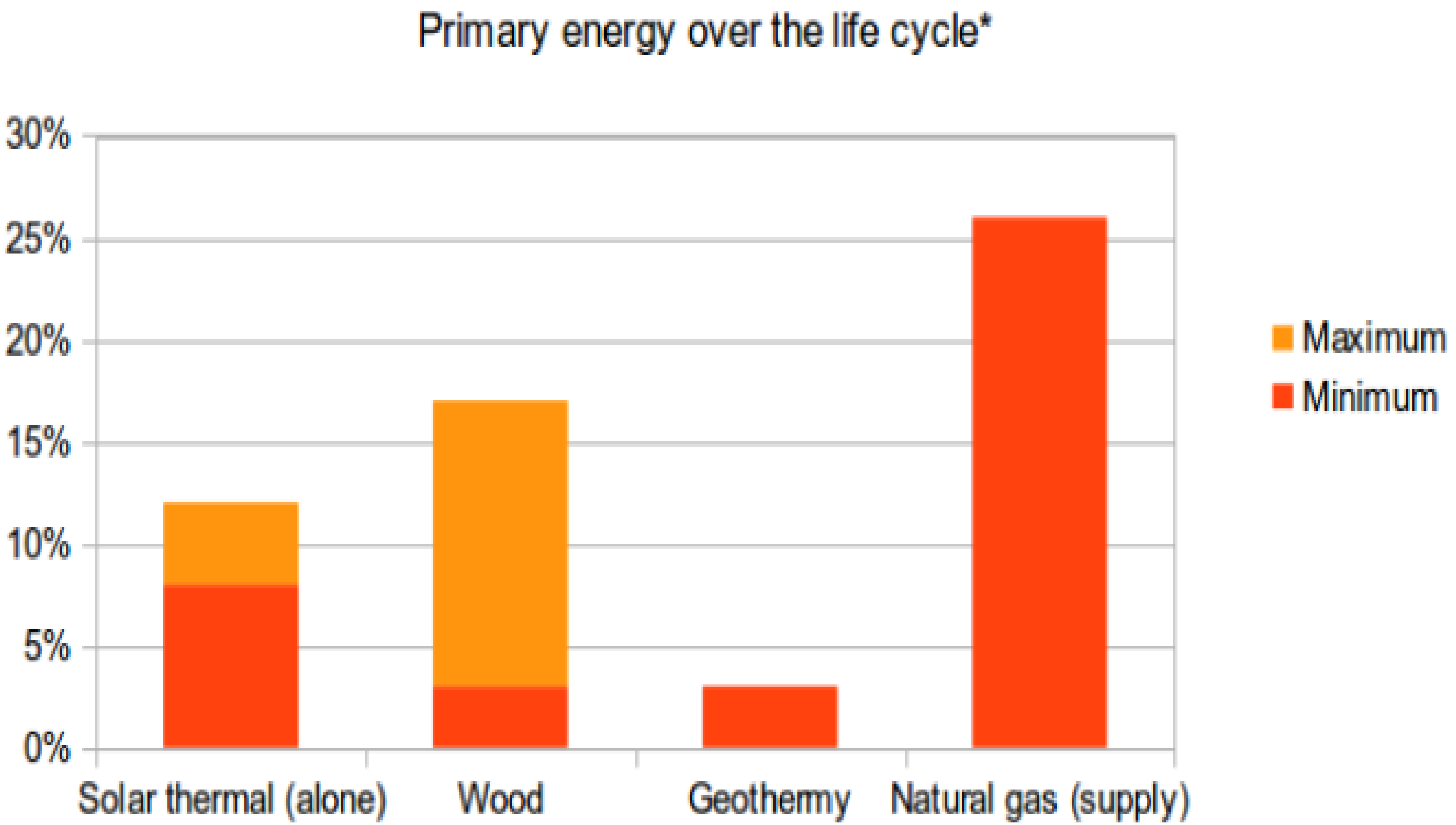
Energy Investment Cost
Conventional Power generation



Energy Investment Cost
Conventional Power generation



Energy Investment Cost
Heat production



Impact of a battery storage in PV production in buildings

- GHG emissions : + 20 to 80 g eq. CO_2/kWh
- EIC : + 9 to 20%
- Best performance : Li-ion and NAS batteries

simplified calculation based on : *A Review of Battery LCA State of Knowledge and Critical Needs* Sullivan and Gaines
Argone Laboratory (2010). Only accounts for CO2 and CH4.