ETFOS
ELEKTROTEHNIČKI FAKULTET OSIJEK
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Solar Resources in the Danube region

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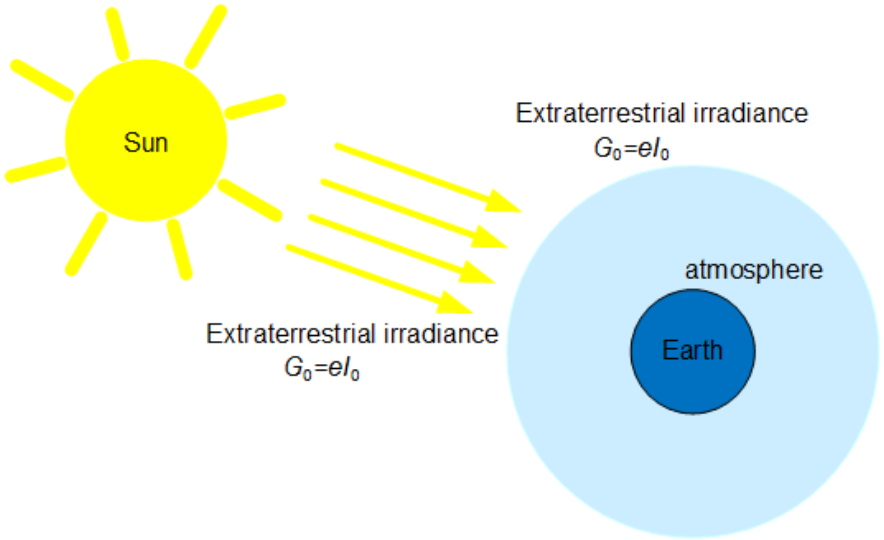
Annual Energy from Sun Radiation vs. Energy Reserves and Needs

Extraterrestrial irradiance:
G_0=1321 W/m^2 - Earth farthest from the Sun
G_0=1412 W/m^2 - Earth is closest to the sun

Solar constant
I_0=1367 W/m^2



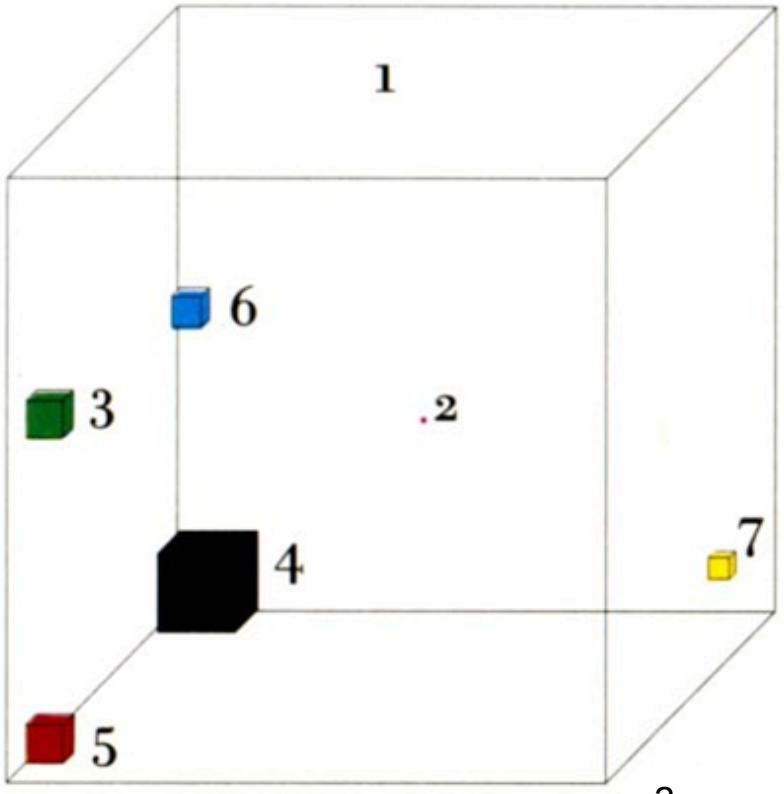
Total Earth surface: 510.1x10^6 sqkm resulting in average annual Sun radiation energy over 10^9 (billion!!!) TWh/yr (Enormous!!!)

(1) Annual Energy from Sun Radiation to Earth

(2) Direct Usage of Sun Energy

(3) Overall Natural Gas Reserves
(4) Overall Coal Reserves
(5) Overall Oil Reserves
(6) Overall Uranium Reserves

(7) Annual World Energy Consumption



Definition of potential: REN21 methodology for RES

When focusing on the availability of renewable energy sources, it is important to define the type of potential that is considered. In the literature, various types of potentials are defined. There is no one single definition for the various types of potentials.

Definition of potential according to REN 21:

- **Theoretical potential**: The highest level of potential is the theoretical potential. This potential only takes into account restrictions with respect to natural and climatic parameters.
- **Geographical potential**: Most renewable energy sources have geographical restrictions, e.g. land use land cover that reduce the theoretical potential. The geographical potential is the theoretical potential limited by the resources at geographical locations that are suitable.
- **Technical potential**: The geographical potential is further reduced due to technical limitations as conversion efficiencies, resulting in the technical potential.
- **Economic potential:** The economic potential is the technical potential at cost levels considered competitive.
- **Market potential**: The market potential is the total amount of renewable energy that can be implemented in the market taking into account the demand for energy, the competing technologies, the costs and subsidies of renewable energy sources, and the barriers.

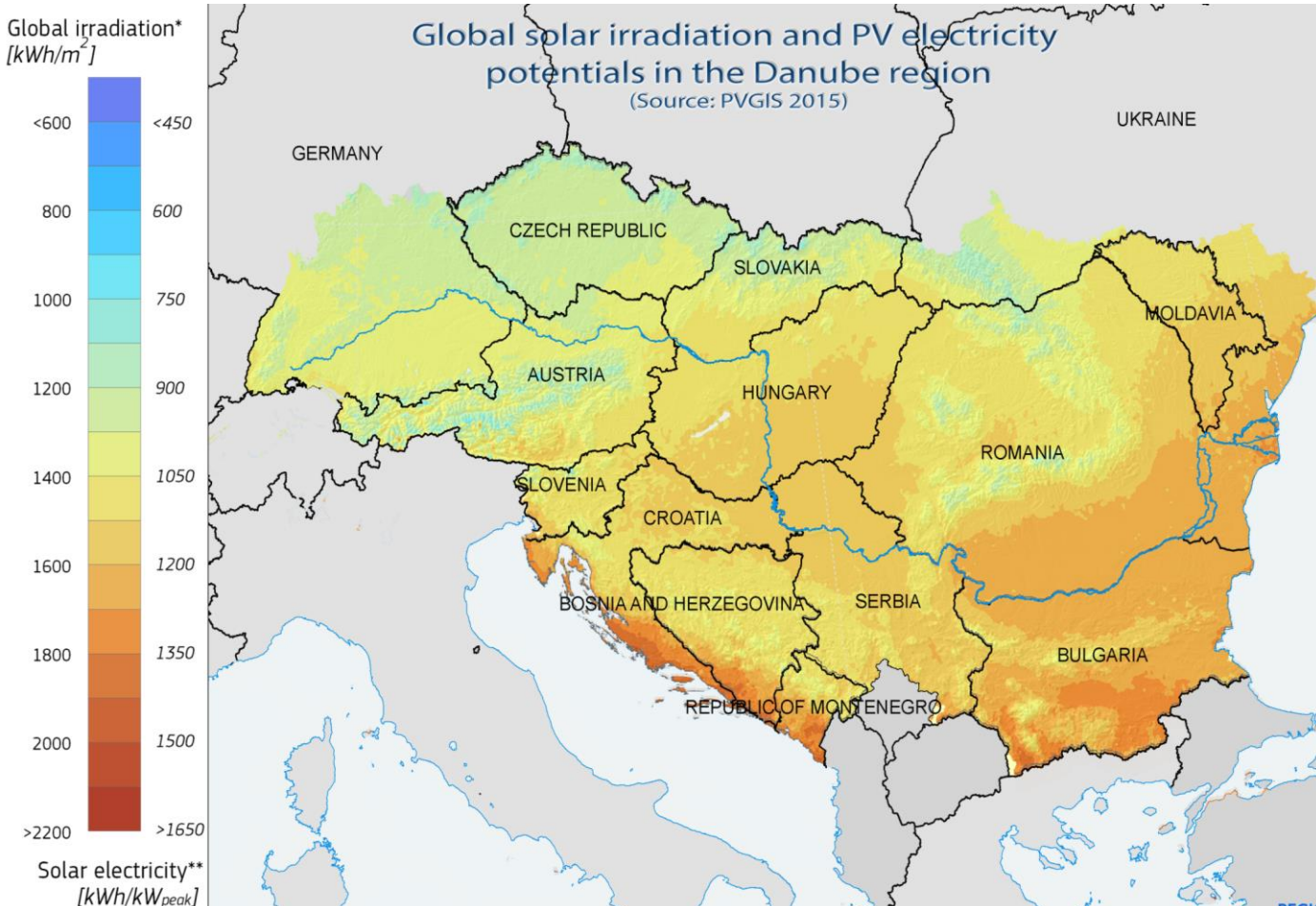
Source: ECOFYS: Global Potential of Renewable Energy Sources: A Literature Assessment'' by order of REN21 - Renewable Energy Policy Network for the 21st Century, 2005

Definition of potential: PVGIS methodology for Solar energy

- **Photovoltaic Geographical Information System (PVGIS)**
  Geographical Assessment of Solar Resource and Performance of Photovoltaic Technology

  Research, demonstration and policy-support instrument for **geographical** assessment of the solar energy resource in the context of integrated management of distributed energy generation. F**or technical, environmental and socio-economic factors of solar** (electricity) generation. GIS databases for Europe, Africa and South-West Asia

Source:
http://re.jrc.ec.europa.eu/pvgis/



European Commission

Joint research centre
Institute for Energy and Transport

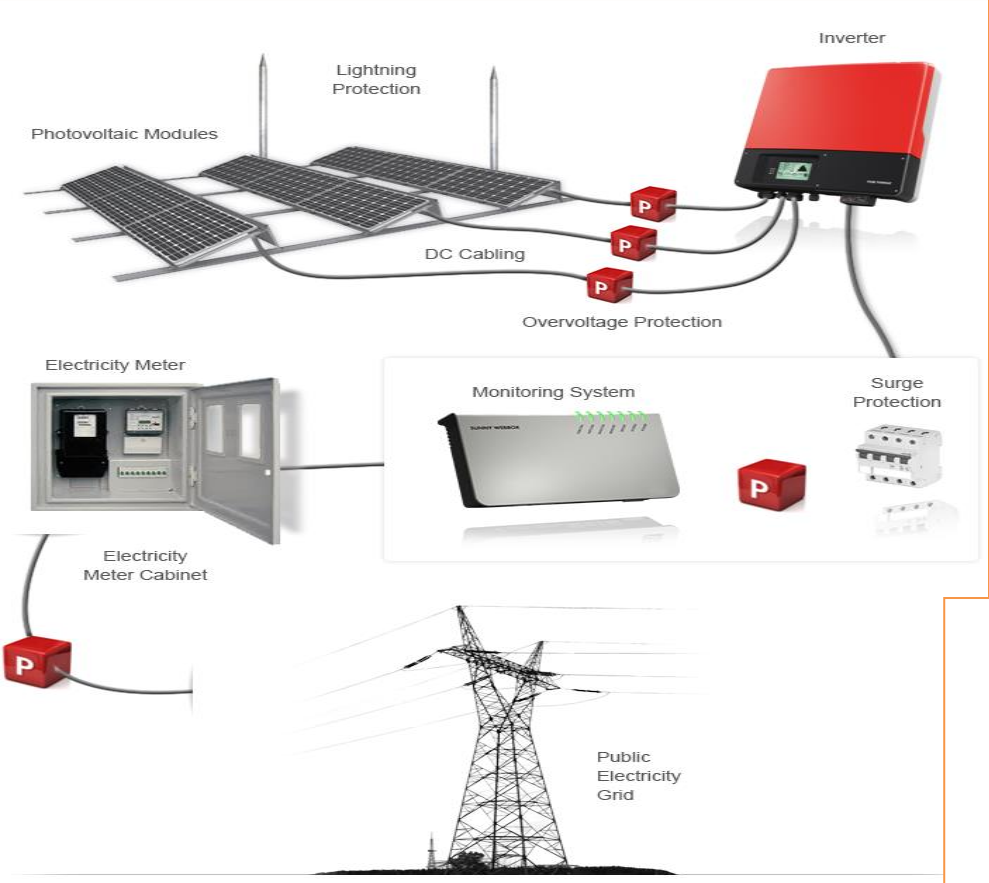
Choice of technology:

- **PV Photovoltaic systems** (electricity)
- **CSP Concentrated solar thermal power plants** (electricity and heat)
- **SHC Solar collectors and heating and cooling systems** (heat)

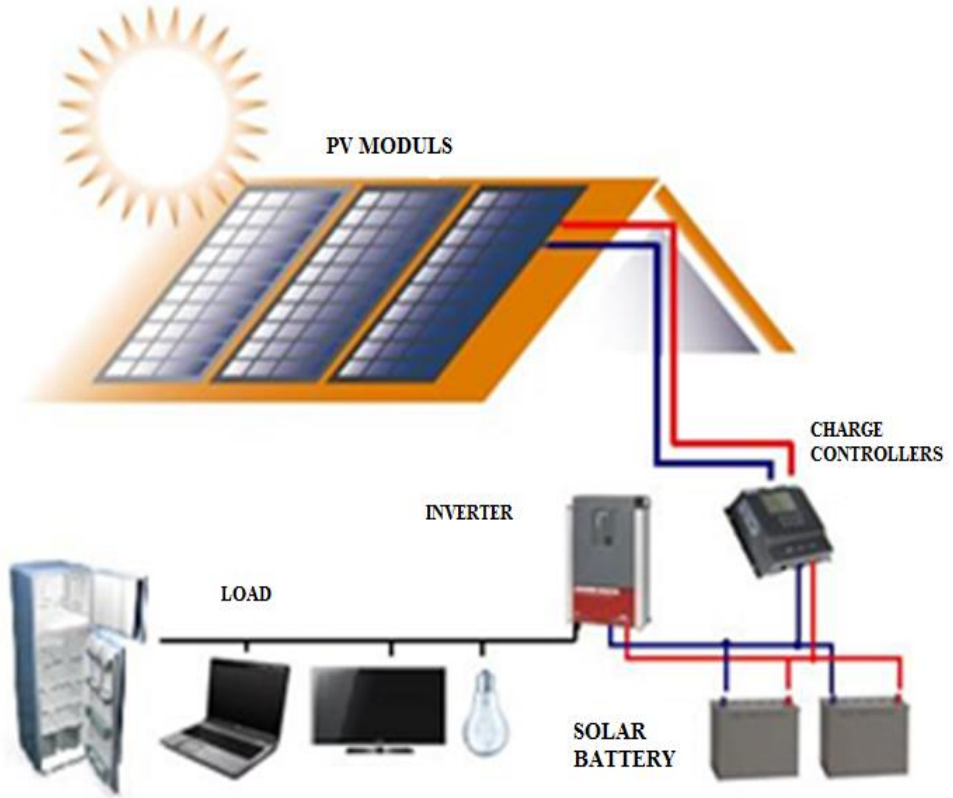
		START 2004[1]	END 2012	END 2013
INVESTMENT				
New investment (annual) in renewable power and fuels[2]	billion USD	39.5	249.5	**214.4** (249.4)
POWER				
Renewable power capacity (total, not including hydro)	GW	85	480	**560**
Renewable power capacity (total, including hydro)	GW	800	1,440	**1,560**
Hydropower capacity (total)[3]	GW	715	960	**1,000**
Bio-power capacity	GW	<36	83	**88**
Bio-power generation	TWh	227	350	**405**
Geothermal power capacity	GW	8.9	11.5	**12**
Solar PV capacity (total)	GW	2.6	100	**139**
Concentrating solar thermal power (total)	GW	0.4	2.5	**3.4**
Wind power capacity (total)	GW	48	283	**318**
HEAT				
Solar hot water capacity (total)[4]	GW_{th}	98	282	**326**
TRANSPORT				
Ethanol production (annual)	billion litres	28.5	82.6	**87.2**
Biodiesel production (annual)	billion litres	2.4	23.6	**26.3**
POLICIES				
Countries with policy targets	#	48	138	**144**
Feed-in Number of states / provinces / countries	#	34	97	**98**
RPS / quota policies Number of states / provinces / countries	#	11	79	**79**
Tendering Number of states / provinces / countries	#	8	45	**55**
Heat obligations / mandates Number of countries	#	n/a	19	**19**
Biofuel obligations / mandates[5] Number of countries	#	10	52	**63**

Source: REN21 Renewables 2014 Global Status Report

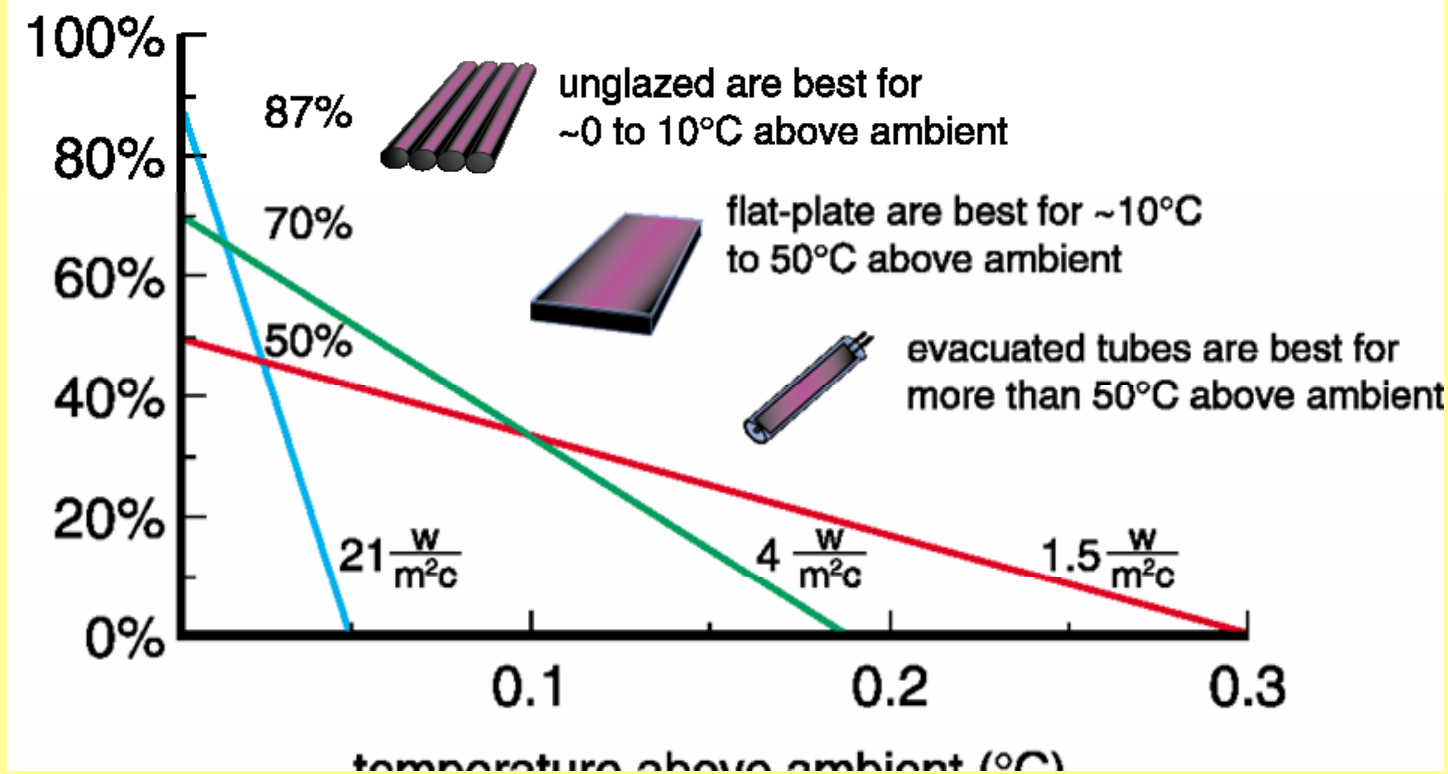
On-grid PV system in principal



Off-grid PV system in principal



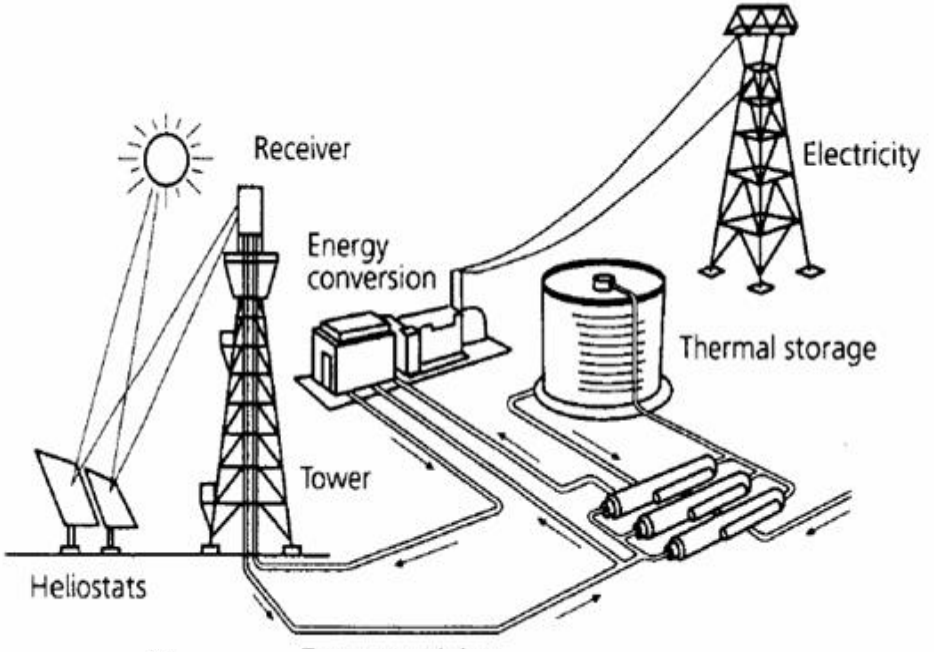
Solar collector efficiency and temperature



Parabolic through concentrated solar thermal power plant (CSP)

Linear parabolic reflectors

Solar tower CSP (with central receiver)



Dish Stirling CSP

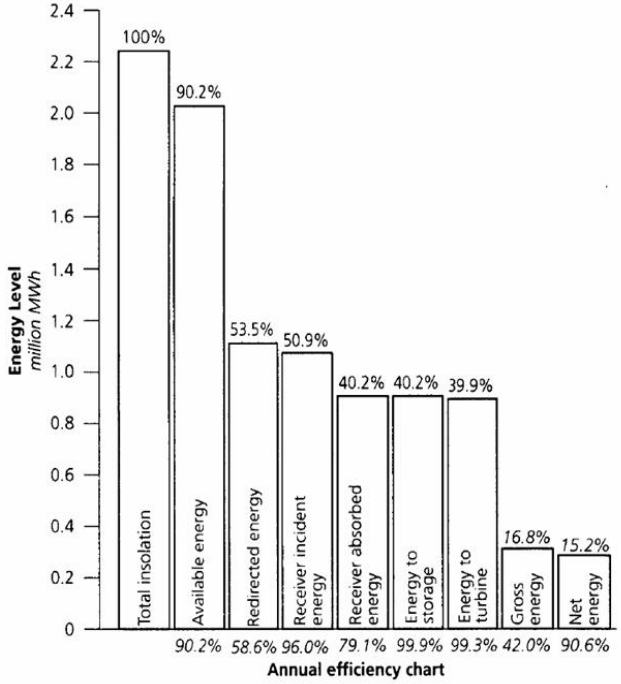
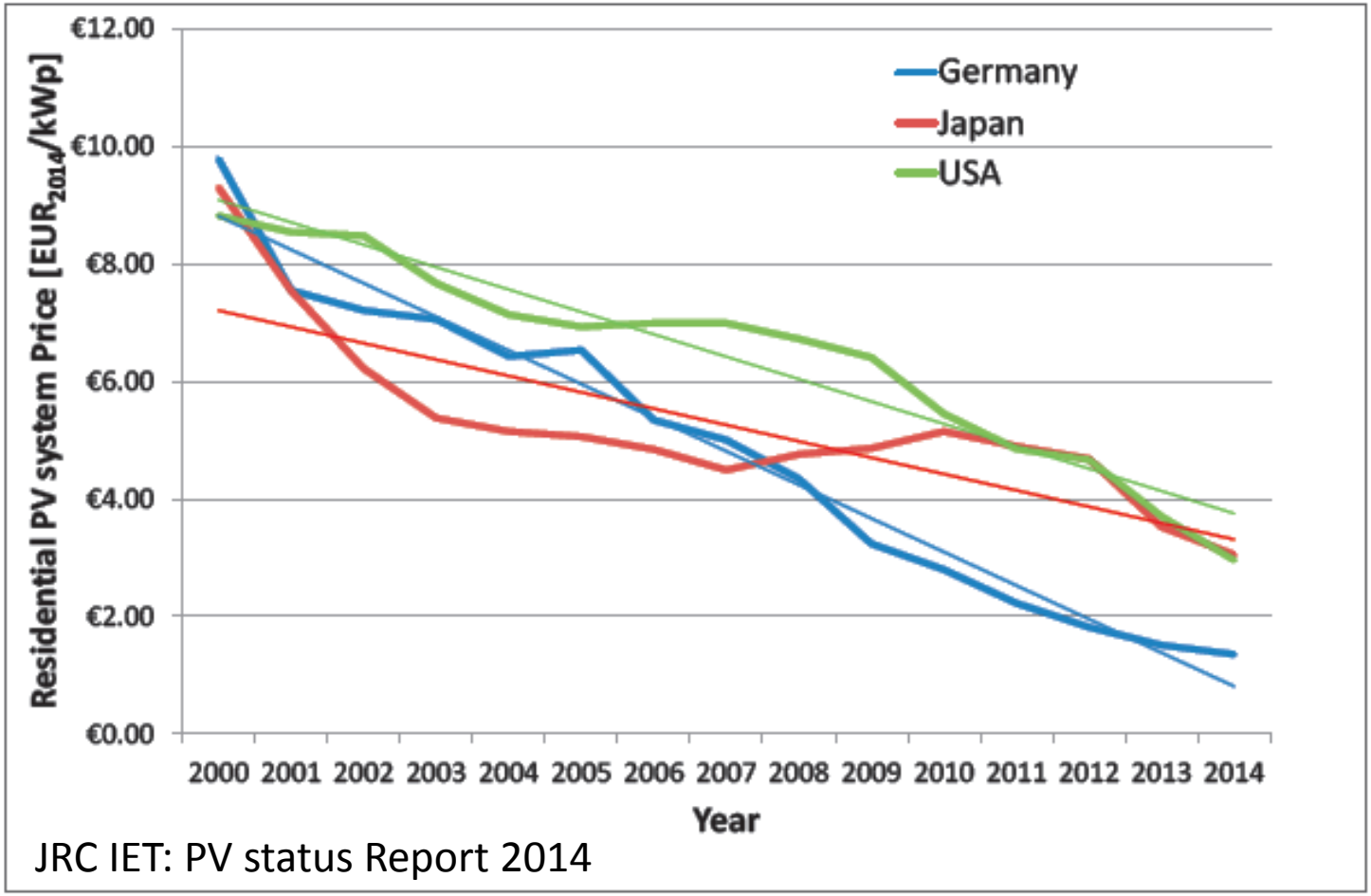


FIGURE 23: Annual efficiency of a 100 MW$_e$ central receiver The efficiencies at the bottoms of the bars are component efficiencies; those a the top are cumulative efficiencies.

Technical, Economic and Market Potential

Constraints

- Limited area (topography, geology), ecological, cultural, political constraints
- Electricity market price vs. feed-in (incentive) policy vs. investments drops



JRC IET: PV status Report 2014

Fig. 9: Residential PV system price development over the last decade (data sources: IEA PVPS, BSW, DoE SunShot Initiative, Eurostat, OECD key economic data)

Technical potentials

Economics of RES: small-scale PV LCOE vs. Sun radiation

Table 1: LCOE of PV-generated electricity for residential systems with a system price of EUR 1400/kWp (excluding VAT, because the differences in the various countries are too large), 1.5 % O&M cost, an annual generation of 1000 kWh/kWp/year and financial lifetimes of 20 years

	Price [EUR/kWp]	LCOE Product [EURct/kWh]	LCOE Capital [EURct/kWh]			LCOE O&M 2 % [EURct/kWh]	LCOE Total [EURct/kWh]		
Return on investment		0 %	3 %	5 %	10 %		3 %	5 %	10 %
PV module	560	2.80	0.85	1.48	3.18	1.12	4.77	5.40	7.10
Inverter	140	0.70	0.21	0.37	0.79	0.28	1.19	1.35	1.77
Balance of systems	270	1.35	0.41	0.71	1.53	0.54	2.30	2.60	3.42
Engineering, procurement & construction	300	1.50	0.46	0.79	1.70	0.60	2.56	2.89	3.80
Other (fees, permits, insurances...)	130	0.65	0.20	0.34	0.74	0.26	1.11	1.25	1.65
Total	1400	7.00	2.14	3.70	7.95	2.80	11.94	13.50	17.70

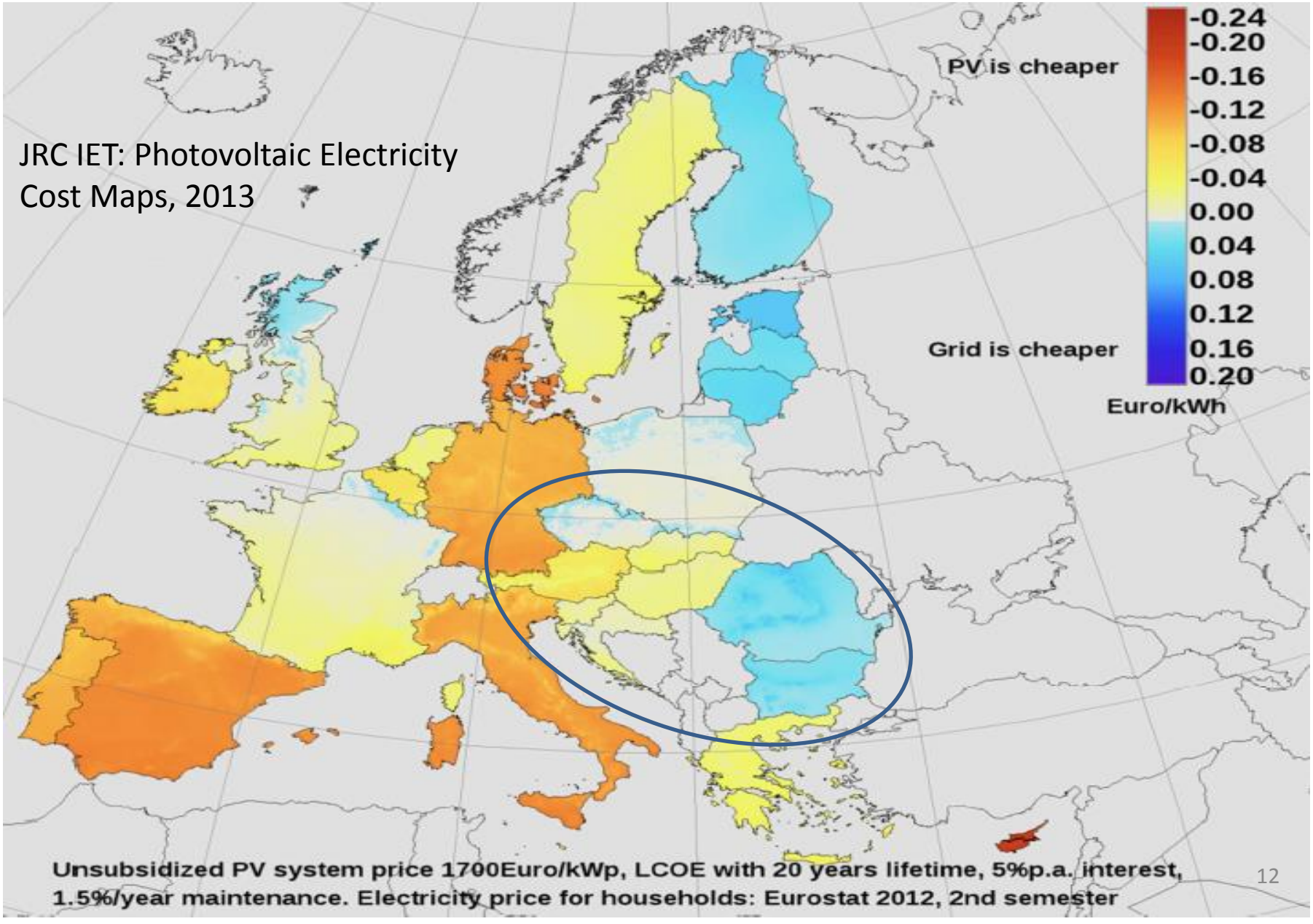
Table 2: LCOE of PV-generated electricity for residential systems with a system price of EUR 1400/kWp (excluding VAT, because the differences in the various countries are too large), 2 % O&M costs, an annual generation of 1300 kWh/kWp/year and a financial lifetime of 20 years

	Price [EUR/kWp]	LCOE Product [EURct/kWh]	LCOE Capital [EURct/kWh]			LCOE O&M 2 % [EURct/kWh]	LCOE Total [EURct/kWh]		
Return on investment		0 %	3 %	5 %	10 %		3 %	5 %	10 %
PV module	560	2.15	0.66	1.14	2.45	0.86	3.67	4.15	5.46
Inverter	140	0.54	0.16	0.28	0.61	0.22	0.92	1.04	1.37
Balance of systems	270	1.04	0.32	0.55	1.18	0.41	1.77	2.00	2.63
Engineering, procurement & construction	300	1.15	0.36	0.61	1.31	0.47	1.97	2.23	2.93
Other (fees, permits, insurances...)	130	0.50	0.15	0.26	0.57	0.20	0.85	0.96	1.27
Total	1400	5.38	1.65	2.85	6.12	2.16	9.18	10.38	13.65

JRC IET: PV status Report 2014

Technical potentials

Electricity household retail (grid) price vs. PV LCOE 2012



Ecological characteristics: waste disposal vs EBTP & CO_{2eq}

Module ecological characteristics	Mono Si Bisol BMO250	CIS Solar Frontier SF-150	Amorph Si Masdar MPV-100S	High-eff mono Si Panasonic VBHN240SE10	Poly Si Bisol BMU250
Waste disposal (direct environmental impact)	High efficiency = less waste materials	Medium efficiency= more waste materials	Smallest eff, shorter lifetime = the most waste, but low cell production temp results in smaller material use	Even higher efficiency = even less watste materials	Simillar efficiency as with mono Si
Energy consumption and CO_2 equivalent	High energy consumption = longer EBTP and CO_2 equival	Short EBPT and low CO_2 equivalent	Low cell production temp = smaller energy consumption	Short EBTP and high CO_2 equivalent	Shorter EBTP than mono Si, lower CO_2 eq, do not contain toxsic matter

Legend:

Bad | Medium | Good | The best

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