Sustainable
RE Power Supplies

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- **Cert. in Electrical and Electronics (Udon. Tech.)**
- **Dipl. In Electrical Power (RMUTI)**
- **B.Eng. In Electrical Power (RMUTT, Thailand)**
- **Diploma in Instrumentation (NAIT, Canada)**
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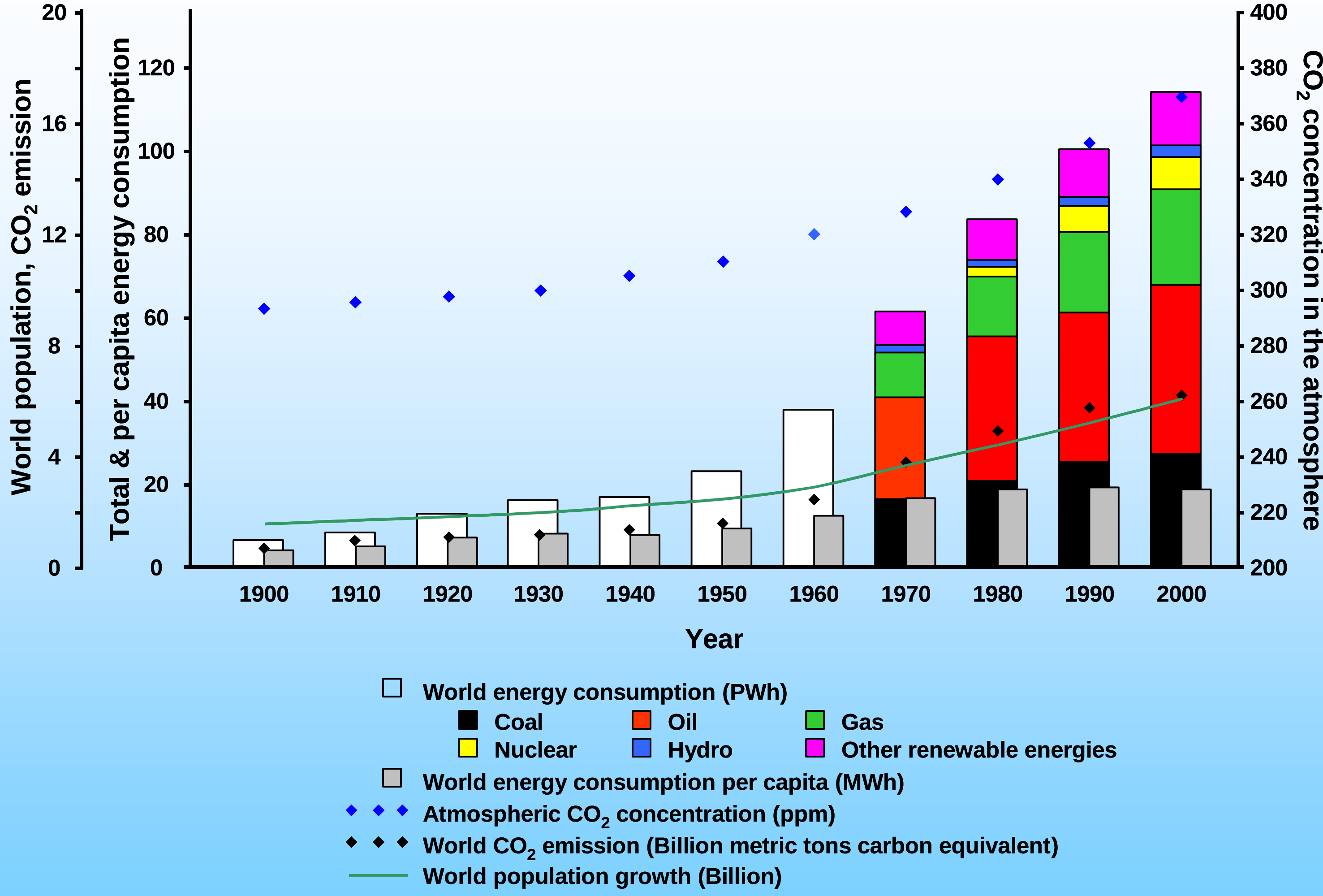
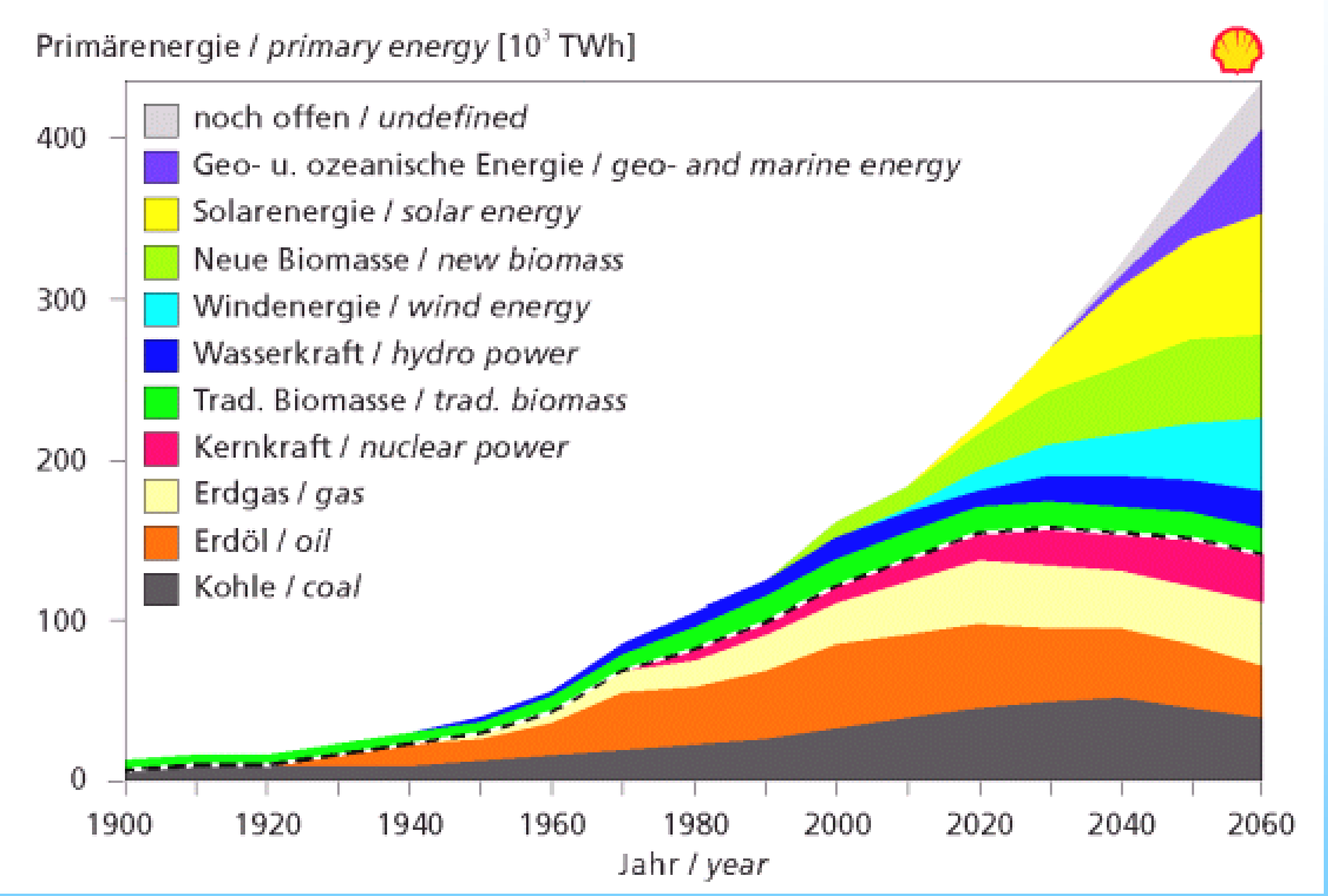
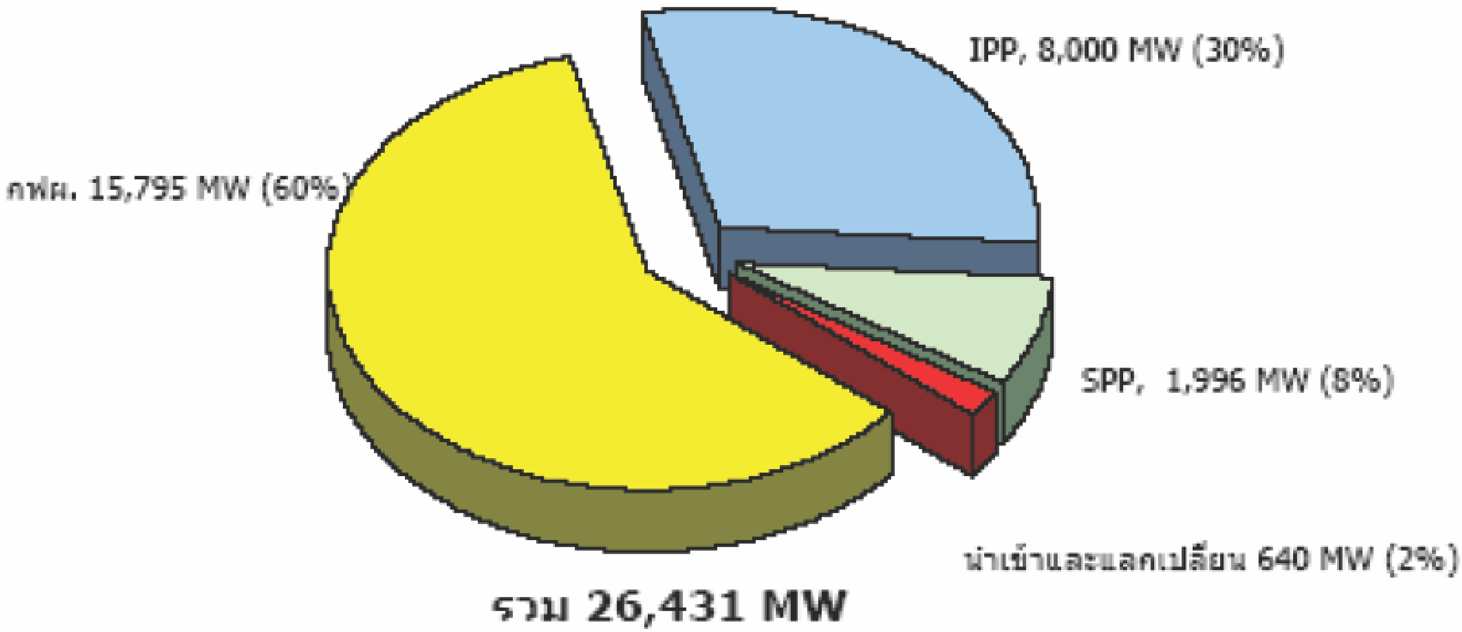
World's Energy Situation



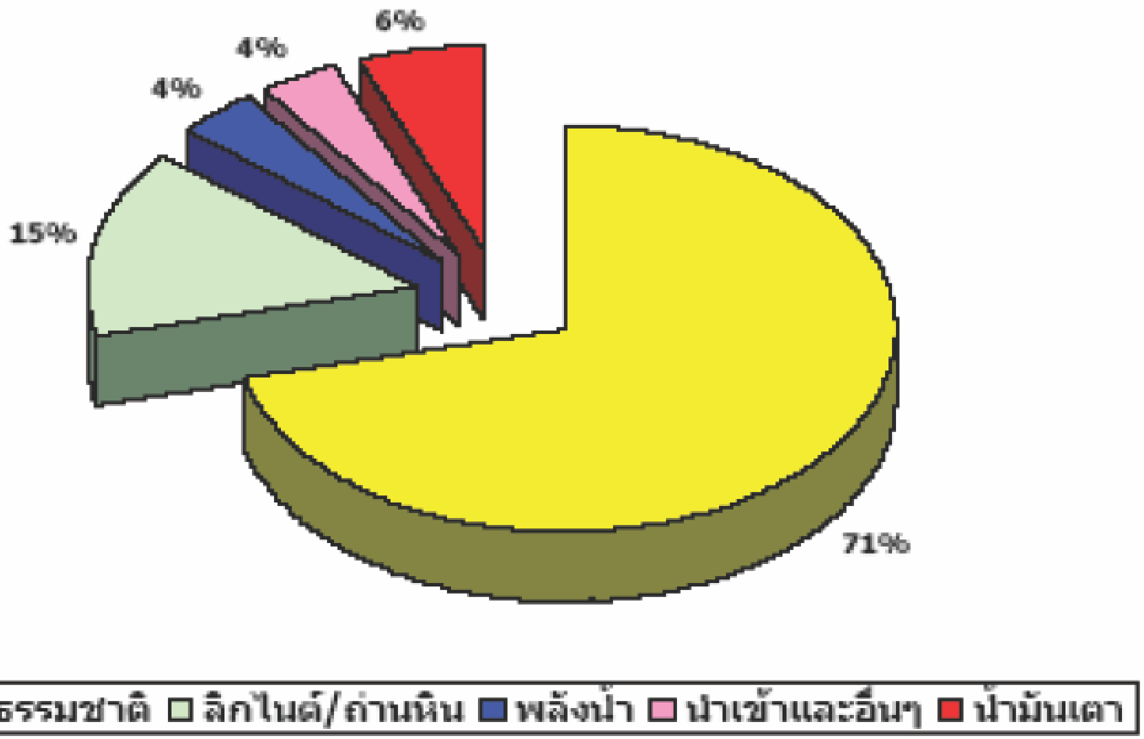
Development of world energy



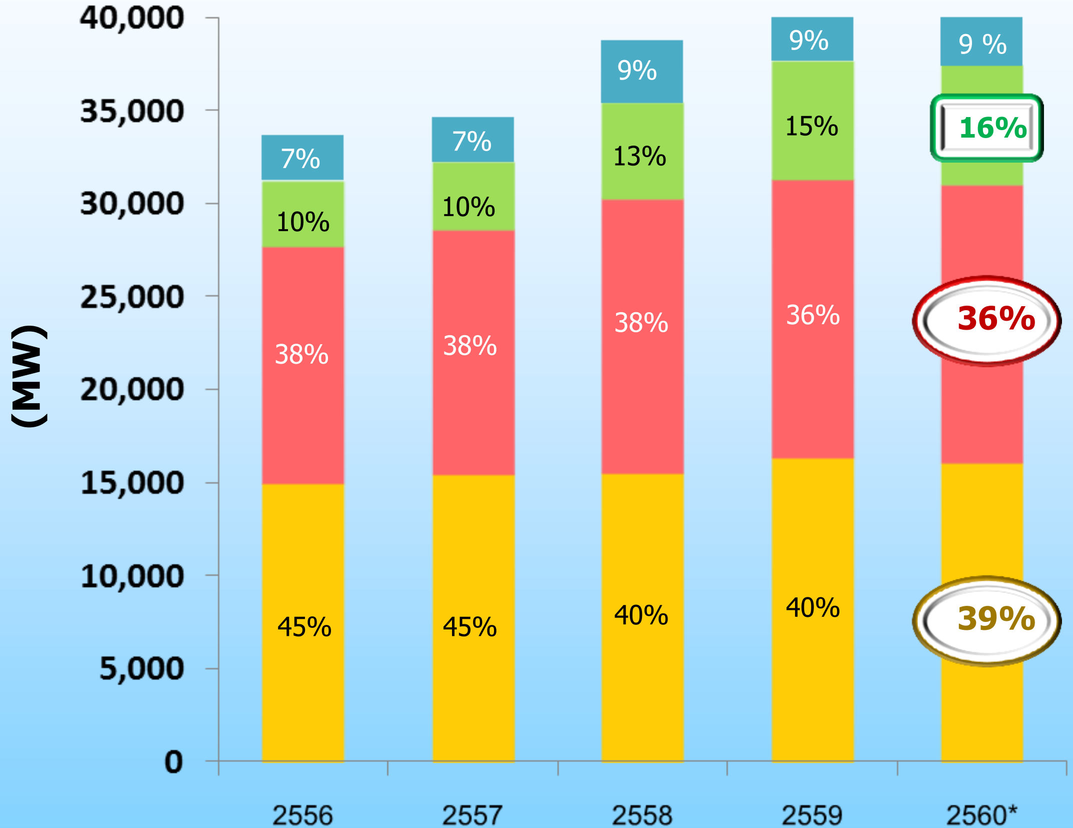
Electricity Capacity 2548 (2005)



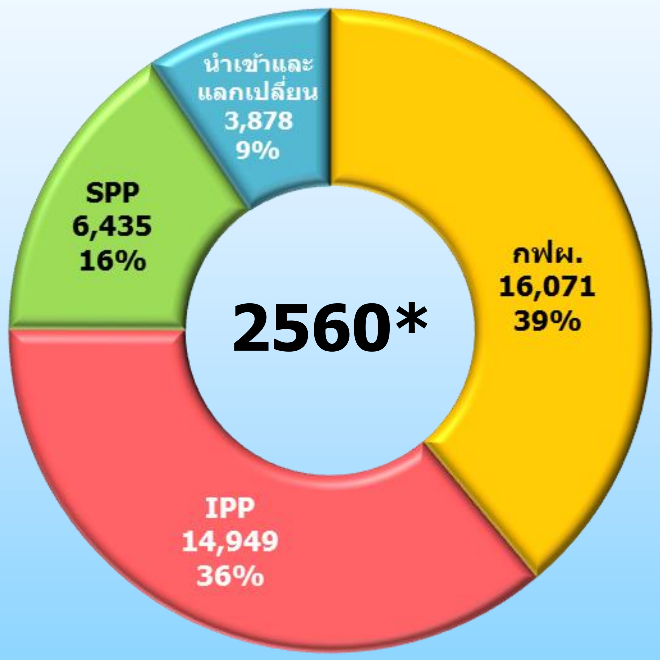
Electricity by Fuel



Electricity Capacity

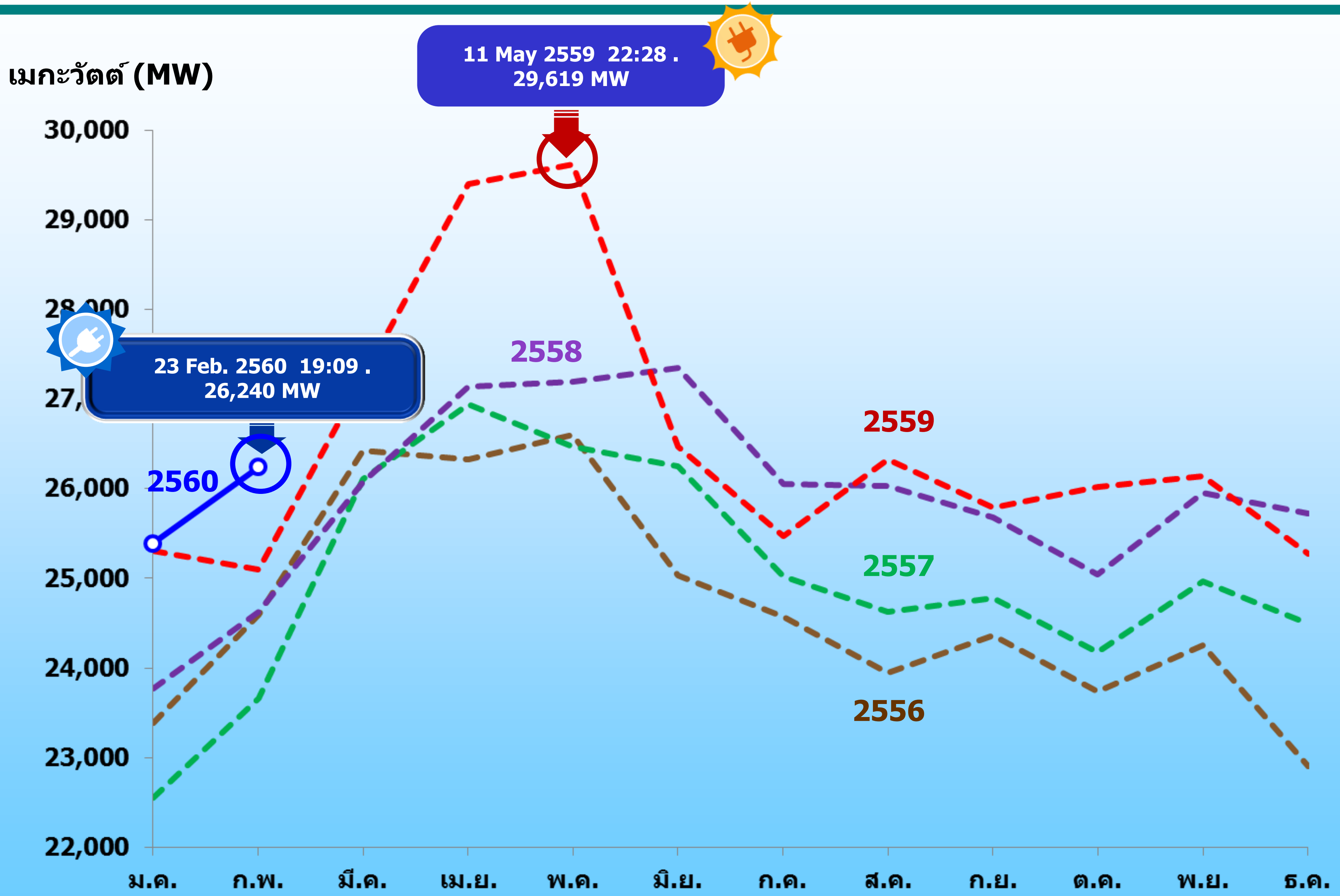


Electricity Capacity

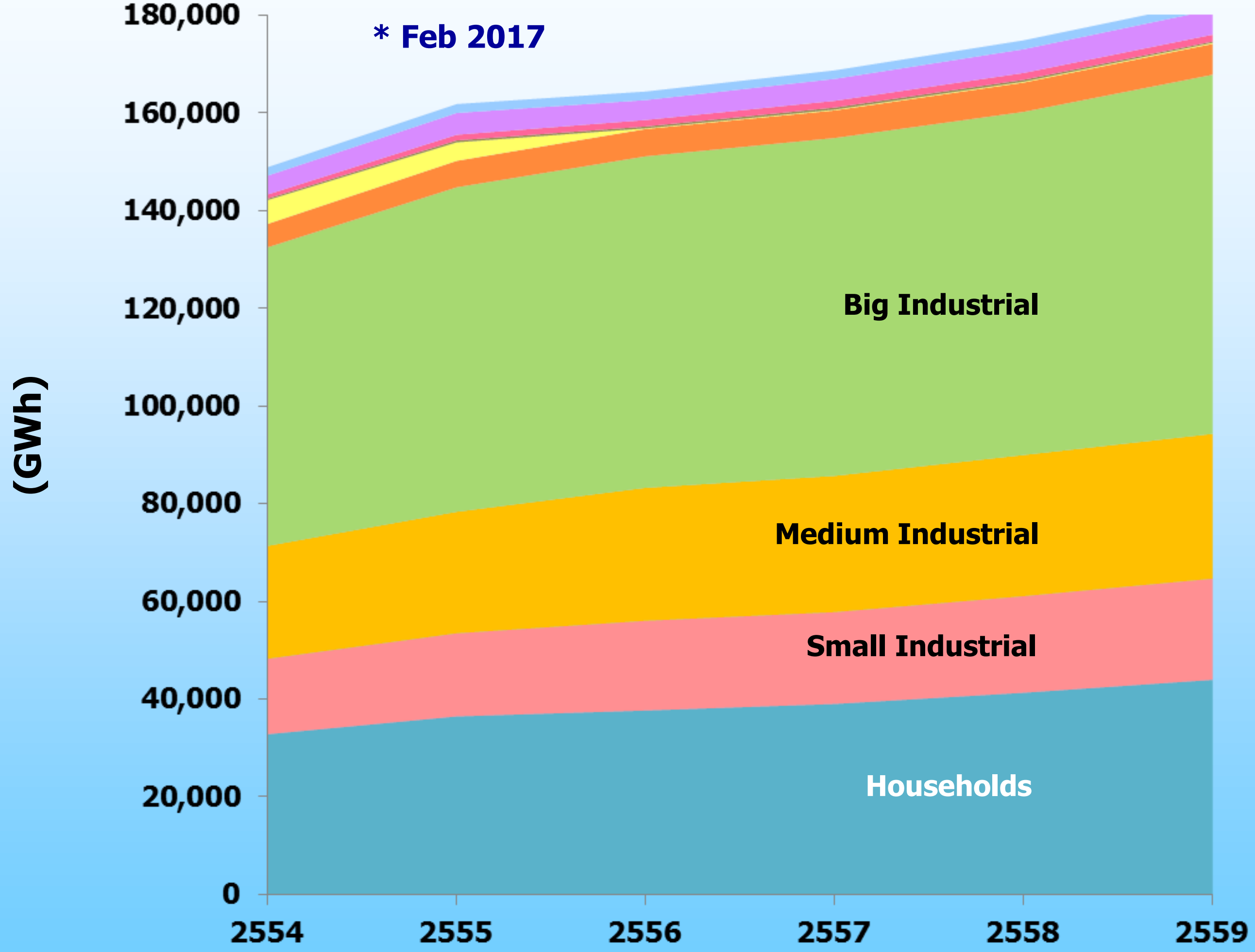


Total 41,332 MW

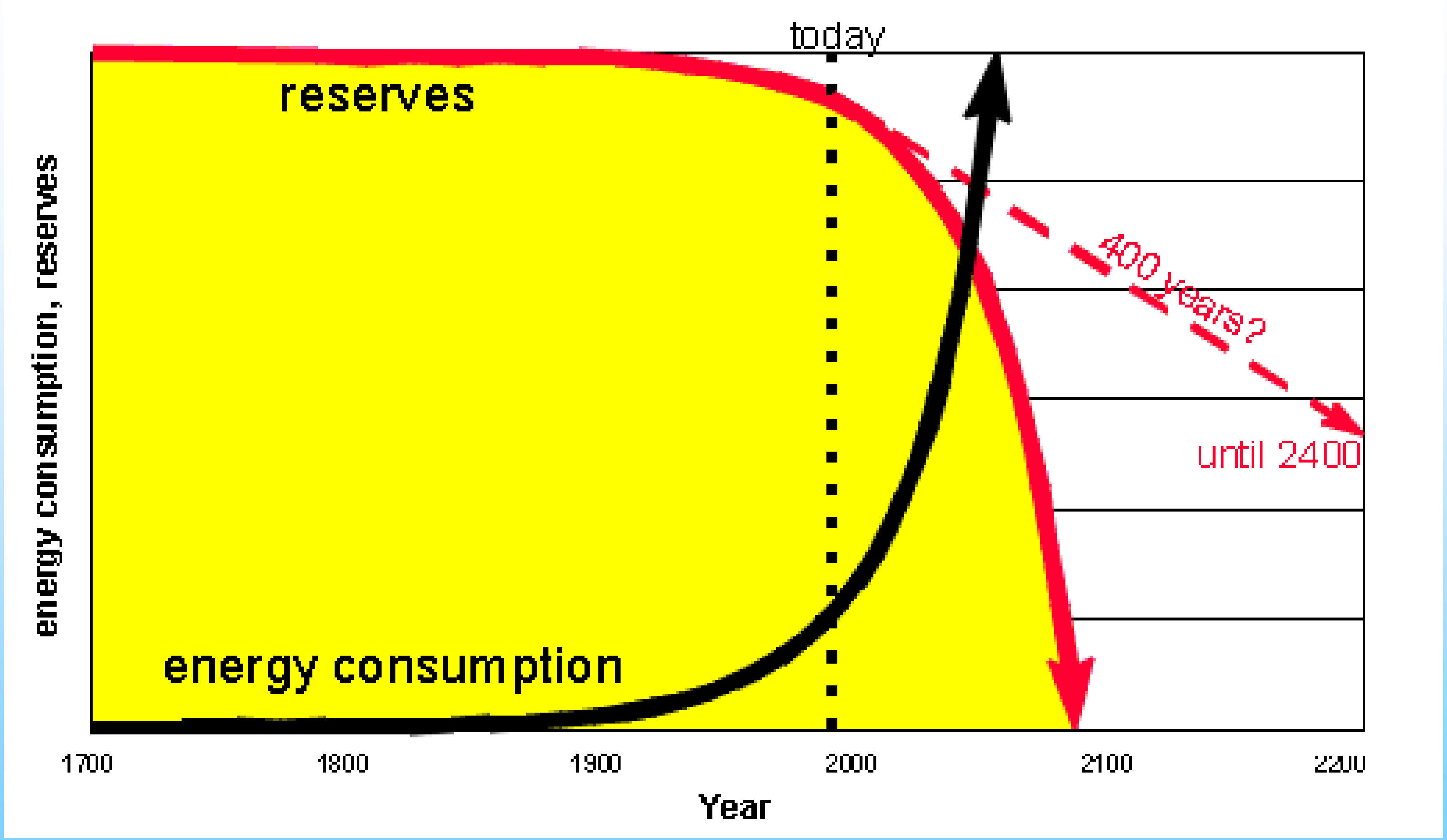
Peak Load (EGAT)



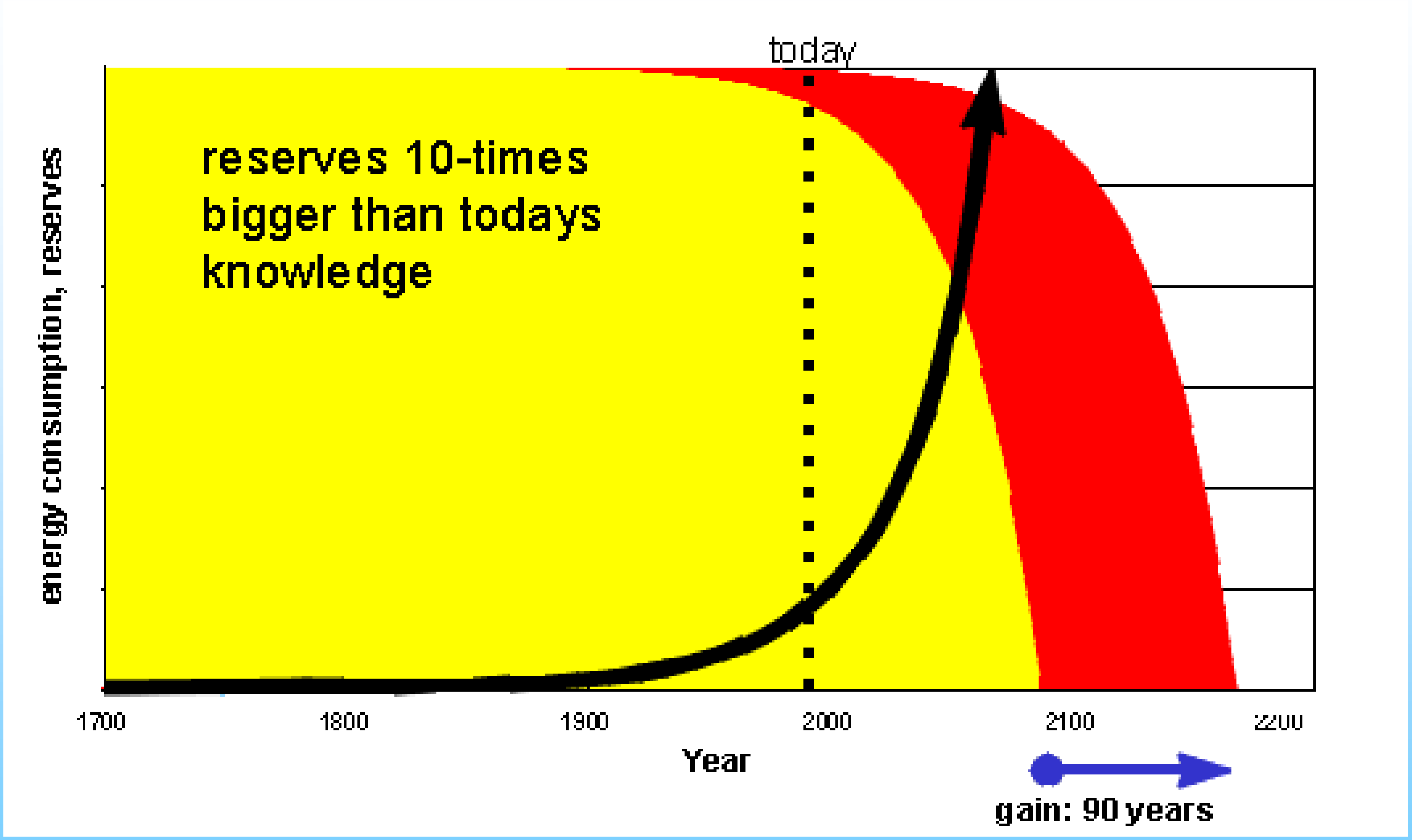
Load Consumptions



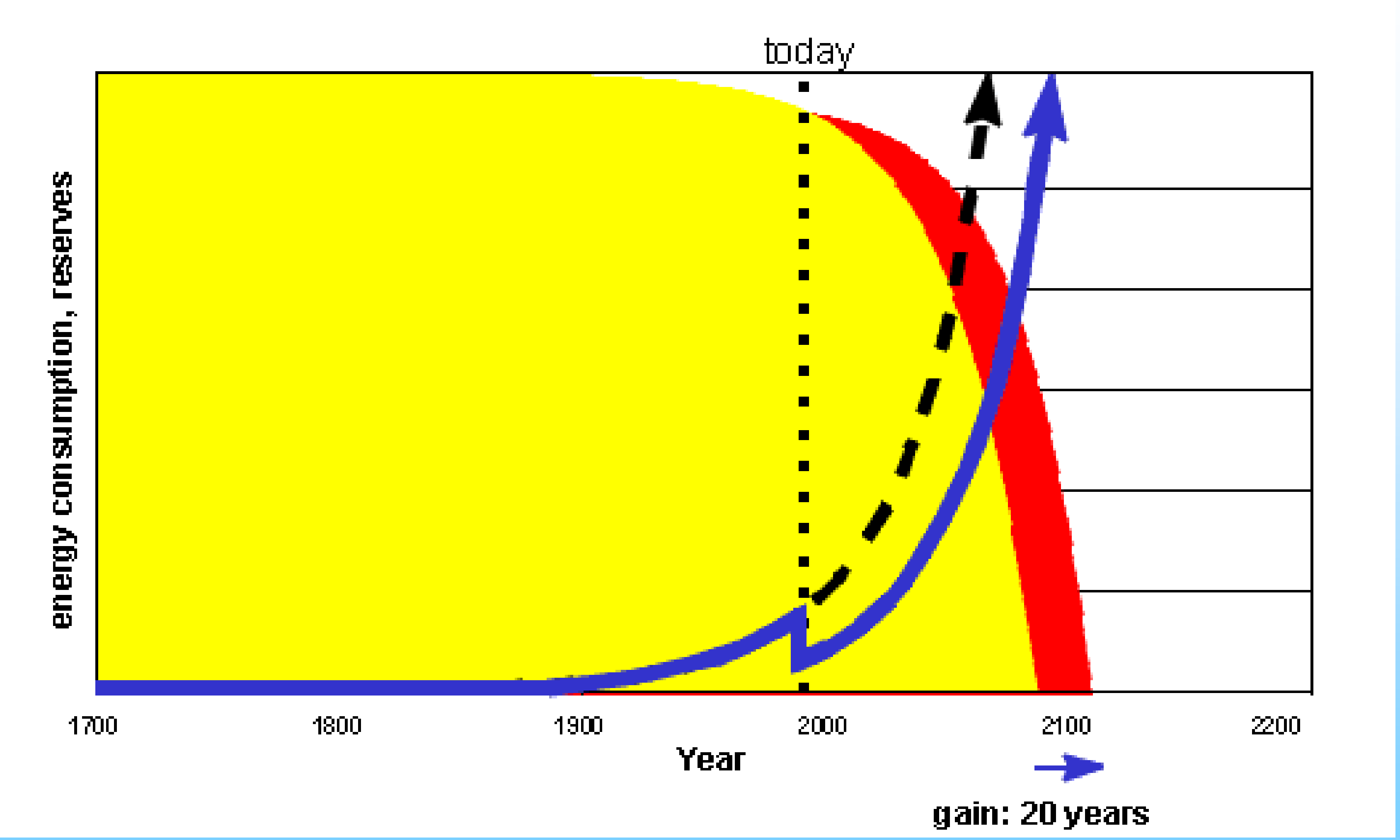
Energy and resource



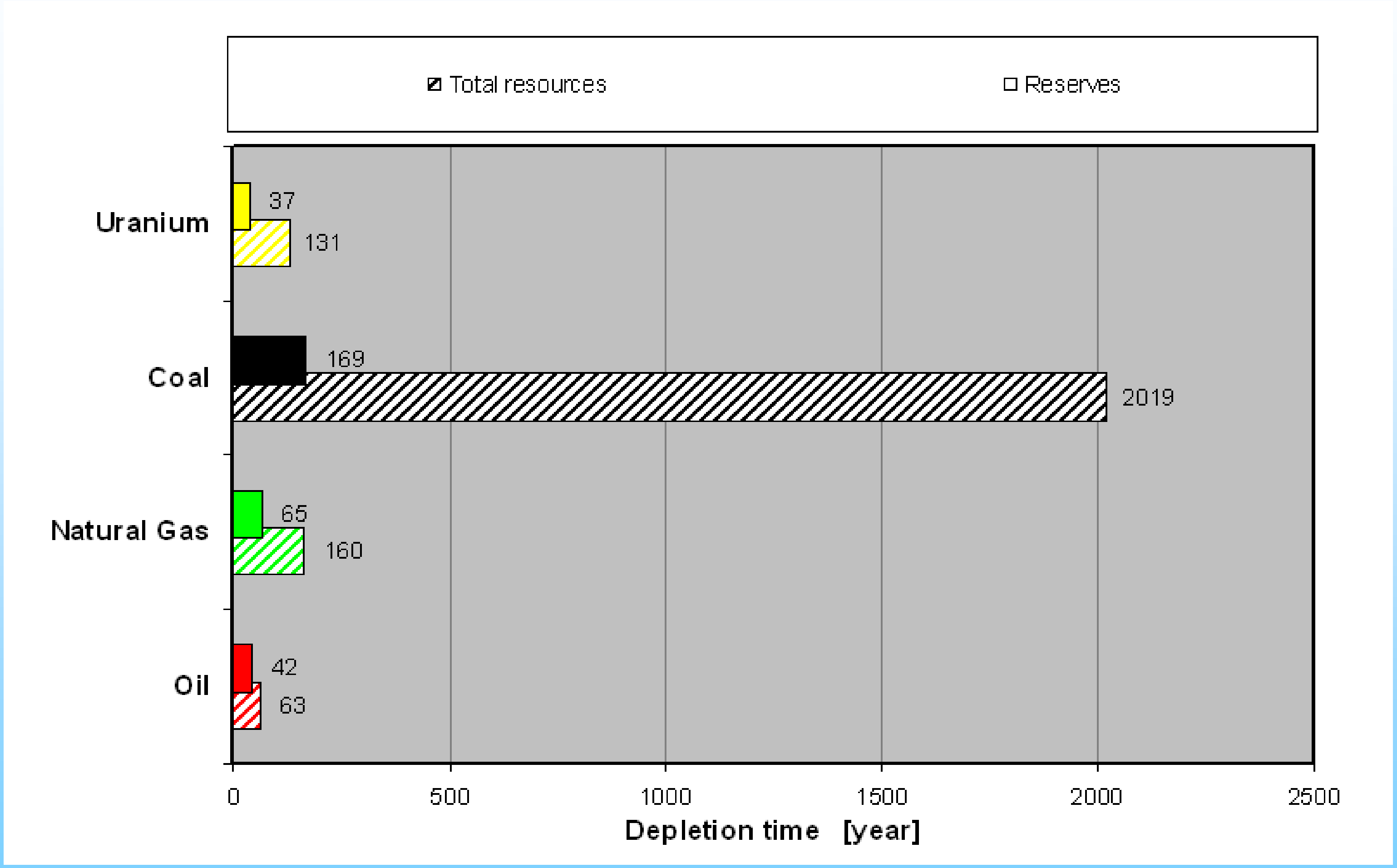
Energy and resource



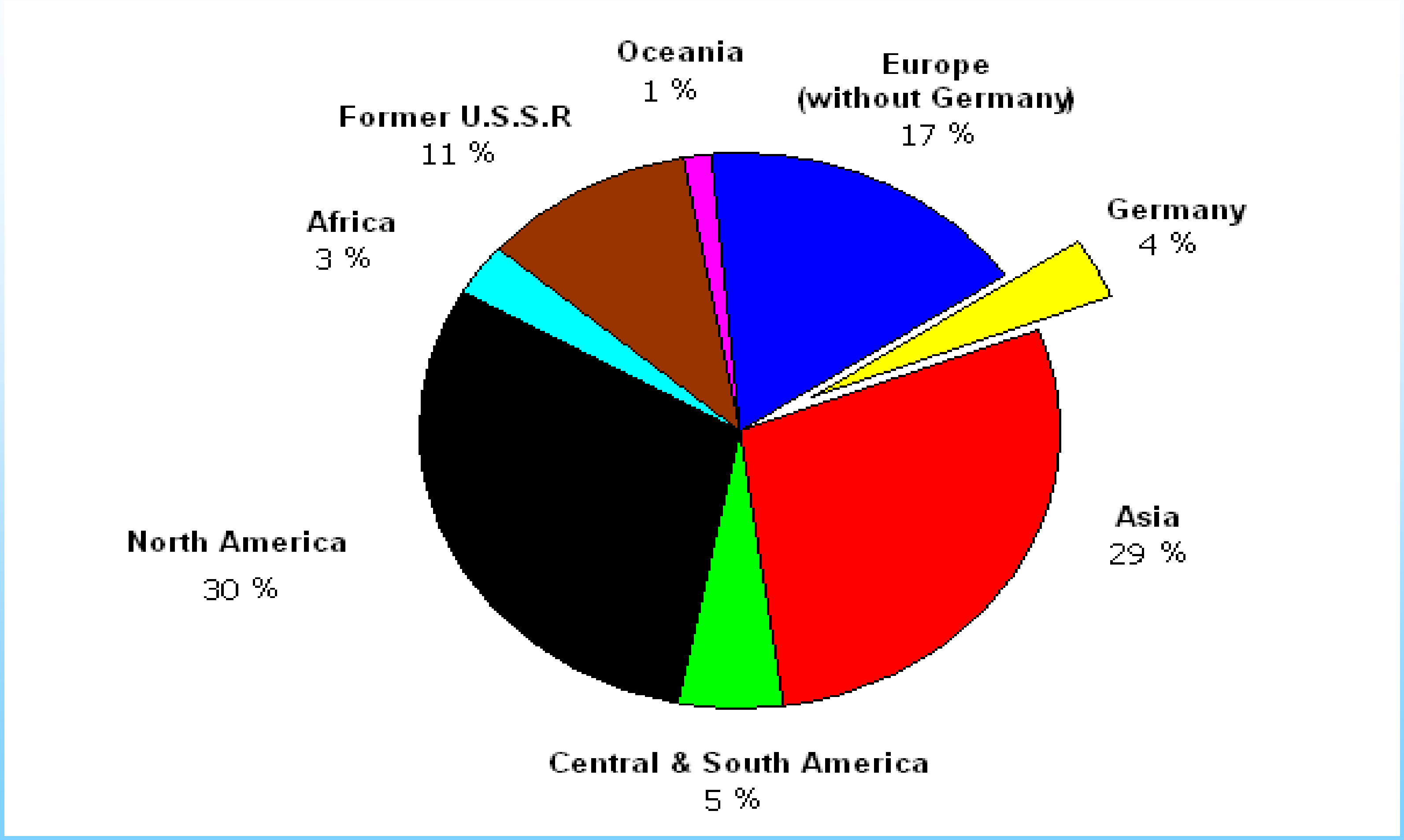
Energy and resource



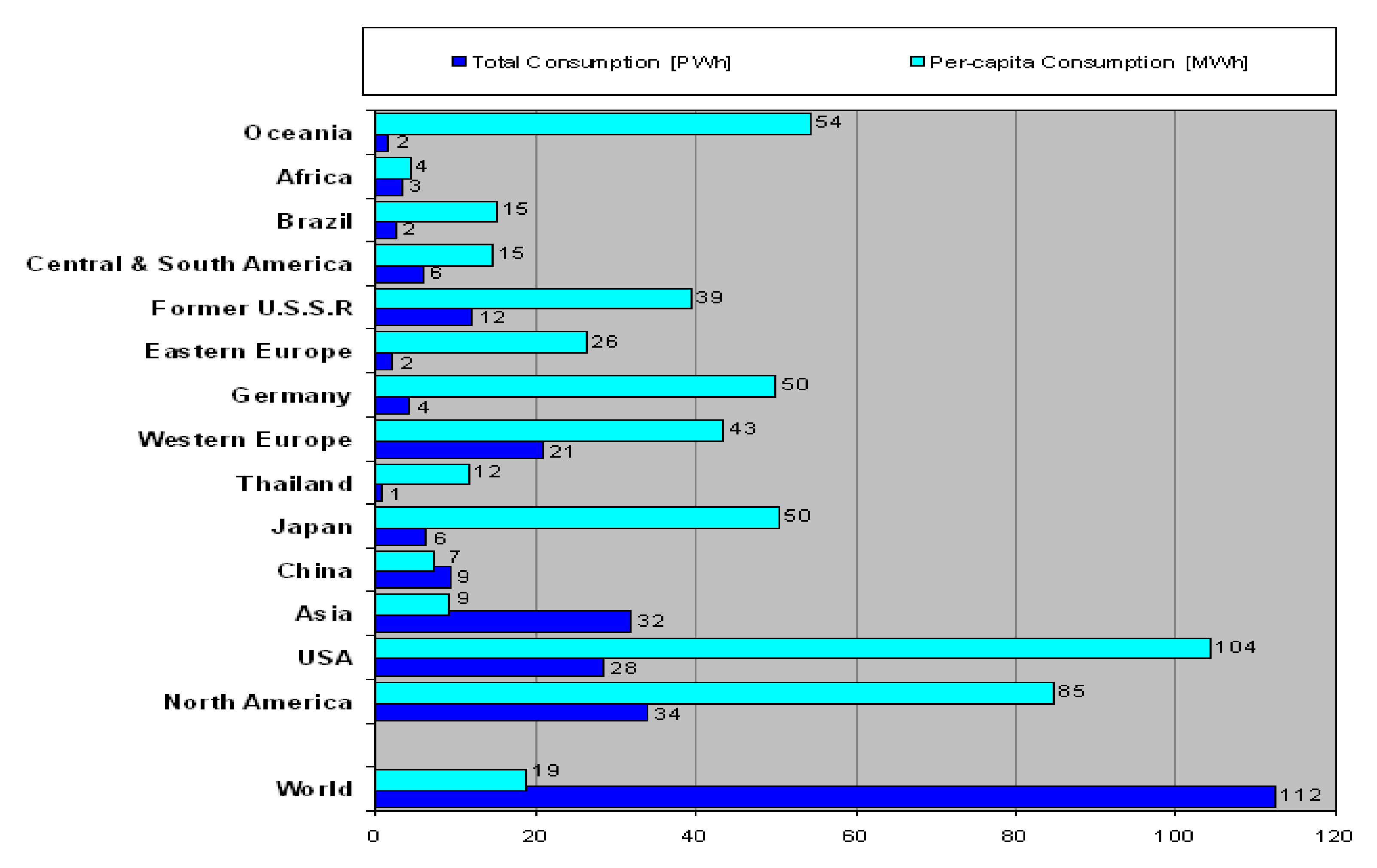
Depletion time of primary resource



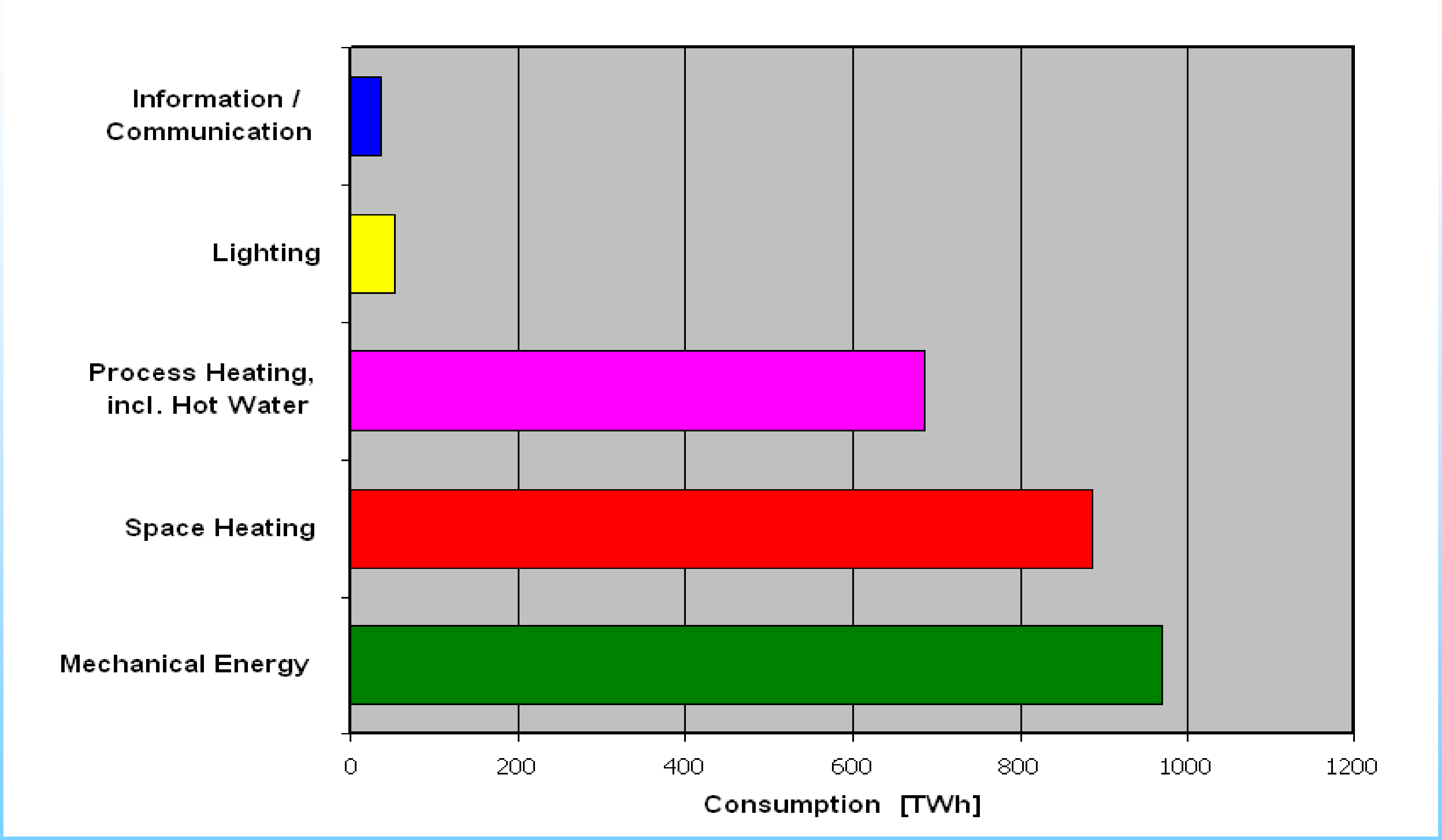
World Energy Consumption



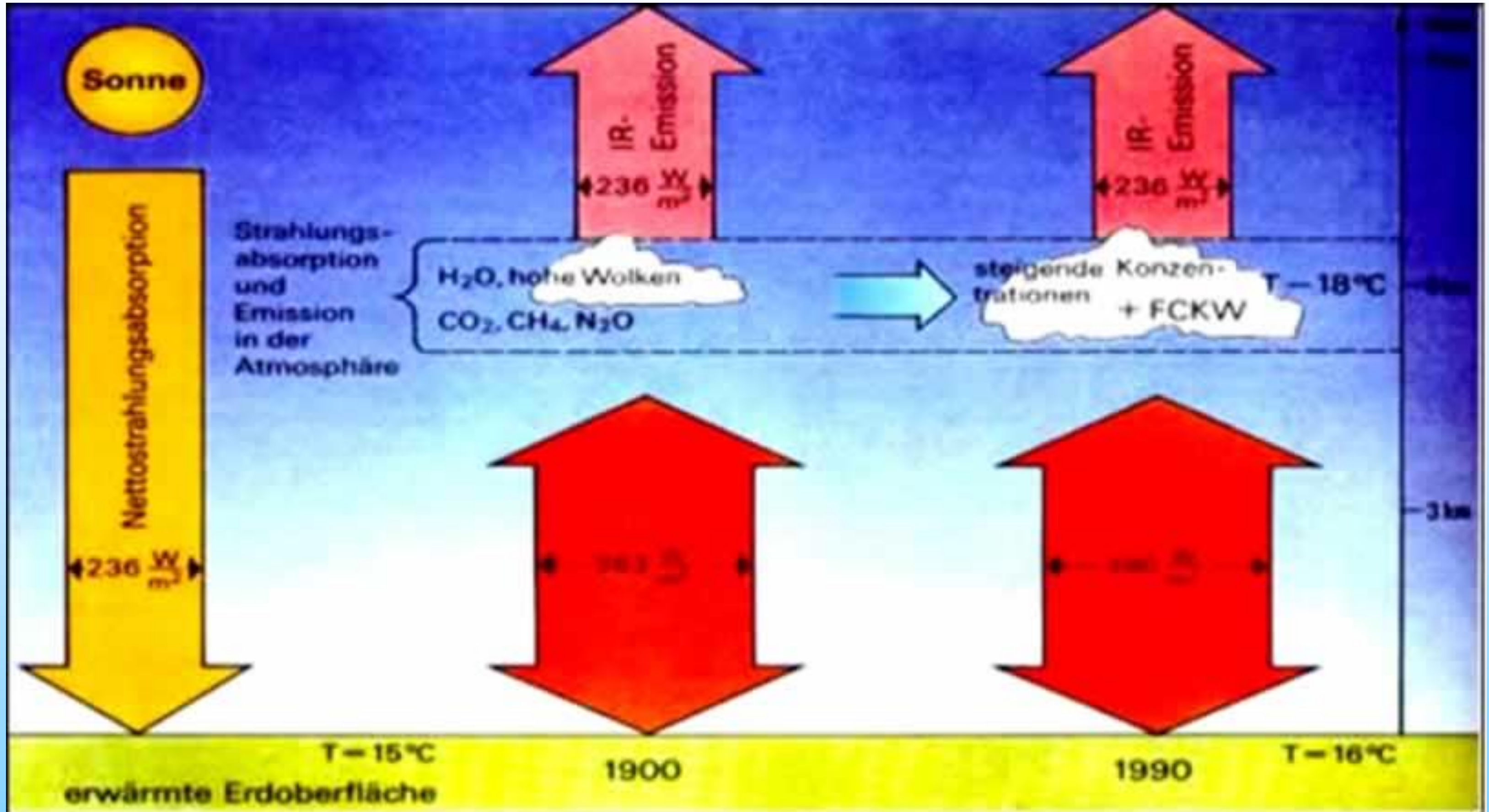
Per-capital energy consumption worldwide



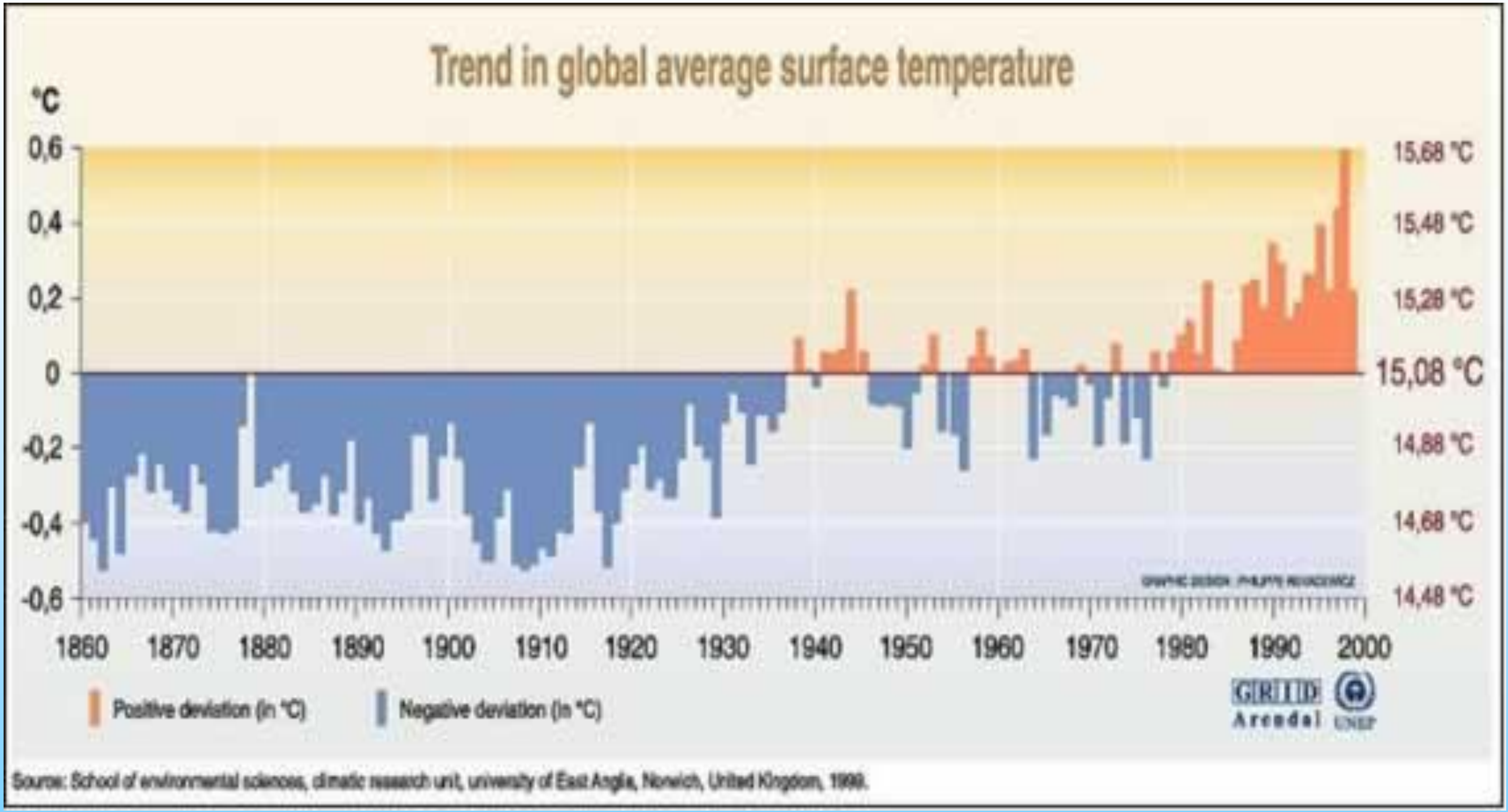
Energy Use in Germany

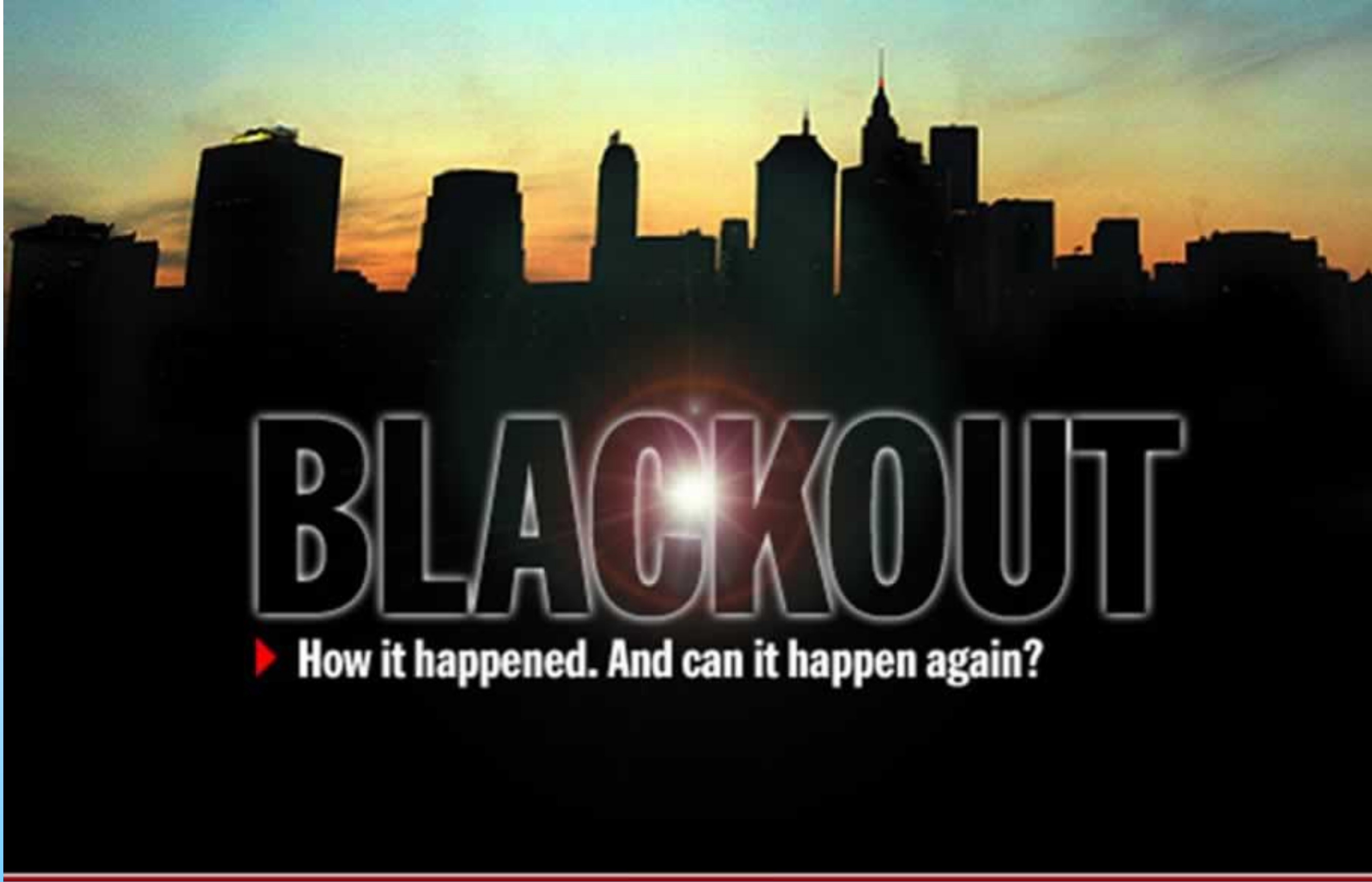


Greenhouse Effect



Global average temperature

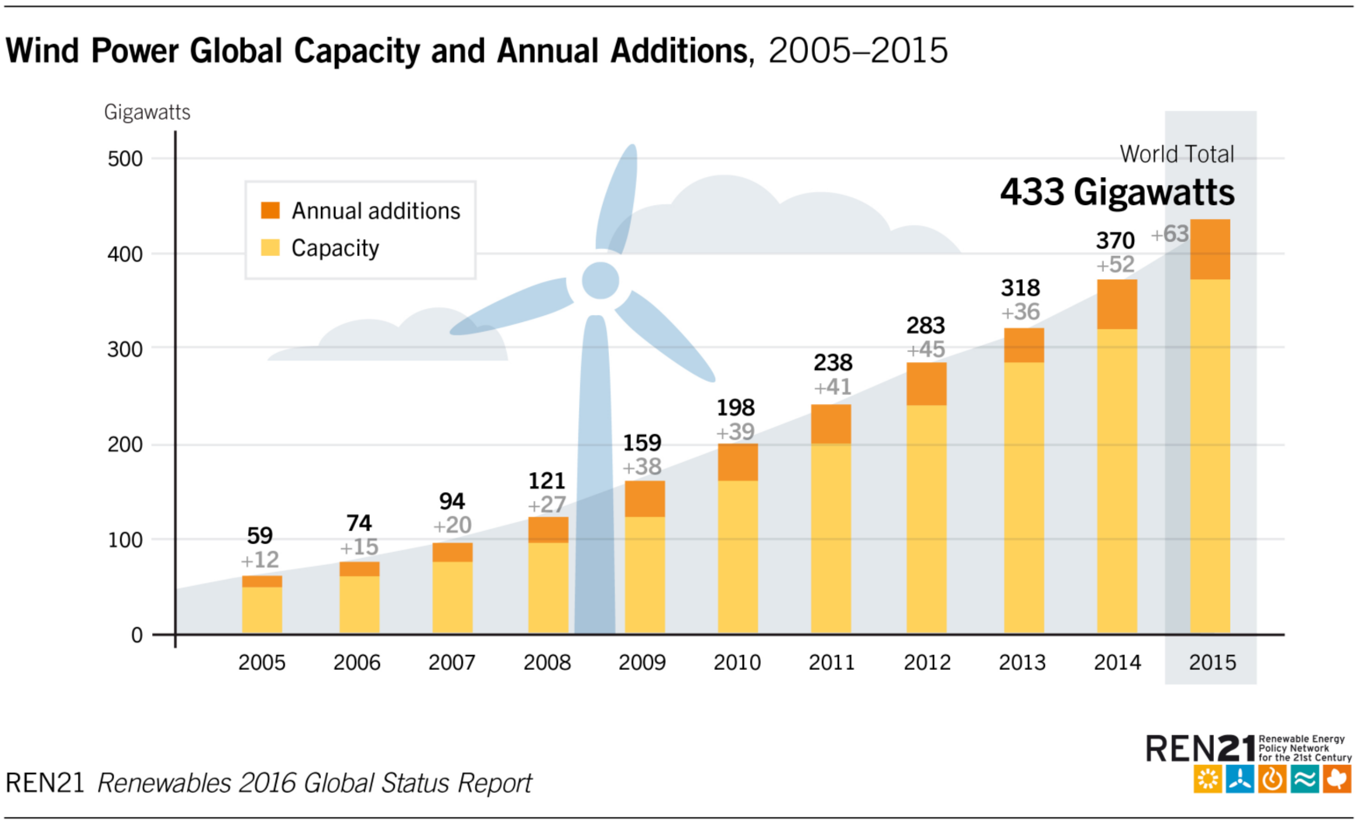



BLACKOUT
How it happened. And can it happen again?

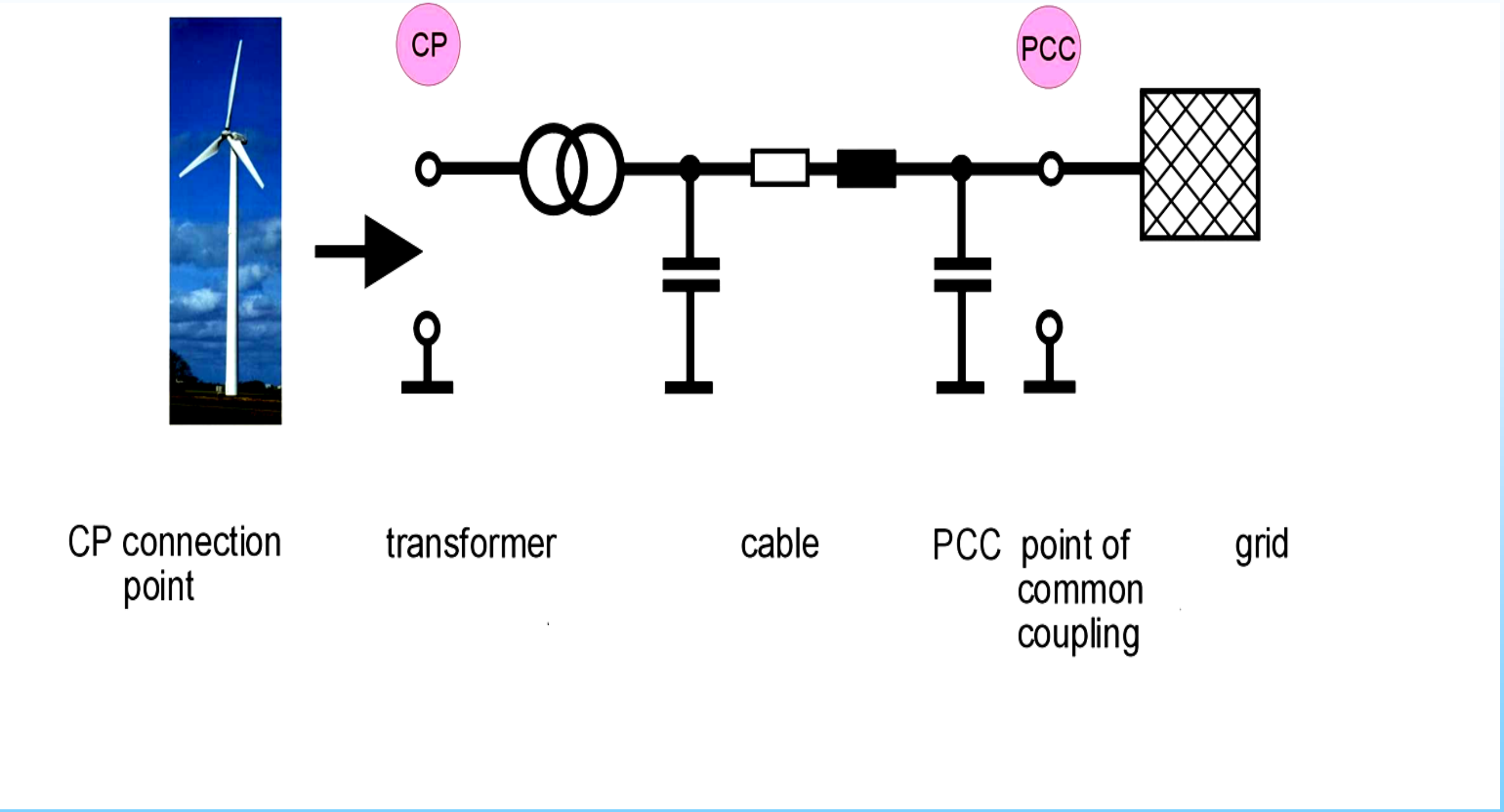
New York Blackout

Oil Crisis 1973

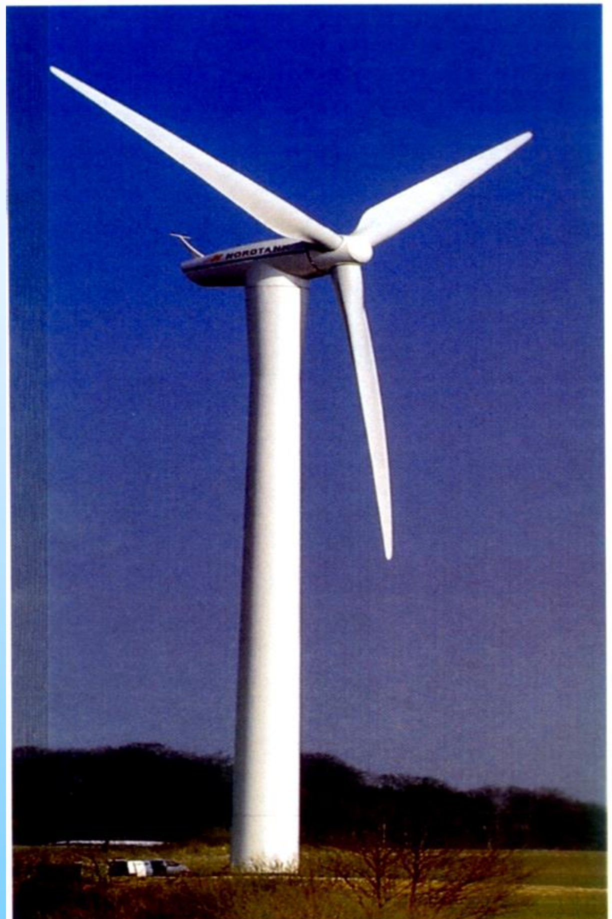
Wind Energy Production



Grid connection



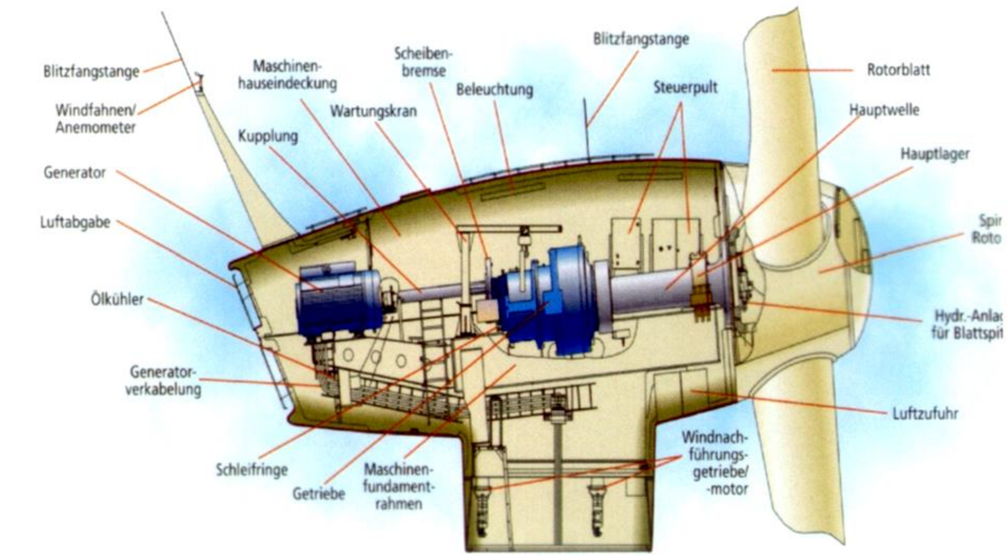
Wind Power Technology



NTK 1500/64

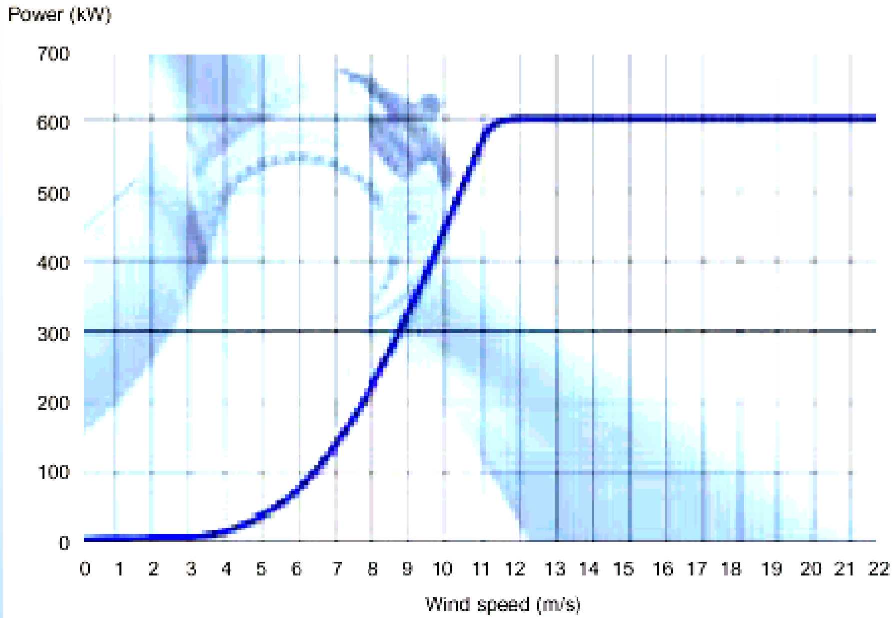
Nordtank Windkraftanlagen GmbH

Technische Daten: NM 1500/64



Nennleistung: 1500 kW
Durchmesser: 64,0 m
Nabenhöhe: 68 / 80 m

Characteristics



Basis: Air density: 1.225 kg / m^3, Turbulence 10%

SOUND LEVEL:

Sound Level LW 99.9 dB(A)
(imission-relevant **Sound level**
calculated at 10 m/s in 10 m height)

Minimum clearance to centre of mast base

hub height:	60 m	70 m
Mixed area 45 dB(A):	205 m	205 m
Residential area 40 dB(A):	325 m	335 m
Exclusively residential area 35 dB(A):	485 m	495 m

Production Technology

Wind technology

Transportation

Transportation

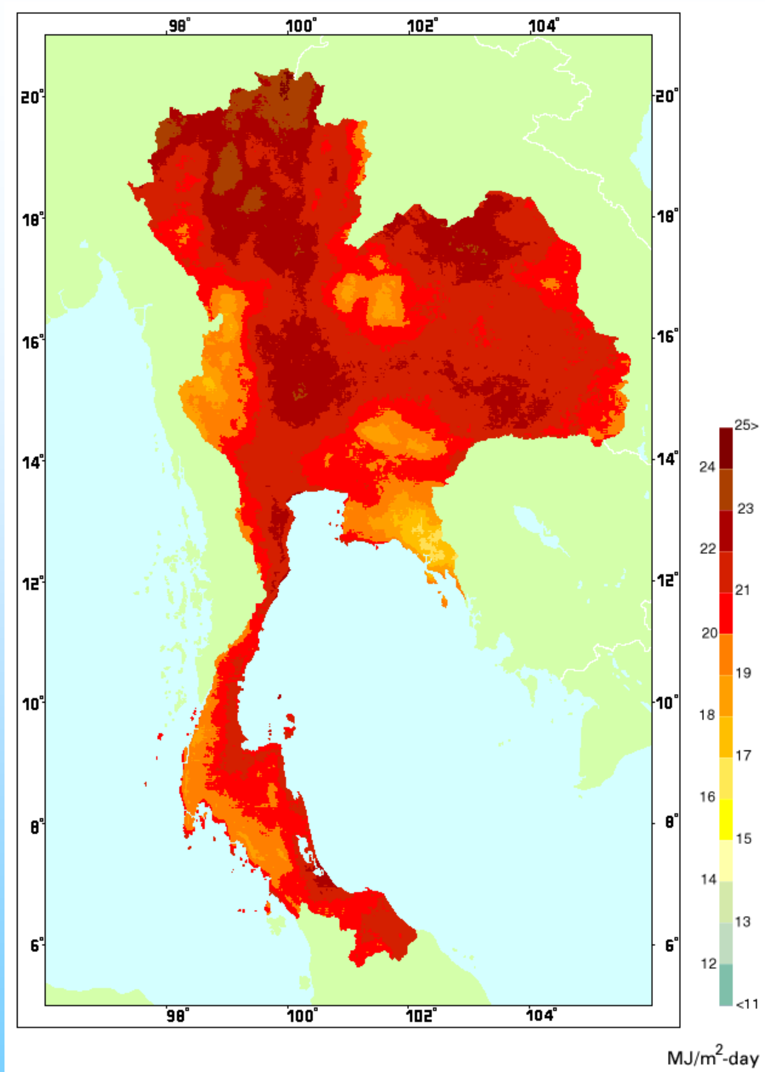
Wind Power Plants

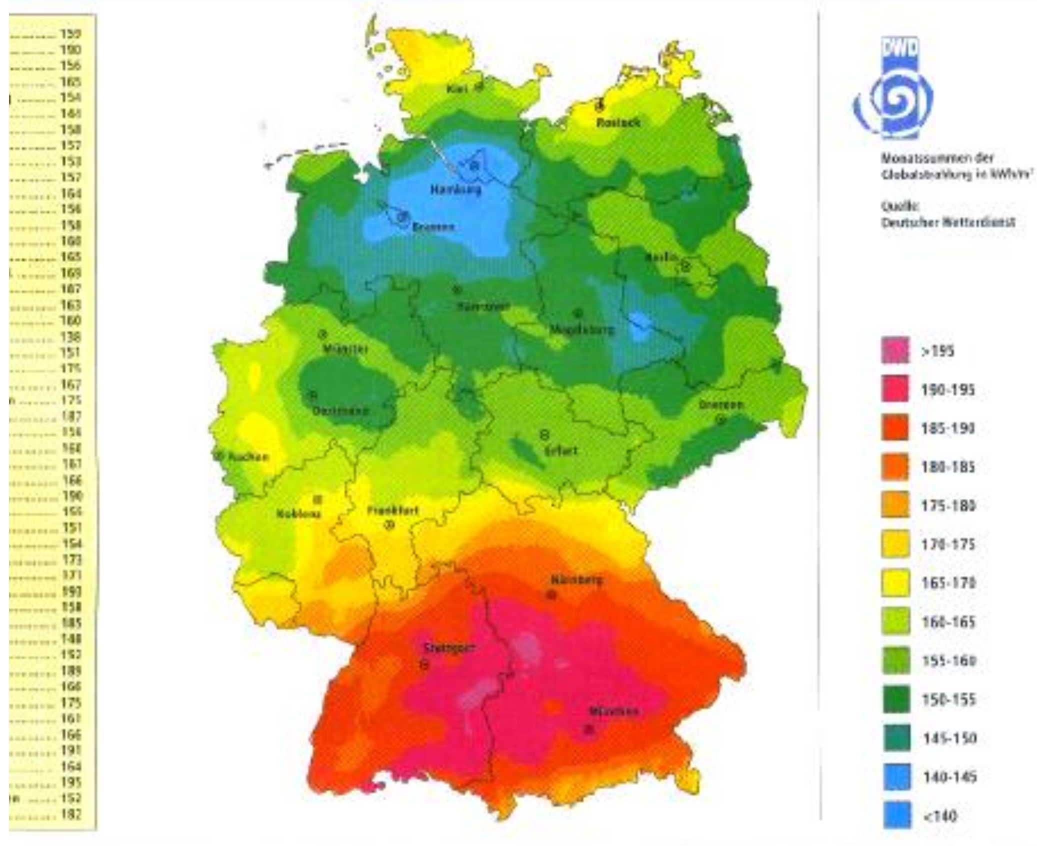
Wind Power Plants

Wind Power Plants

Wind Power Plants

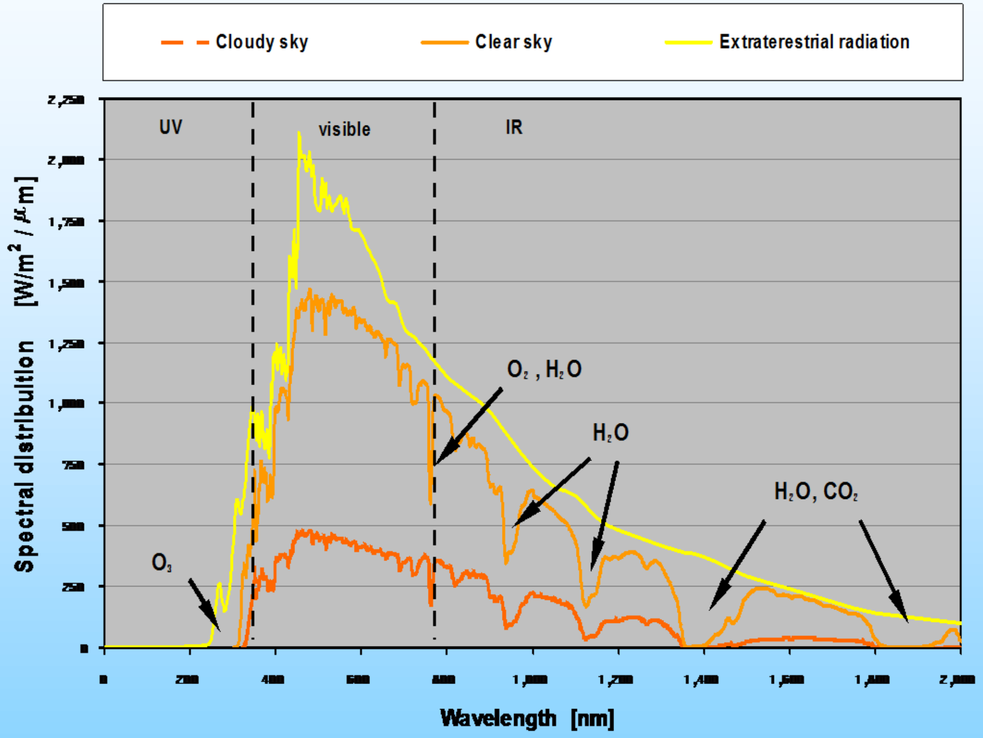
Radiation in Germany and Thailand





What is Solar Energy?

- **Originates with the thermonuclear fusion reactions occurring in the sun.**
- **Represents the entire electromagnetic radiation (visible light, infrared, ultraviolet, x-rays, and radio waves).**



Advantages and Disadvantages

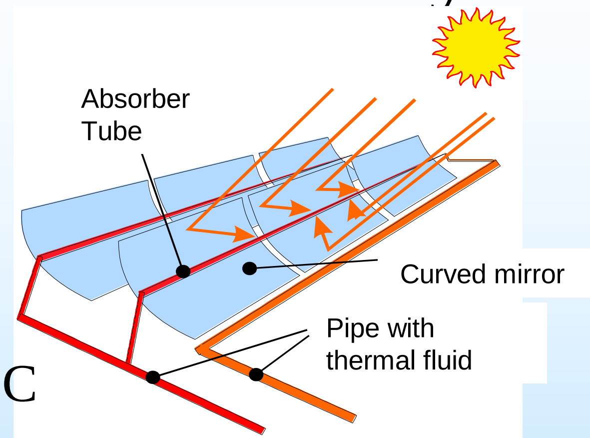
- Advantages
  - All chemical and radioactive polluting byproducts of the thermonuclear reactions remain behind on the sun, while only pure radiant energy reaches the Earth.
  - Energy reaching the earth is incredible. By one calculation, 30 days of sunshine striking the Earth have the energy equivalent of the total of all the planet's fossil fuels, both used and unused!
- Disadvantages
  - Sun does not shine consistently.
  - Solar energy is a diffuse source. To harness it, we must concentrate it into an amount and form that we can use, such as heat and electricity.
  - Addressed by approaching the problem through:

    1) collection, 2) conversion, 3) storage.

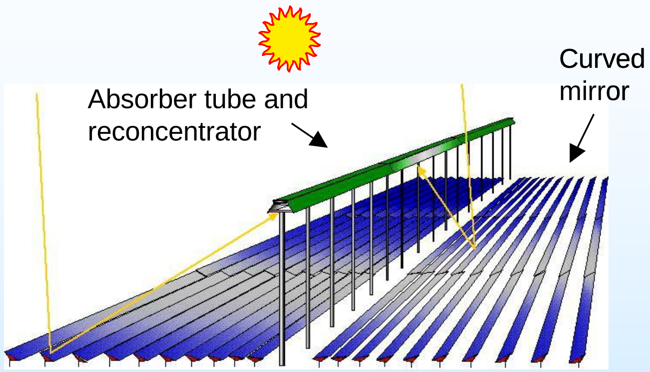
Solar Thermal Power

Concentrating solar technologies: basic layout schemes

Linear Concentration
C: 100, T: ~ 500° C

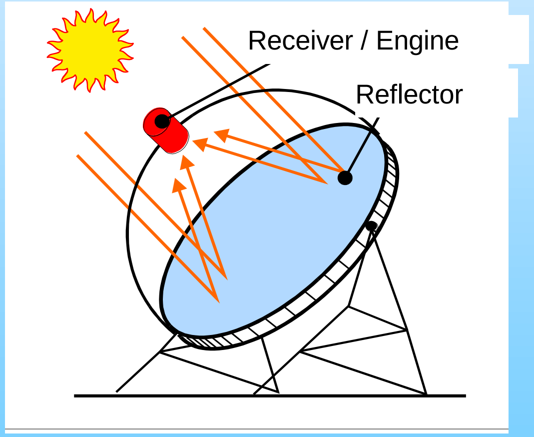


Parabolic Trough

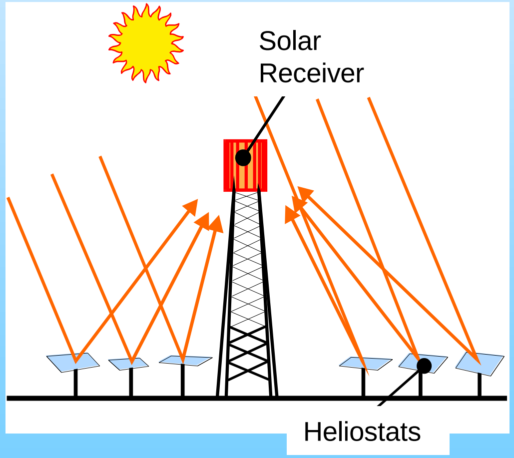


Linear Fresnel

Point Concentration
C: 1000+, T: ~ 1000° C



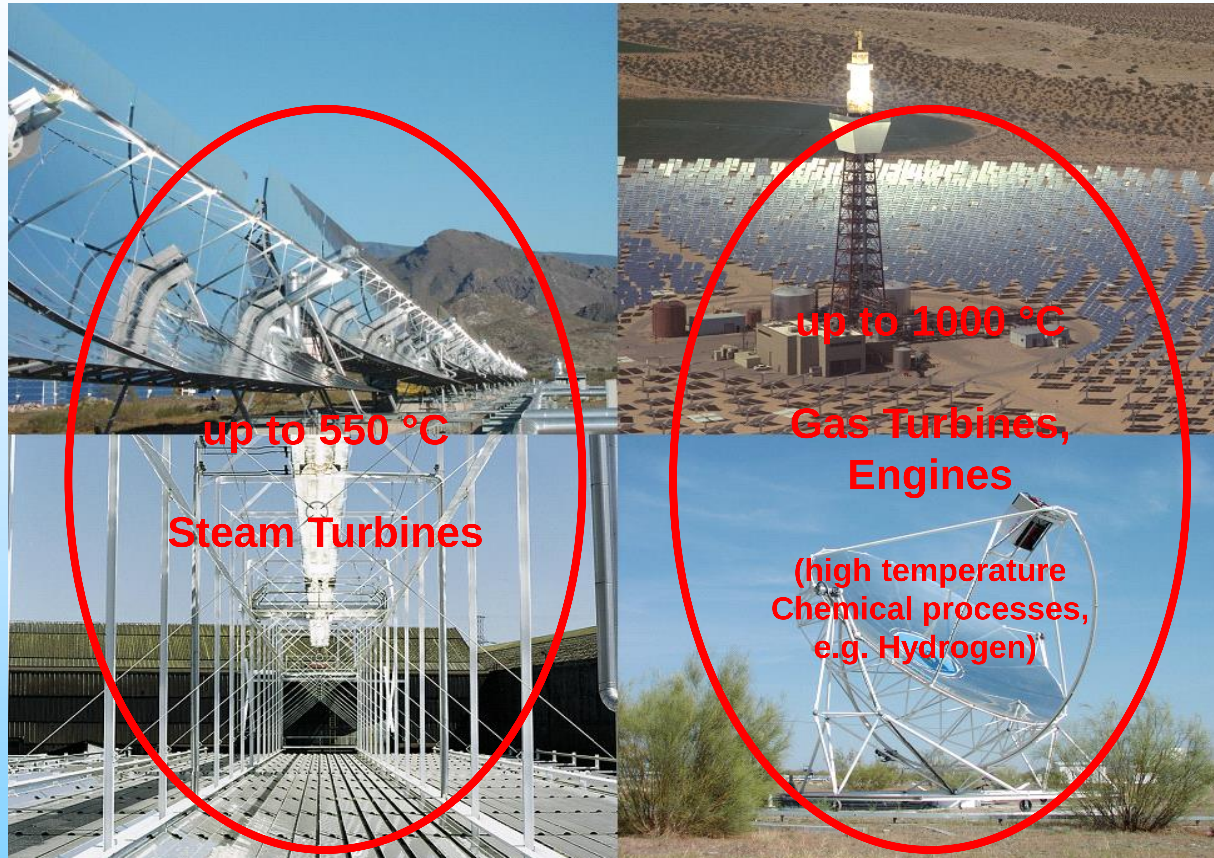
Dish/Engine



Central Receiver

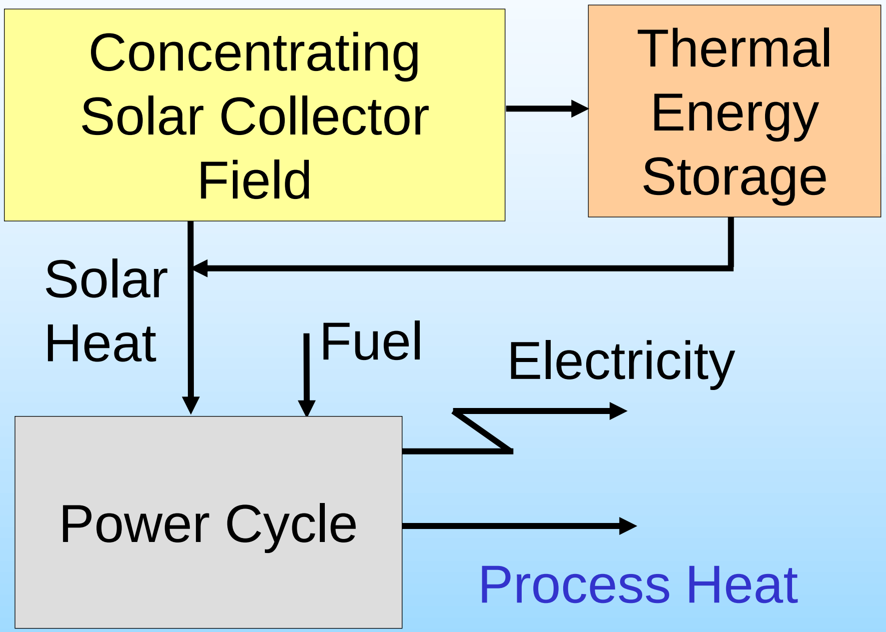
Concentrating Solar Thermal Power: System Examples

parabolic trough (PSA) **solar tower (SNL)**



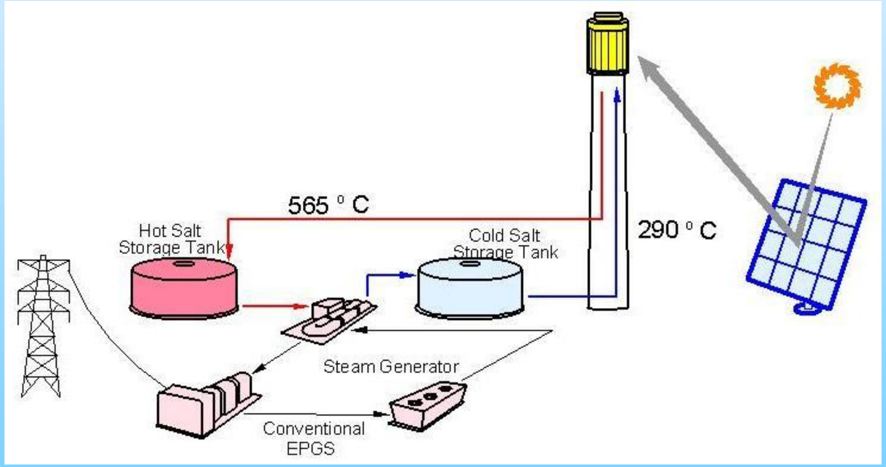
linear Fresnel (SPG, MAN) **parabolic dish (SBP)**

Principle of a Concentrating Solar Thermal Power Plant



- concentrated, storable solar thermal energy as fuel saver
- firm capacity, power on demand via storage or hybrid operation
- additional process heat for cooling, drying, seawater desalination, etc.

Thermal Storage:
Molten Salt Storage technology for solar tower plants

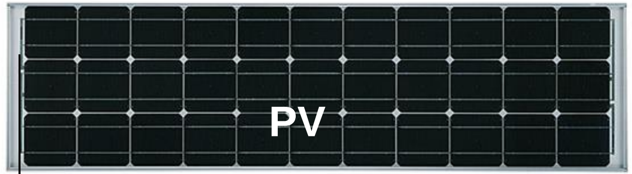


- preferred use for plant layout with molten salt
- commercial systems with nitrate salts
- hot-cold tank design
- thermal capacity proportional to **ΔT**
- *investment cost ~ 10-20 $/kWh*

- risk of liquid salt freezing
- increased effort concerning trace heating, pumps, valves, gaskets etc.
- higher operation temperature limited by salt decomposition

Characteristics:

PV - CSP



	PV	CSP
Solar Radiation Type	Direct + diffuse	Direct
Plant Size	Watt - MW	10 MW - n 100 MW
Installation	everywhere (roofs etc.)	Unused, flat land
Capacity:	700 – 2000 full load hours	2000 – 7000 full load hours
Backup:	Extern	Intern (fossil / storage)
Proven lifespan	> 20 years	> 20 years
Yearly production (2004)	2500 GWh	800 GWh
Electricity cost today	0,25 – 0,50 €/kWh	0,13 – 0,20 €/kWh

Photovoltaic: PV

PV Technology Classification

Silicon Crystalline Technology
Technology

Thin Film

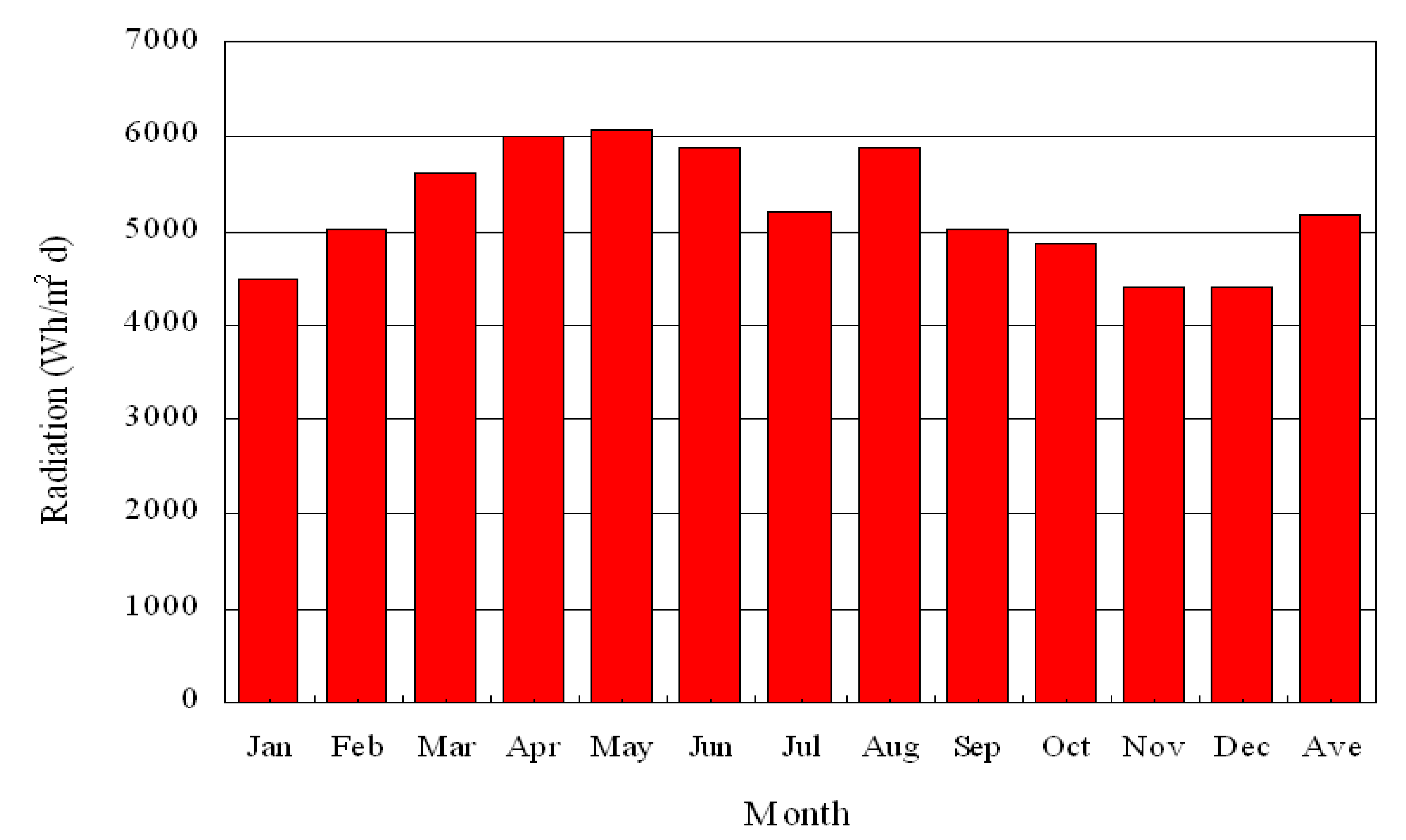
- Mono Crystalline PV Cells
  Silicon PV Cells
- Multi Crystalline PV Cells
  Crystalline PV Cells

- Amorphous
- Poly

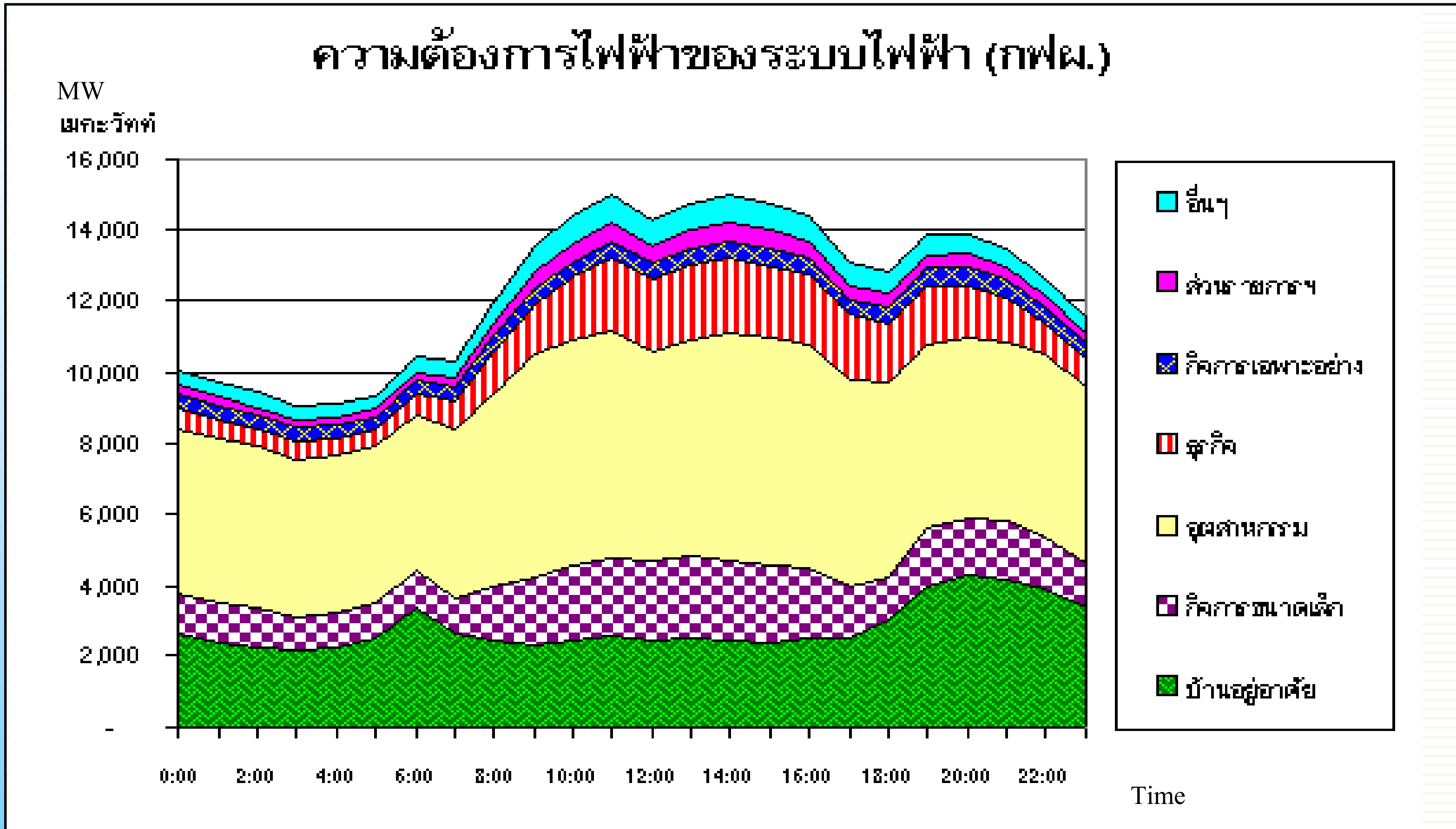
(Non-Silicon based)

- Module efficiencies 10-16% under STC

Solar radiation in Thailand

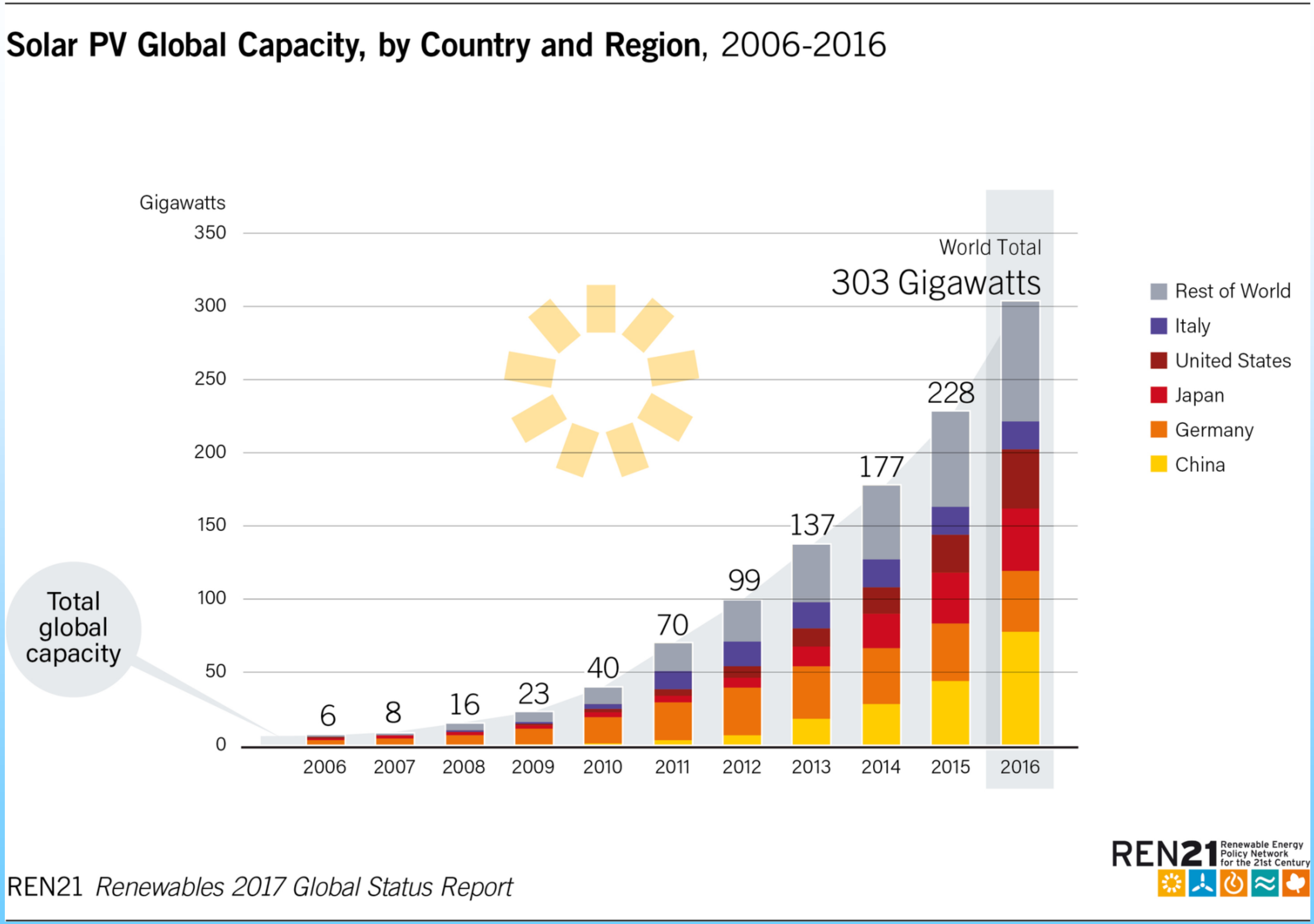


Load Profile in Thailand

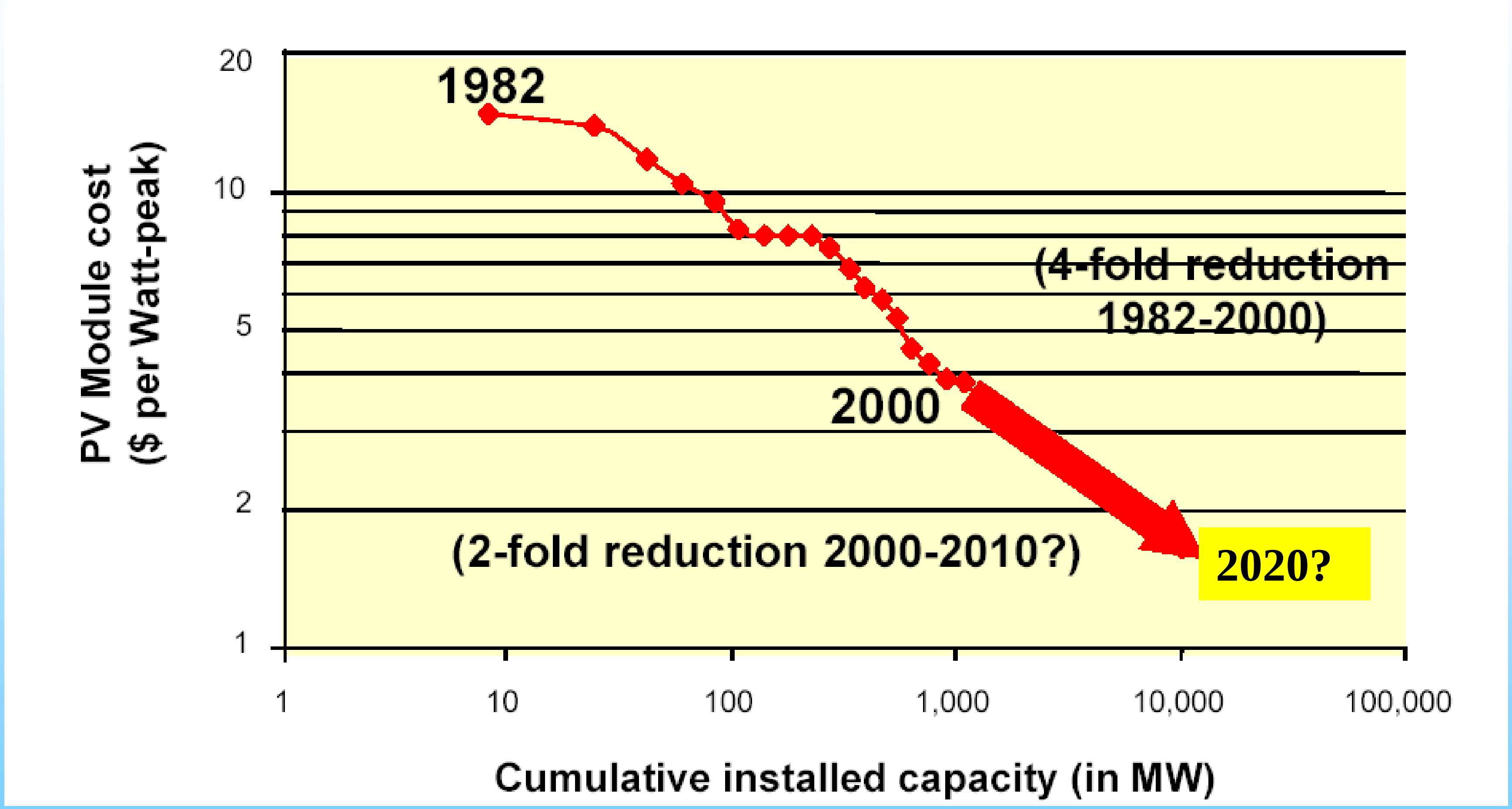


PV Trends

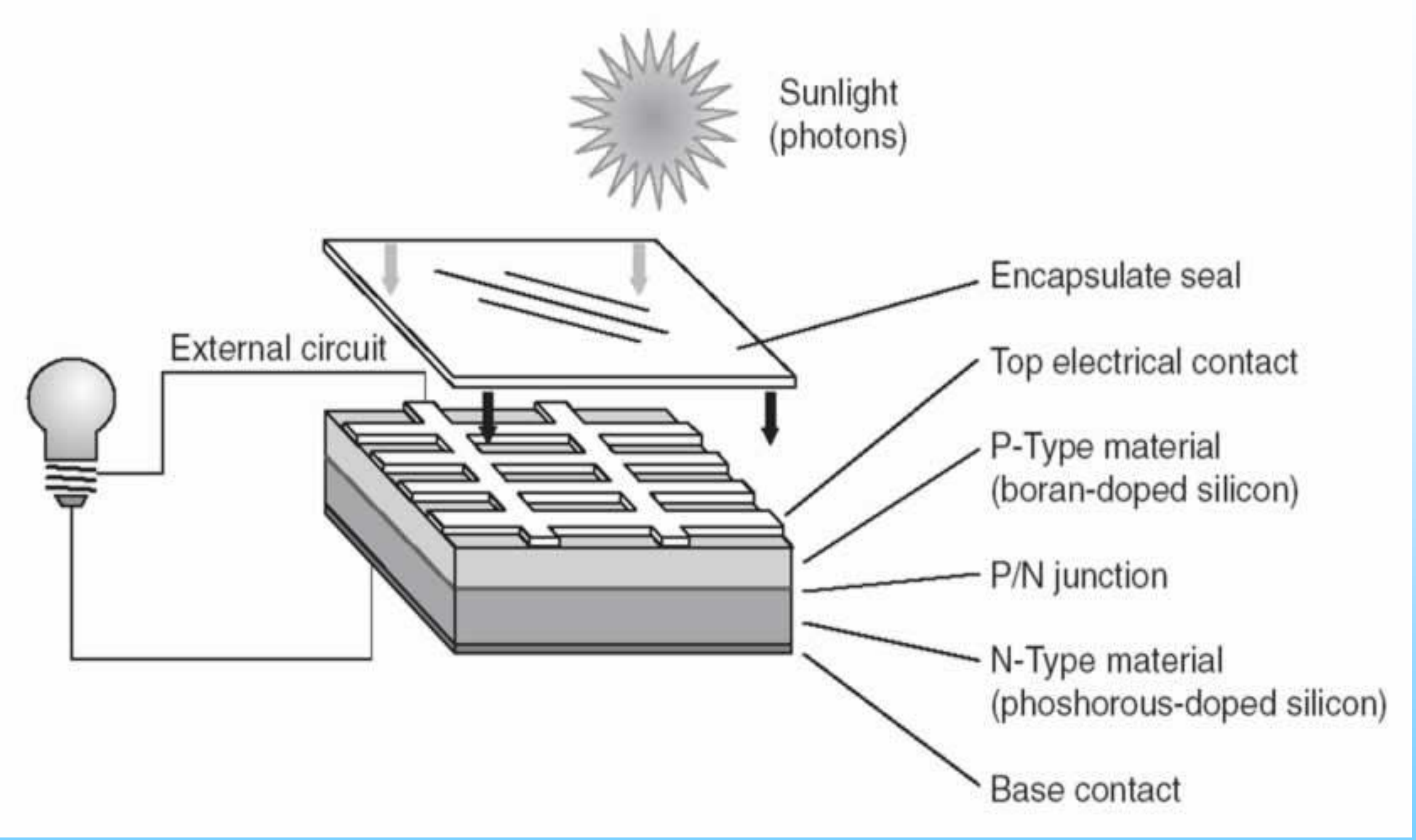
Figure: 16



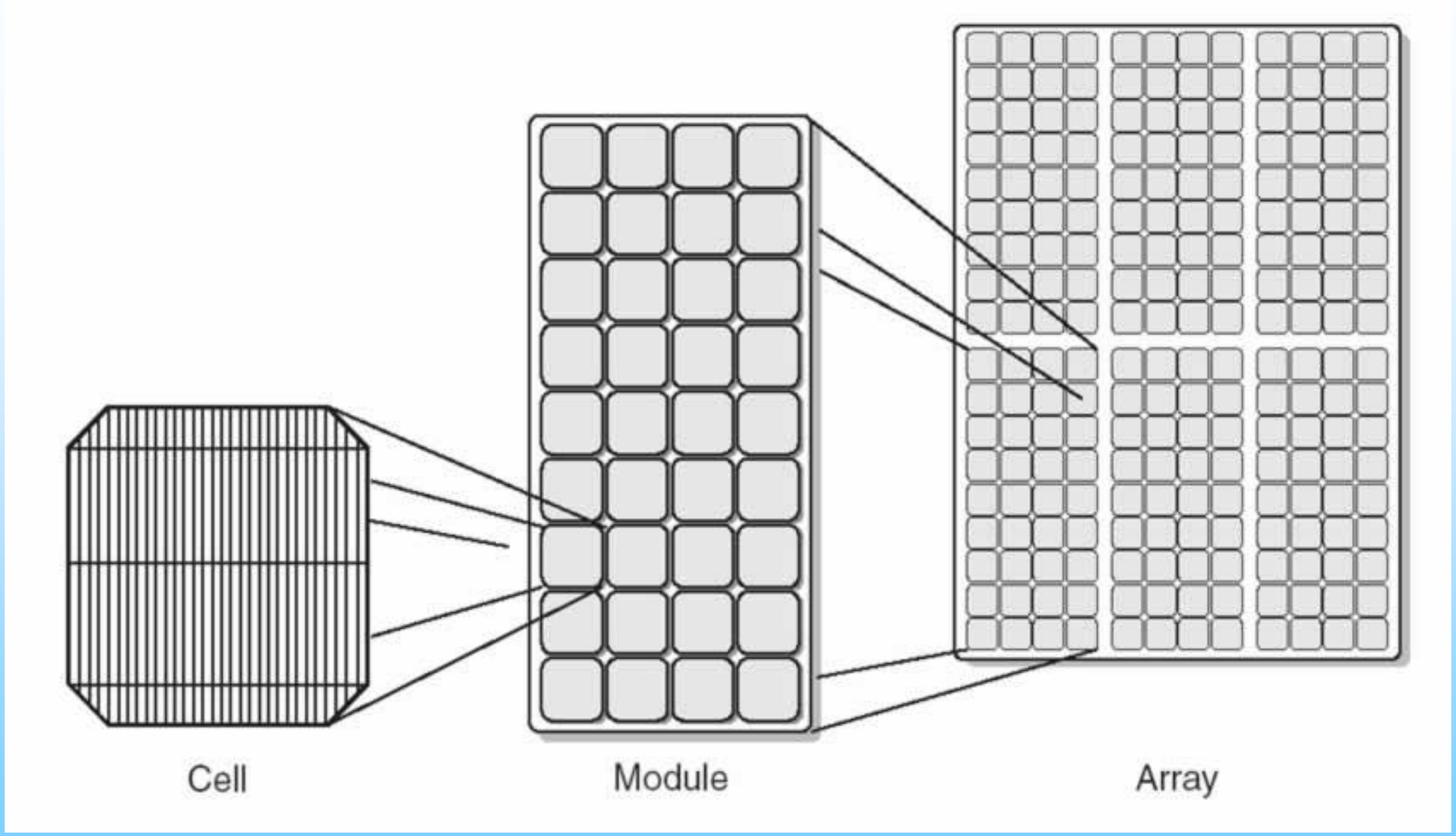
Trend of PV module cost



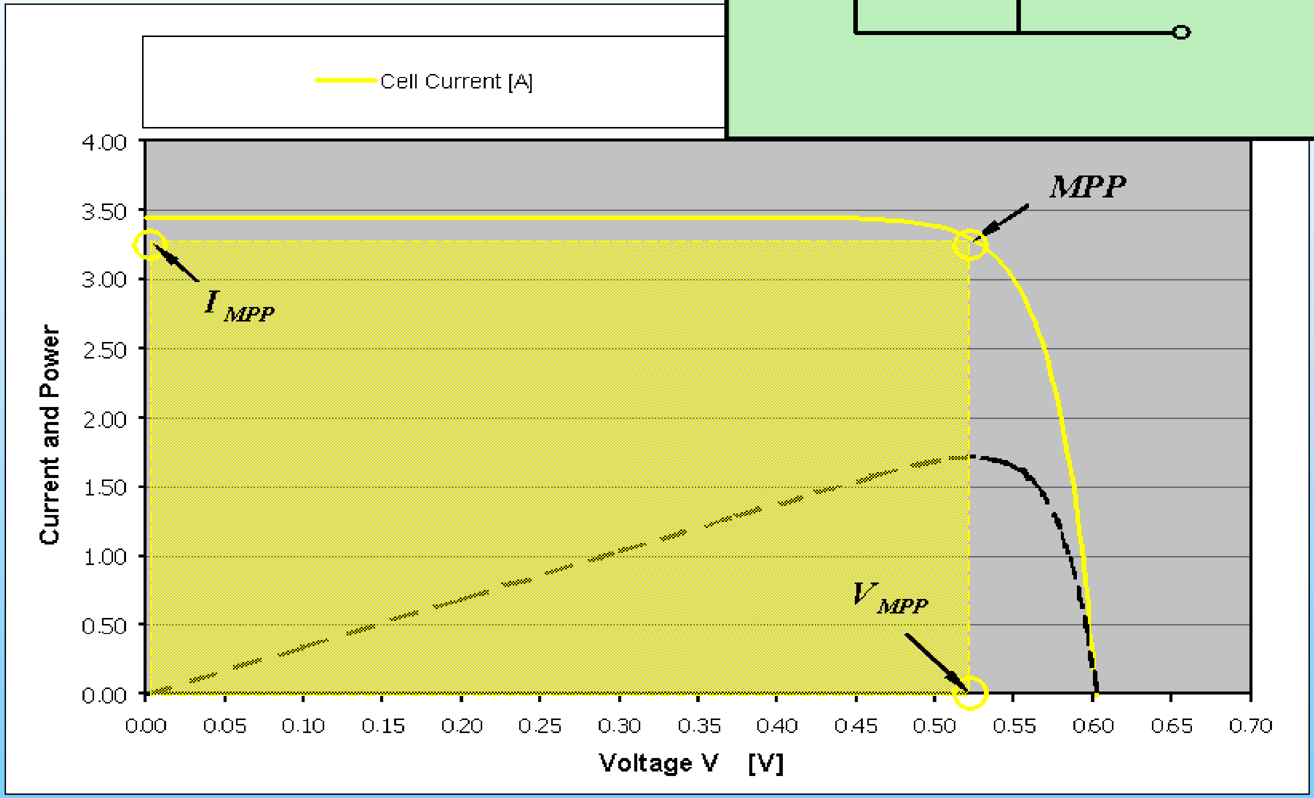
Use of PV system

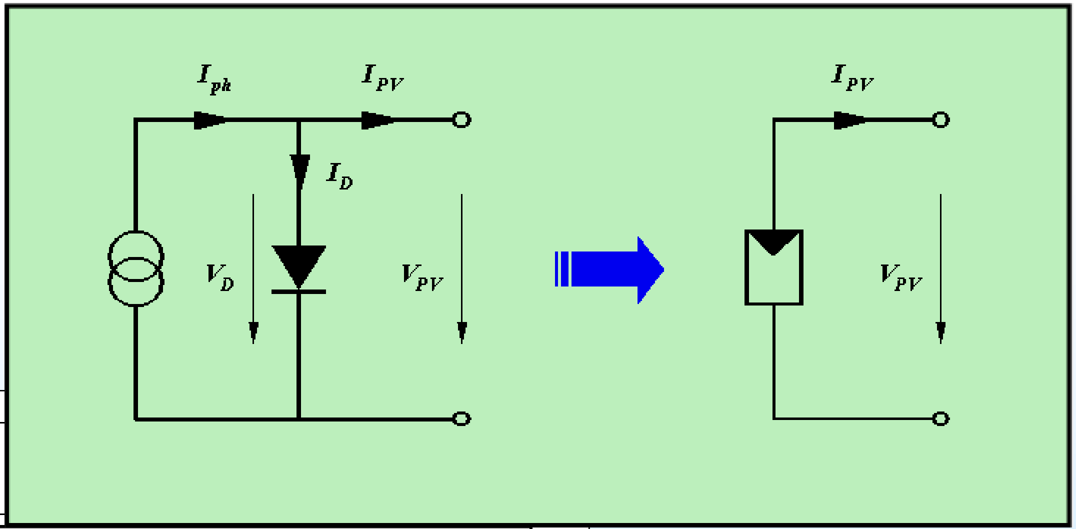


PV cells, module and arrays

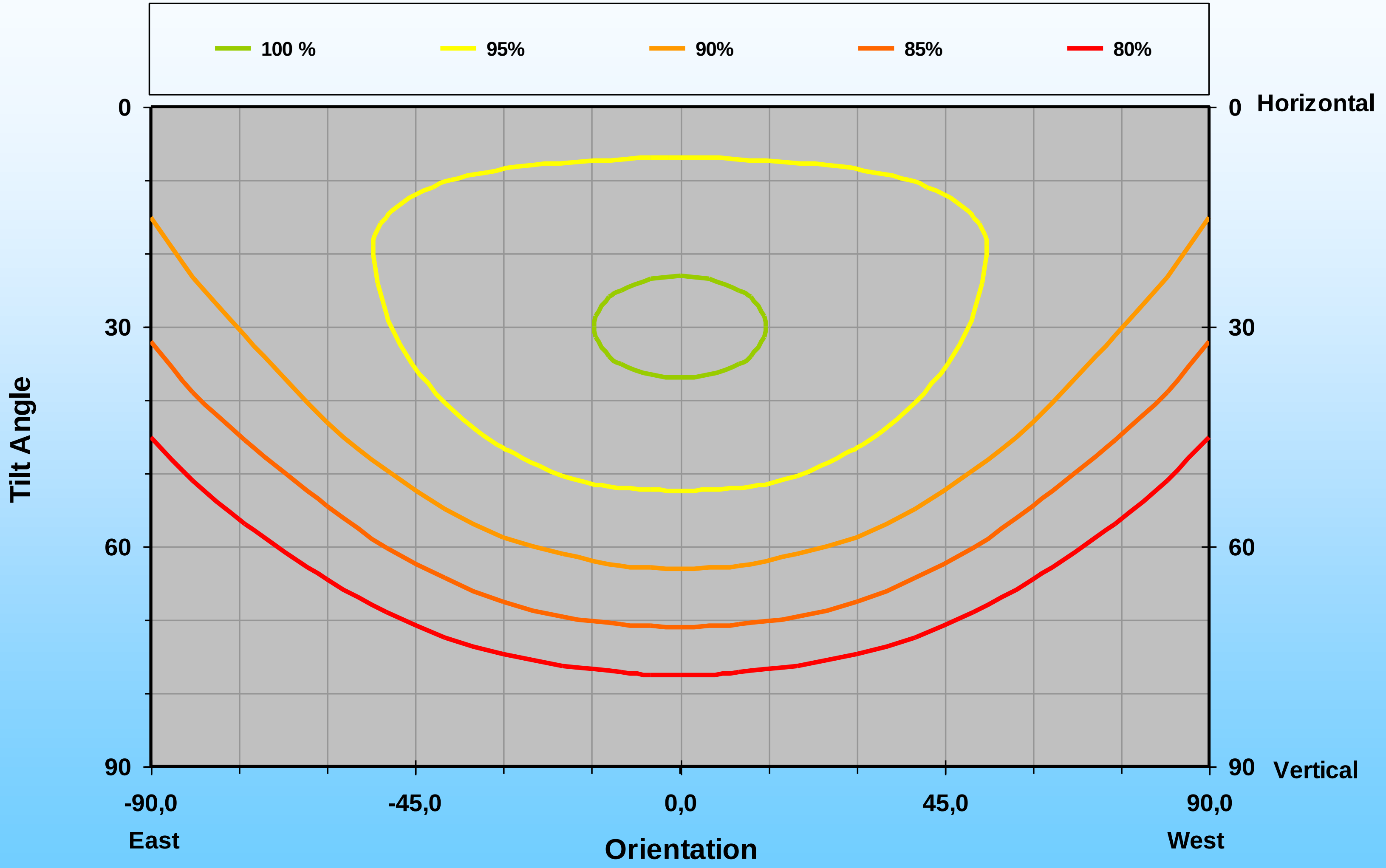


System component: PV Generator





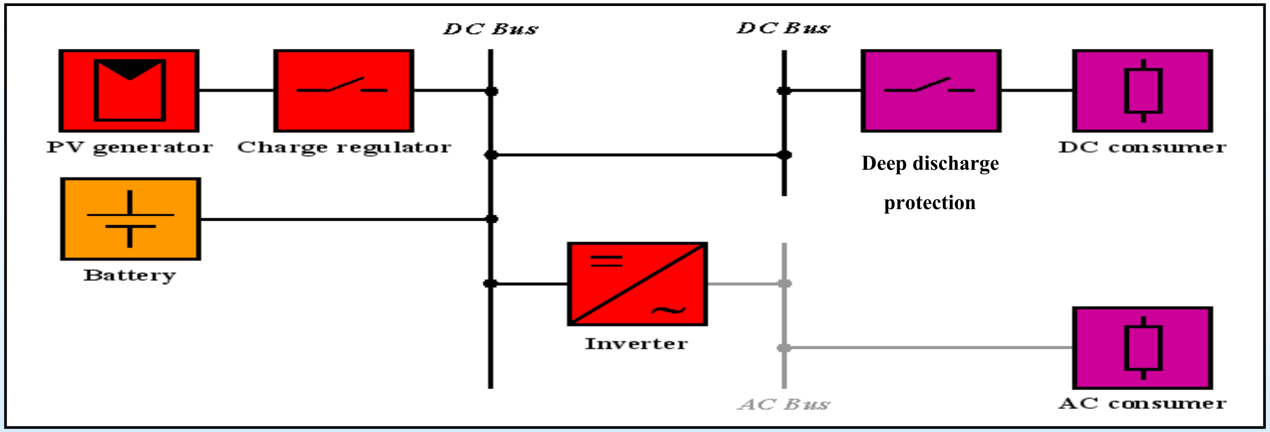
Orientation of PV



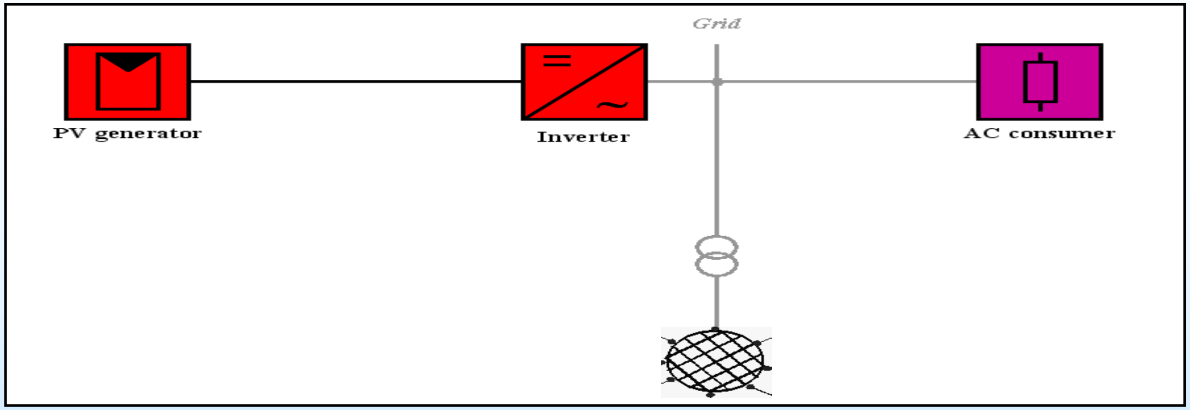
Application of PV system

- 1 Autonomous or Stand-alone
- 2 Grid-connected
- 3 Hybrid system

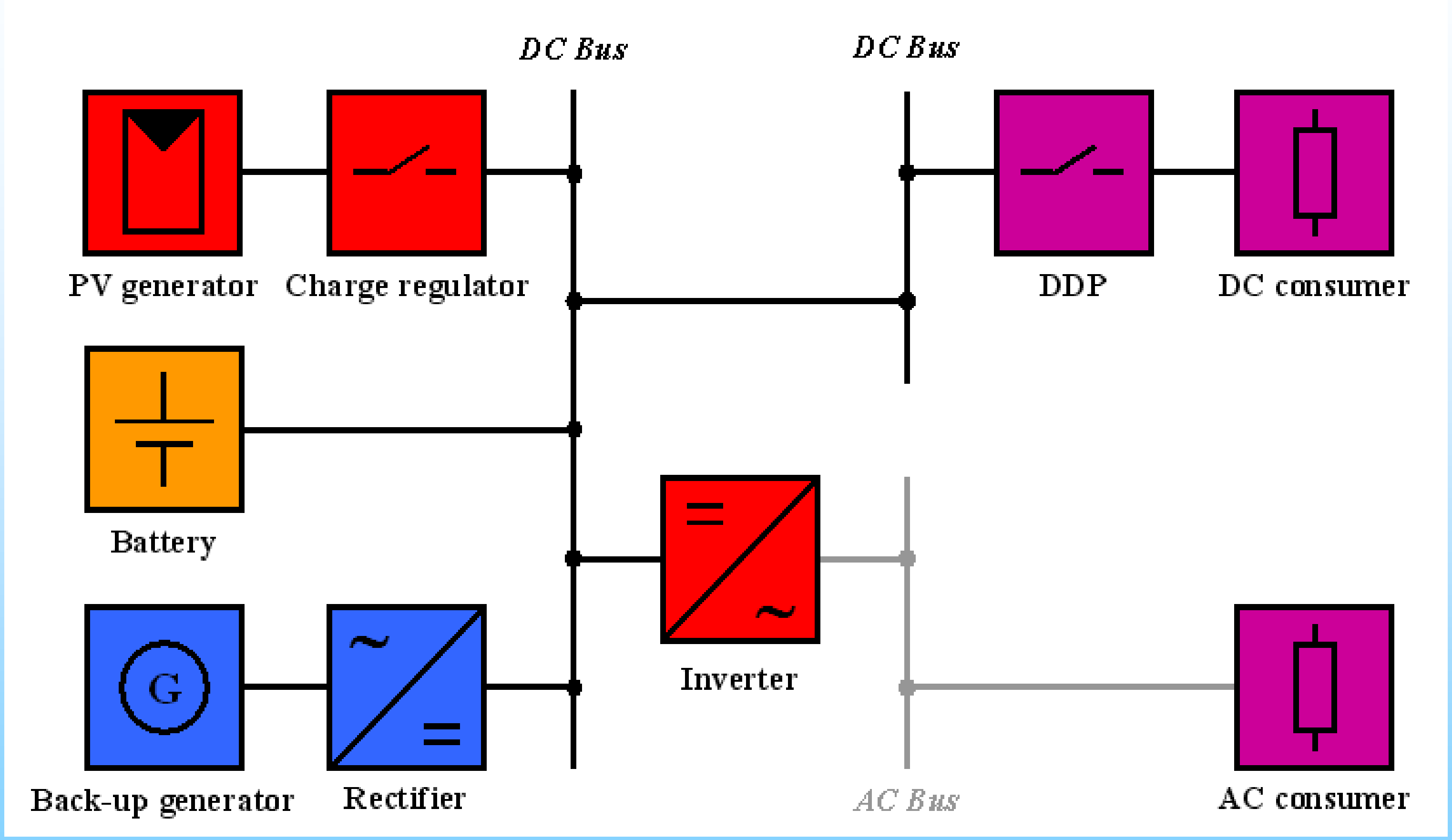
Autonomous or Stand-alone



Grid-connected



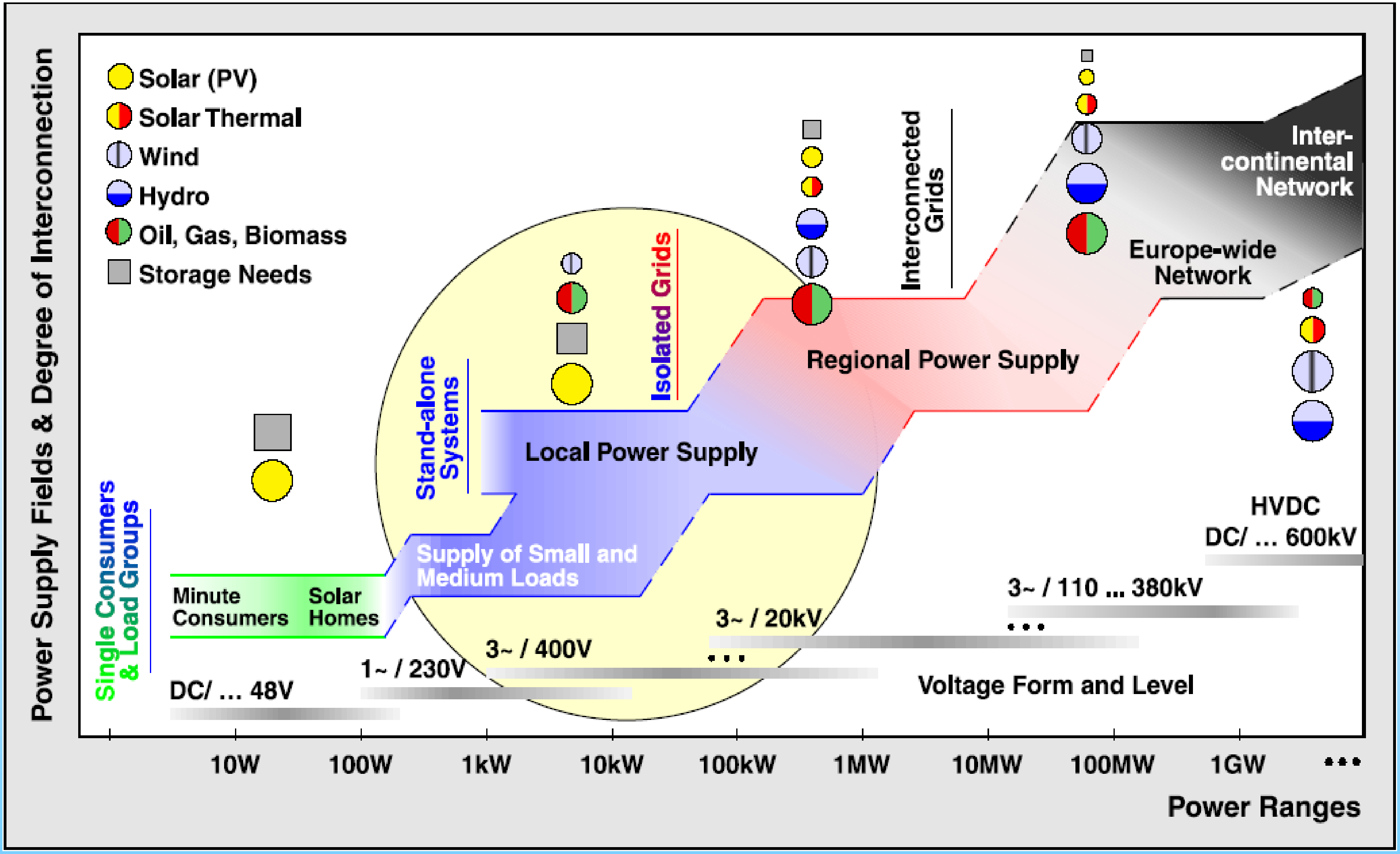
Hybrid system



PV application

PV application

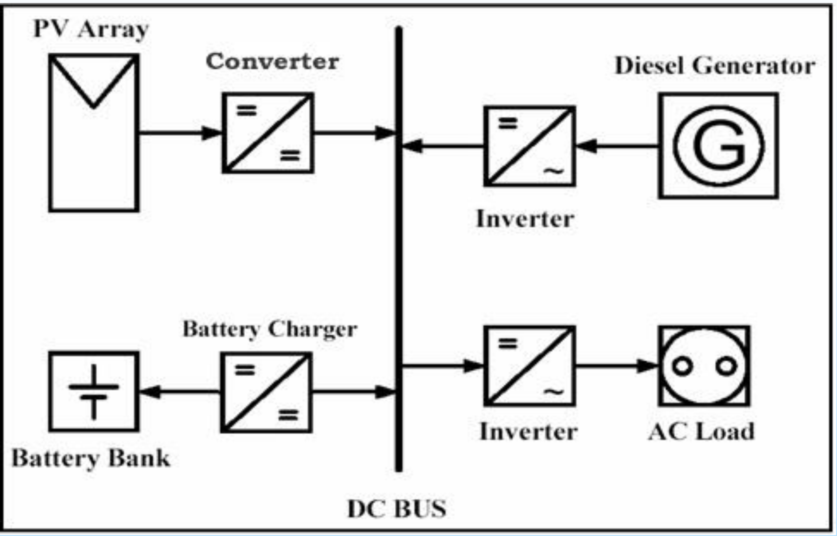
Classification of Hybrid systems for rural electrification



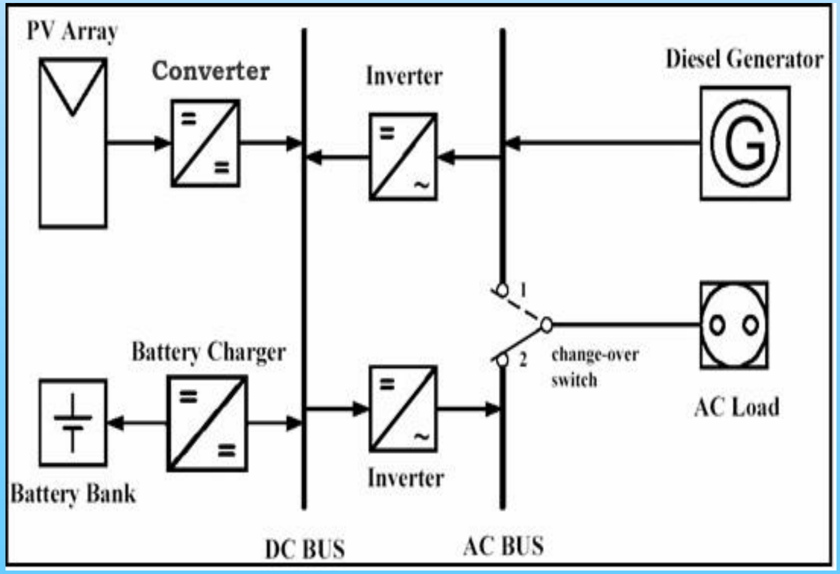
Source: Kleinkauf

PV-Diesel Hybrid System

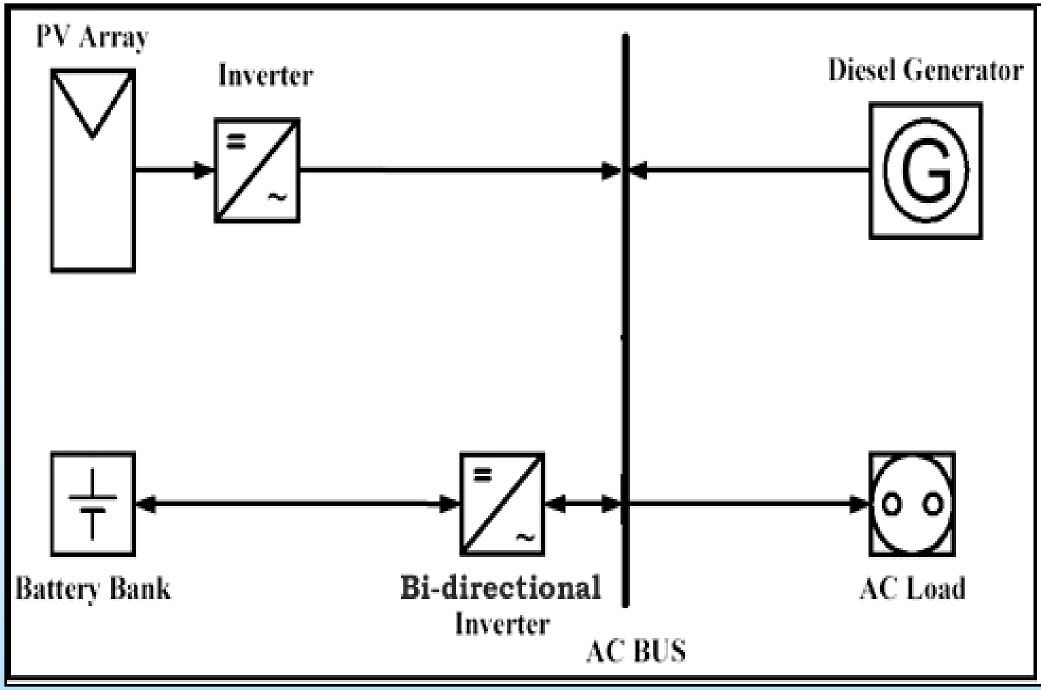
DC-coupled hybrid system



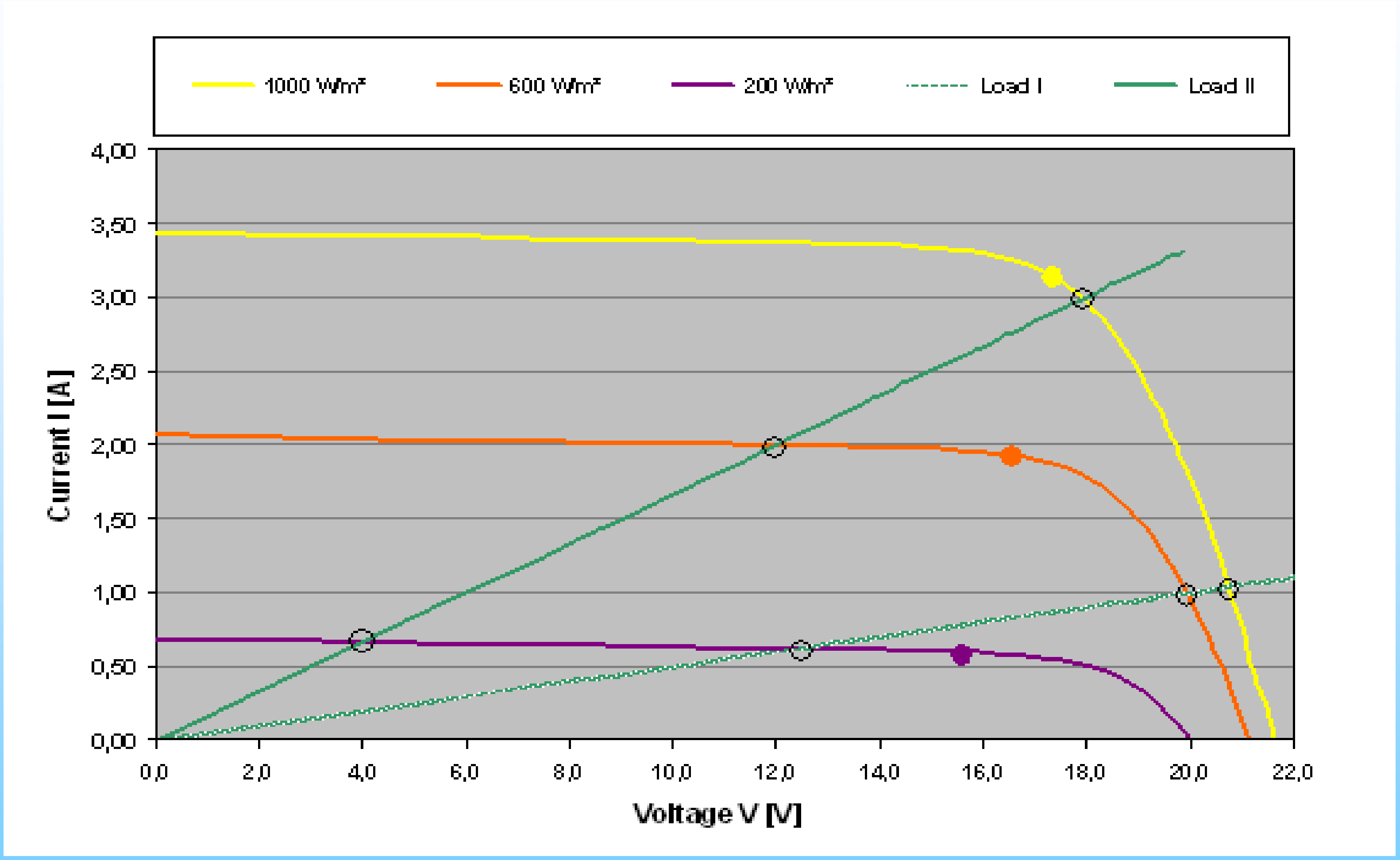
DC-AC coupled hybrid system



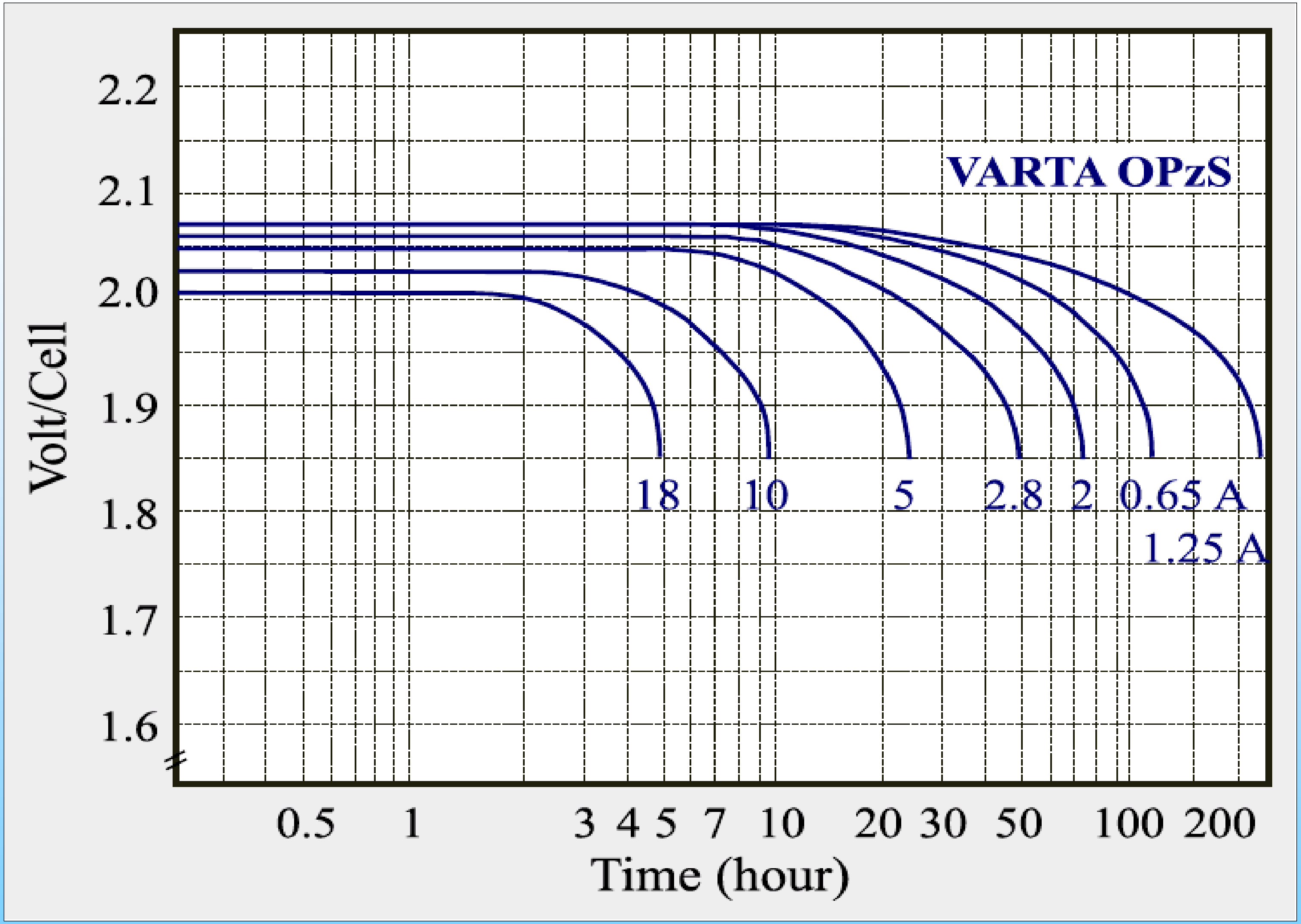
AC-coupled hybrid system

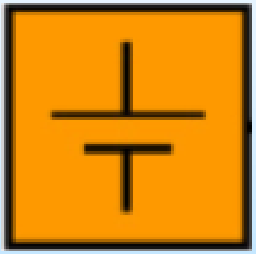


I-V curve


1000 W/m²
600 W/m²
200 W/m²
Load I
Load II
4,00
3,50
3,00
2,50
2,00
1,50
1,00
0,50
0,00
Current I [A]
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
18,0
20,0
22,0
Voltage V [V]

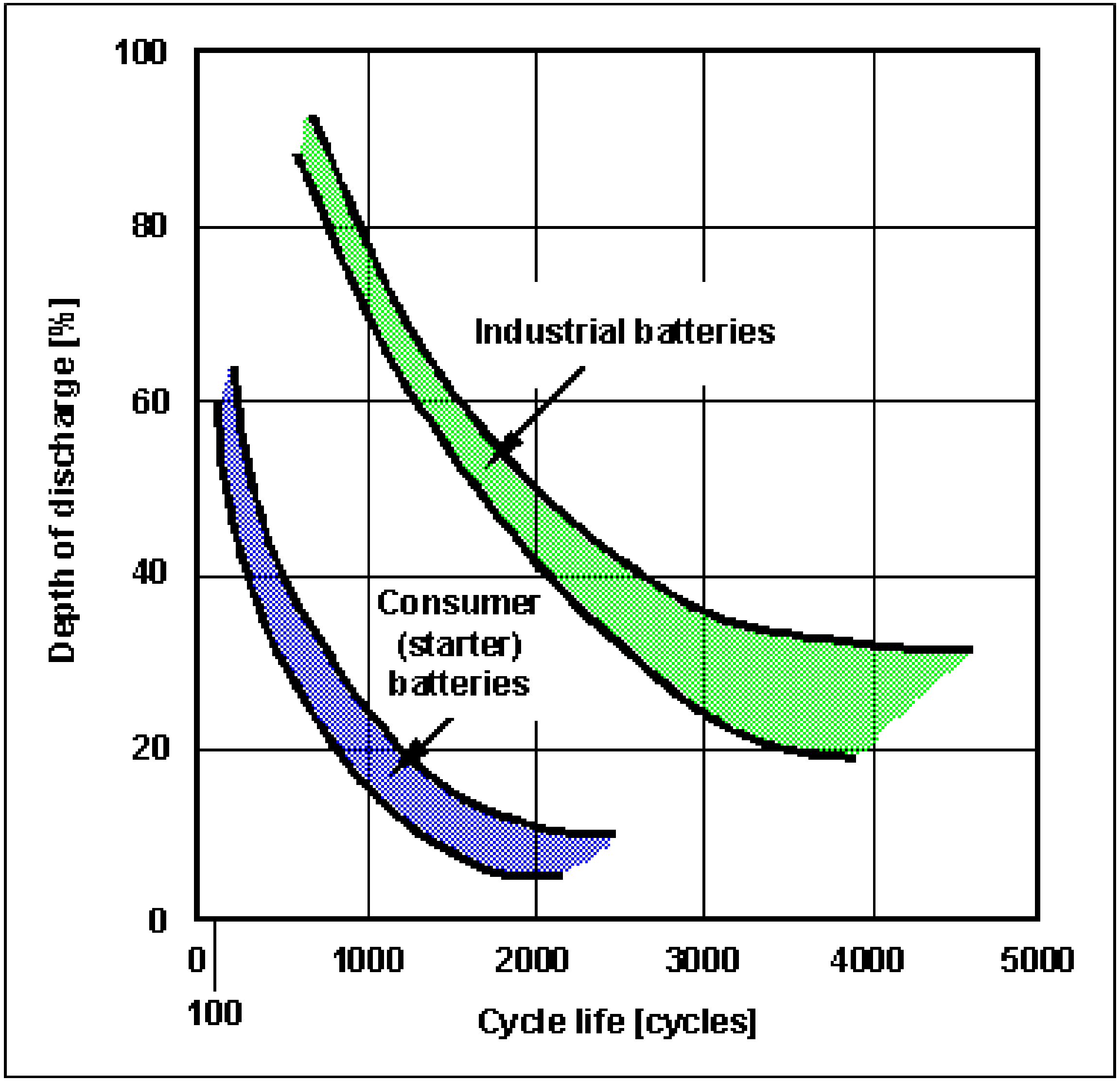
System component: Battery



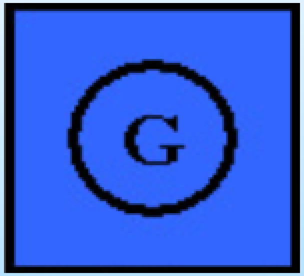


Battery

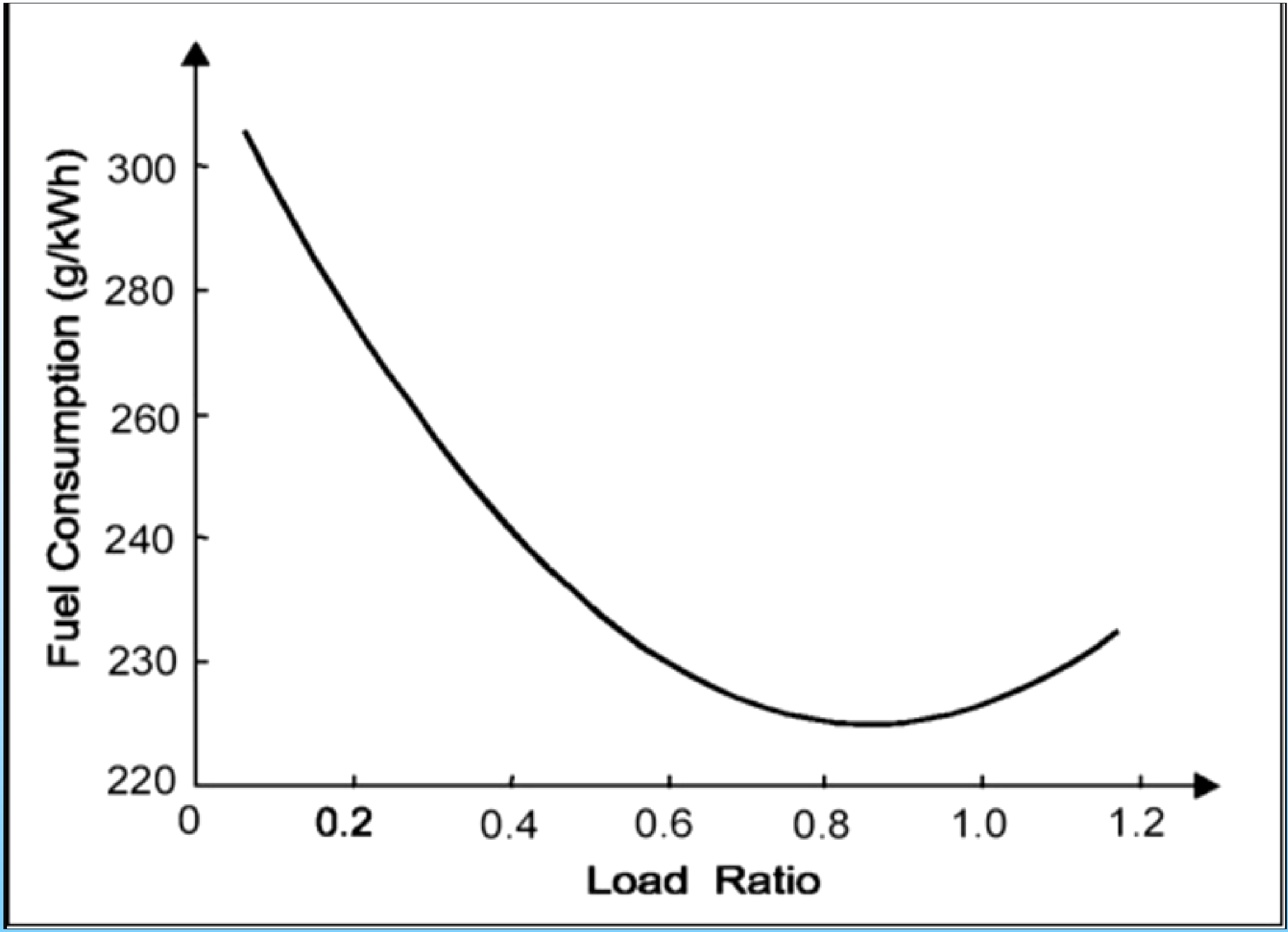
Cycle life of the Battery



System component:
Diesel Generator

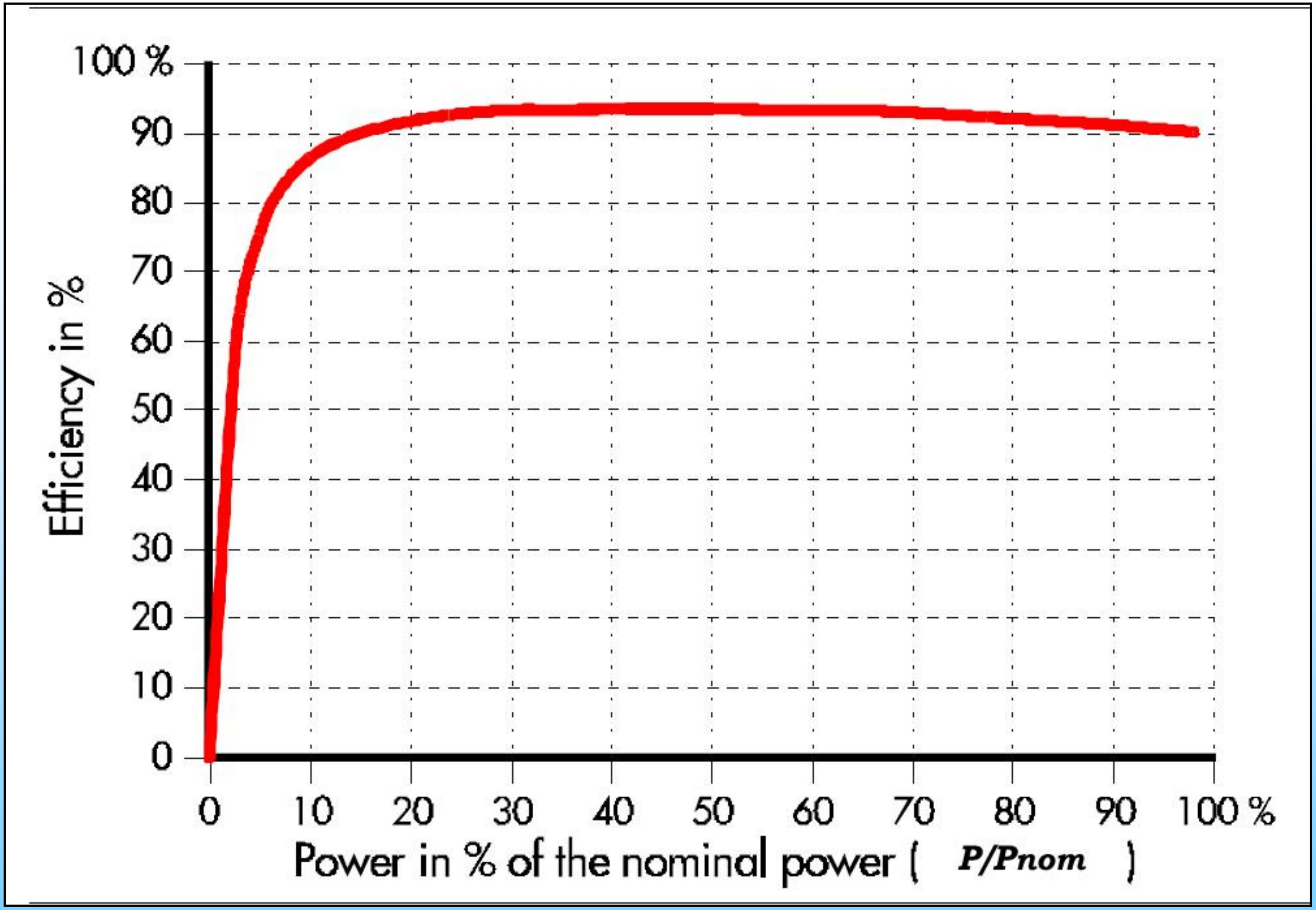


Diesel Generator



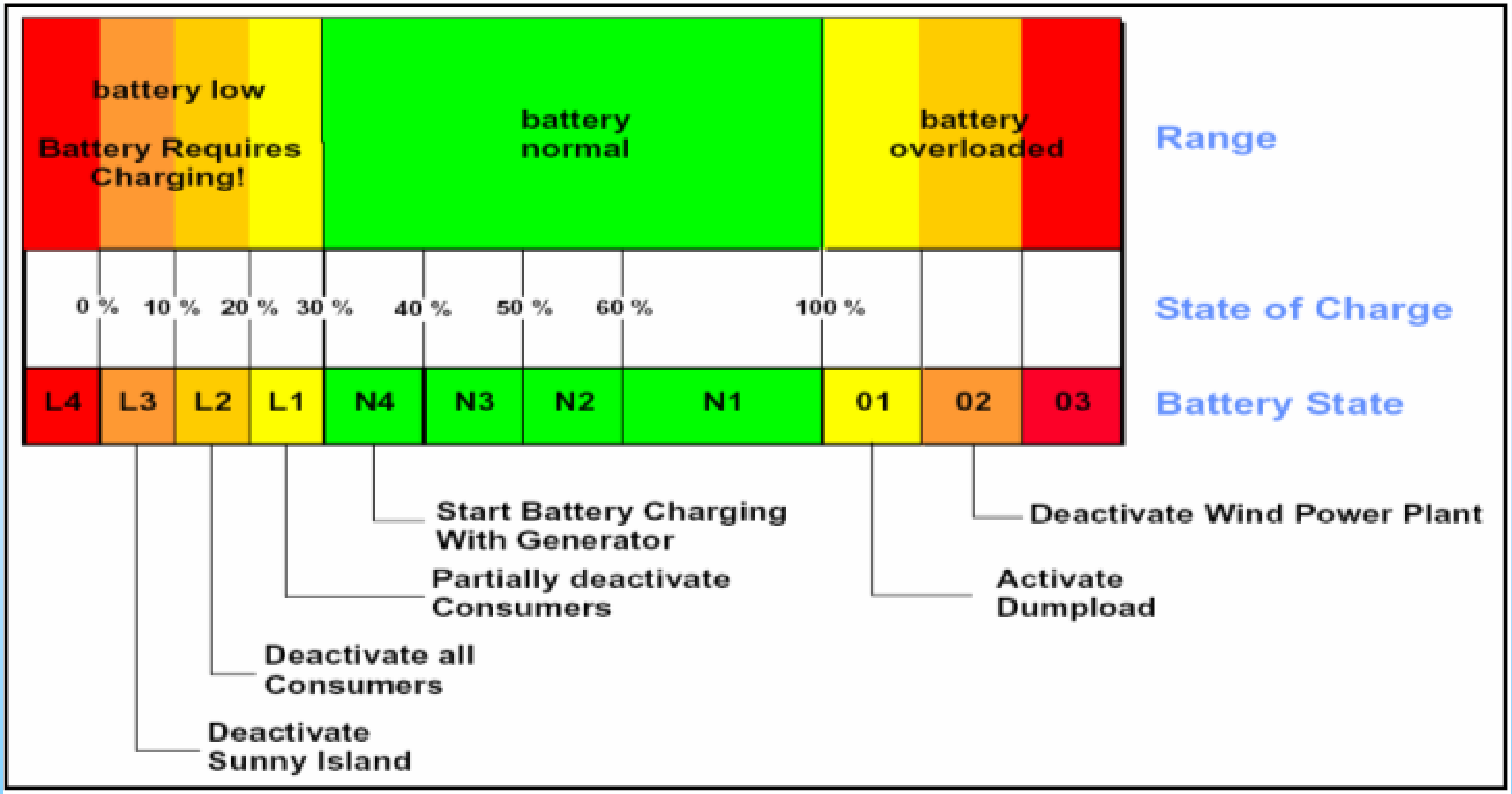
System component: Inverter

Inverter

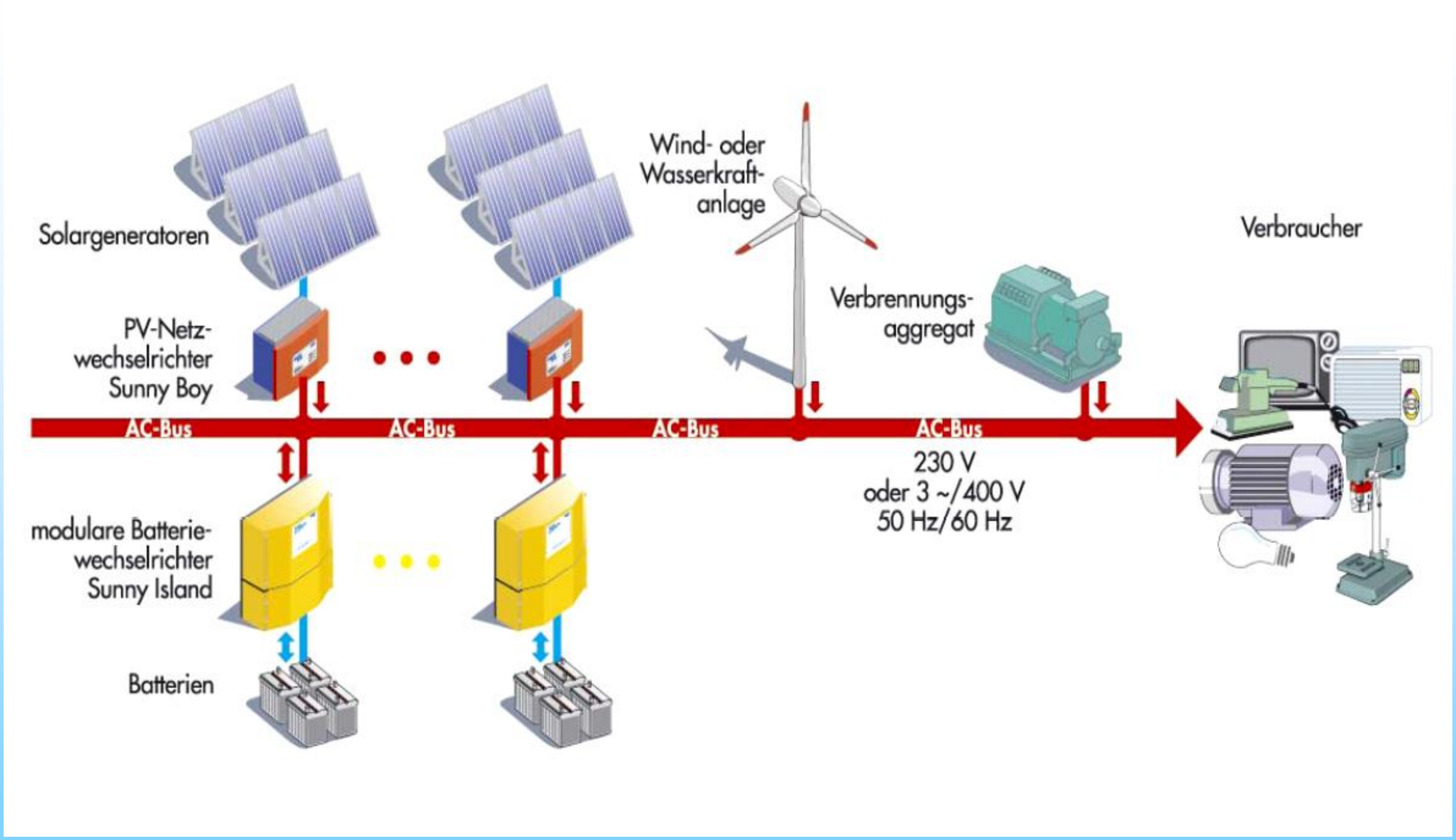


Source: SMA

Island Gird 1 Phase

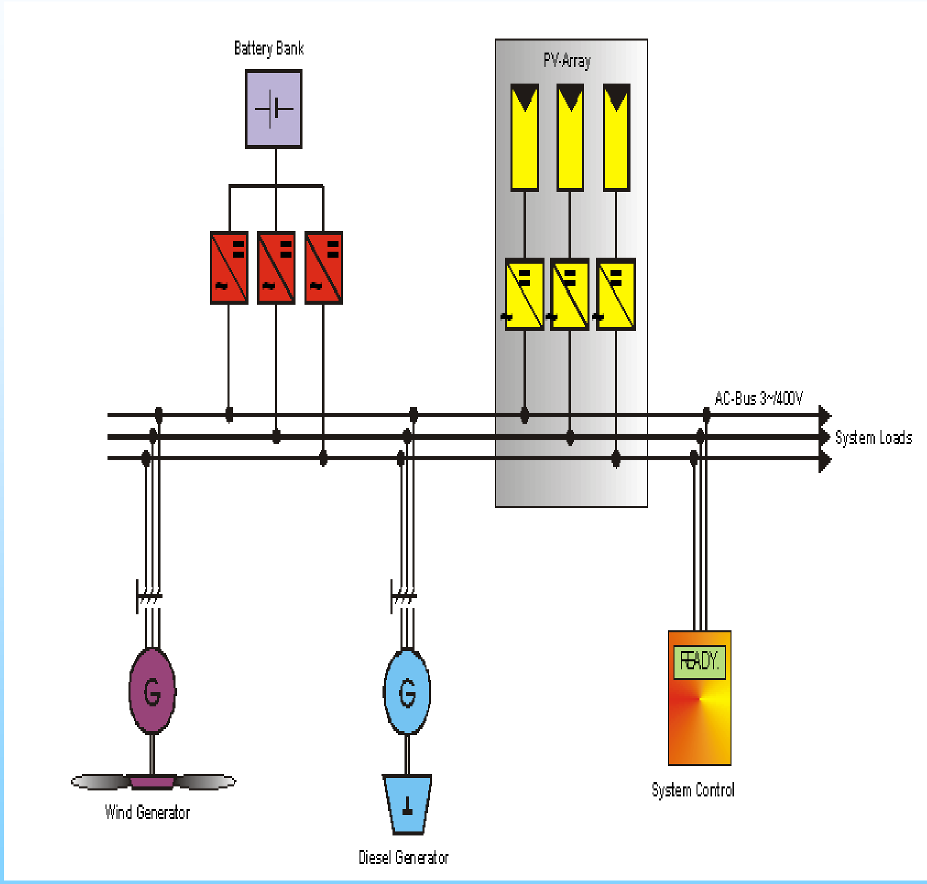


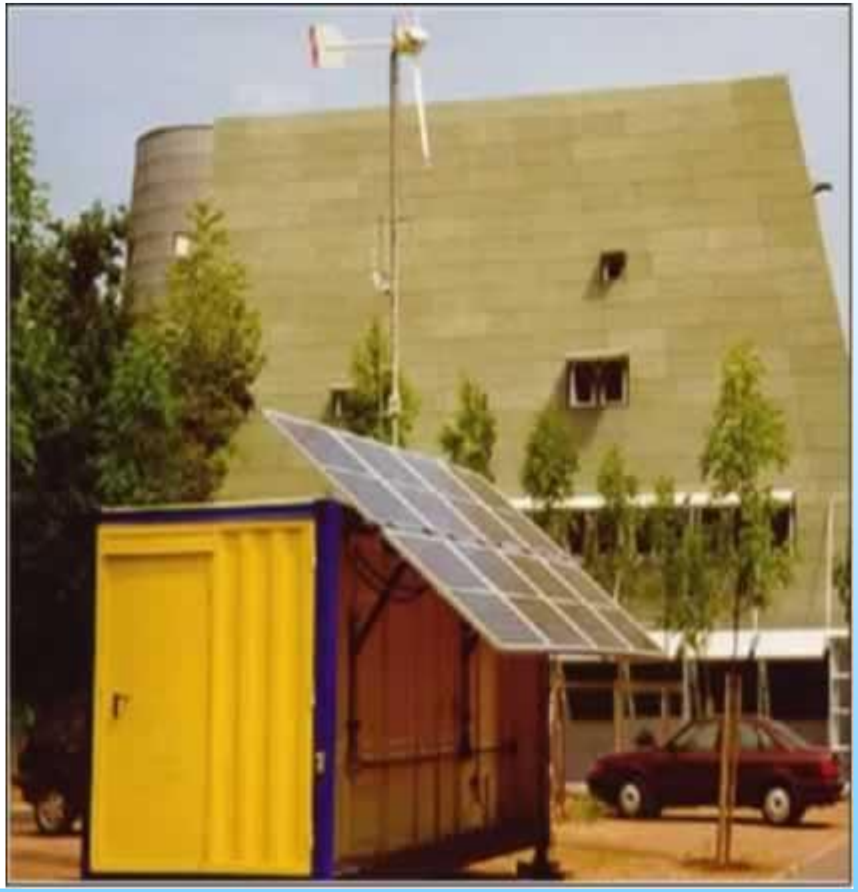
Island grid system



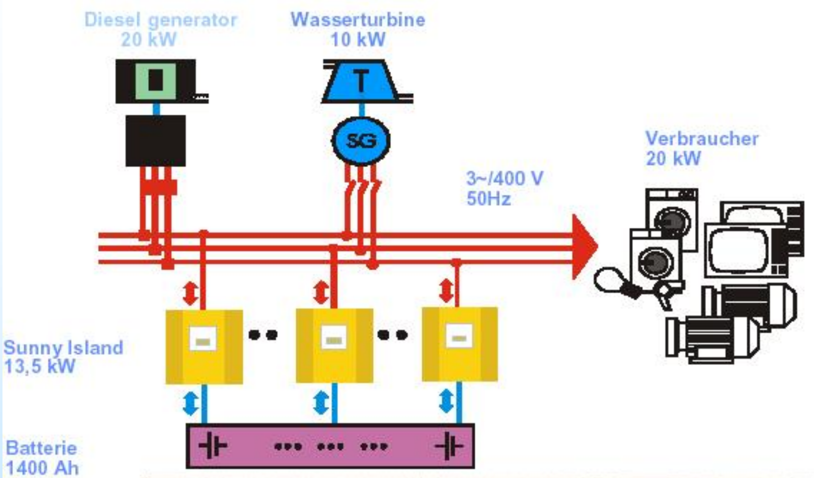
Source: SMA

Hybrid system

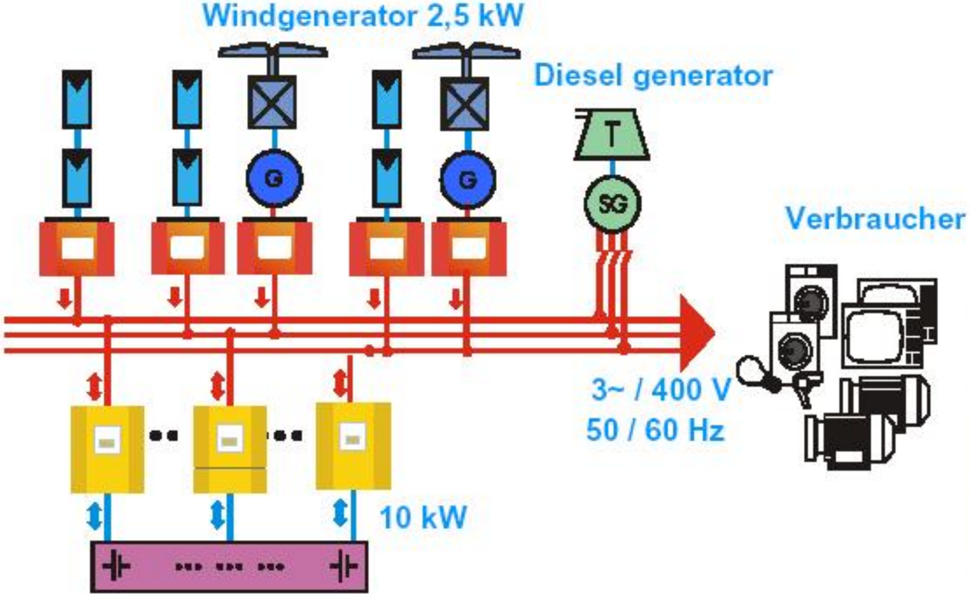




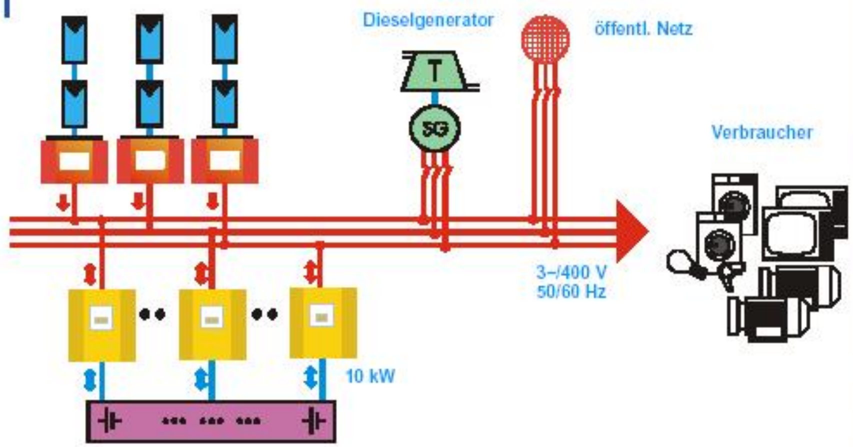
Island Gird 1 Phase



Island Gird 1 Phase



Island Gird 1 Phase



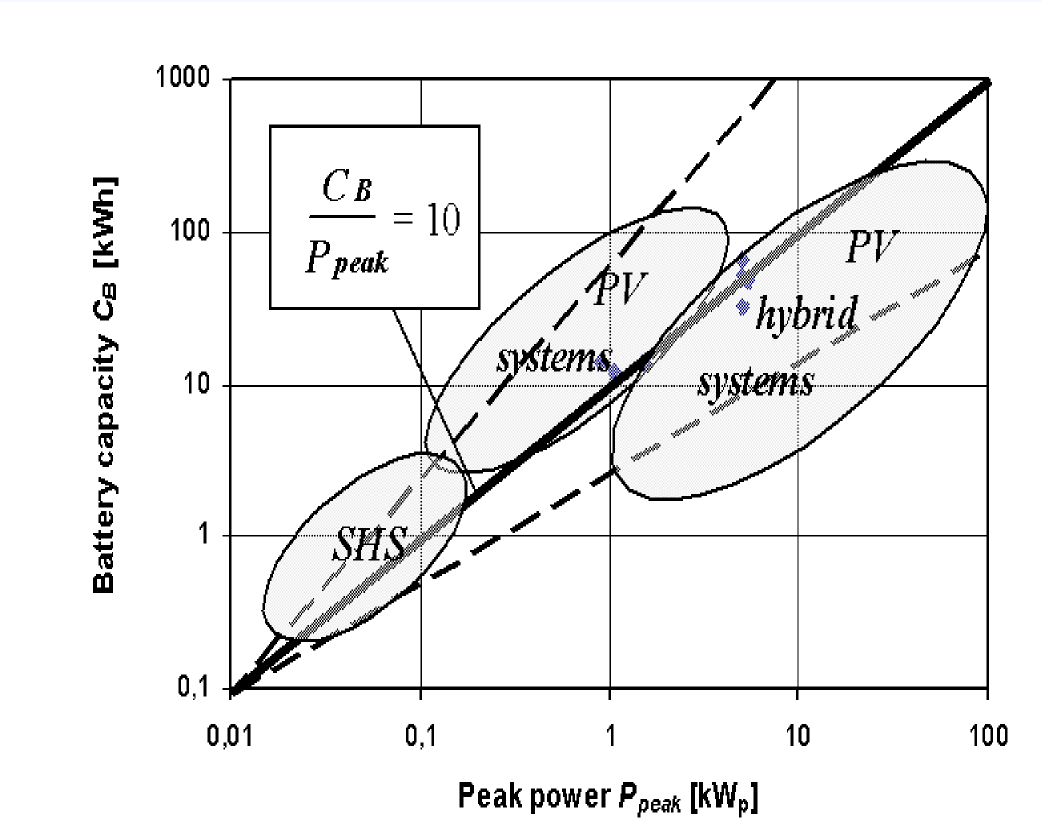
PV Sizing

$$P_{peak} = \frac{E_{el} \cdot I_{STC}}{E_{glob} \cdot Q}$$

P_{peak} = peak power of the PV array under STC [kW_p]
E_{el} = real electric output energy of the system [kWh/a]
I_{STC} = incident solar radiation under STC [1 kW/m^2]
E_{glob} = annual global solar radiation [kWh/m^2a]
Q = quality factor of the system

Component/System	Q
PV module (Crystalline)	0.85…0.95
PV array	0.80…0.90
PV system (Grid-connected)	0.60…0.75
PV system (Stand-alone)	0.10…0.40
Hybrid system (PV/Diesel)	0.40…0.60

Battery Sizing



$$C_B = \frac{L \cdot T_A}{DOD \cdot D_T \cdot \eta_C \cdot \eta_W \cdot \eta_B}$$

- C_B = battery capacity [kWh]
- L = daily mean energy consumption [kWh/d]
- T_A = number of autonomy days [d]
- DOD = maximum depth of discharge [decimal]
- D_T = derate for temperature [decimal]
- η_C = efficiency of power conversion [decimal]
- η_W = efficiency of wiring [decimal]
- η_B = efficiency of battery [decimal]

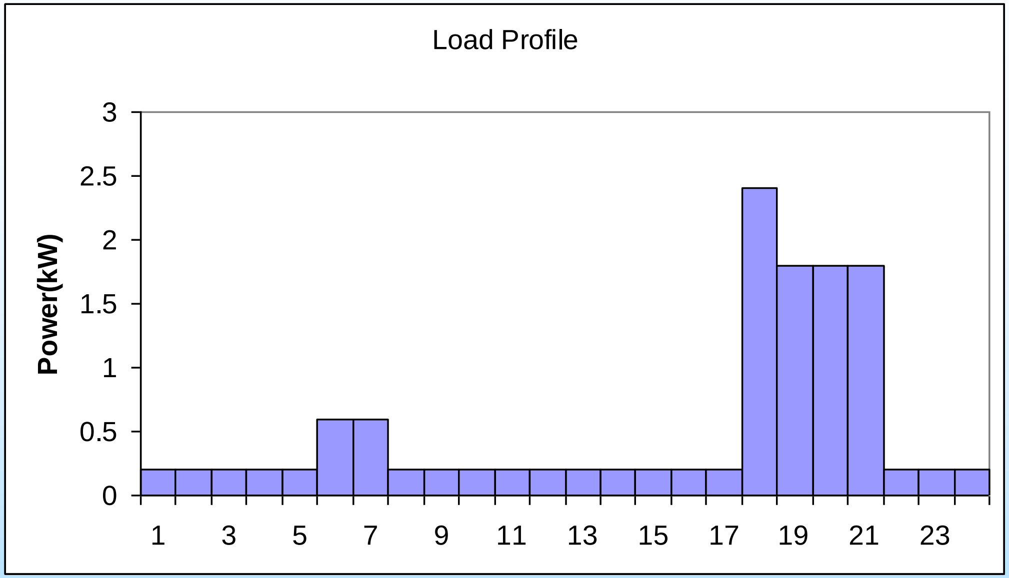
↓PV cost by Annuity Method

$$a = NPV \cdot \frac{i \cdot (1+i)^n}{(1+i)^n - 1} \quad \textbf{(7-1)}$$

a	=	annuity [currency]
NPV	=	net present value [currency]
i	=	fictitious interest [1]
n	=	planning horizon [a]

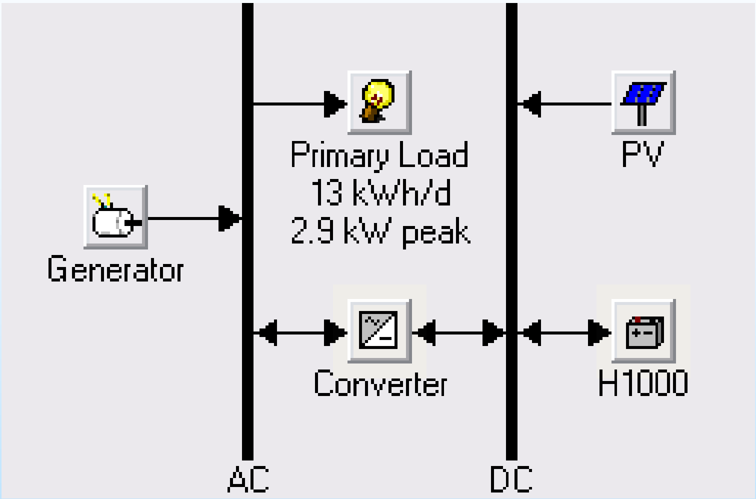
	$n = 5$	$n = 10$	$n = 15$	$n = 20$	$n = 25$
$i = 5$	23.10	12.95	9.63	8.02	7.10
$i = 8$	25.05	14.90	11.68	10.19	9.37
$i = 10$	26.38	16.27	13.15	11.75	11.02
$i = 20$	33.44	23.85	21.39	20.54	20.21

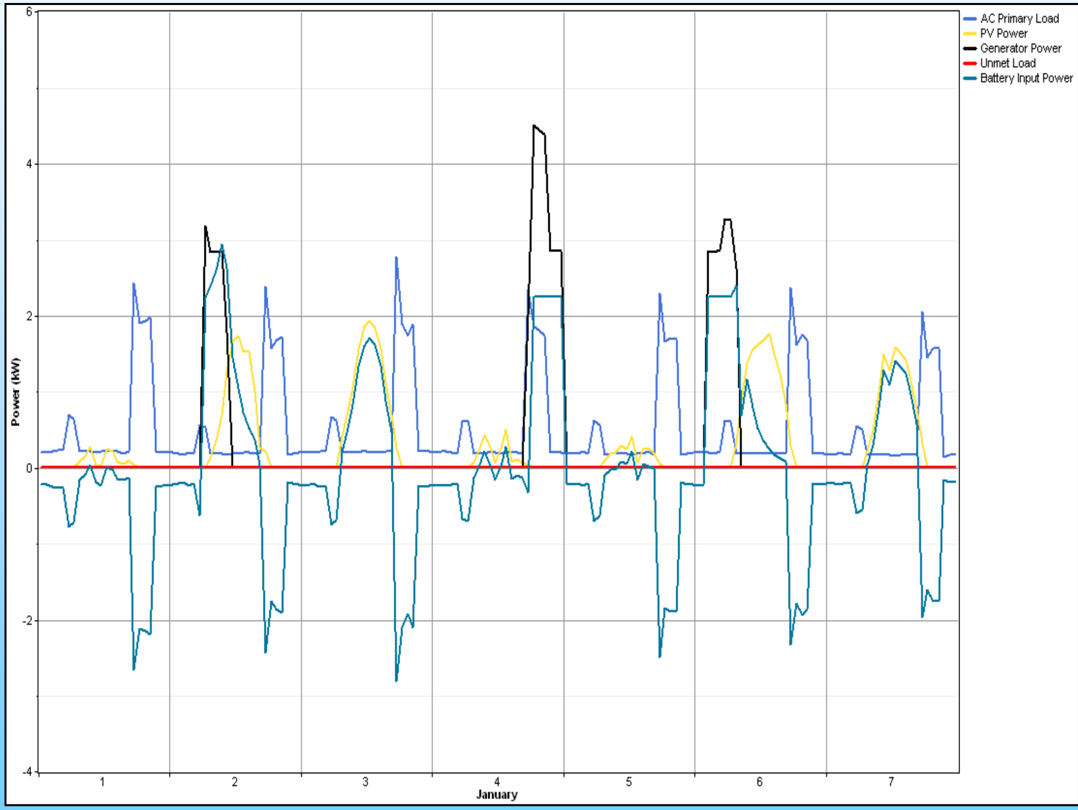
Example PV sizing



- 14 kW/h/d, Radiation in Thailand = 5 kW/h/m2/d, Q factor = 0.6
- PVpeak = 14 x 1 kW/m2 / 5 kW/h/m2/d * 0.6
- = 4.6 kW
- Battery = 4.6 x 10
- = 46 kW
- Gen = ?

Simulation

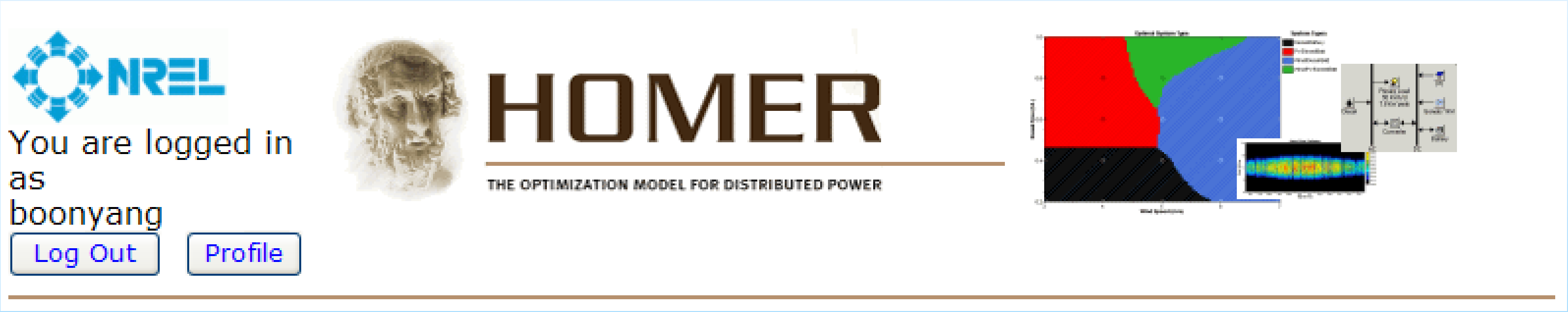




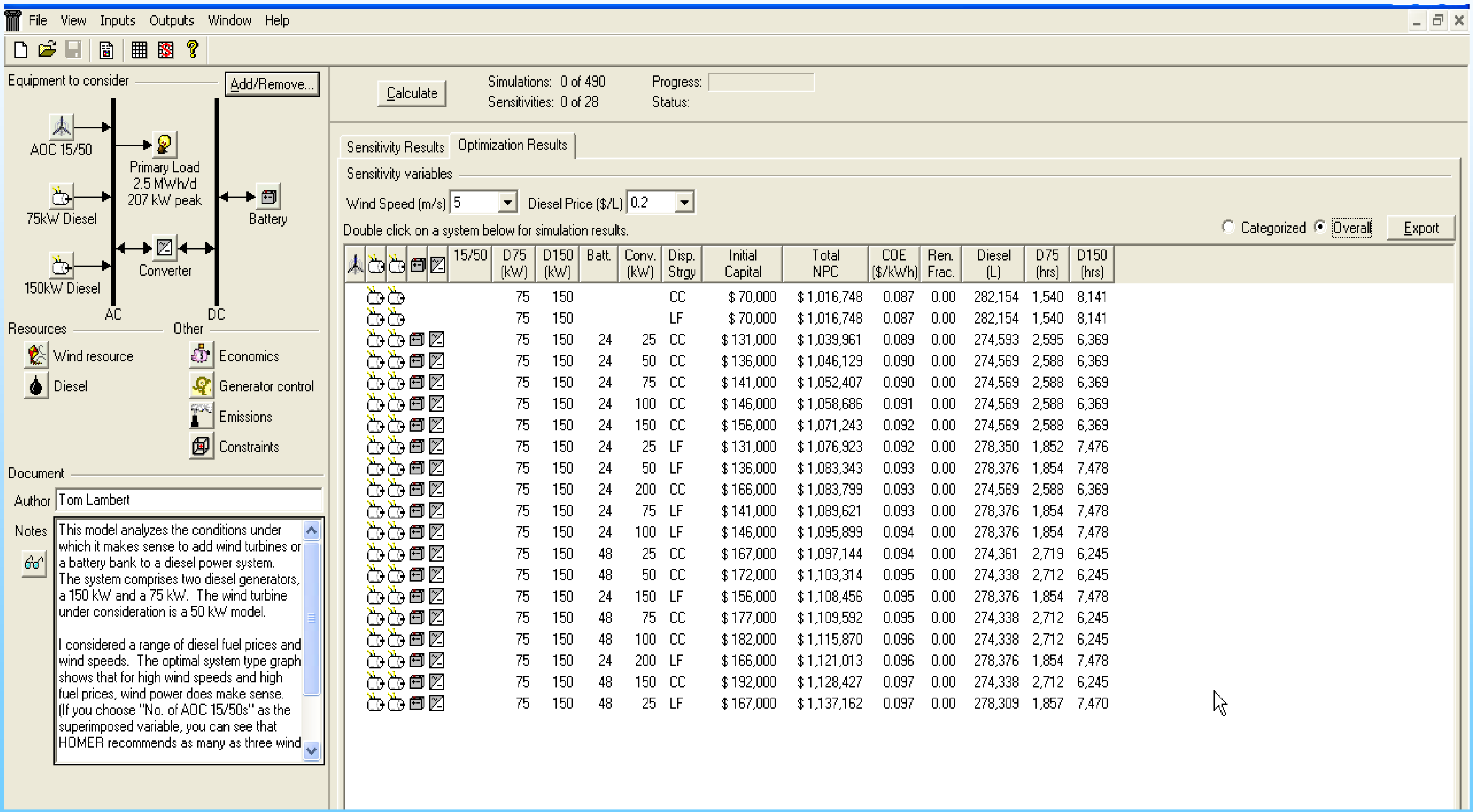
- Confirm the design
- System outlook

Simulation Software

- www.nrel.gov/homer



Homer



15/50	D75 (kW)	D150 (kW)	Batt.	Conv. (kW)	Disp. Strgy	Initial Capital	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	D75 (hrs)	D150 (hrs)
	75	150			CC	$ 70,000	$ 1,016,748	0.087	0.00	282,154	1,540	8,141
	75	150			LF	$ 70,000	$ 1,016,748	0.087	0.00	282,154	1,540	8,141
	75	150	24	25	CC	$ 131,000	$ 1,039,961	0.089	0.00	274,593	2,595	6,369
	75	150	24	50	CC	$ 136,000	$ 1,046,129	0.090	0.00	274,569	2,588	6,369
	75	150	24	75	CC	$ 141,000	$ 1,052,407	0.090	0.00	274,569	2,588	6,369
	75	150	24	100	CC	$ 146,000	$ 1,058,686	0.091	0.00	274,569	2,588	6,369
	75	150	24	150	CC	$ 156,000	$ 1,071,243	0.092	0.00	274,569	2,588	6,369
	75	150	24	25	LF	$ 131,000	$ 1,076,923	0.092	0.00	278,350	1,852	7,476
	75	150	24	50	LF	$ 136,000	$ 1,083,343	0.093	0.00	278,376	1,854	7,478
	75	150	24	200	CC	$ 166,000	$ 1,083,799	0.093	0.00	274,569	2,588	6,369
	75	150	24	75	LF	$ 141,000	$ 1,089,621	0.093	0.00	278,376	1,854	7,478
	75	150	24	100	LF	$ 146,000	$ 1,095,899	0.094	0.00	278,376	1,854	7,478
	75	150	48	25	CC	$ 167,000	$ 1,097,144	0.094	0.00	274,361	2,719	6,245
	75	150	48	50	CC	$ 172,000	$ 1,103,314	0.095	0.00	274,338	2,712	6,245
	75	150	24	150	LF	$ 156,000	$ 1,108,456	0.095	0.00	278,376	1,854	7,478
	75	150	48	75	CC	$ 177,000	$ 1,109,592	0.095	0.00	274,338	2,712	6,245
	75	150	48	100	CC	$ 182,000	$ 1,115,870	0.096	0.00	274,338	2,712	6,245
	75	150	24	200	LF	$ 166,000	$ 1,121,013	0.096	0.00	278,376	1,854	7,478
	75	150	48	150	CC	$ 192,000	$ 1,128,427	0.097	0.00	274,338	2,712	6,245
	75	150	48	25	LF	$ 167,000	$ 1,137,162	0.097	0.00	278,309	1,857	7,470

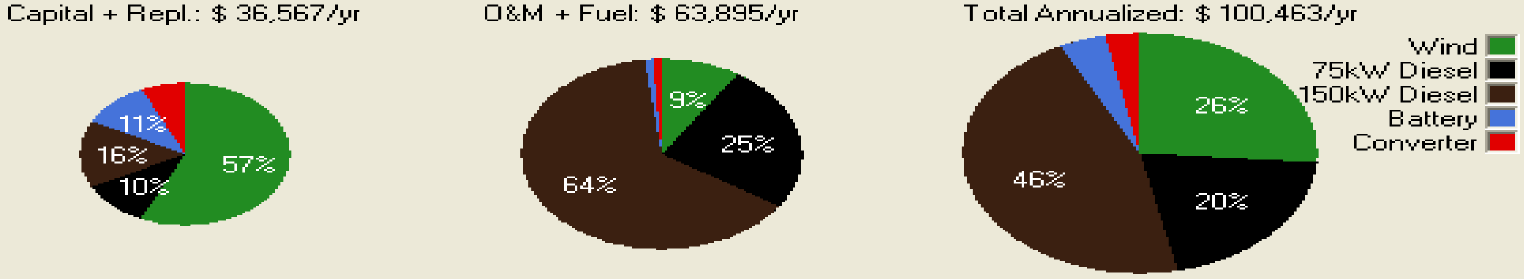
Homer

Simulation Results

System Architecture: 1 AOC 15/50 | 50 kW Inverter
75 kW 75kW Diesel | 50 kW Rectifier
150 kW 150kW Diesel | Cycle Charging
24 Surrette 4KS25P

Total NPC: $ 1,284,253
Levelized COE: $ 0.110/kWh

Cost | Electrical | AOC 15/50 | 75kW Diesel | 150kW Diesel | Battery | Emissions | Hourly Data



Component	Initial Capital ($)	Annualized Capital ($/yr)	Annualized Replacement ($/yr)	Annual O&M ($/yr)	Annual Fuel ($/yr)	Total Annualized ($/yr)
AOC 15/50	265,000	20,730	0	6,000	0	26,730
75kW Diesel	30,000	2,347	1,434	297	16,017	20,096
150kW Diesel	40,000	3,129	2,570	7,338	33,323	46,359
Battery	36,000	2,816	1,195	720	0	4,731
Converter	30,000	2,347	0	200	0	2,547
Totals	401,000	31,369	5,198	14,555	49,340	100,463

XML Report | HTML Report | Help | Close

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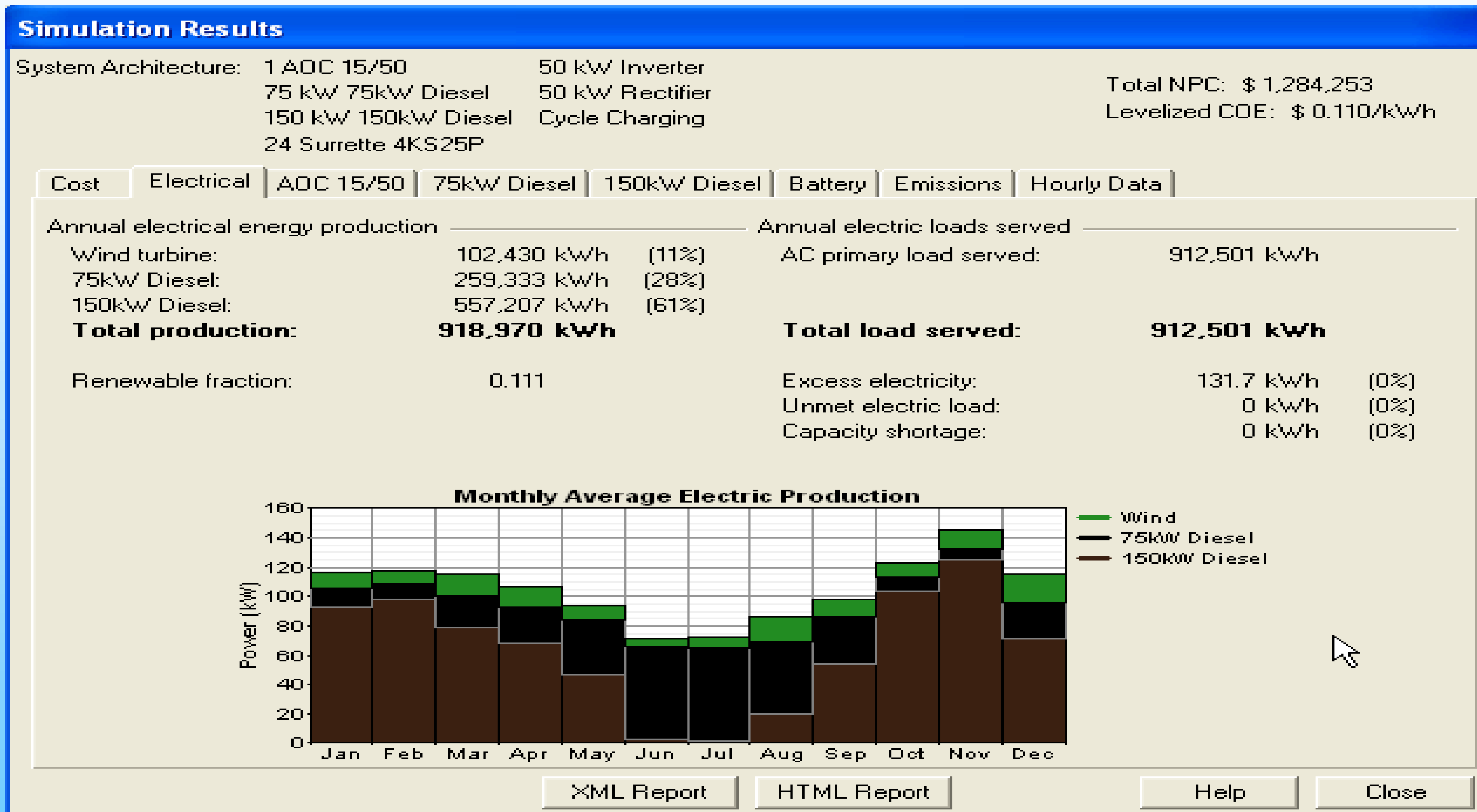
Simulation Results
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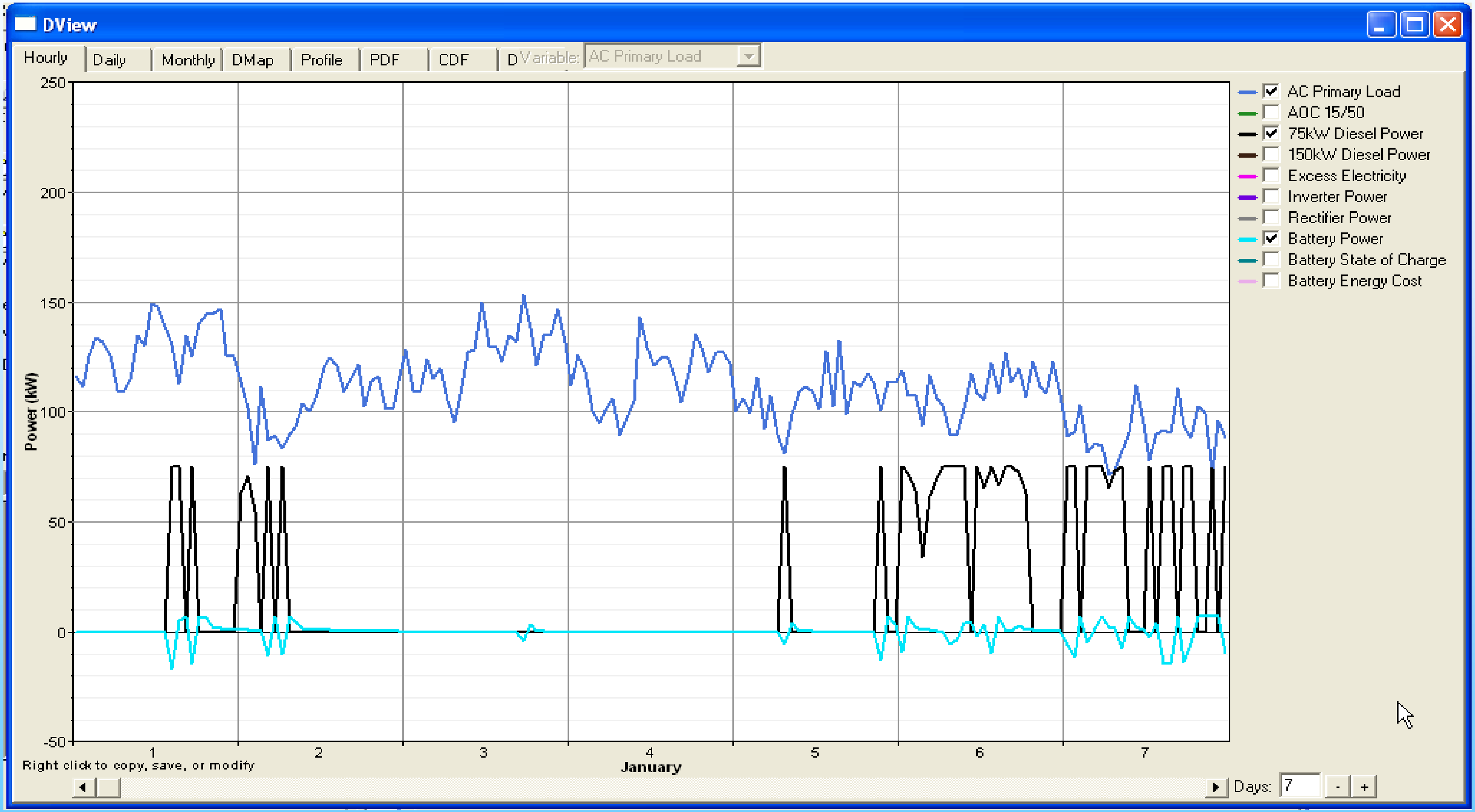
150 kW 150kW Diesel
24 Surrette 4KS25P
50 kW Inverter
50 kW Rectifier
Cycle Charging
Total NPC: $ 1,284,253
Levelized COE: $ 0.110/kWh
Cost
Electrical
AOC 15/50
75kW Diesel
150kW Diesel
Battery
Emissions
Hourly Data
Annual electrical energy production
Wind turbine: 102,430 kWh (11%)
75kW Diesel: 259,333 kWh (28%)
150kW Diesel: 557,207 kWh (61%)
Total production: 918,970 kWh
Renewable fraction: 0.111
Annual electric loads served
AC primary load served: 912,501 kWh
Total load served: 912,501 kWh
Excess electricity: 131.7 kWh (0%)
Unmet electric load: 0 kWh (0%)
Capacity shortage: 0 kWh (0%)
Monthly Average Electric Production
Power (kW)
0
20
40
60
80
100
120
140
160
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Wind
75kW Diesel
150kW Diesel
XML Report
HTML Report
Help
Close

Homer


DView
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Variable:
AC Primary Load
250
200
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100
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Power (kW)
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January
Right click to copy, save, or modify
AC Primary Load
AOC 15/50
75kW Diesel Power
150kW Diesel Power
Excess Electricity
Inverter Power
Rectifier Power
Battery Power
Battery State of Charge
Battery Energy Cost
Days:
7
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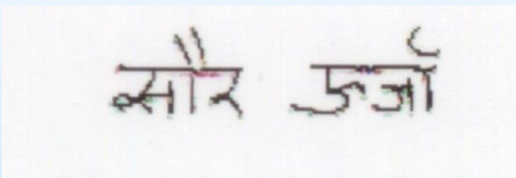

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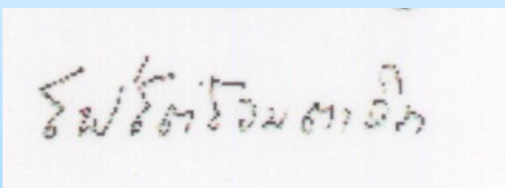

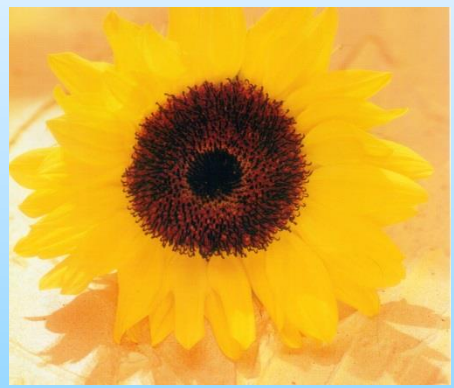

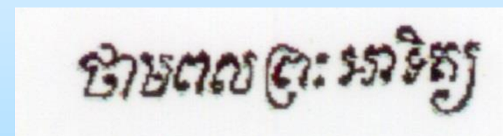

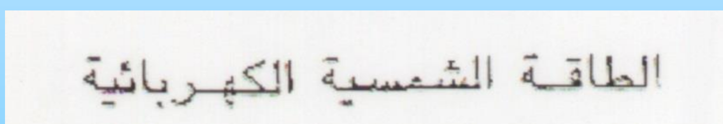

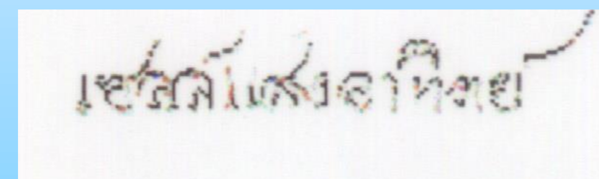

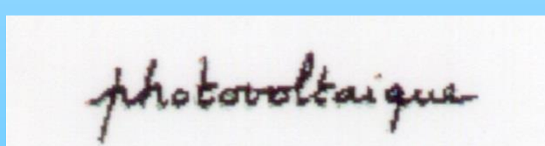

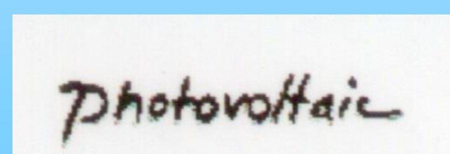

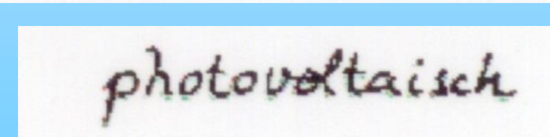

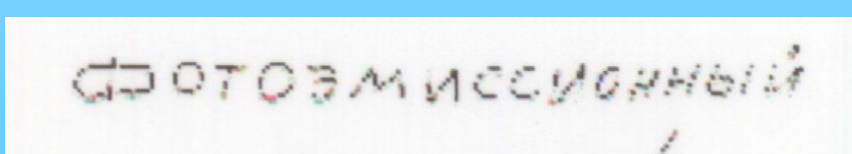

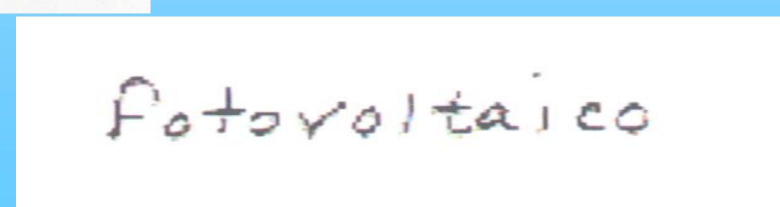

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