Energy and Environment

Technical Solutions to use Renewable Energy Carriers

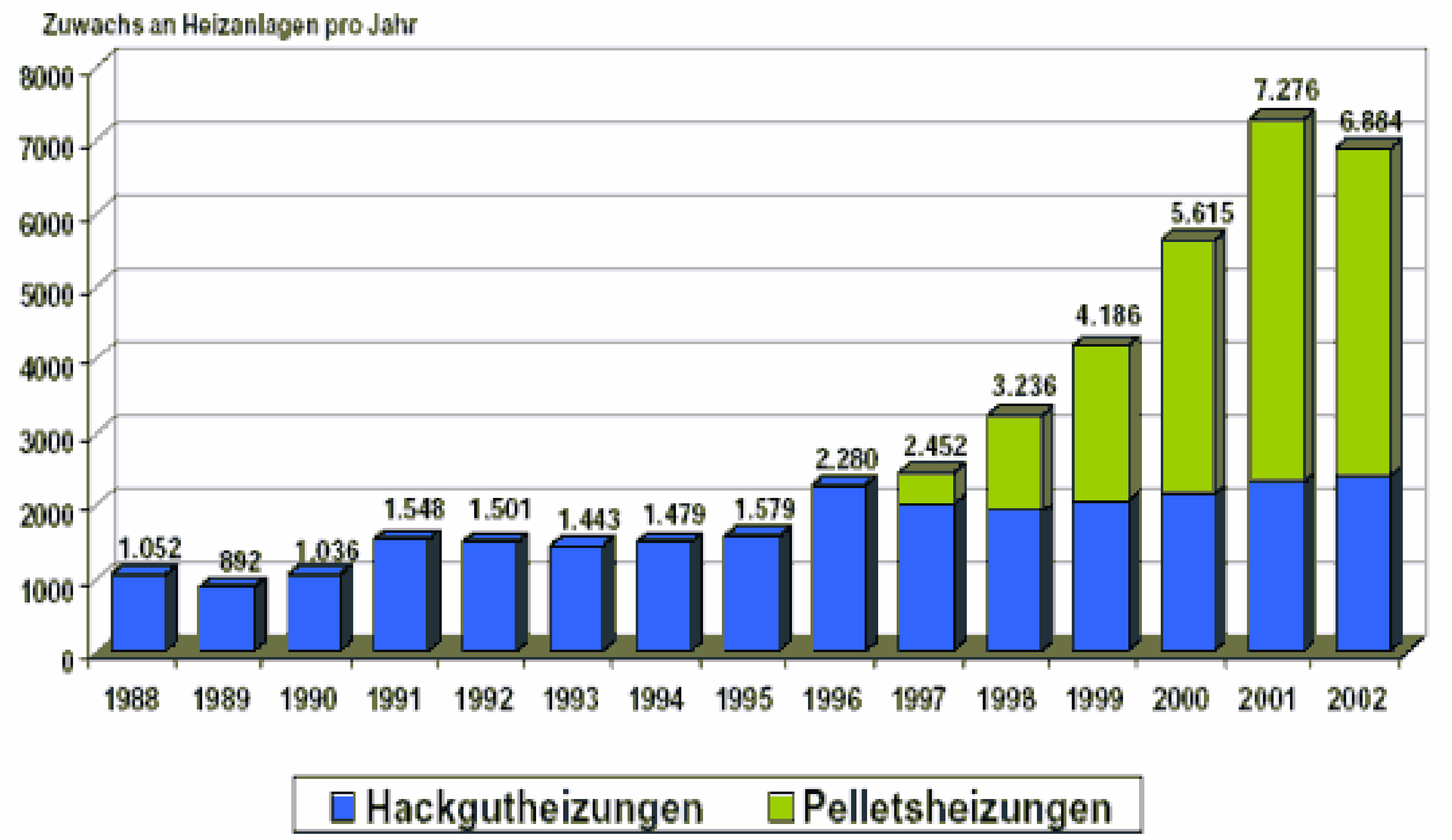
Part A: Heat Application

Technical Solutions to use Renewable Energy Carriers

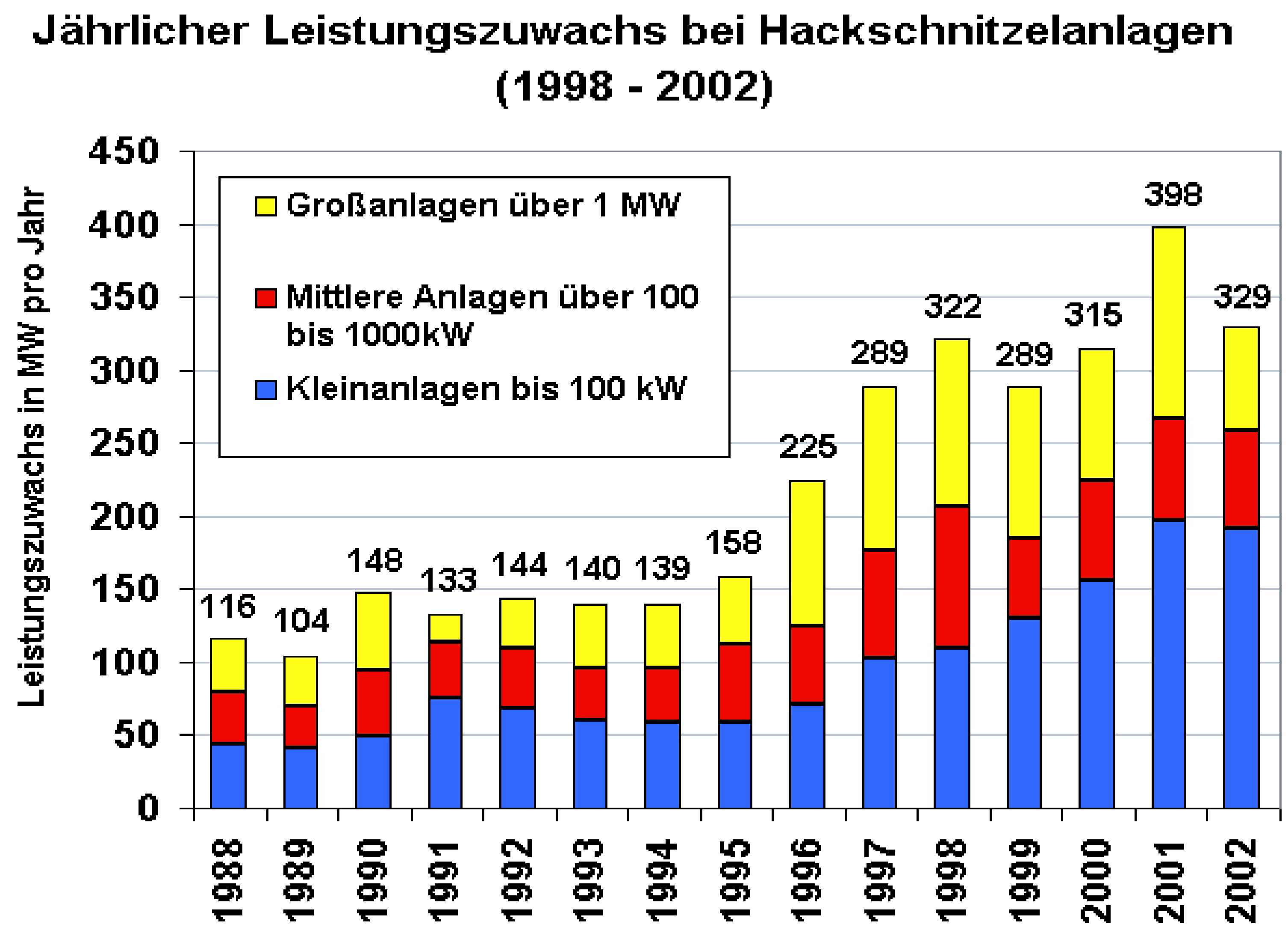
Part A: Heat Application
Part B: Electricity Production
Part C: Mobility

Biomass

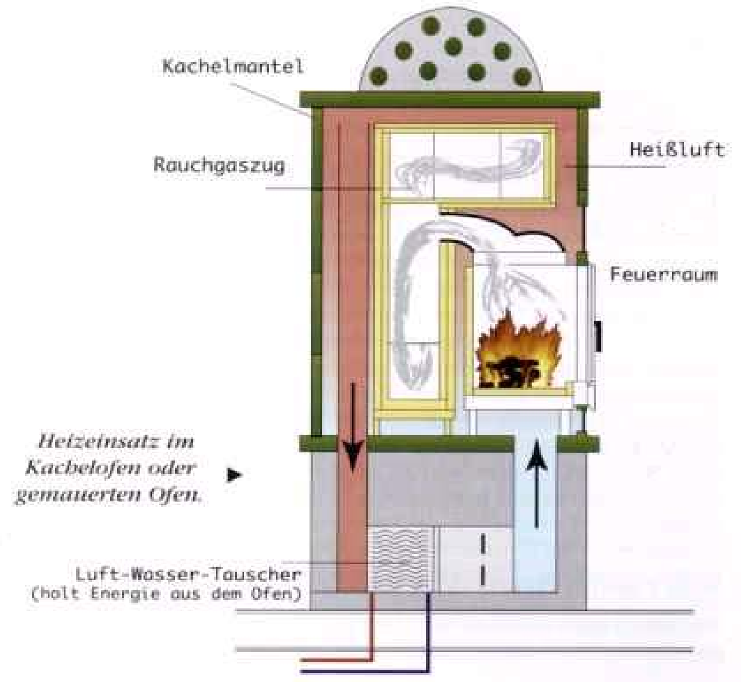
Yearly increase of biomass heating systems in Austria

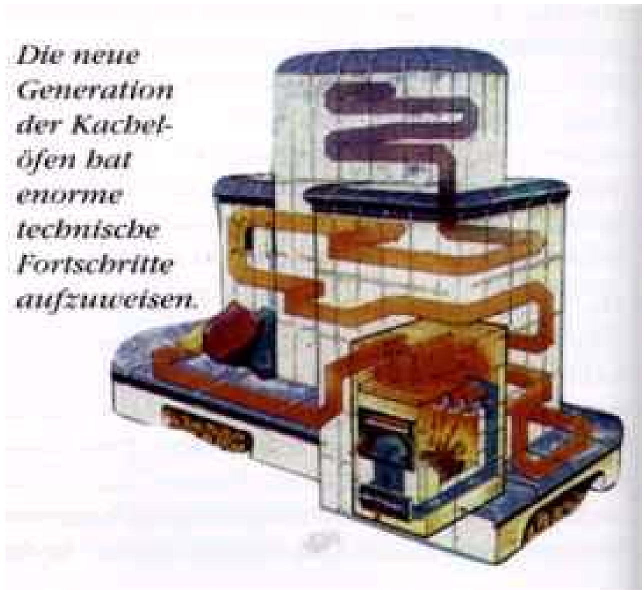


Yearly increase of wood chip heating systems in Austria



„Kachelofen“





- Positioning that several rooms can be heated, with water HX inside a coupling to a water heating system can be done
- Efficiency about 60-70 %
- High startup emissions (cold burning chamber)

"Kaminofen"

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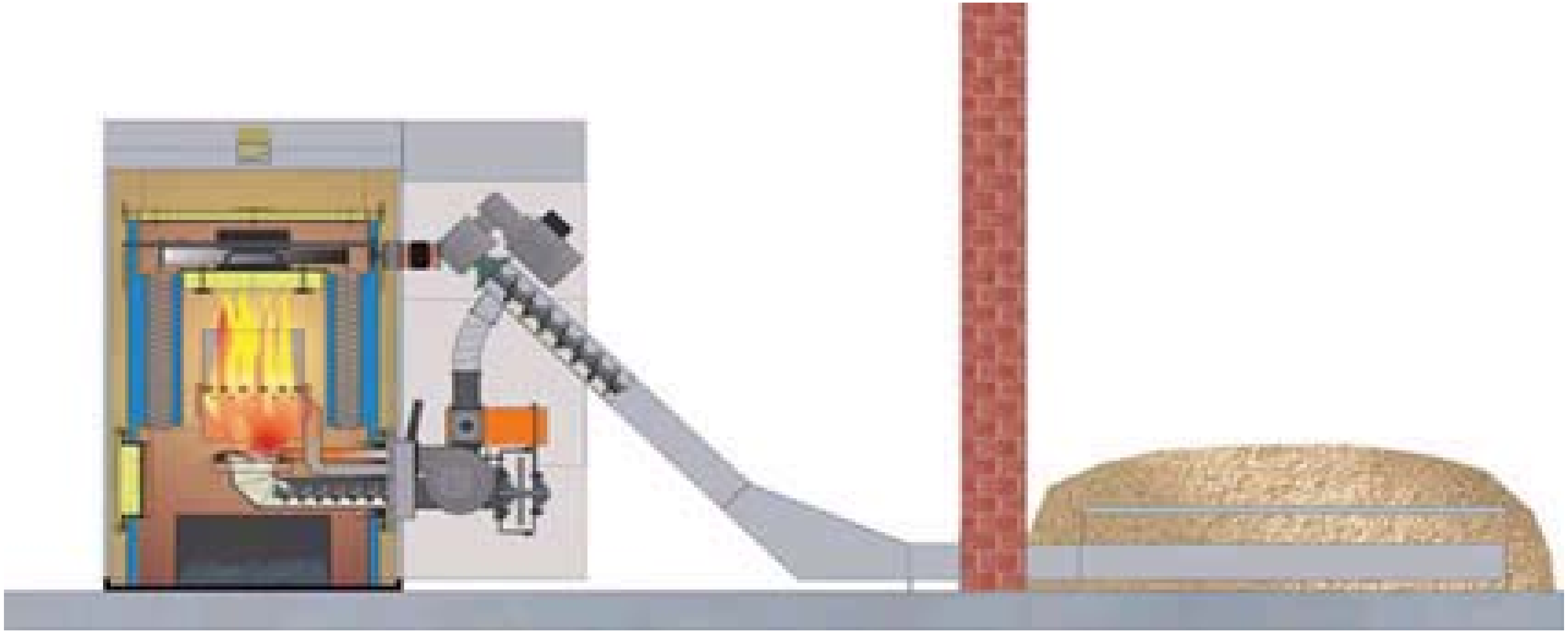
Log wood burner with downward flame

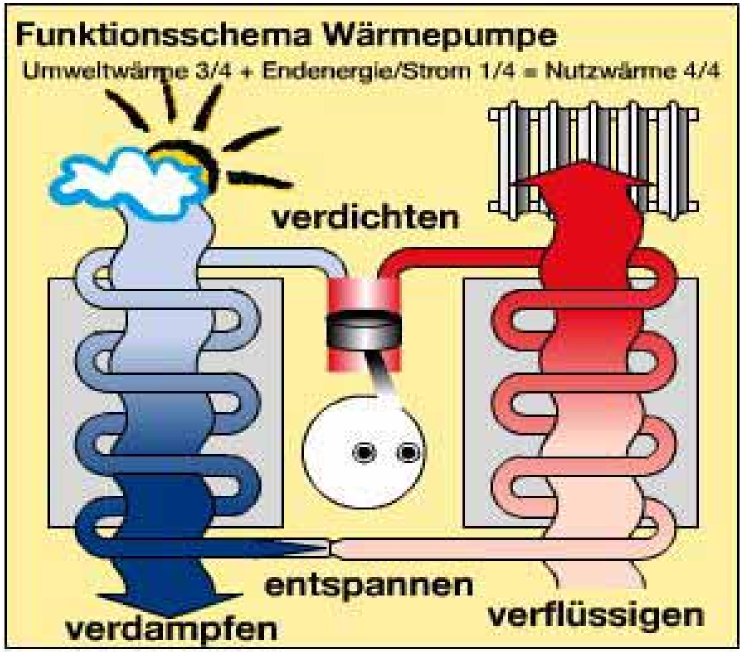
- Logs and ash is transported autmomatically downwards
- Logs are dries before burned
- Burning chamber is NOT cooled

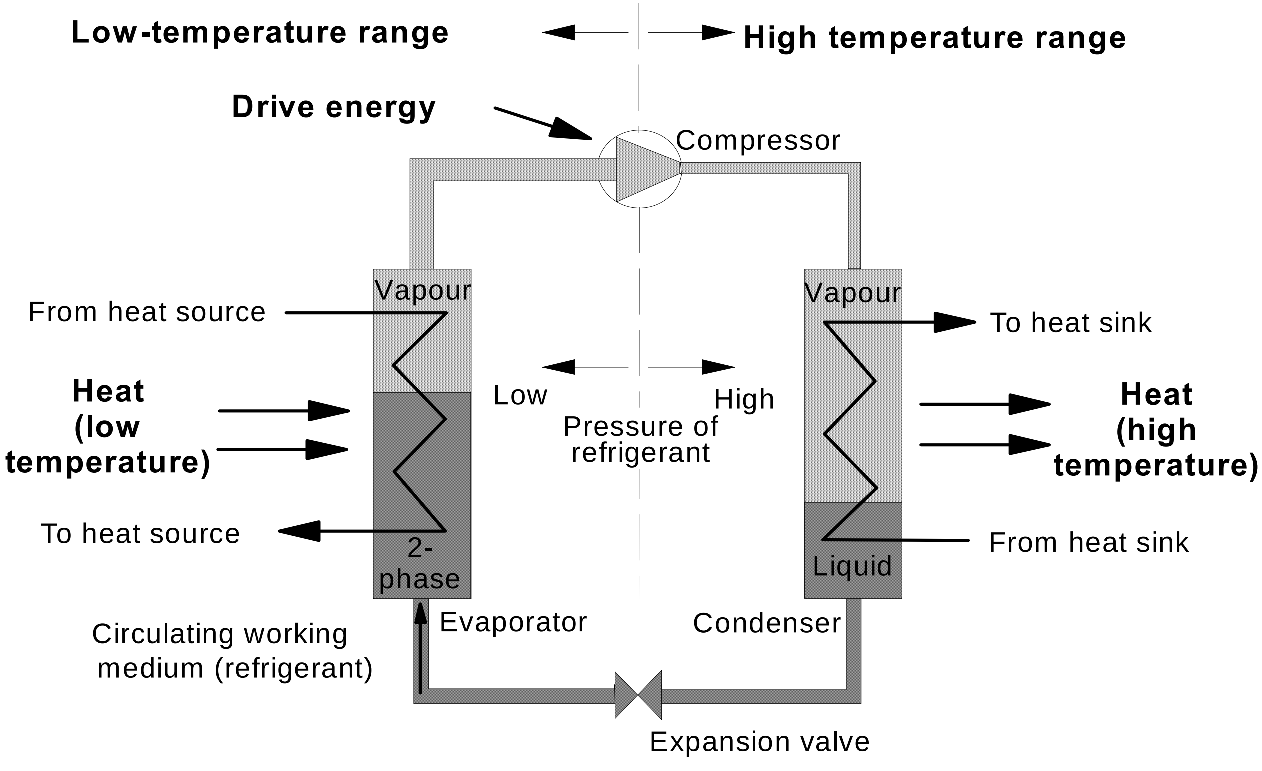
Automatic wood chips/pellets burner



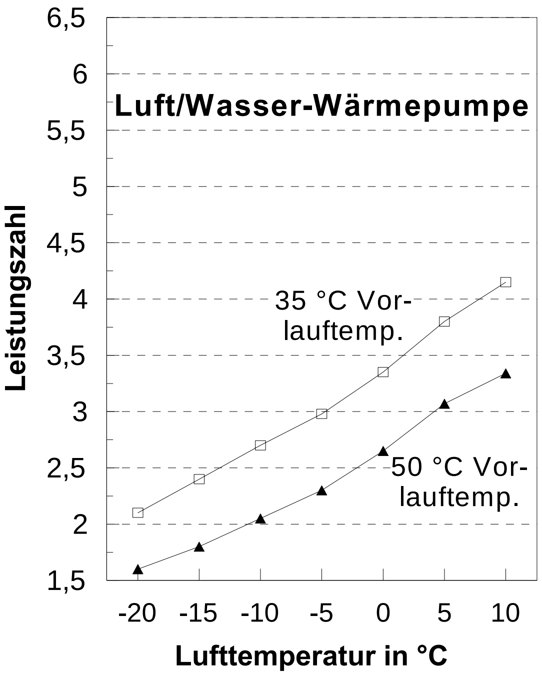
- Similar maintenance a soil or gas burners
- Similar emissions as oil burner
- Slightly higher investment than oil burner
- Biomass store has to be reached yb the blowing tube of the truck

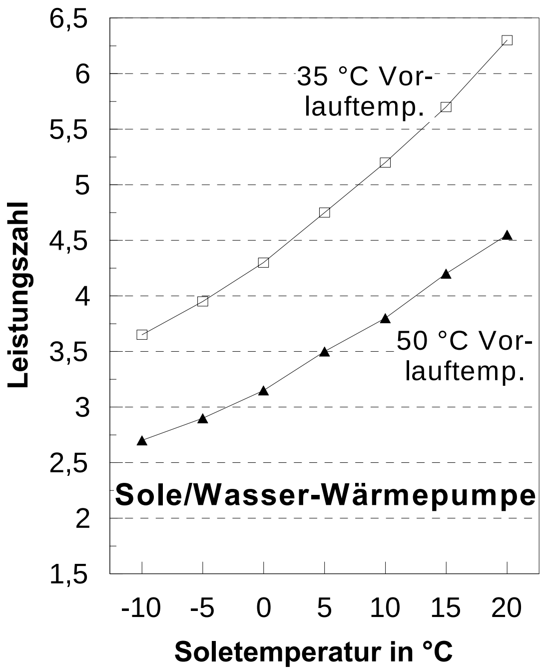
Heat pumps

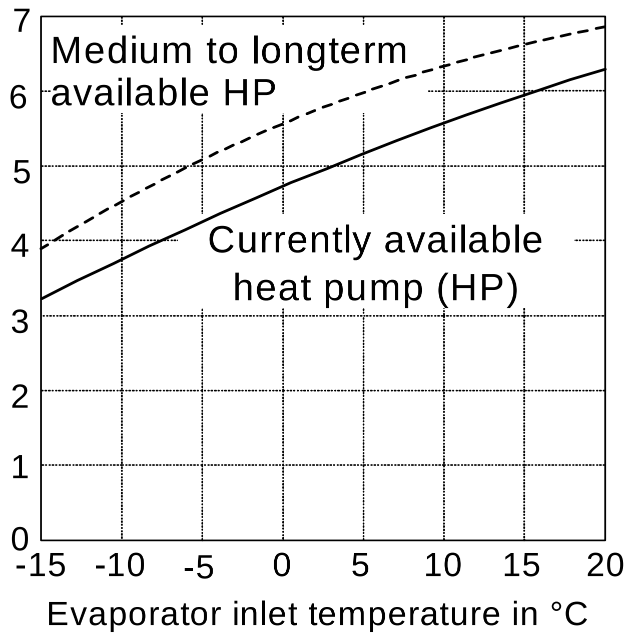

Funktionsschema Wärmepumpe
Umweltwärme 3/4 + Endenergie/Strom 1/4 = Nutzwärme 4/4
verdichten
entspannen
verdampfen
verflüssigen

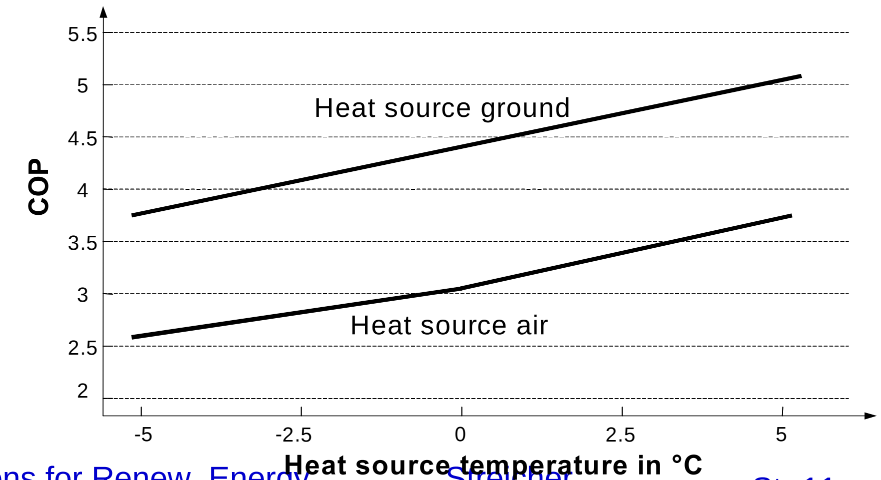

Low-temperature range
High temperature range
Drive energy
Compressor
From heat source
Vapour
Vapour
To heat sink
Heat
(low
temperature)
Low
High
Pressure of
refrigerant
Heat
(high
temperature)
To heat source
2-
phase
Liquid
From heat sink
Circulating working
medium (refrigerant)
Evaporator
Condenser
Expansion valve

Heat pump COP and boundary conditions



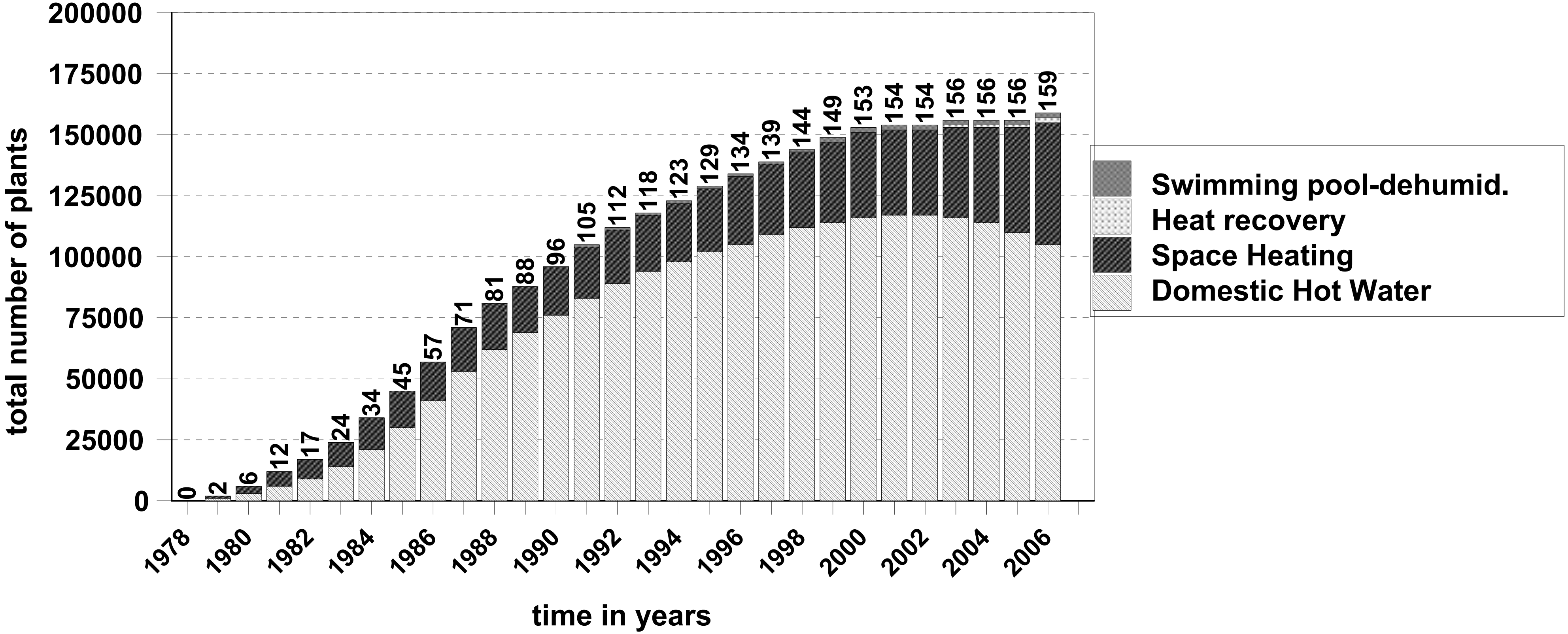




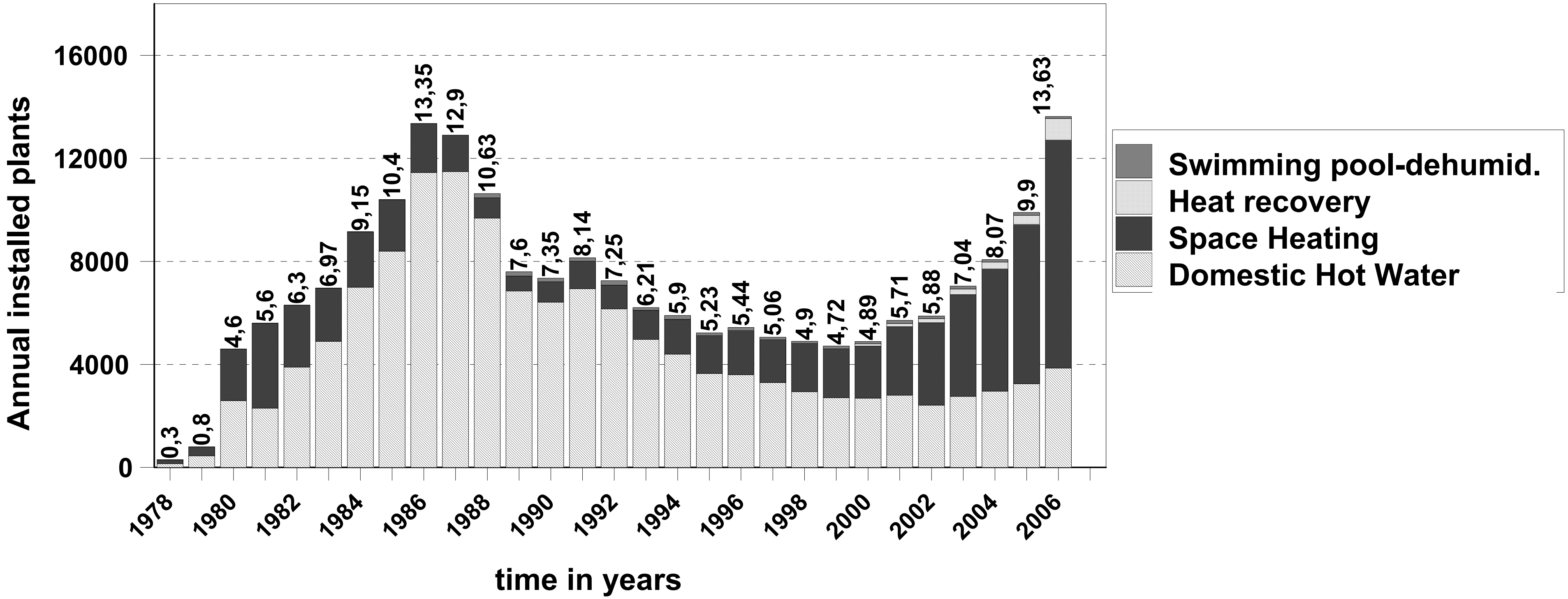


Quelle: Kaltschmitt, Streicher, Wiese, 2006

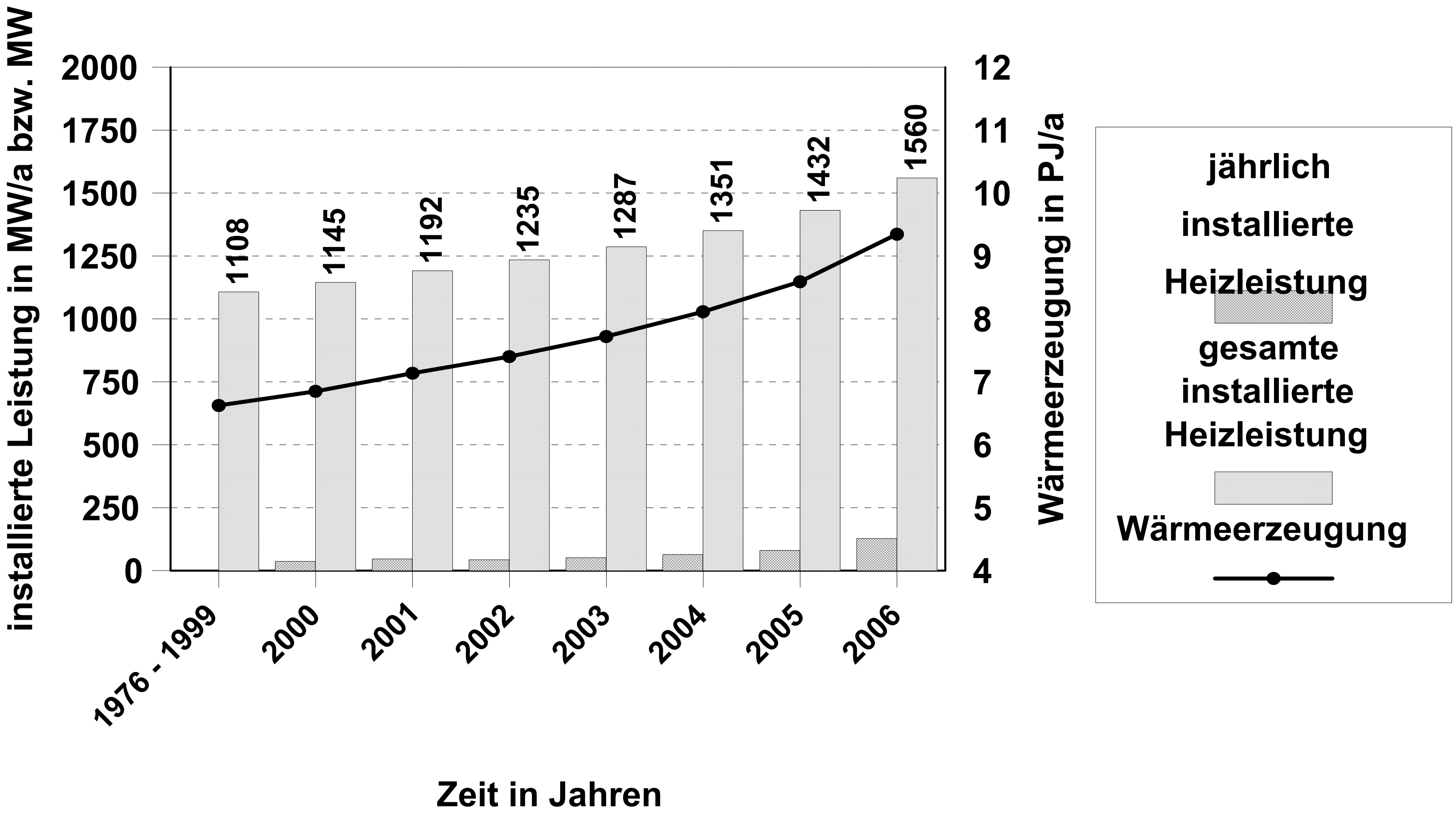
Installed heat pumps in Austria



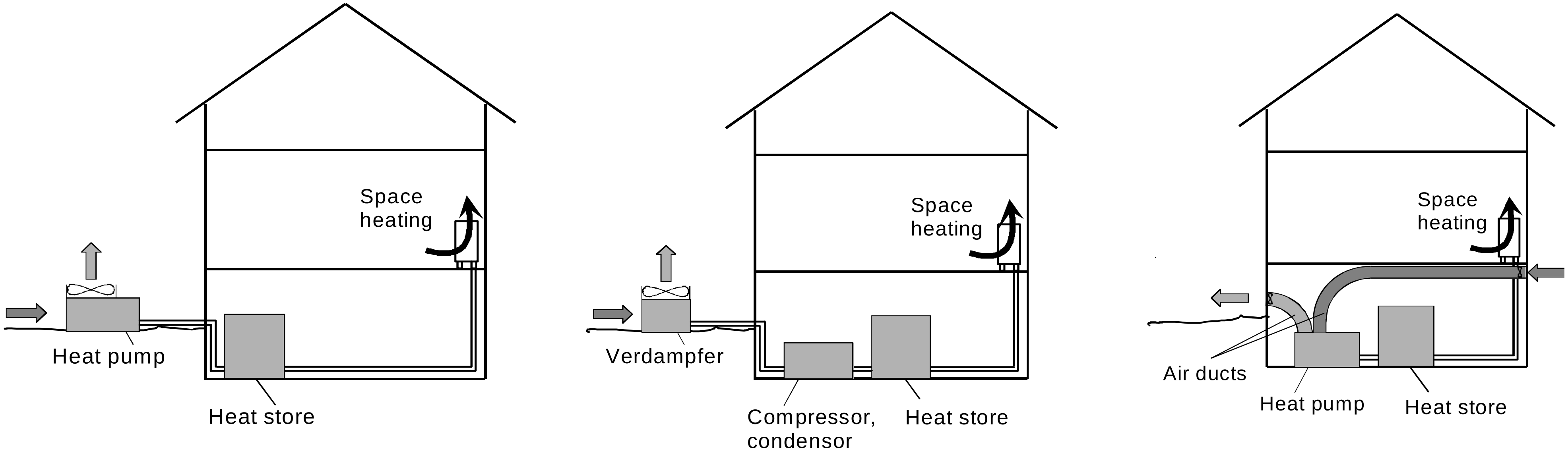
Annual installed Heat Pumps in Austria



Installed Heat Pump Capacity



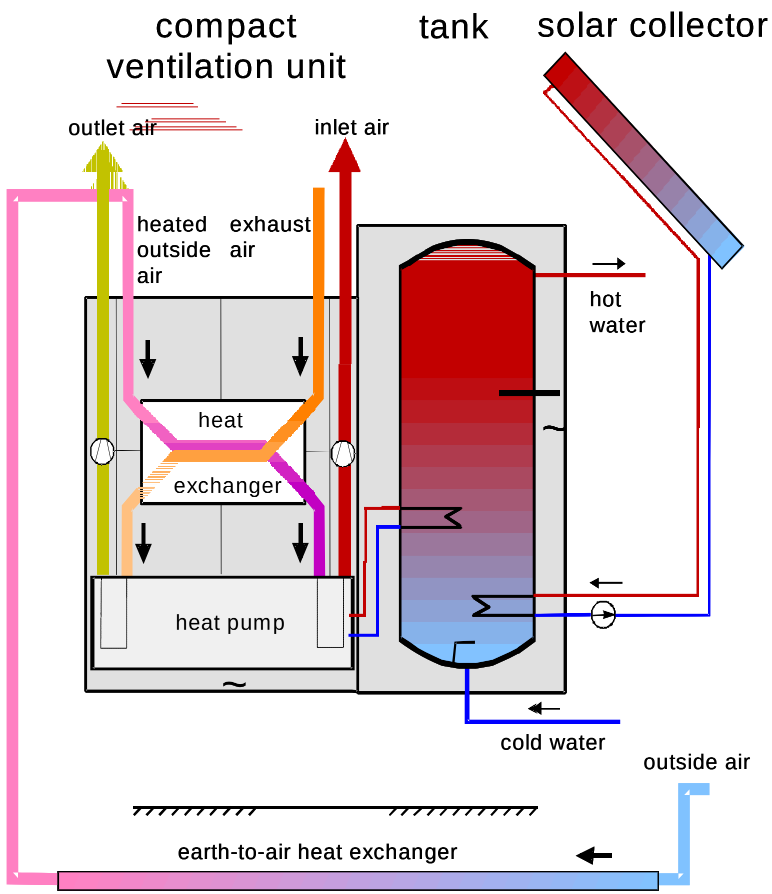
Ambient air as heat source



Quelle: Kaltschmitt, Streicher, Wiese, 2006

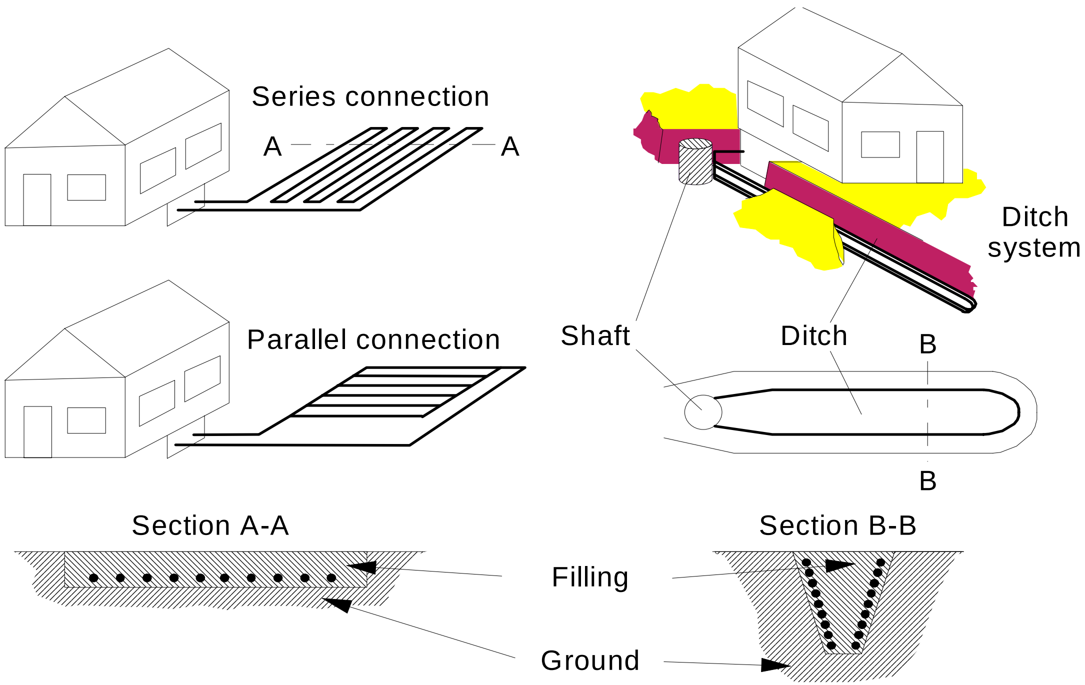
Compact heating and domestic hot water unit

- air-to-air heat recovery
- exhaust air heat pump
- storage
- solar collector
- earth-to-air heat exchanger



Source: Fraunhofer-Institut für Solare Energiesysteme ISE, 2000

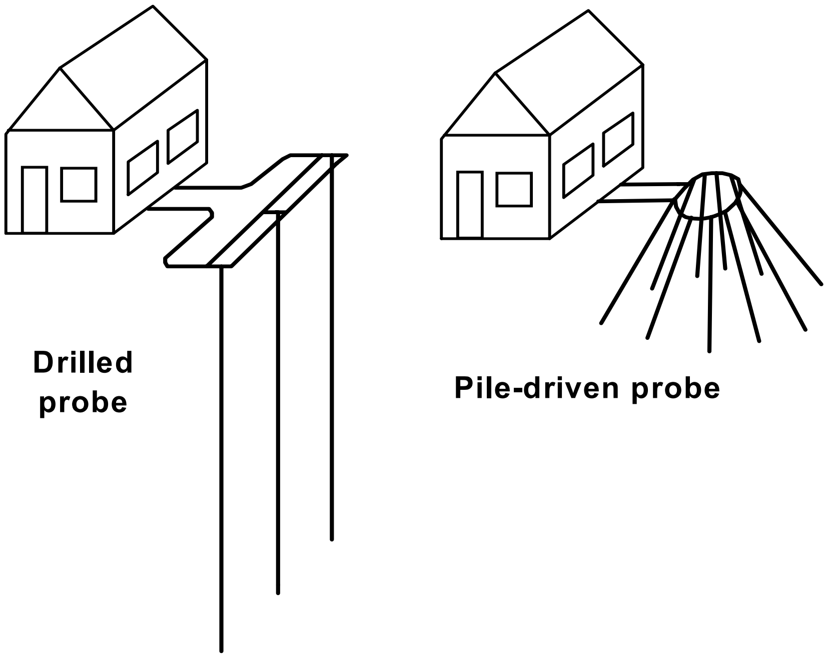
Ground as heat source

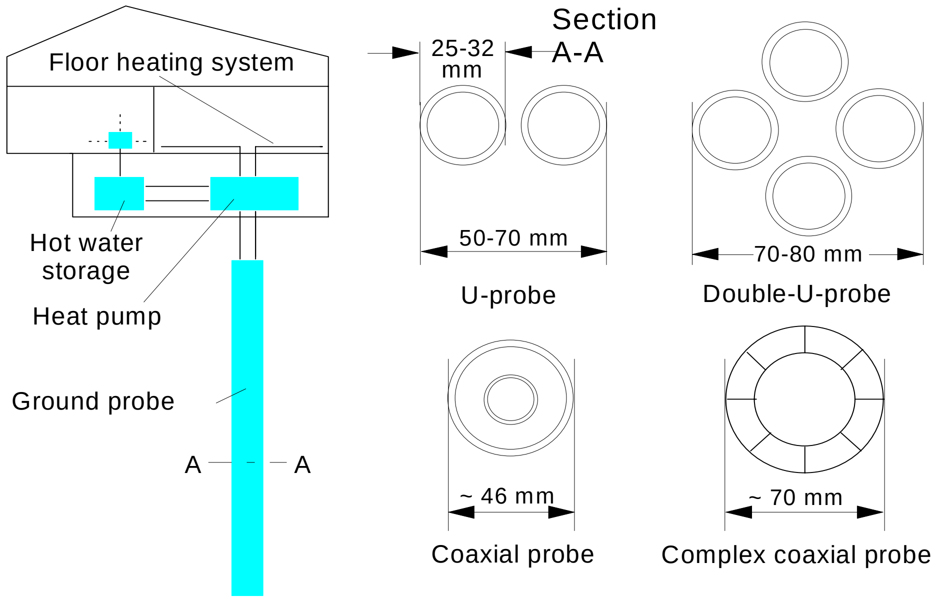


Type of soil	Withdrawn heat capacity
Dry, sandy soil	10 – 15 W/m^2
Humid, sandy soil	15 – 20 W/m^2
Dry loamy soil	20 – 25 W/m^2
Humid loamy soil	25 – 30 W/m^2
Water saturated sand/gravel	30 – 40 W/m^2

Quelle: Kaltschmitt, Streicher, Wiese, 2006, VDI 4640

Ground as heat source





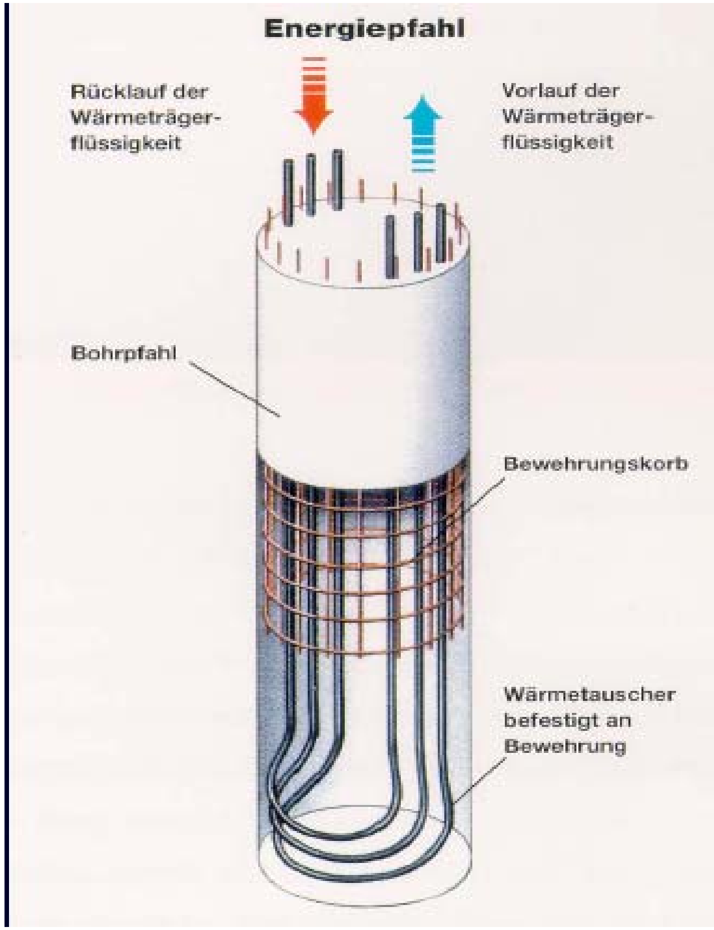
Quelle: Kaltschmitt, Streicher, Wiese, 2006

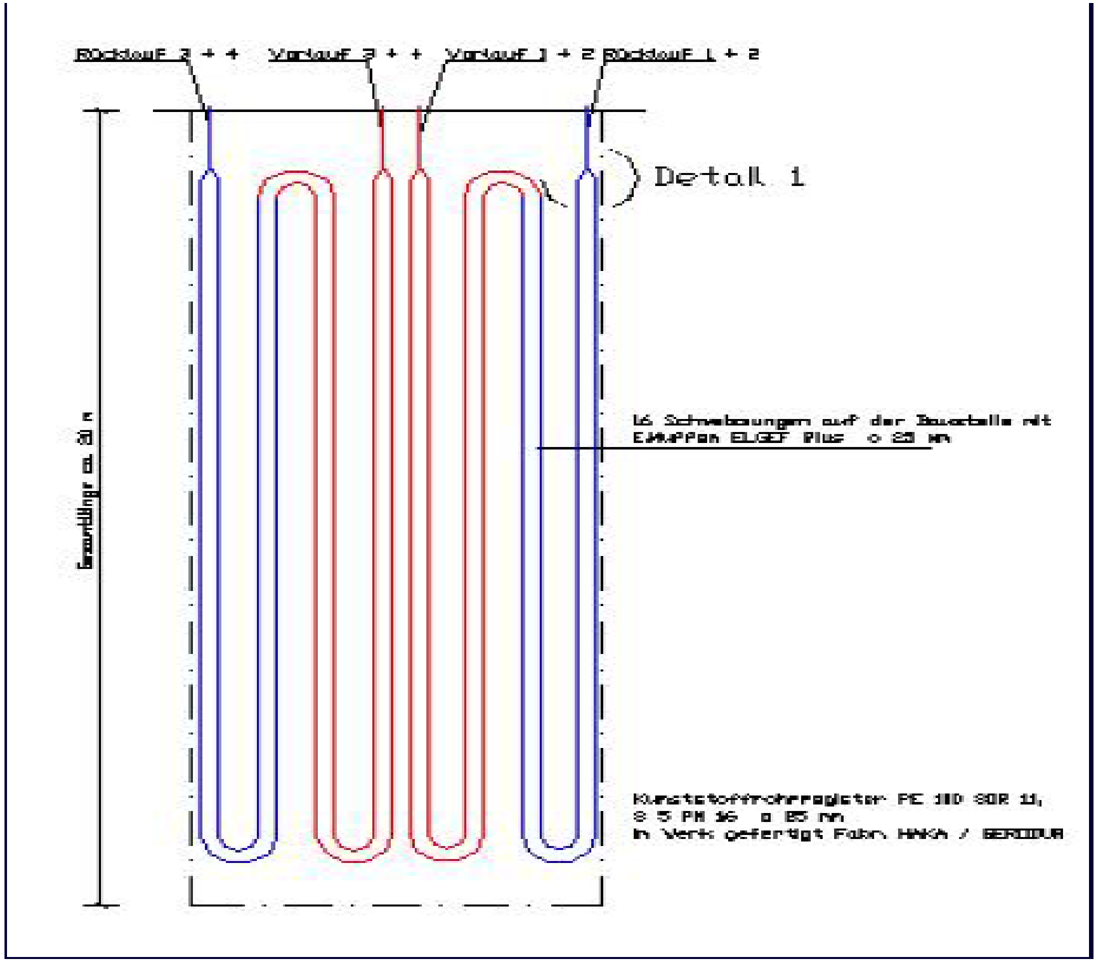
	1 800 h/a	2 400 h/a
General guidelines		
Bad subsoil (dry lose rocks)	25 W/m	20 W/m
Solid rock subsoil, water-saturated lose rock	60 W/m	50 W/m
Solid rock with high heat conductivity	84 W/m	70 W/m
Individual soils		
Gravel, sand, dry	< 25 W/m	< 20 W/m
Gravel, sand, carrying water	65 – 80 W/m	55 – 65 W/m
Gravel, sand, strong groundwater flow, for small systems.	80 – 100 W/m	80 – 100 W/m
Clay, loam, moist	35 – 50 W/m	30 – 40 W/m
Limestone (solid)	55 – 70 W/m	45 – 60 W/m
Sandstone	65 – 80 W/m	55 – 65 W/m
Acidic magmatites (e. g. granite)	65 – 85 W/m	55 – 70 W/m
Alkaline magmatites (e. g. basalt)	40 – 65 W/m	35 – 55 W/m
Gneiss	70 – 85 W/m	60 – 70 W/m

The requirement for using the table: only heat withdrawal (heating incl. hot water) takes place; length of the individual ground probes between 40 and 100 m; smallest space between two ground probes would be a minimum of 5 m for ground probe lengths of 40 to 50 m or at least 6 m for ground probes with lengths of over 50 to 100 m. Suitable ground probes are double-U probes with an individual tube diameter of 25 or 32 mm or coaxial probes with at least a diameter of 60 mm. The values given above can fluctuate considerably, depending on rock formations such as crevasses, foliation and weathering.

Quelle: Kaltschmitt, Streicher, Wiese, 2006, VDI 4640

Energy poles

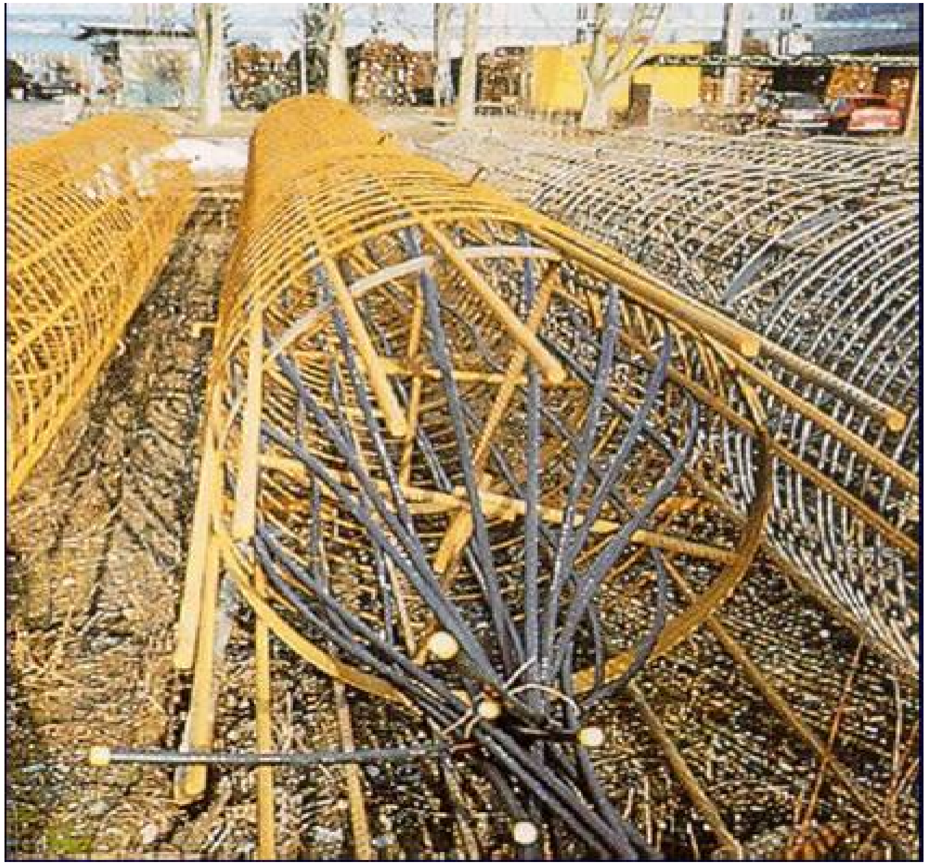




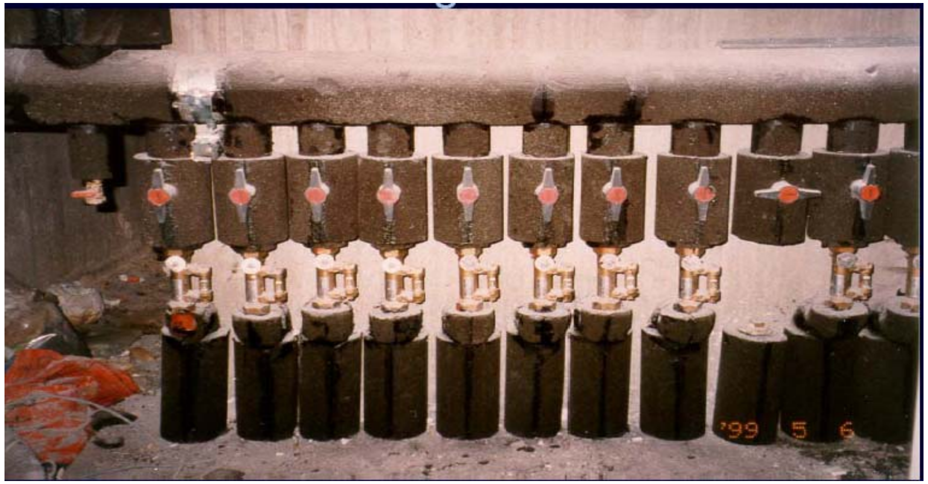
Source: Sauerwein, Bilfinger Berger,

Energy poles

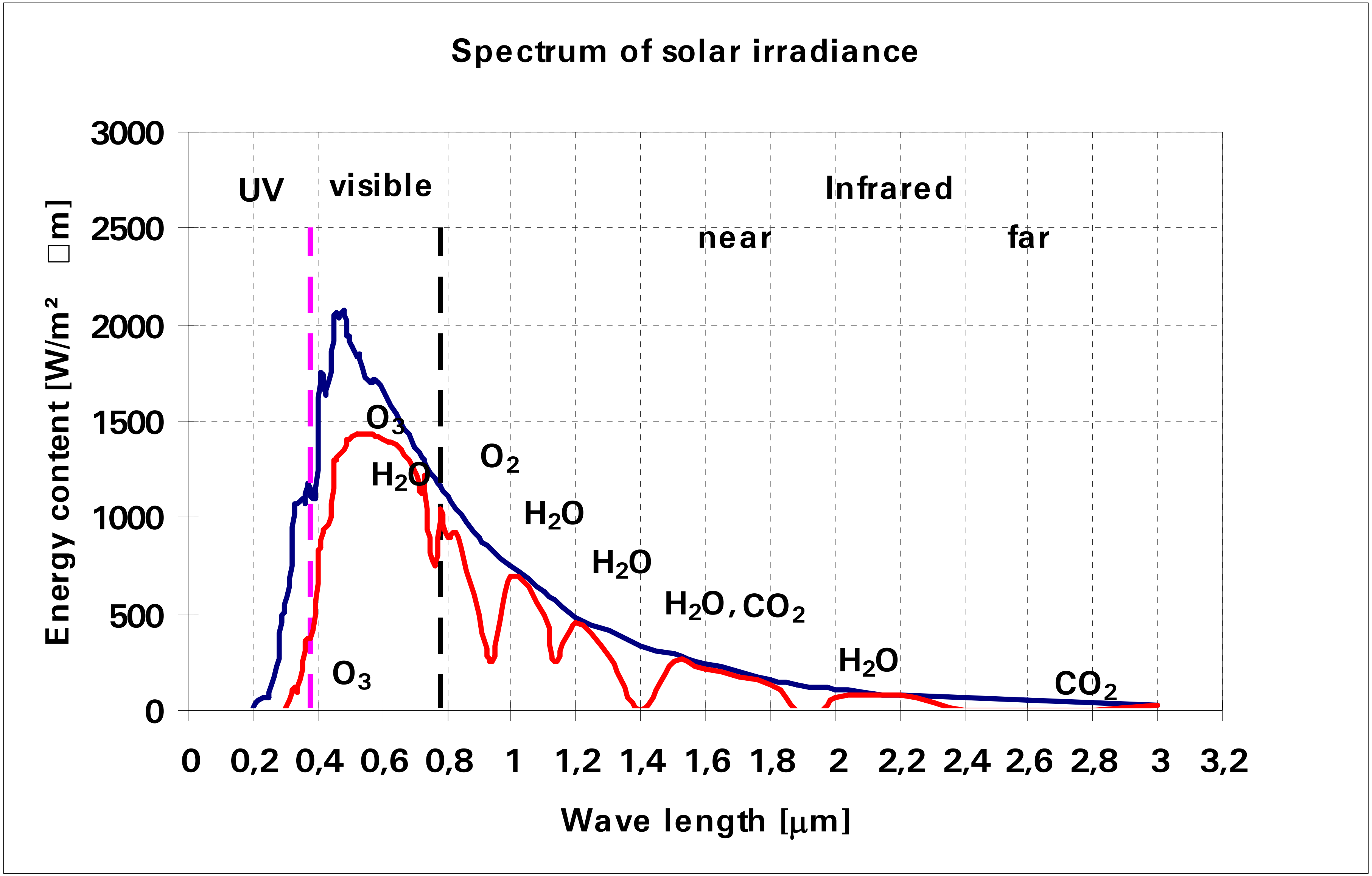
Prefabricated „Bewehrungskorb“

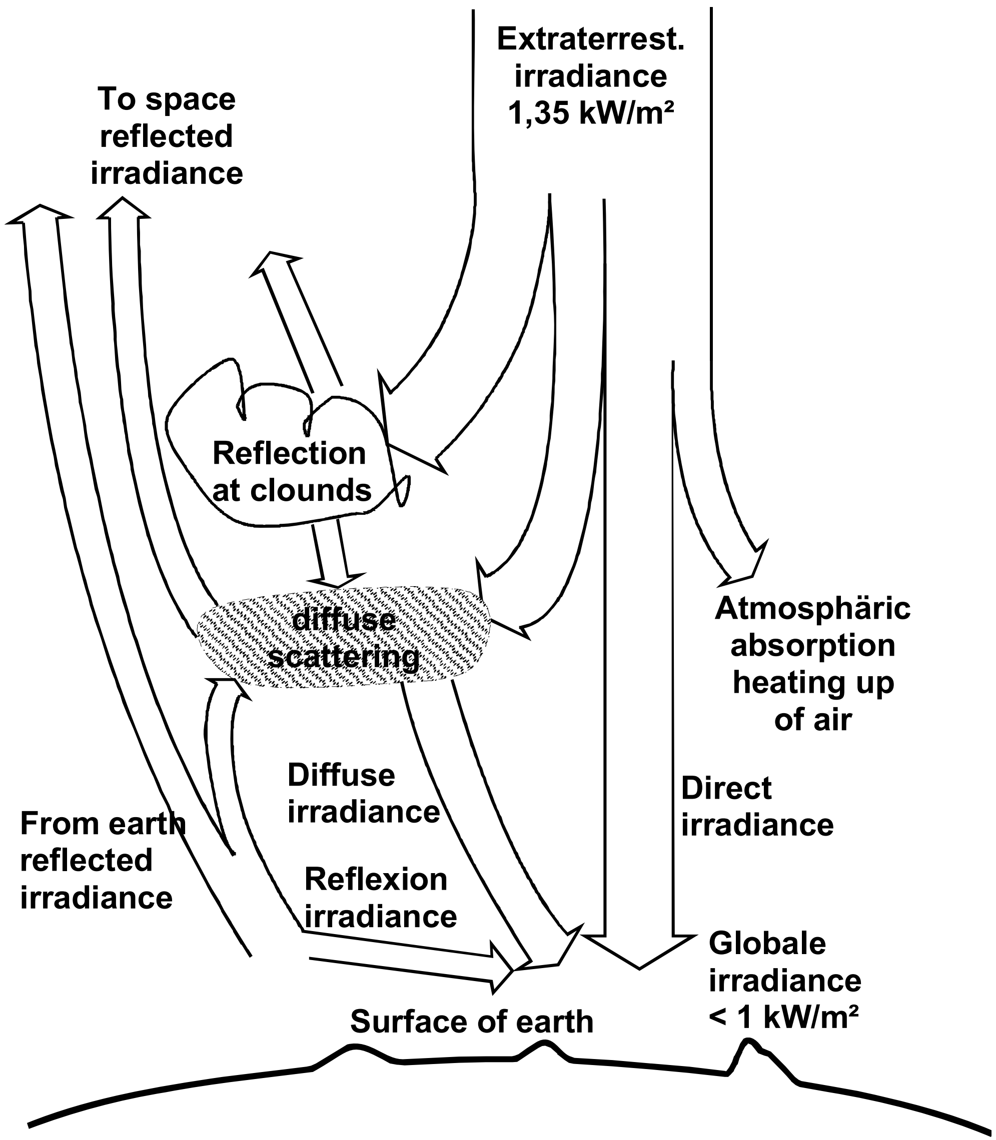


Distribution to Energy Poles

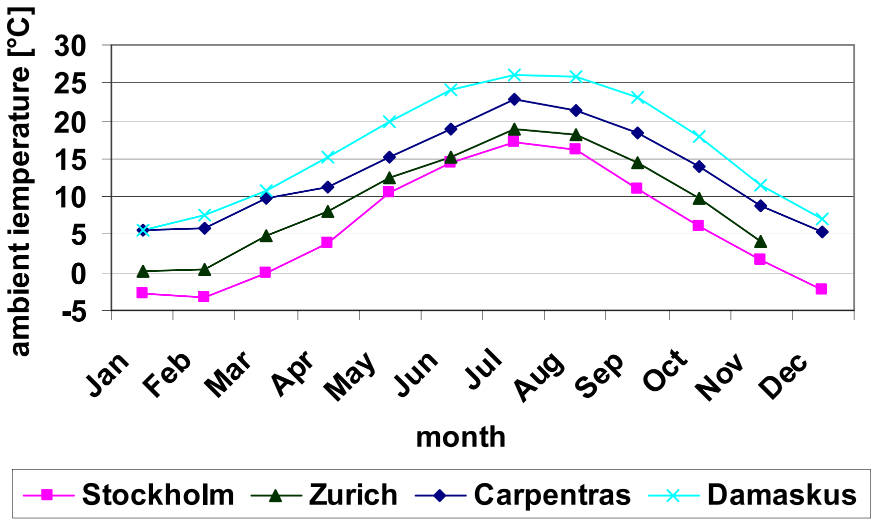


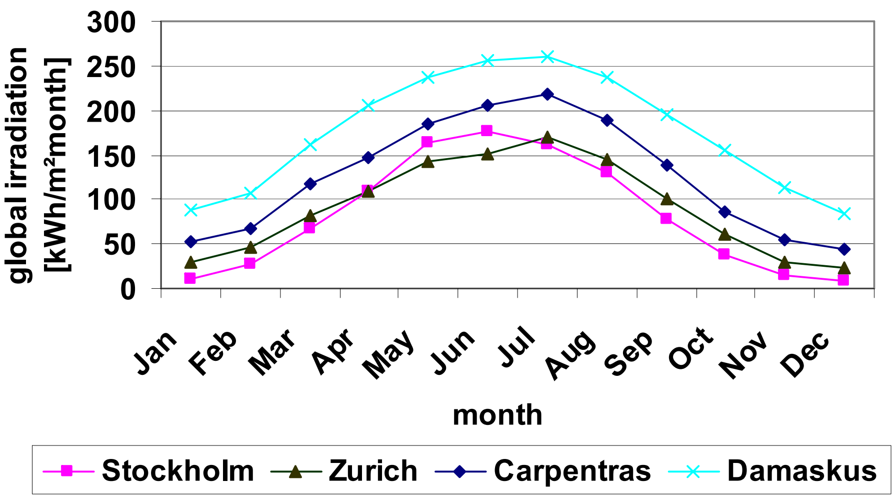
Solar Thermal Systems


Spectrum of solar irradiance
Energy content [W/m² □m]
3000
2500
2000
1500
1000
500
0
UV
visible
Infrared
near
far
O3
H2O
O2
H2O
H2O
H2O, CO2
H2O
CO2
O3
0
0,2
0,4
0,6
0,8
1
1,2
1,4
1,6
1,8
2
2,2
2,4
2,6
2,8
3
3,2
Wave length [µm]

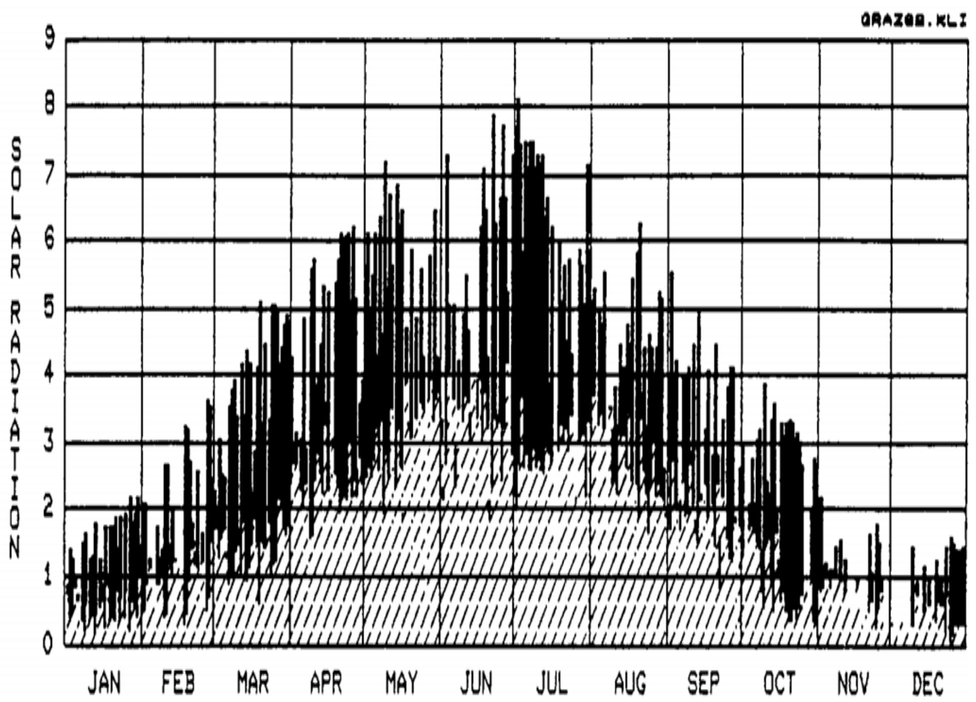

Extraterrest.
irradiance
1,35 kW/m²
To space
reflected
irradiance
Reflection
at clounds
diffuse
scattering
Atmosphäric
absorption
heating up
of air
Diffuse
irradiance
Direct
irradiance
From earth
reflected
irradiance
Reflexion
irradiance
Globale
irradiance
< 1 kW/m²
Surface of earth

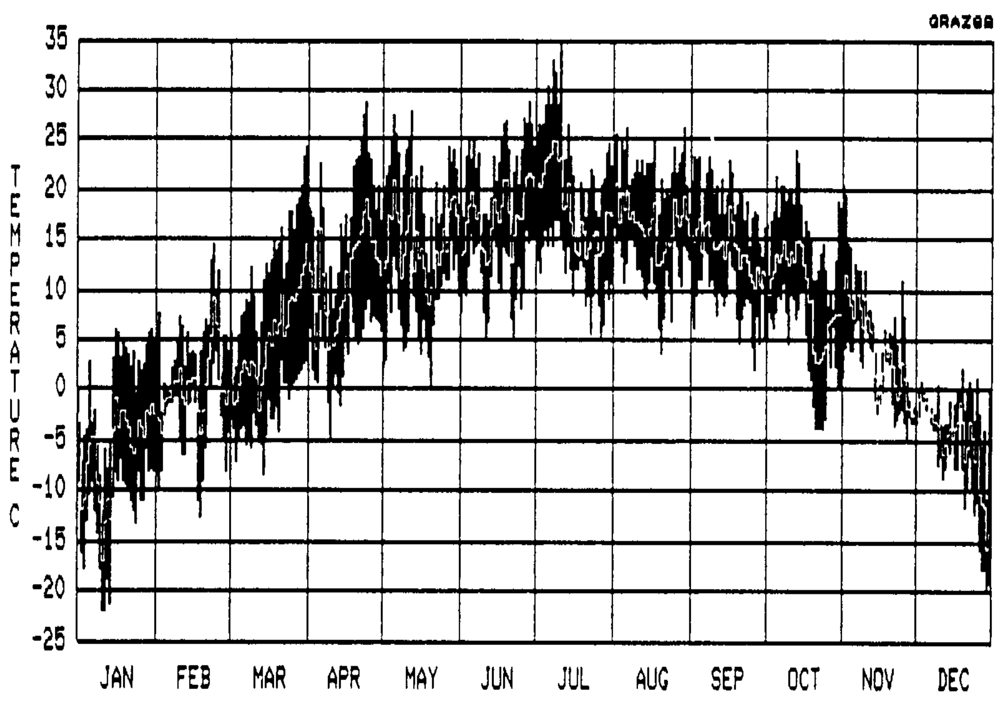
Monthly global irradiation (on a horizontal surface) and ambient temperature of different climates



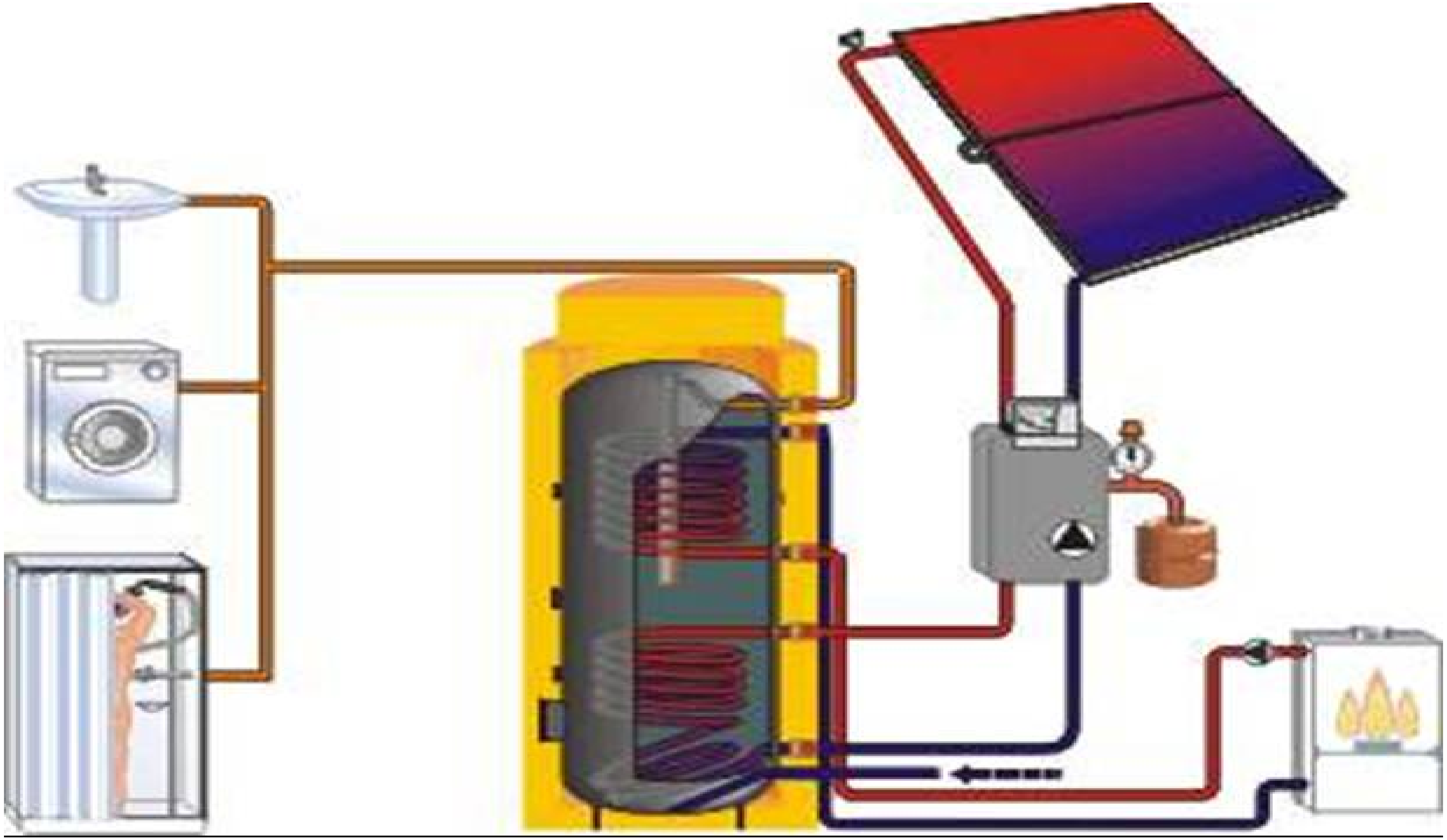


Daily global irradiation (on a horizontal surface) and hourly ambient temperature of Graz climate

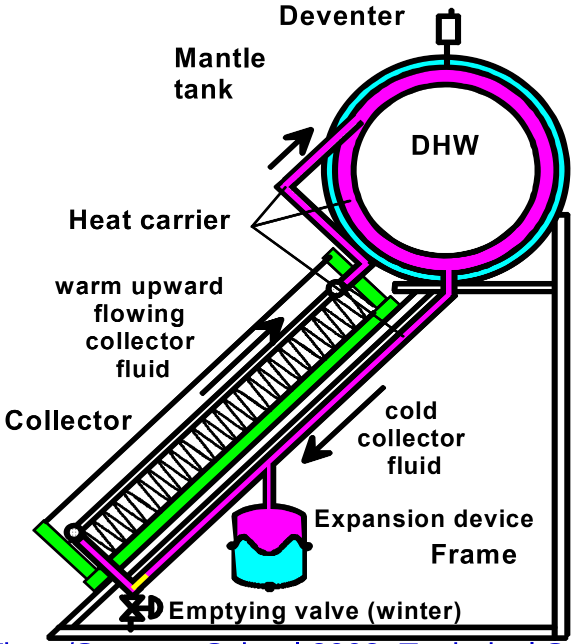


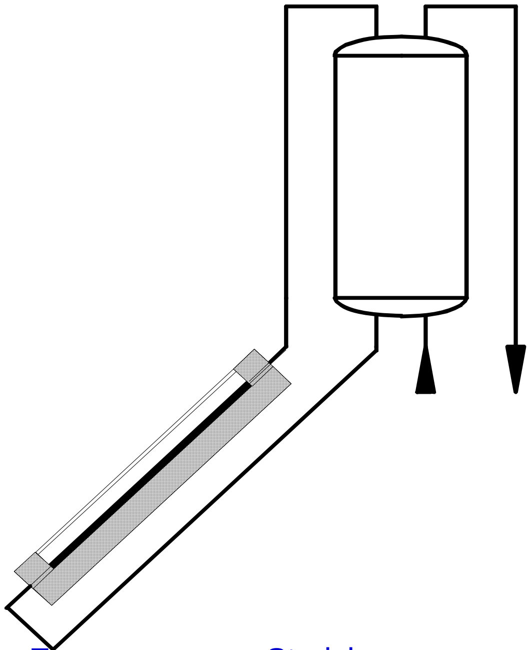


Principle of Solar Thermal Energy Use
Forced Circulation Systems



Principle of Solar Thermal Energy Use Natural Circulation Systems

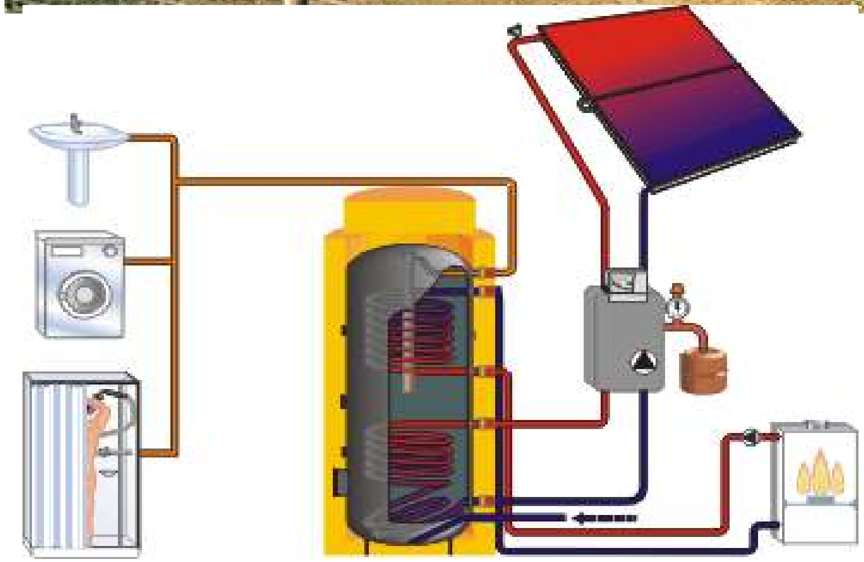




Where to use solar thermal

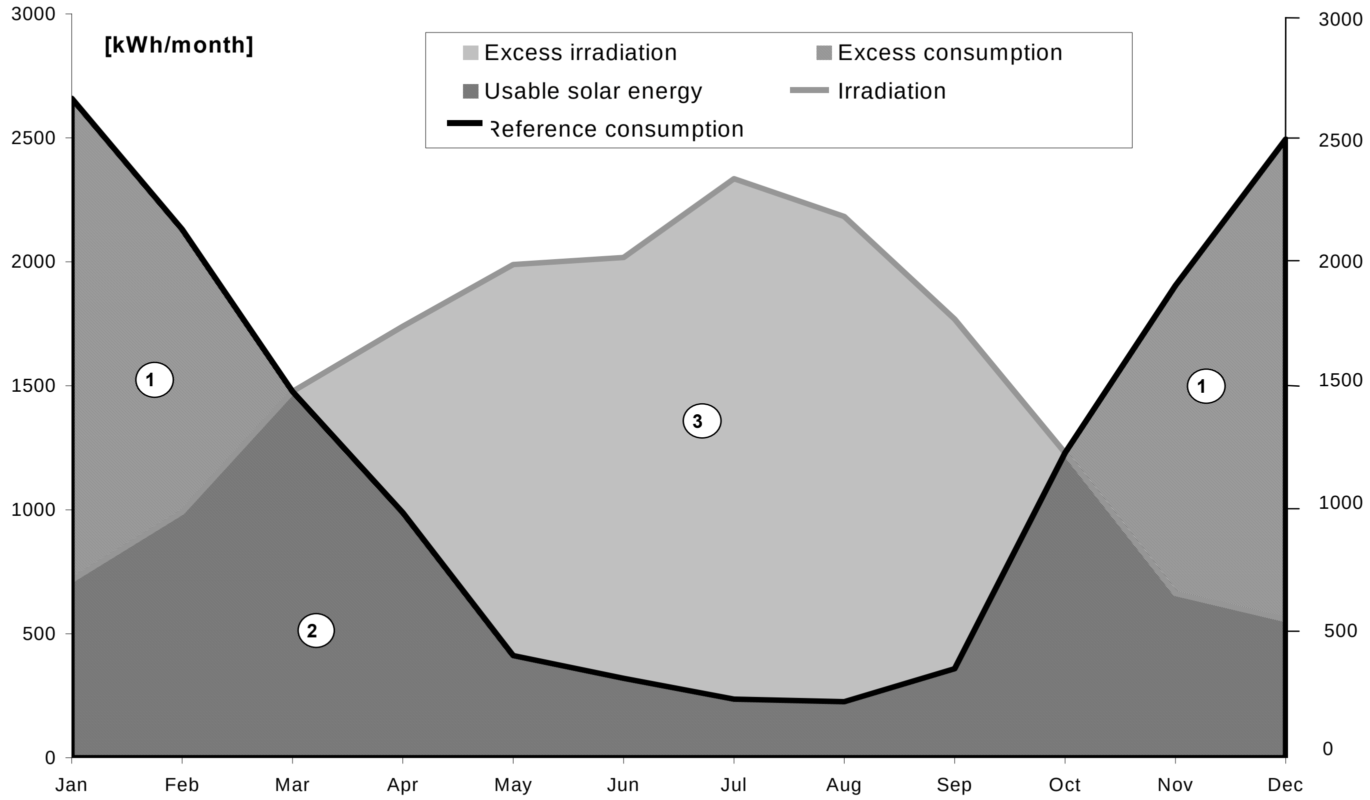
- Domestic hot water (DHW)
- Space heating + DHW
- District heating networks
- Swimming pools
- Cooling
- Process Heat
- Electricity production

Domestic hot water production



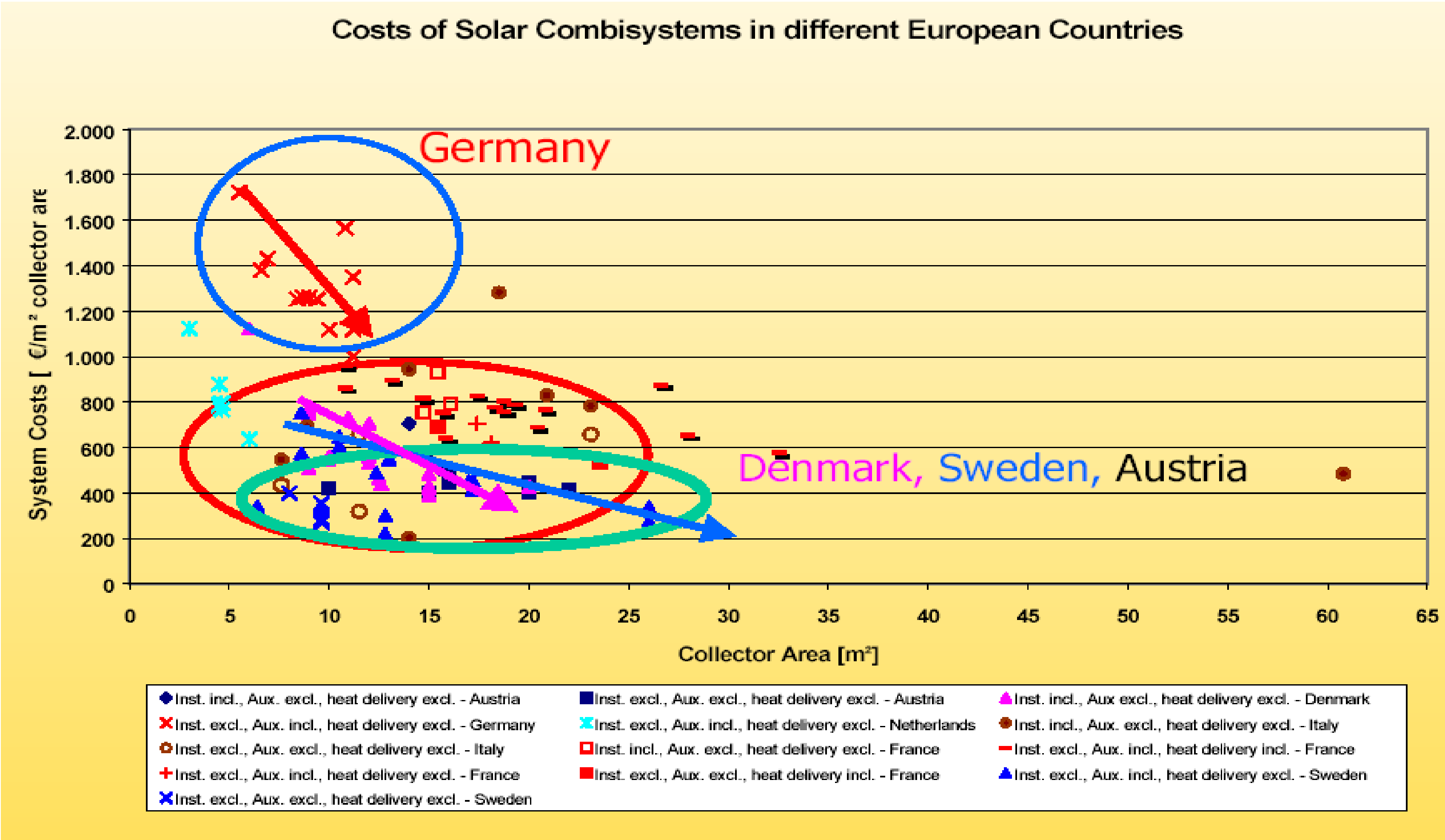
Solar Combisystems

Solar Combisystems
space heating demand



Cost of Solar Combisystems

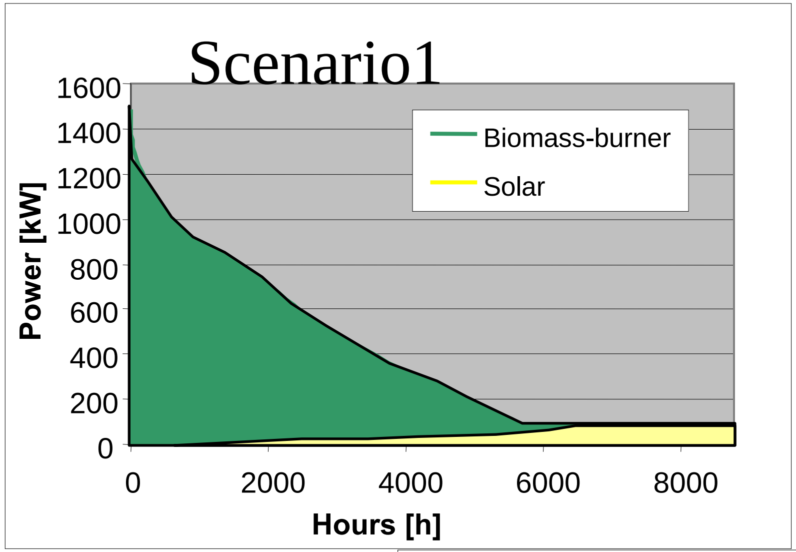
Source: AEE-Intec

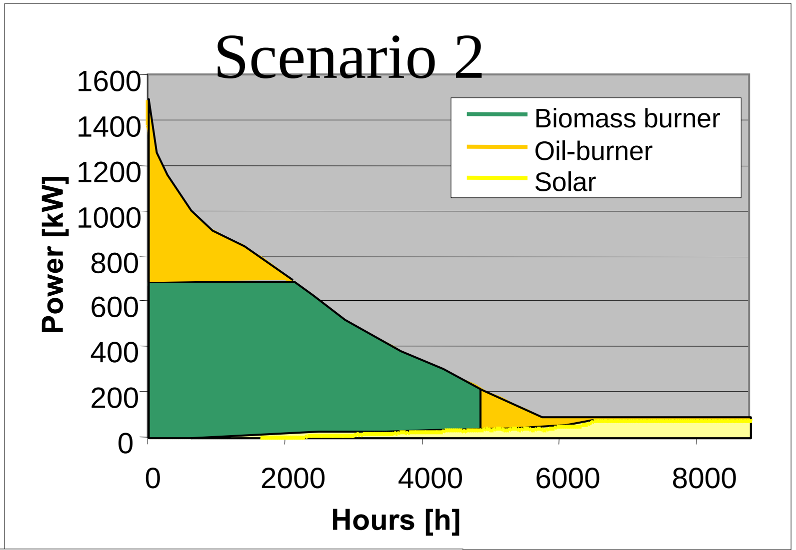


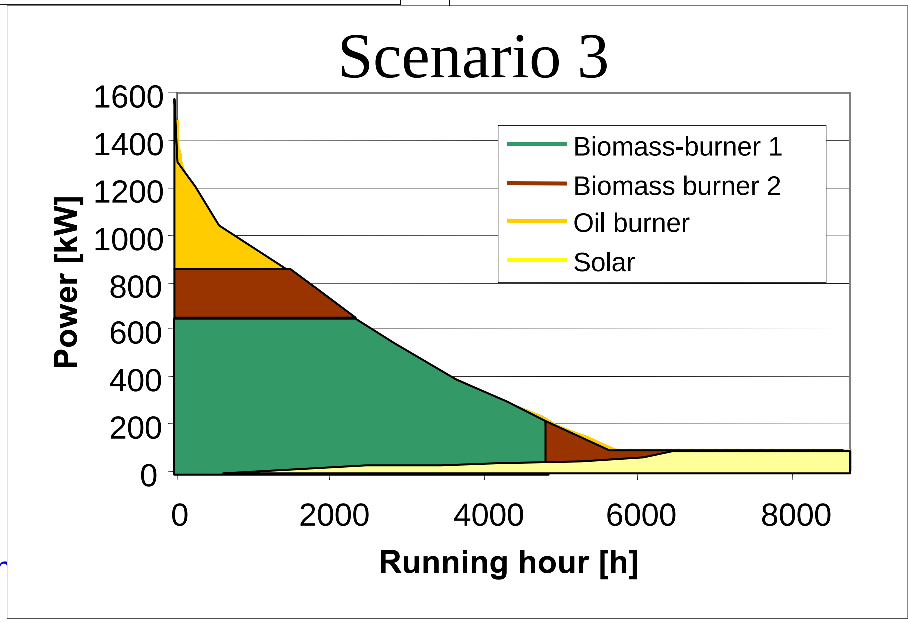
District heating networks

Demand for District Heating Systems

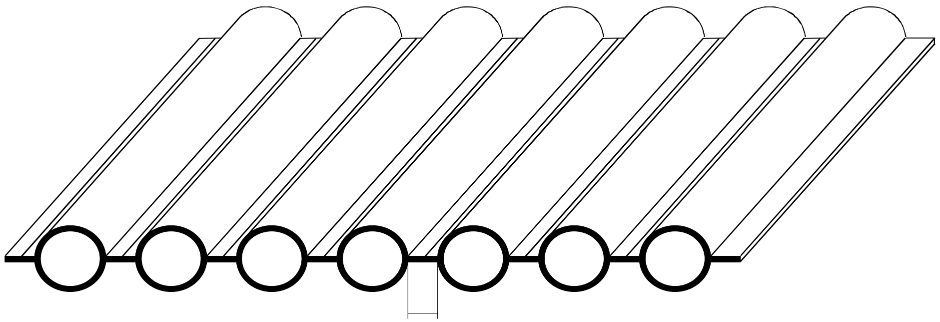
Layout of Boilers and Solar



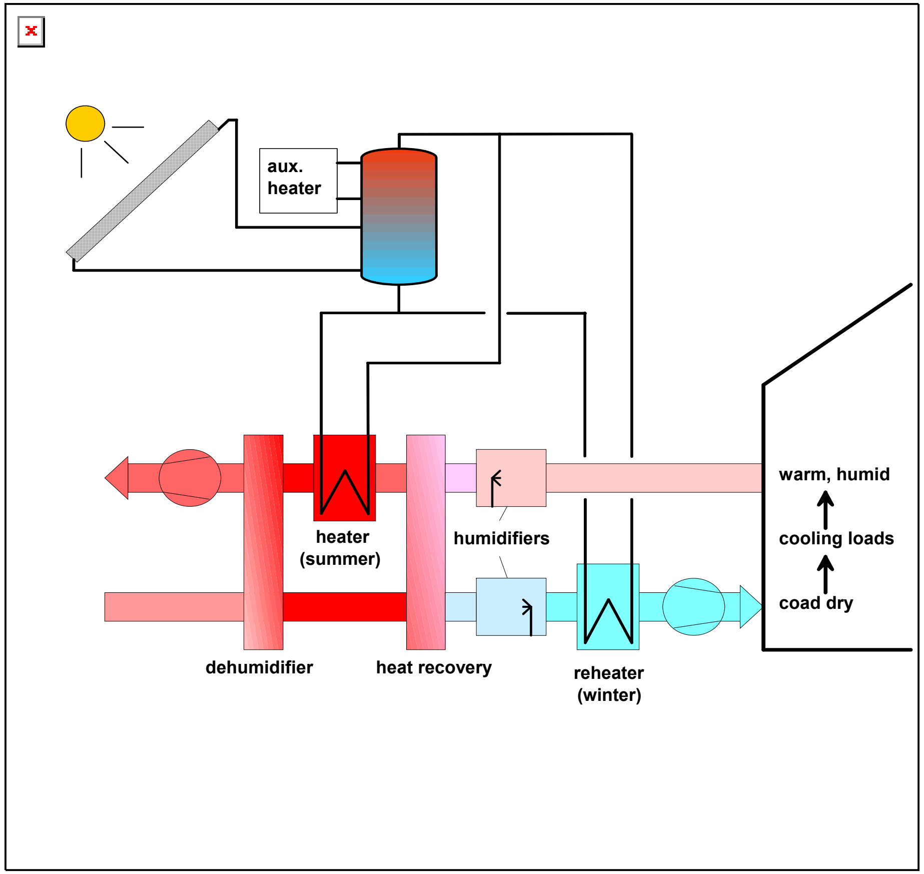




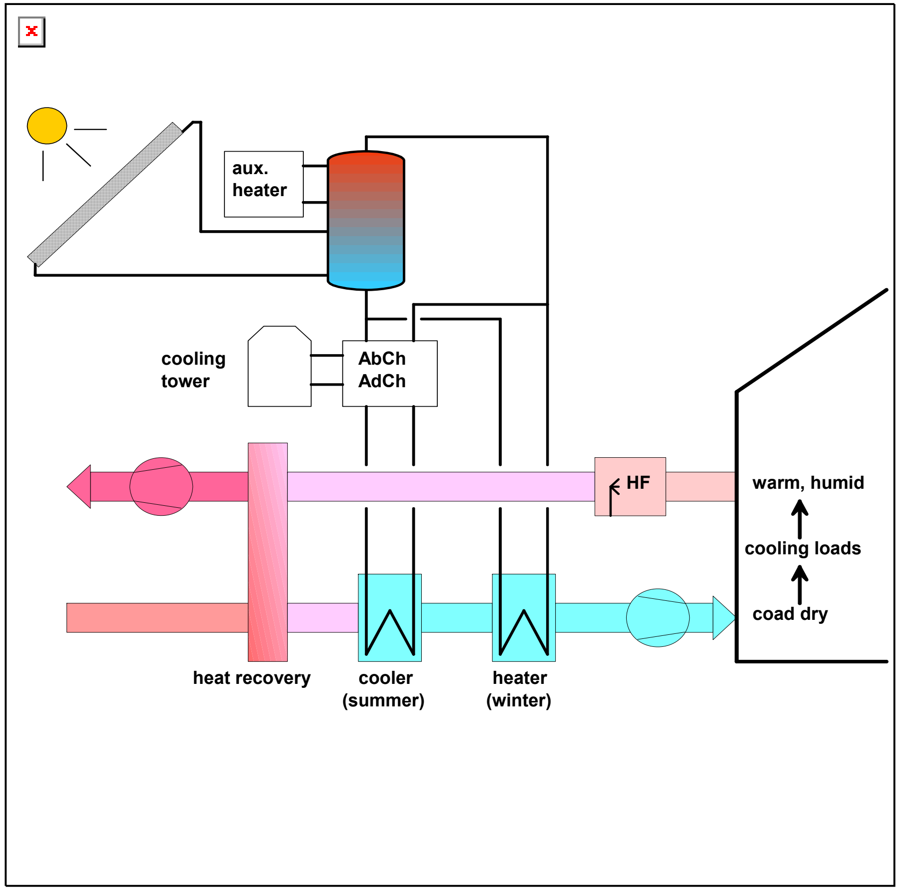
Solar heated swimming pools



Solar assisted cooling



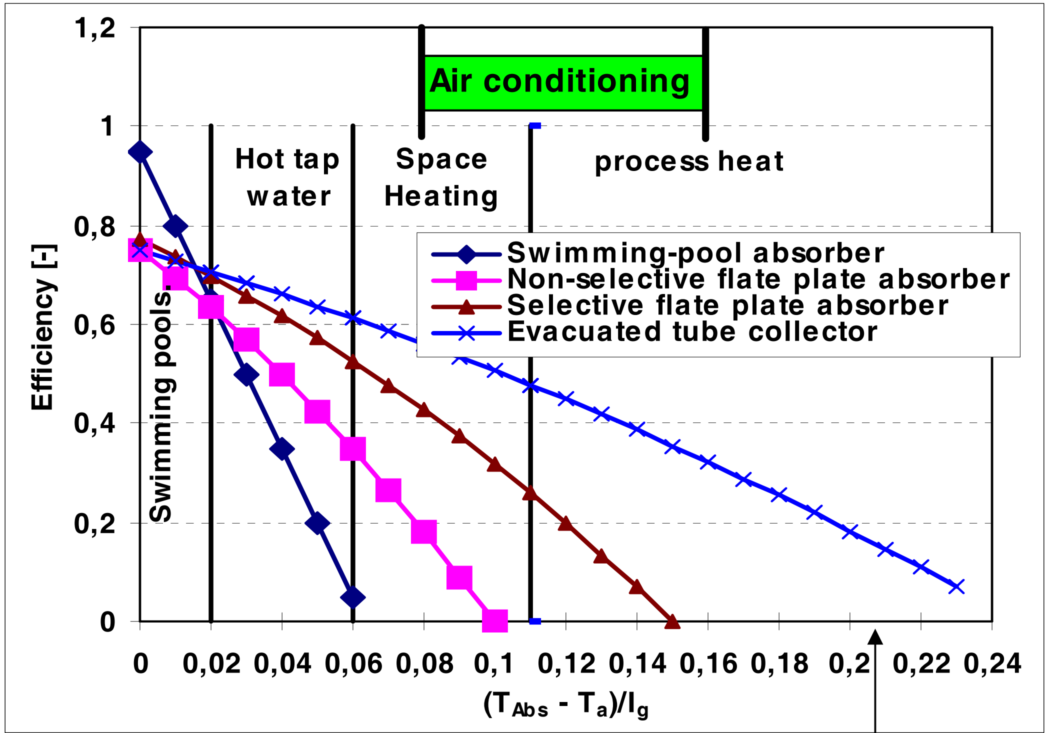
Deccicant system

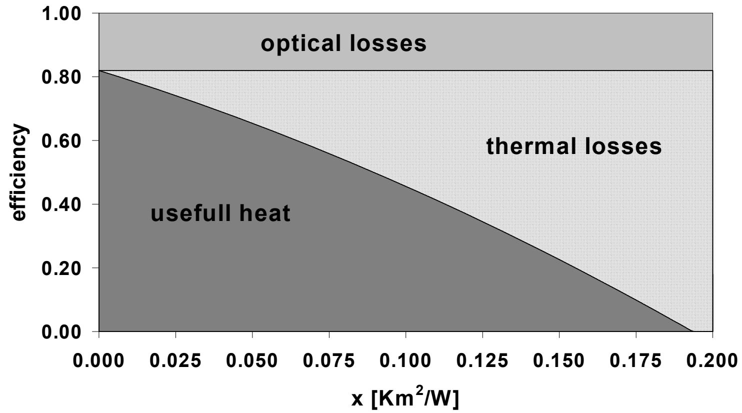


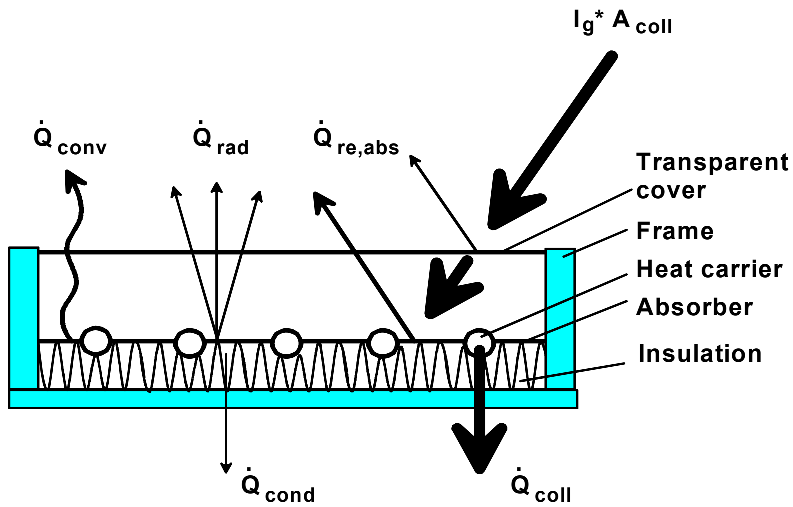
Ab/Adsorption system

Process heat

Collector characteristics

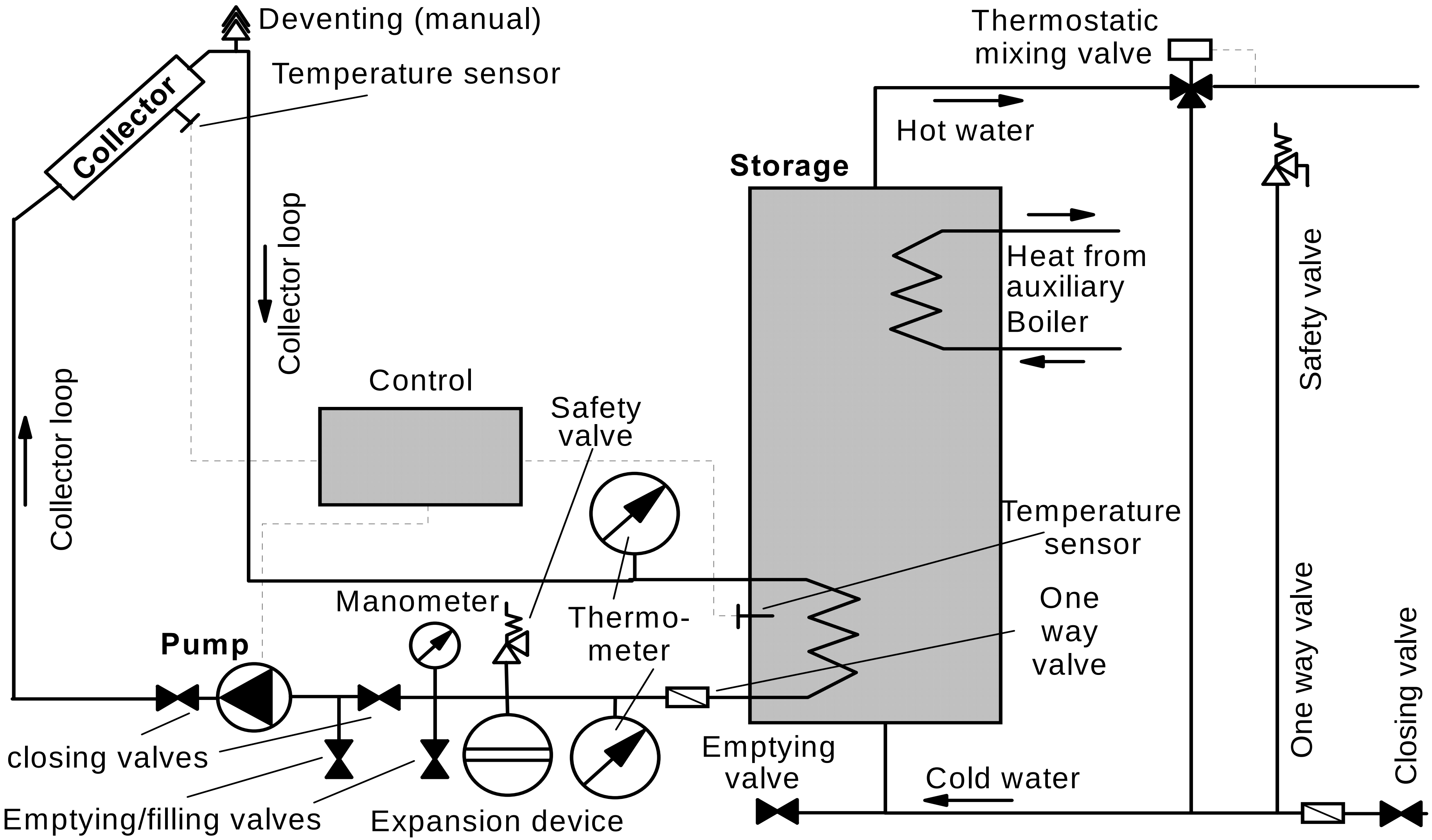






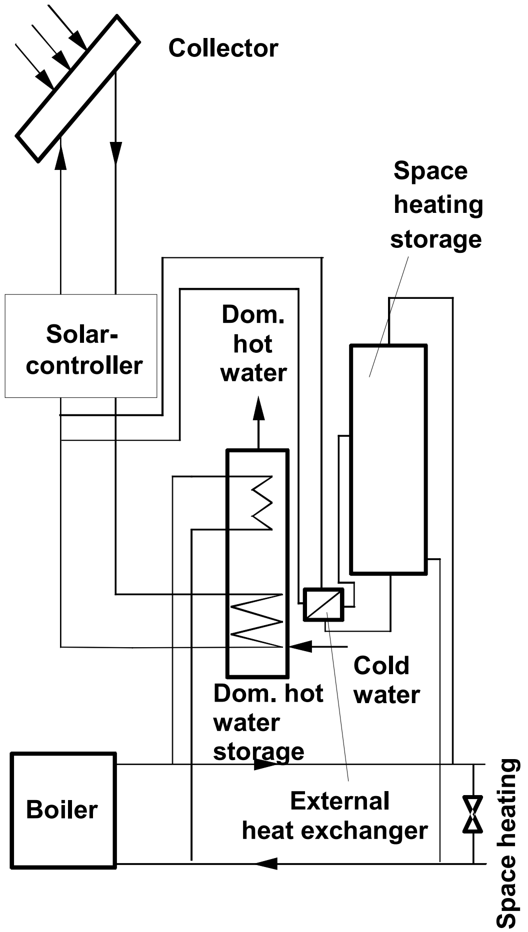
Note : Maximum collector standstill temperature at 1000 W/m² irradiance and 30 °C ambient temperature: Tabs = (0,14*1000)+30 = 170 °C

Domestic hot water forced hydraulics

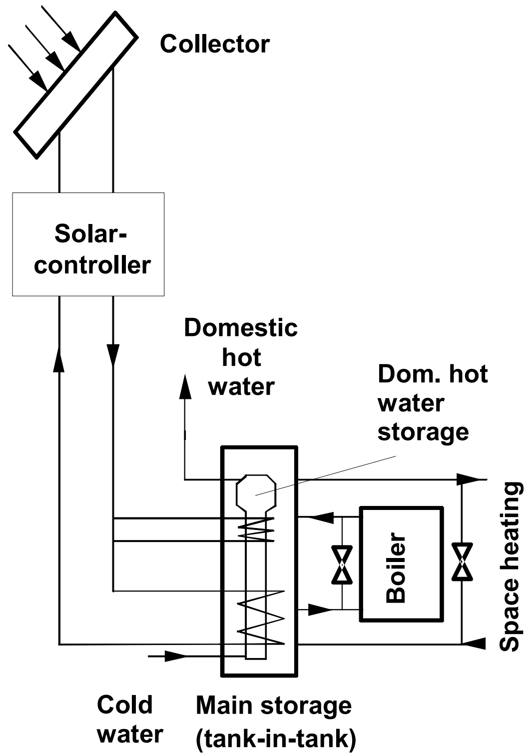


Solar combisystem schemes

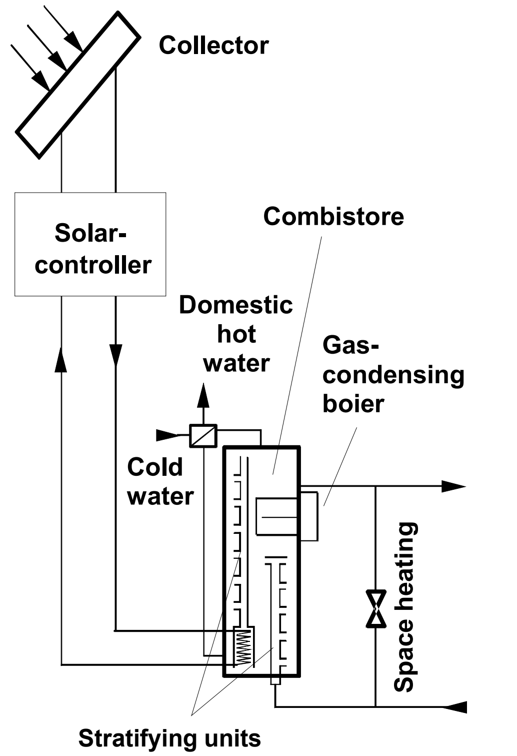
Two stores with oil or gas-fired boiler



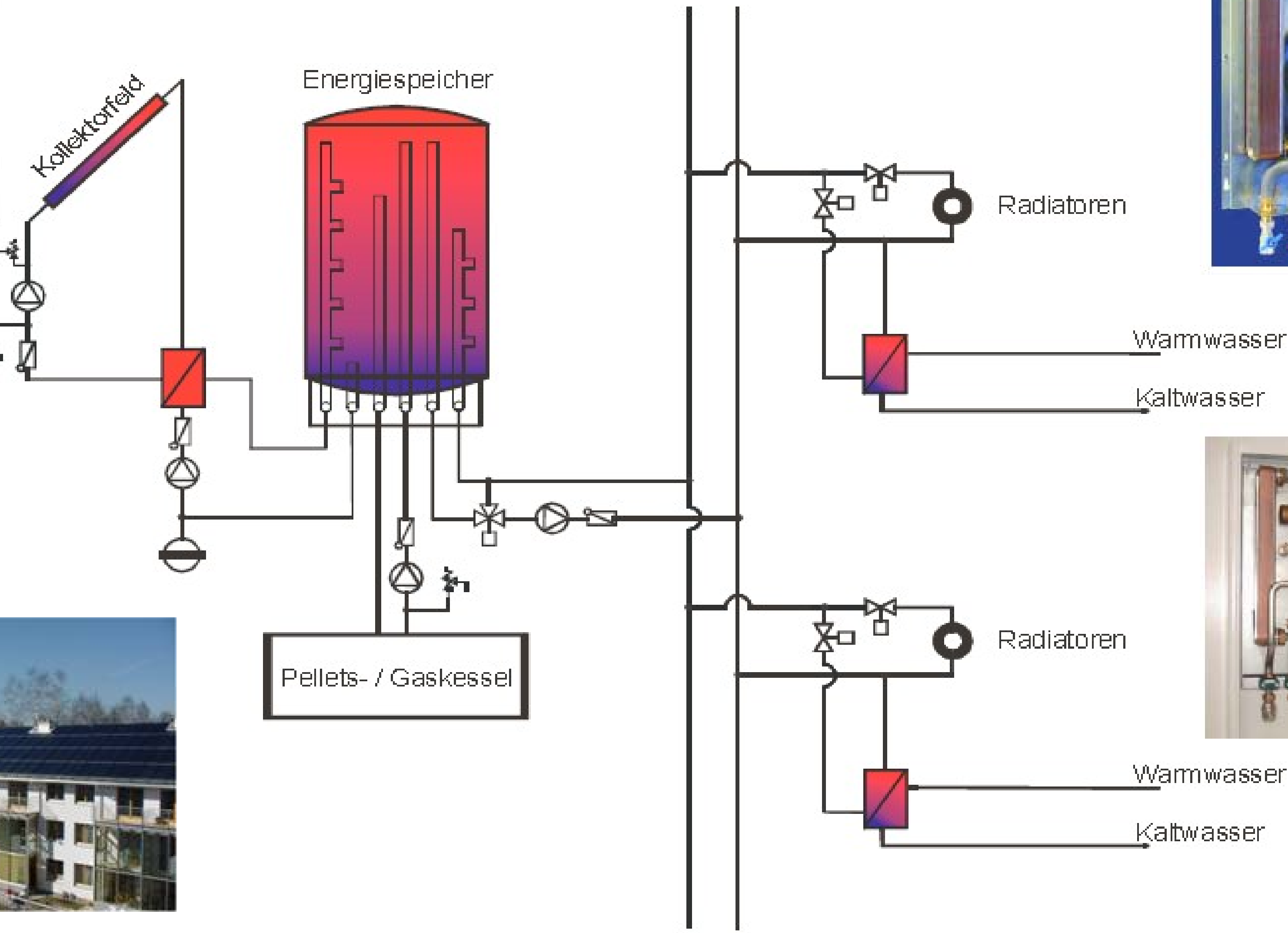
Tank in tank storage with solid fuel boiler



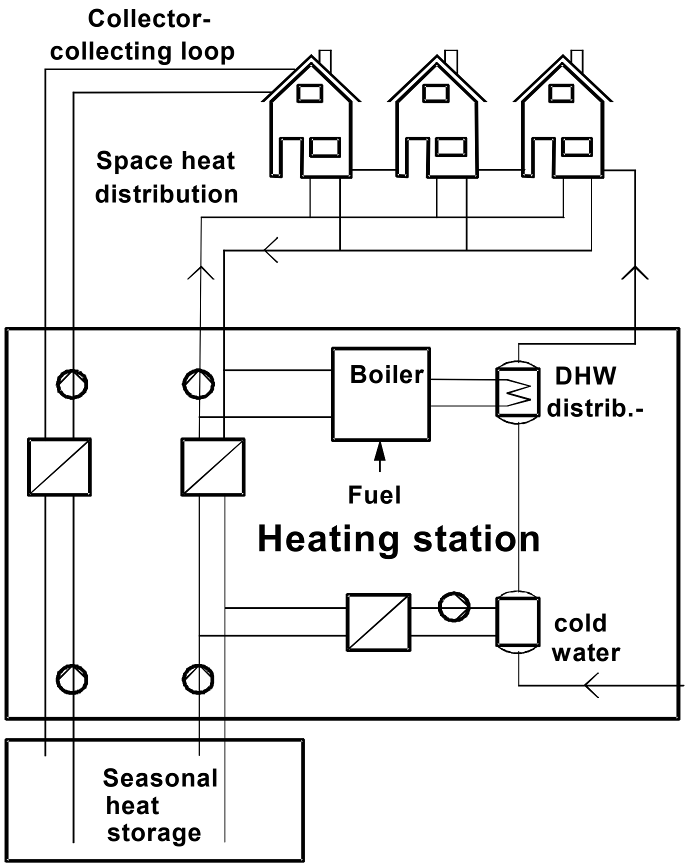
Single storage with inegrated gas-condensing boiler

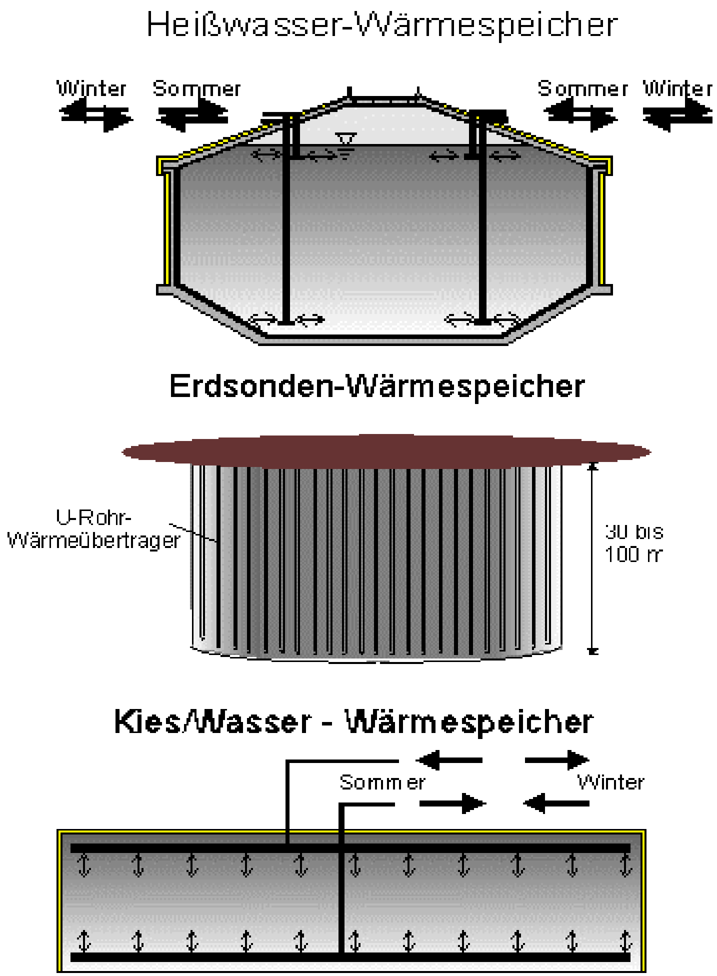


Systems for Multi Family House „Legionella free“, ÖNORM B 5019

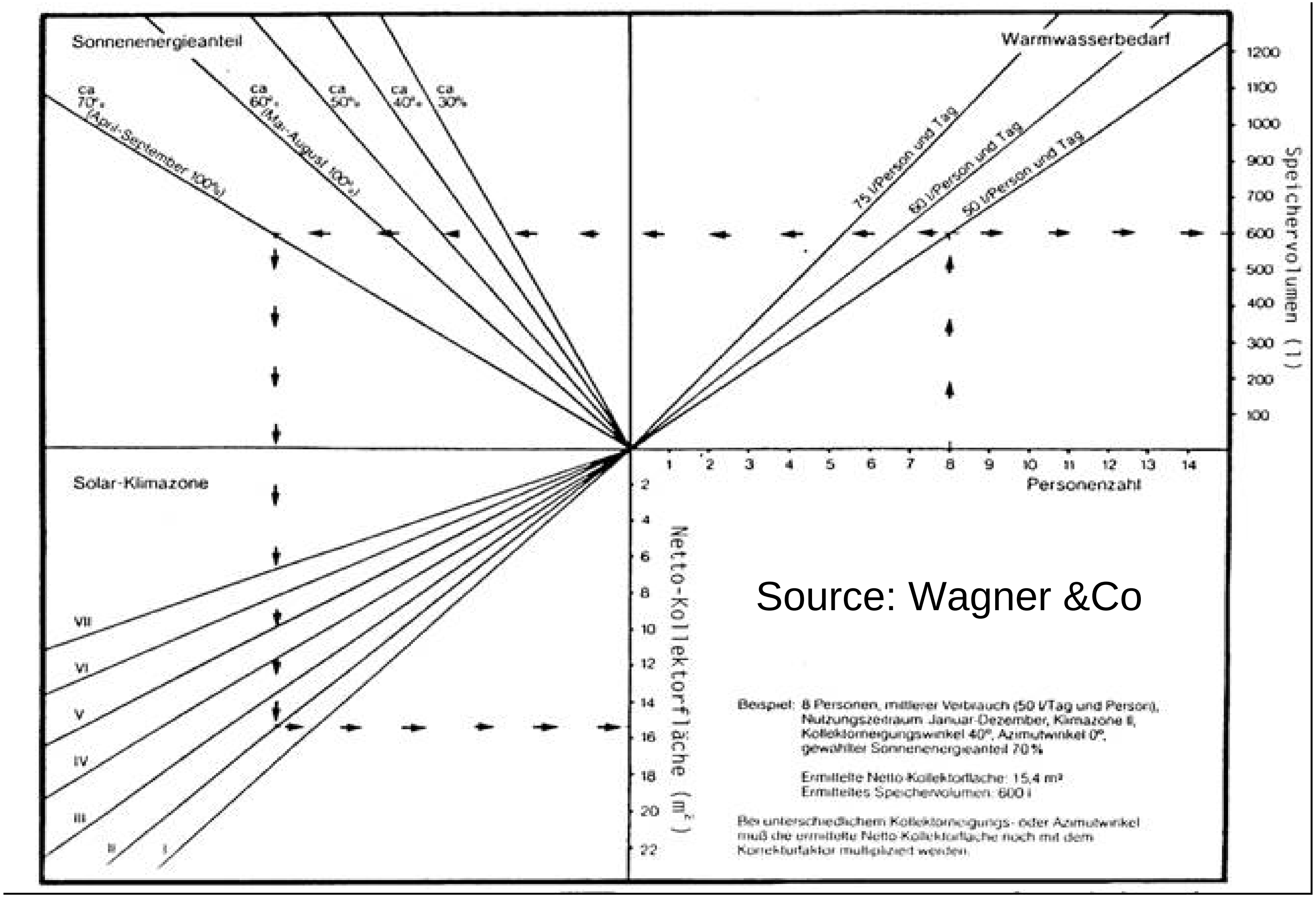


District heating systems, seasonal storage





Simple dimensioning of solar DHW systems

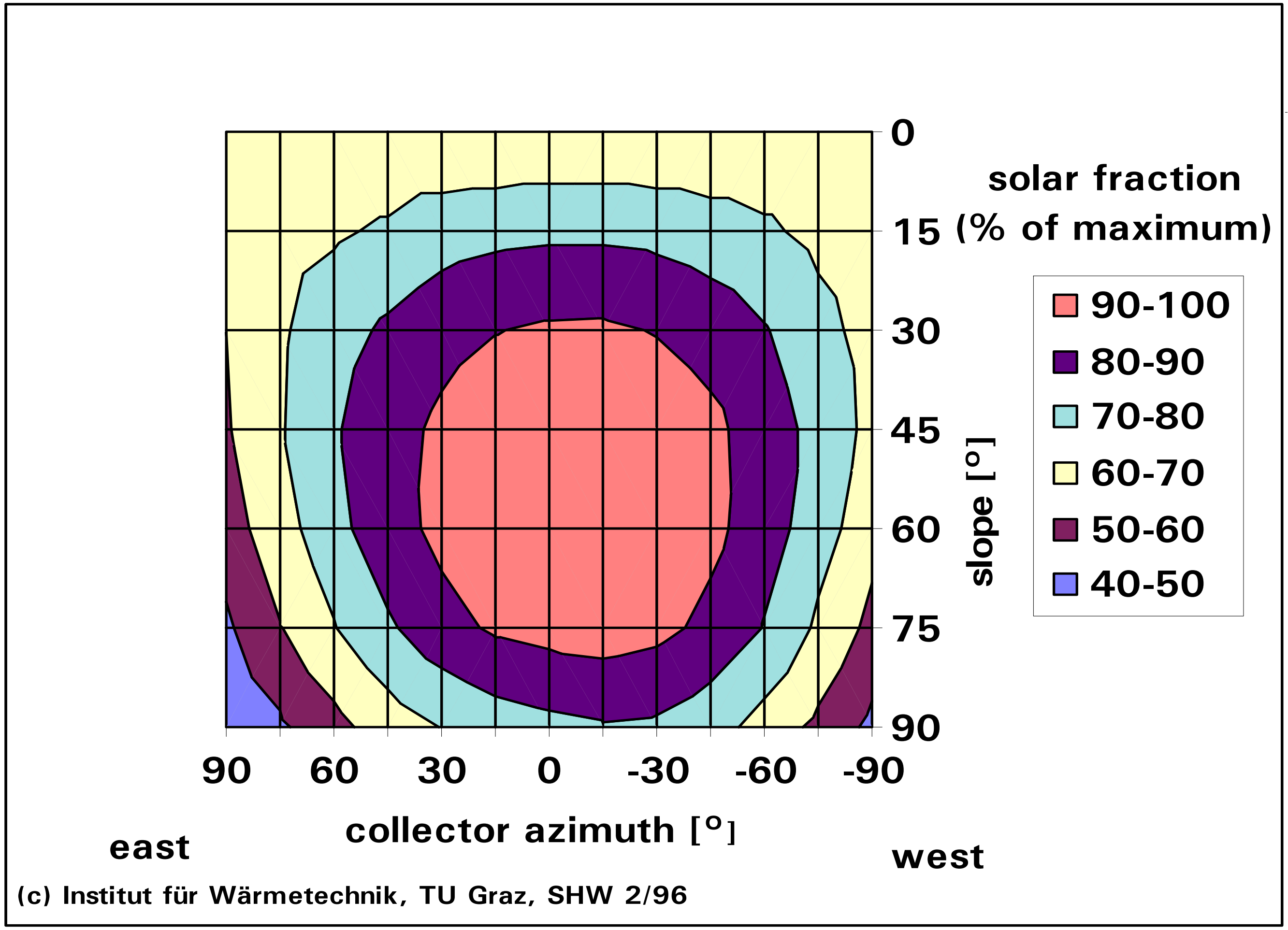


Simple dimensioning of Solar DHW systems

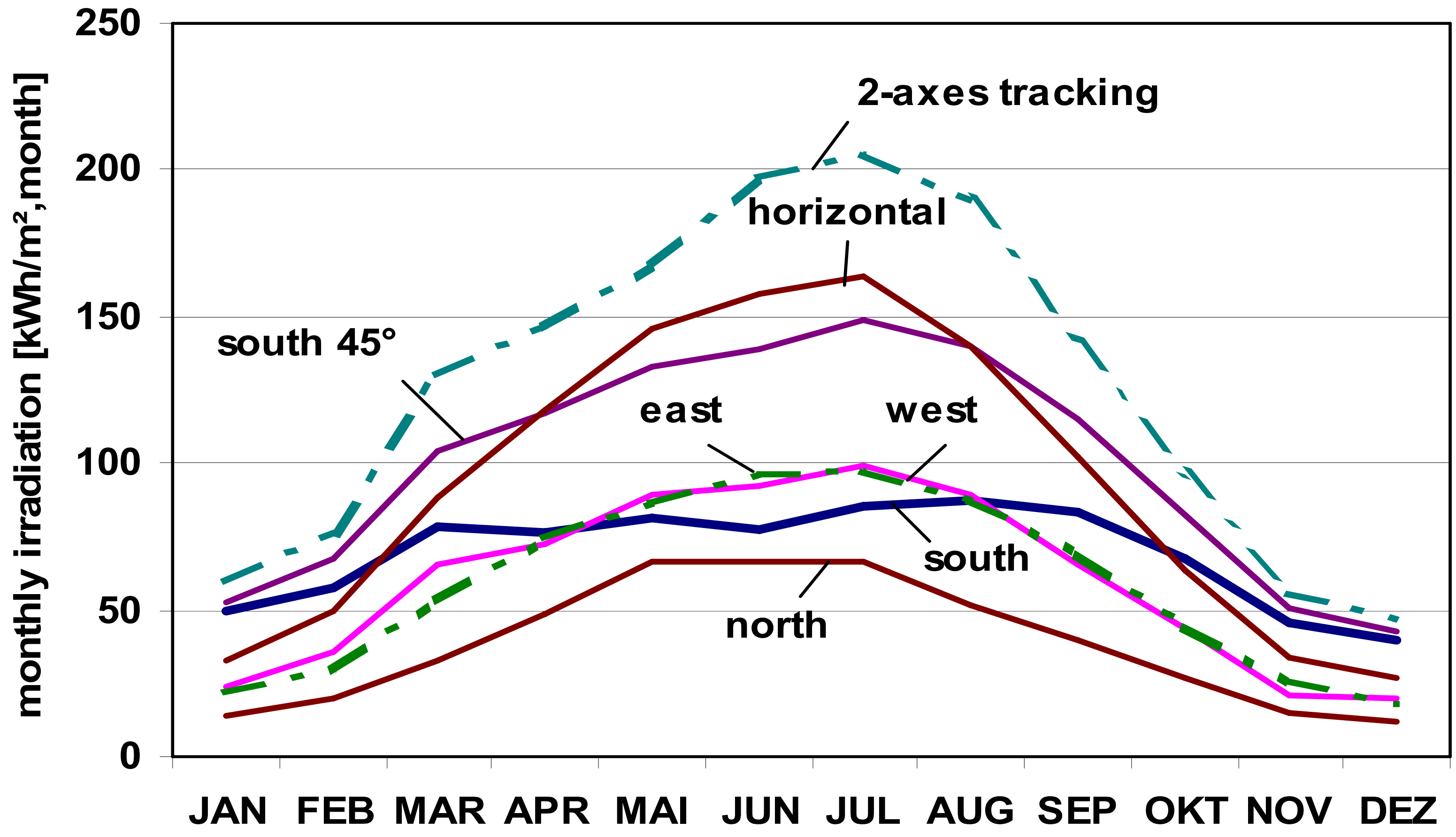
Solar-climate-zone	Hours of sunshine	Global iradiation	
	[h/year]	kWh/m²,day	kWh/m²,year
I	< 1500	ca. 2.5	ca. 920
II	1500 - 1700	ca. 2.8	ca. 1030
III	1700 - 1900	ca. 3.1	ca. 1115
IV	1900 - 2100	ca. 3.4	ca. 1230
V	2100 - 2300	ca. 3.7	ca. 1370
VI	2300 - 2500	ca. 4.1	ca. 1490
VII	> 2500	ca. 4.4	ca. 1610

Source: Wagner &Co

Sensitivity analysis of reference combisystem SFc dependency on slope and azimuth



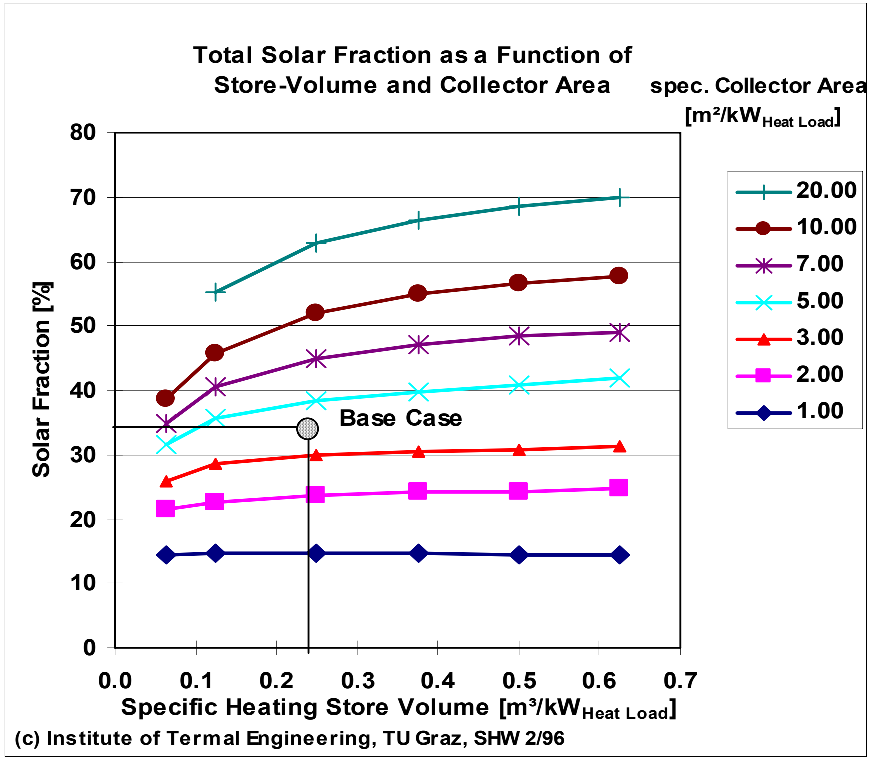
Hemispherical irradiation on surfaces of different orientations for a middle European climate

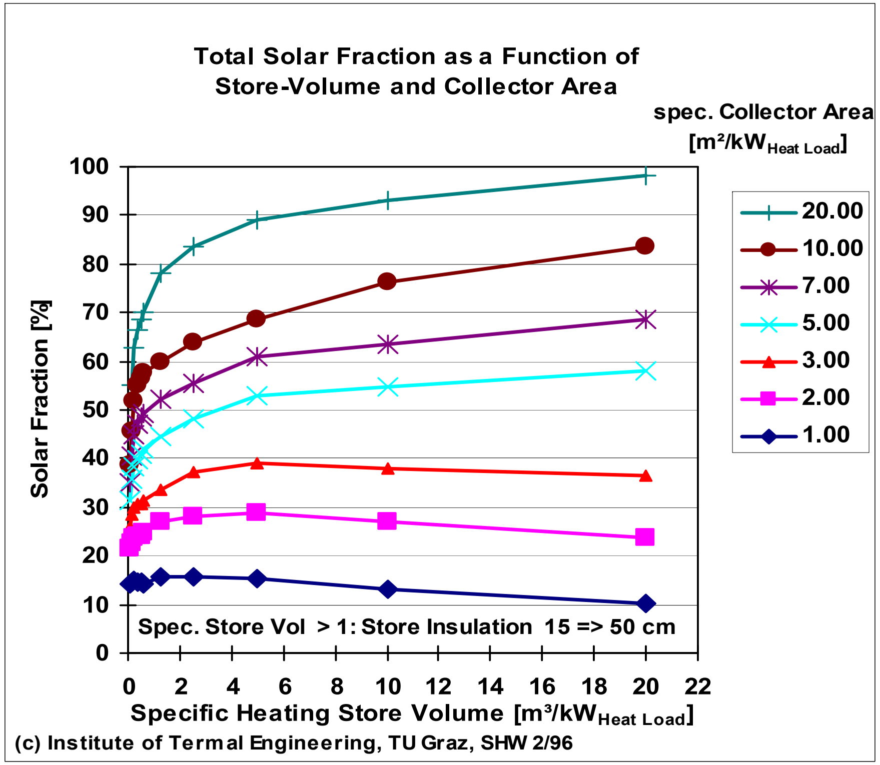


Façade Collectors

- Optimal slope equals to lattitude of loaction
- Optimal orientation about 5° west (northern hemisphere)
- Little decrease of SF_c by opt. slope ± 25°
- Little decrease of SF_c by opt. azimuth ± 30°
- Slope of 90° south is far better than horizontal collector (wall collector)

Sensitivity analysis of reference combisystem
SFc dependency on store volume and collector area

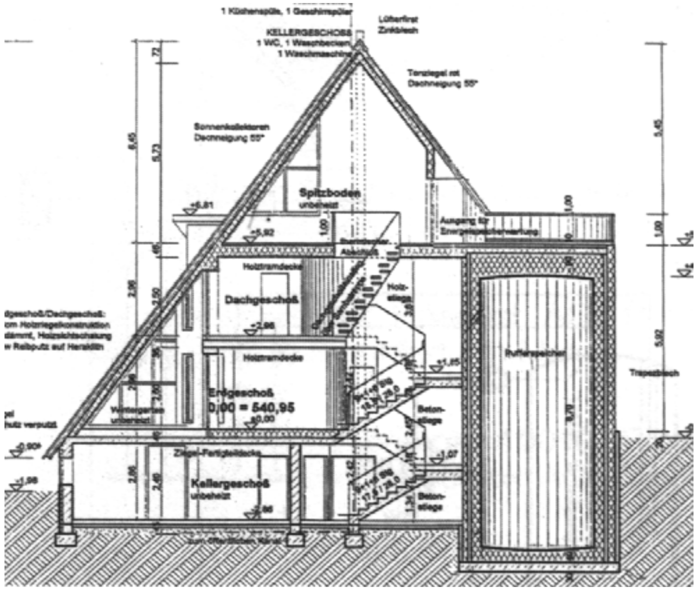


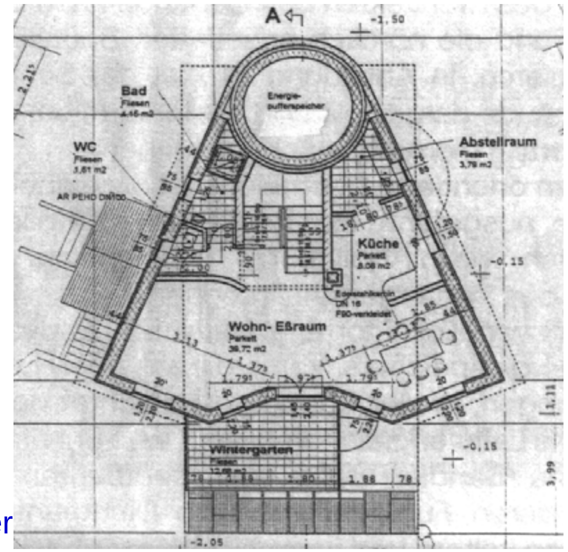


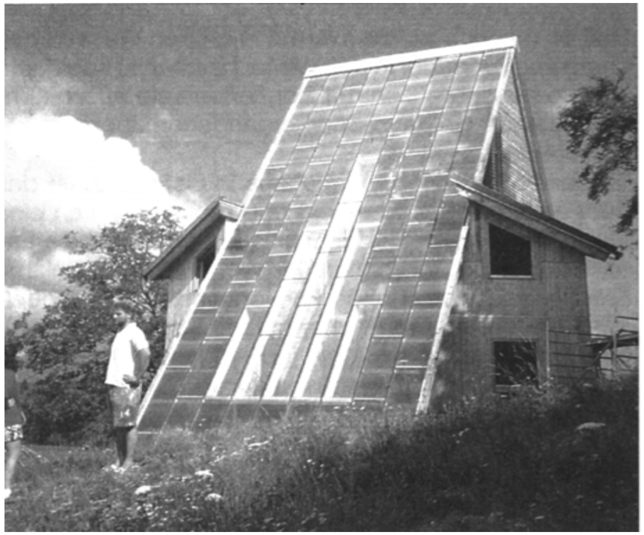
$A_{coll\_p} = A_{coll} / \dot{Q}_{load}$ and

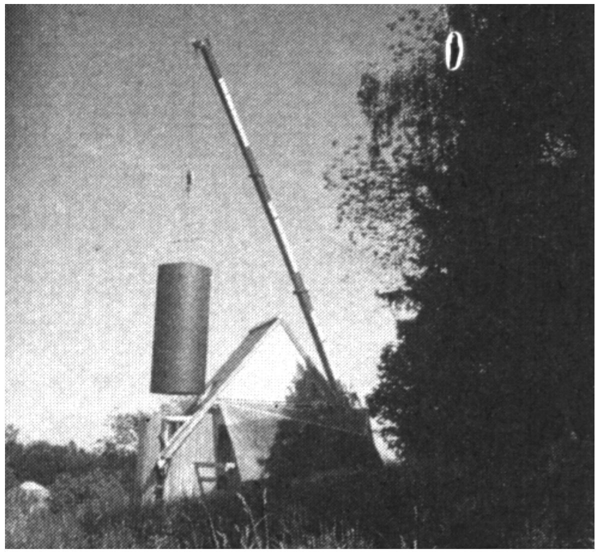
$V_{store\_p} = V_{store} / \dot{Q}_{load}$

Example of purely solar heated house

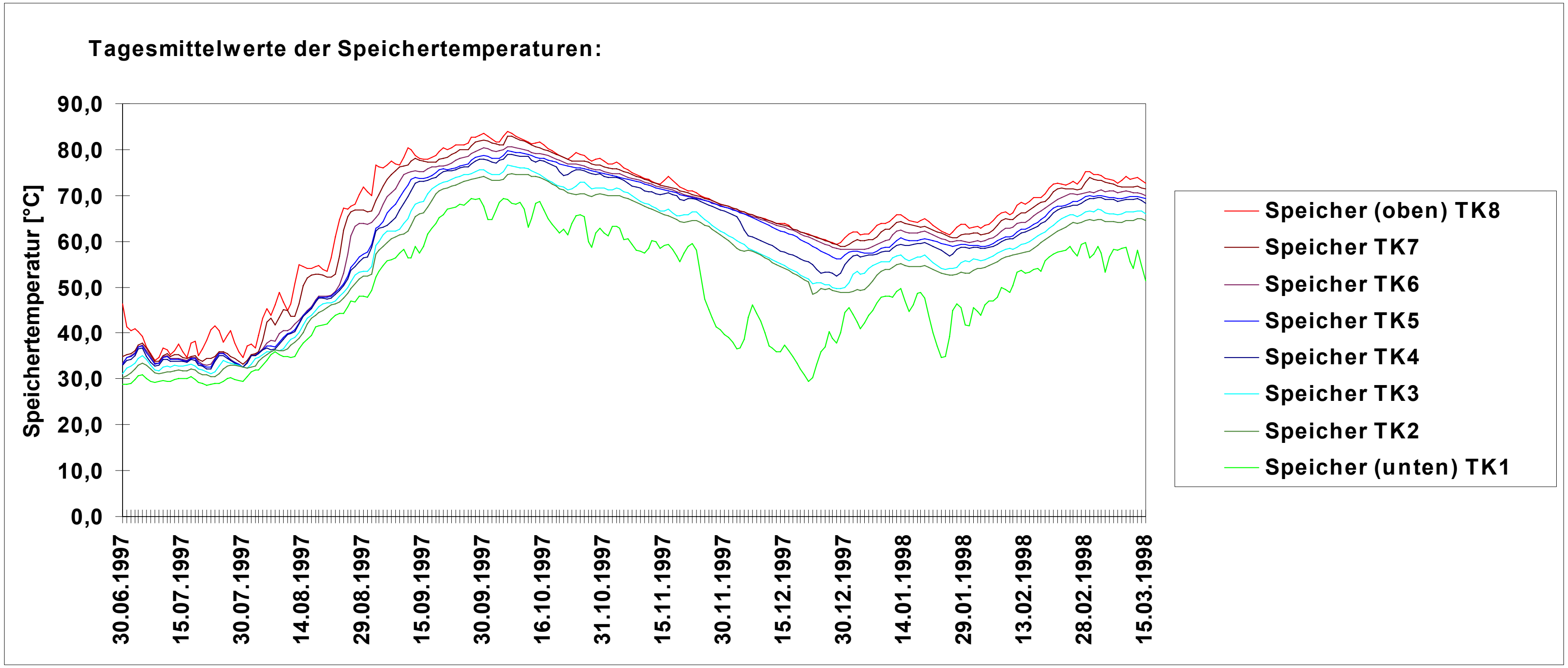








Example of purely solar heated house store temperatures first year

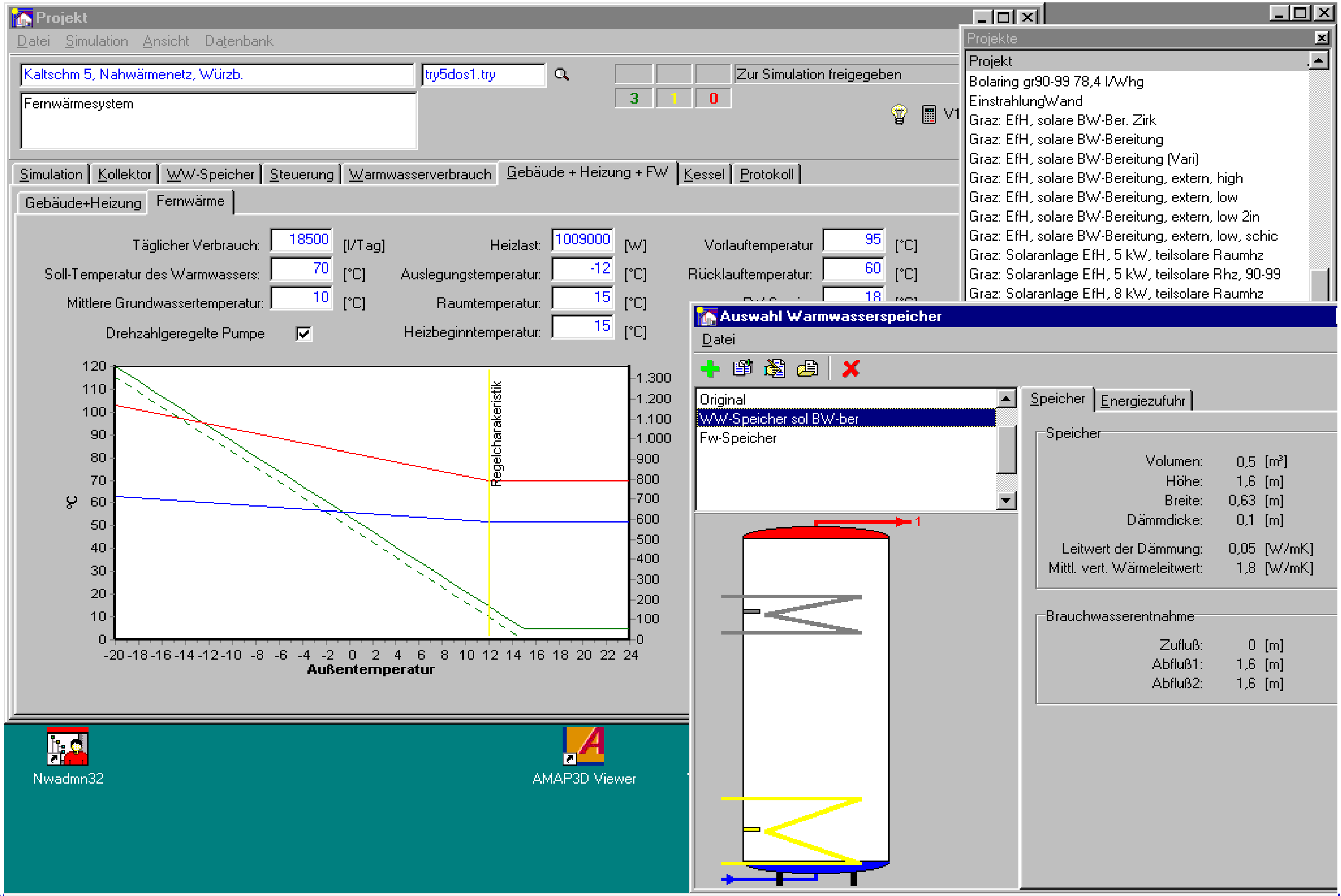


Example of purely solar heated house

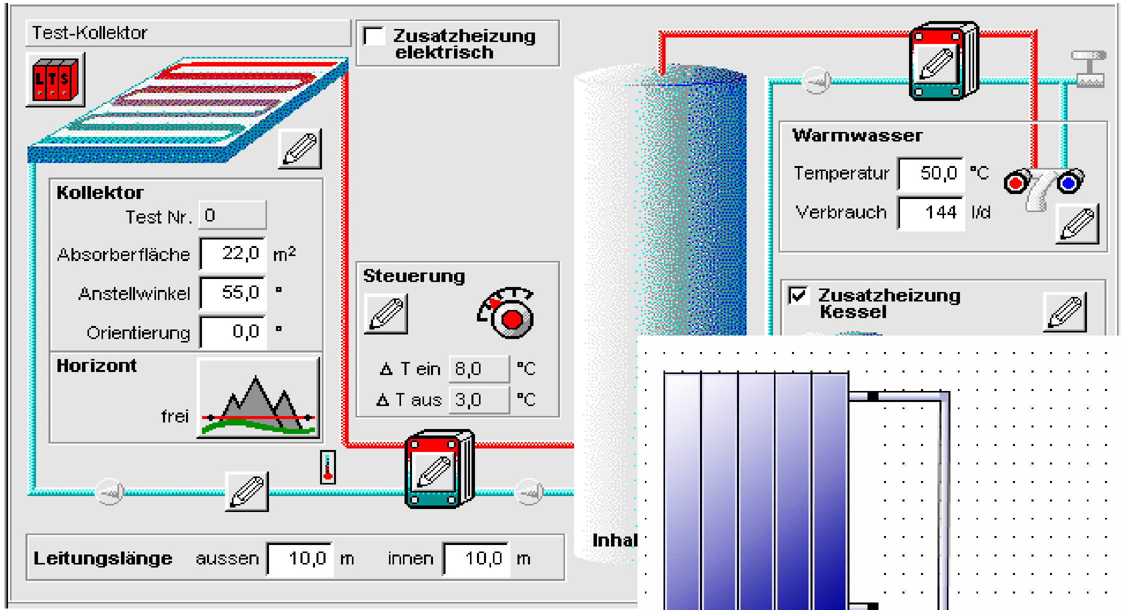
one year energy balance (June 97 – March 98)

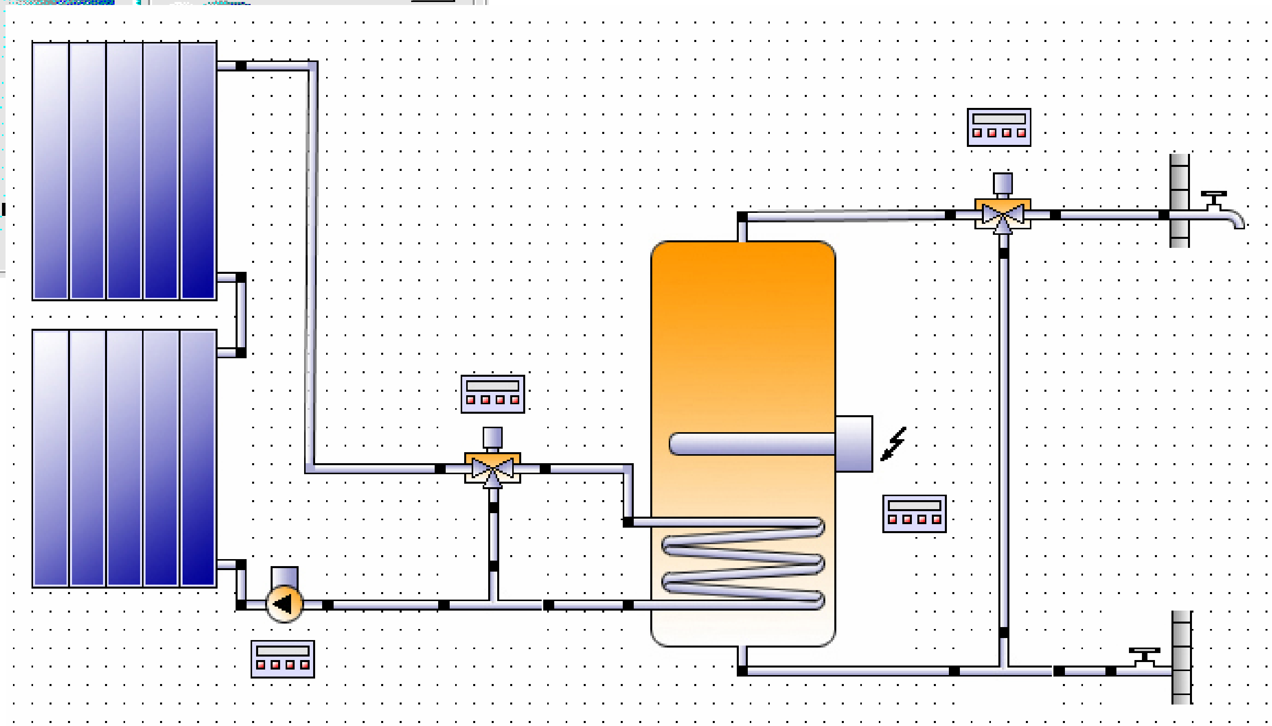
Collectorer yield	16.700 kWh (220 kWh/m²)
Heat to store top	2150 kWh
Heat to store middle	14280 kWh
Σ Heat to store	16430 kWh
Heat delivered top	145 kWh
Heat delivered middle	728 kWh
Heat to space heating	1090 kWh (is it worth this ???)
Heat fo DHW	520 kWh (50 l/d ???)

Simulation programs for solar thermal systems: SHWwin



Simulation programs
for solar thermal systems: Polysun





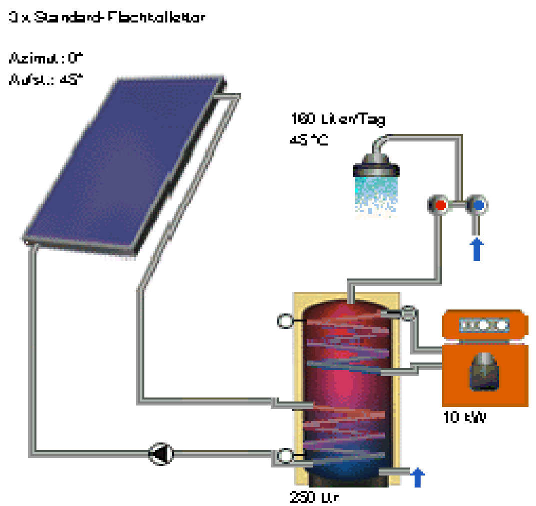
Simulation programs for solar thermal systems: TSOL

Dr.-Ing.G.Valentin+Partner GbR
VALENTIN Energiesoftware

Variante 1 **T*SOL 4.0 Demo**

Projekt: Projekt 1 Datum: 06.09.02

Solaranlage mit biv. WW-Speicher



Ergebnisse der Jahressimulation

Einstrahlung Kollektorfläche:	3,36 MWh	1119,59 kWh/m²
Abgegebene Energie Kollektoren:	1646,64 kWh	548,88 kWh/m²
Abgegebene Energie Kollektorkreis:	1425,84 kWh	475,28 kWh/m²
Energielieferung Trinkwarmwassererwärmung:	2380,71 kWh	
Energie Solarsystem an Warmwasser:	1425,84 kWh	
Zugeführte Energie Zusatzheizung:	1128,79 kWh	

Brennstoffeinsparung:	214,2 l
Vermiedene CO2-Emissionen:	576,4 kg
Deckungsanteil Warmwasser:	55,8 %
Systemnutzungsgrad:	42,5 %

Energy and Environment

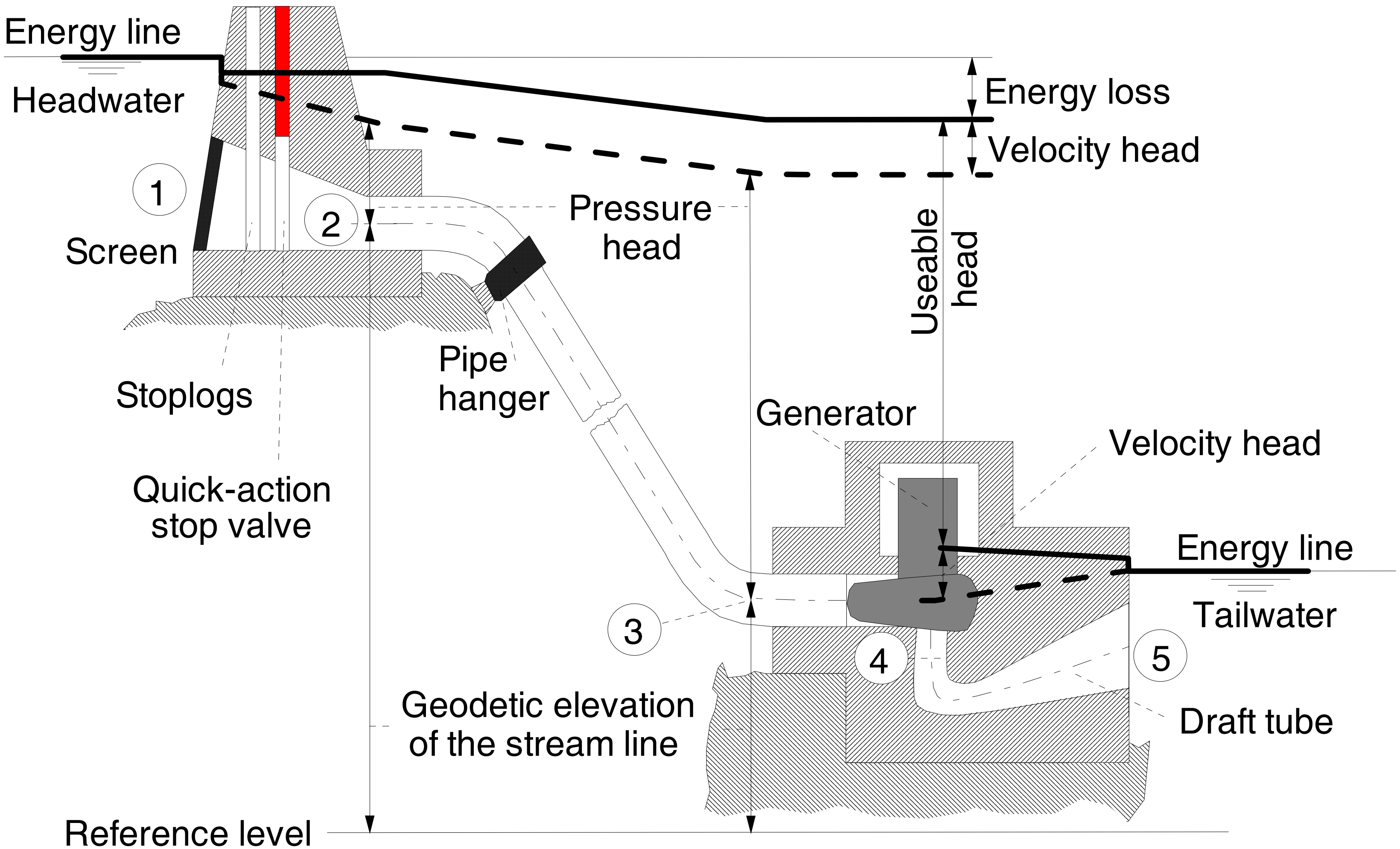
Technical Solutions to use Renewable Energy Carriers

Part B: Electricity Applications

Hydroelectric

BP, stat review 2007

Hydro Power



Source: Kaltschmitt, Streicher, Wiese, Renewable Energy

Power and Energy from Water

According Bernoulli

$$p + \rho_{Wa}\, g\, h + \tfrac{1}{2}\, \rho_{Wa}\, v_{Wa}^2 = const\,.$$

This can be restructured to height-values

$$\frac{p}{\rho_{Wa}\, g} + h + \frac{1}{2}\frac{v_{Wa}^2}{g} = const\,.$$

The useful height can be derived by

$$h_{nutz} = \frac{p_1 - p_2}{\rho_{Wa}\, g} + \left(h_1 - h_2\right) + \frac{v_{Wa,1}^2 - v_{Wa,2}^2}{2\, g}$$

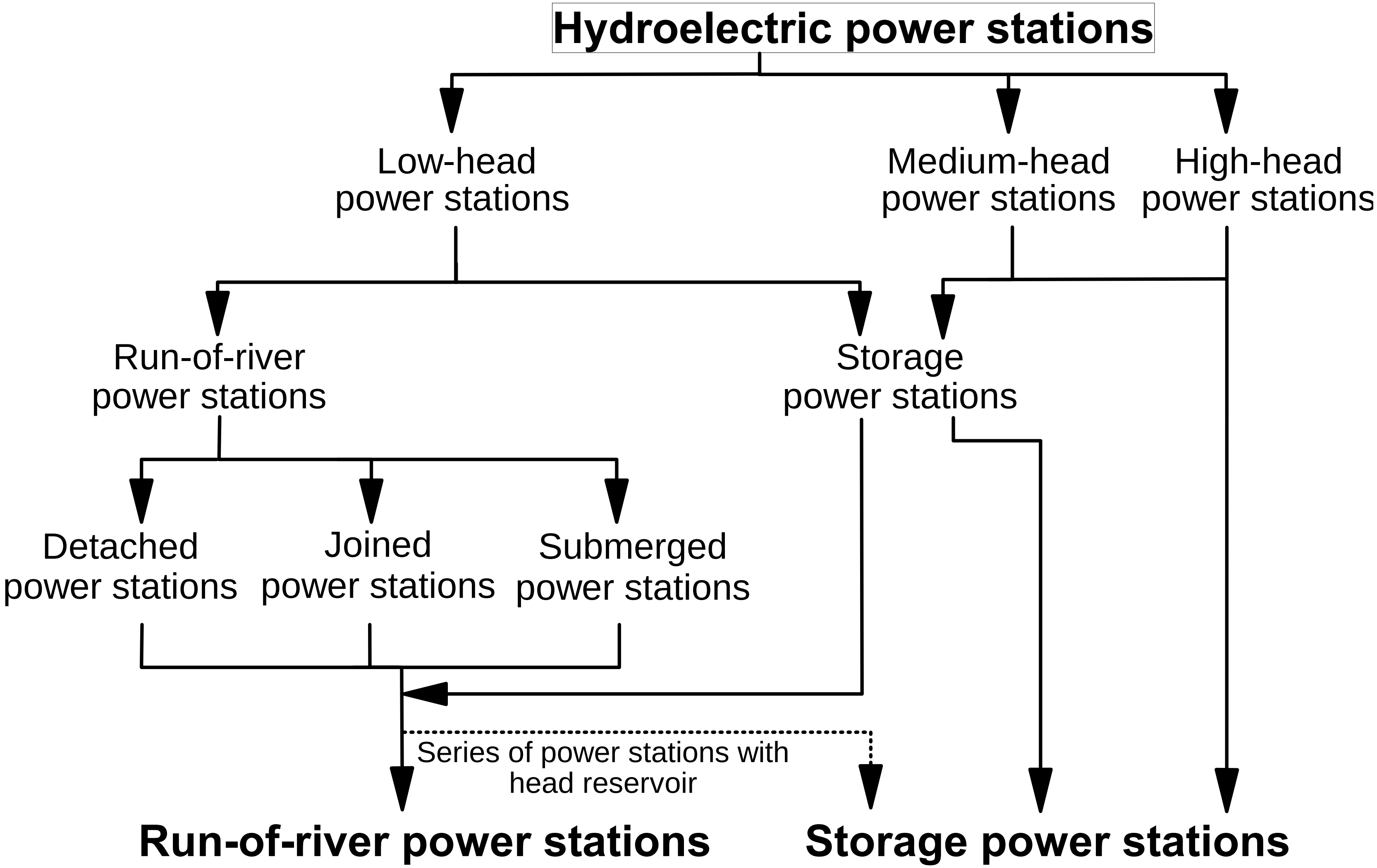
The power from hydro use is calculated by

$$P_{Wa} = \rho_{Wa}\, g\, \dot{q}_{Wa}\, h_{nutz}$$

The total energy of a reservoir therefor is

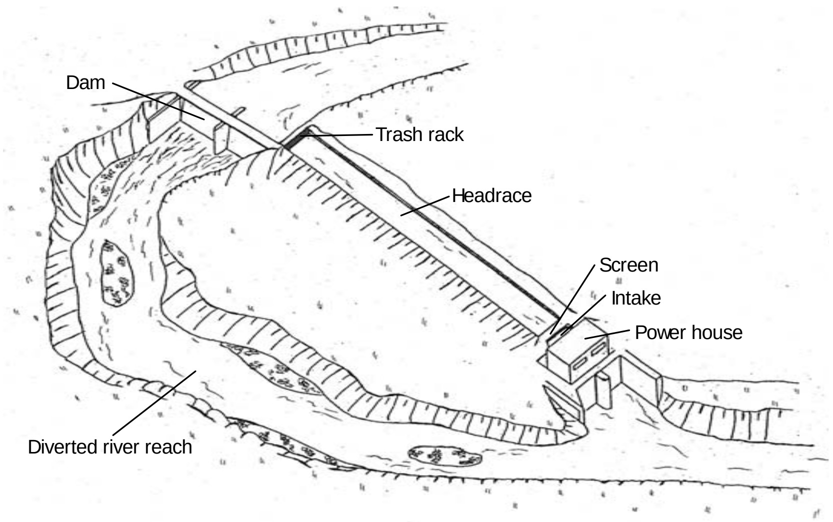
$$E_{Wa} = \rho_{Wa}\, g\, h_{nutz}\, V_{Speicher}$$

Hydro Power

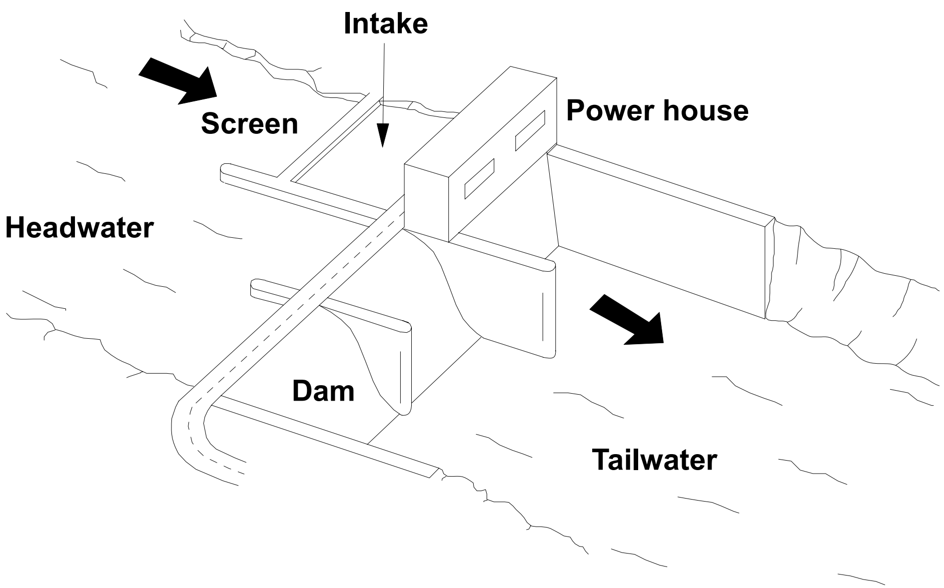


Source: Kaltschmitt, Streicher, Wiese, Renewable Energy

Hydro Power



diversion-type power station

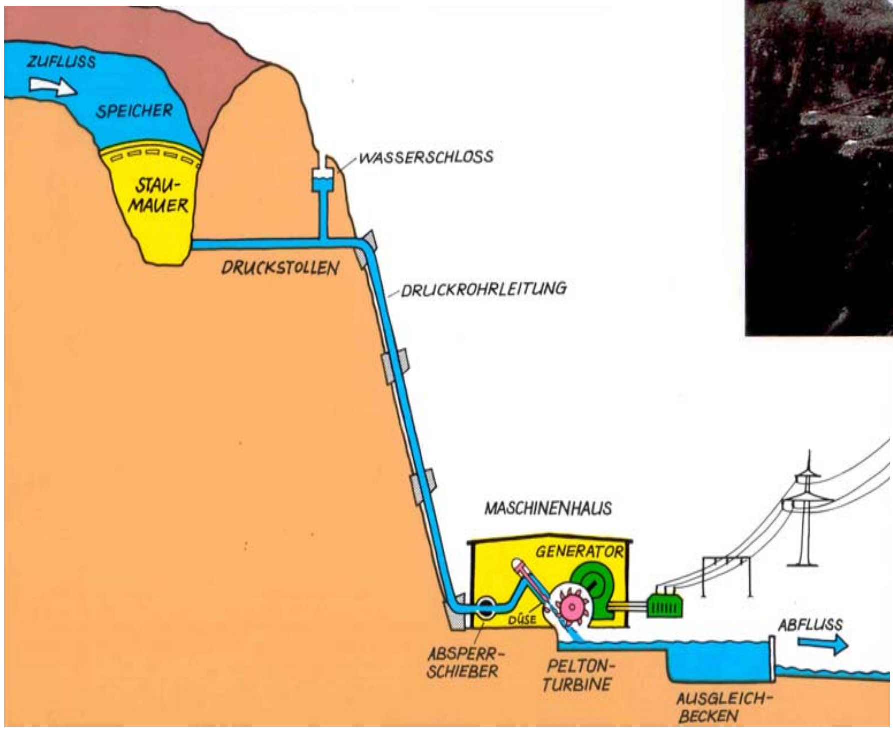


run-of-river power station

Source: Kaltschmitt, Streicher, Wiese, Renewable Energy

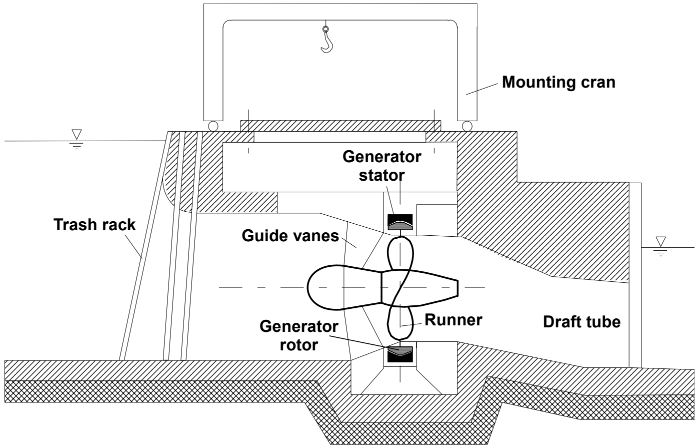
Storage Hydro Power Station

Speicher Zillergründl der Kraftwerksgruppe Zemm/Ziller

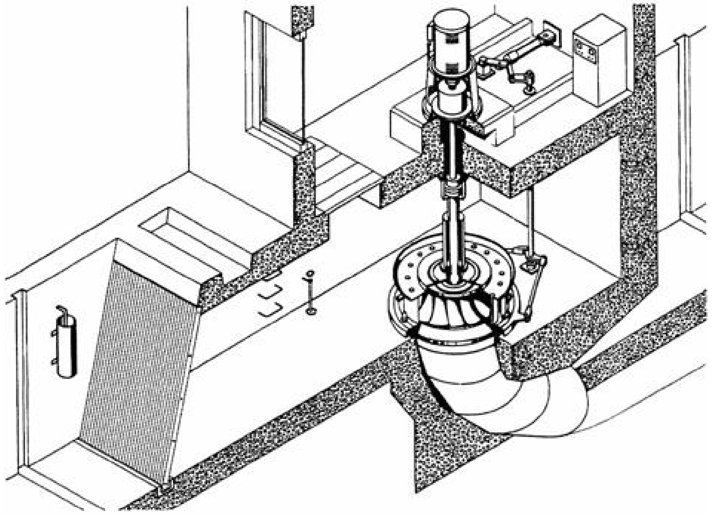


Source: Kaltschmitt

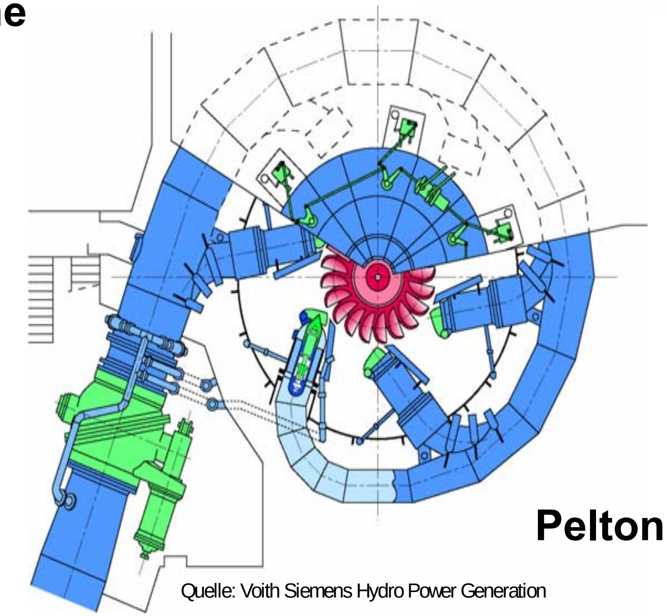
Hydro Power



run-of-river power station with Straflo Turbine



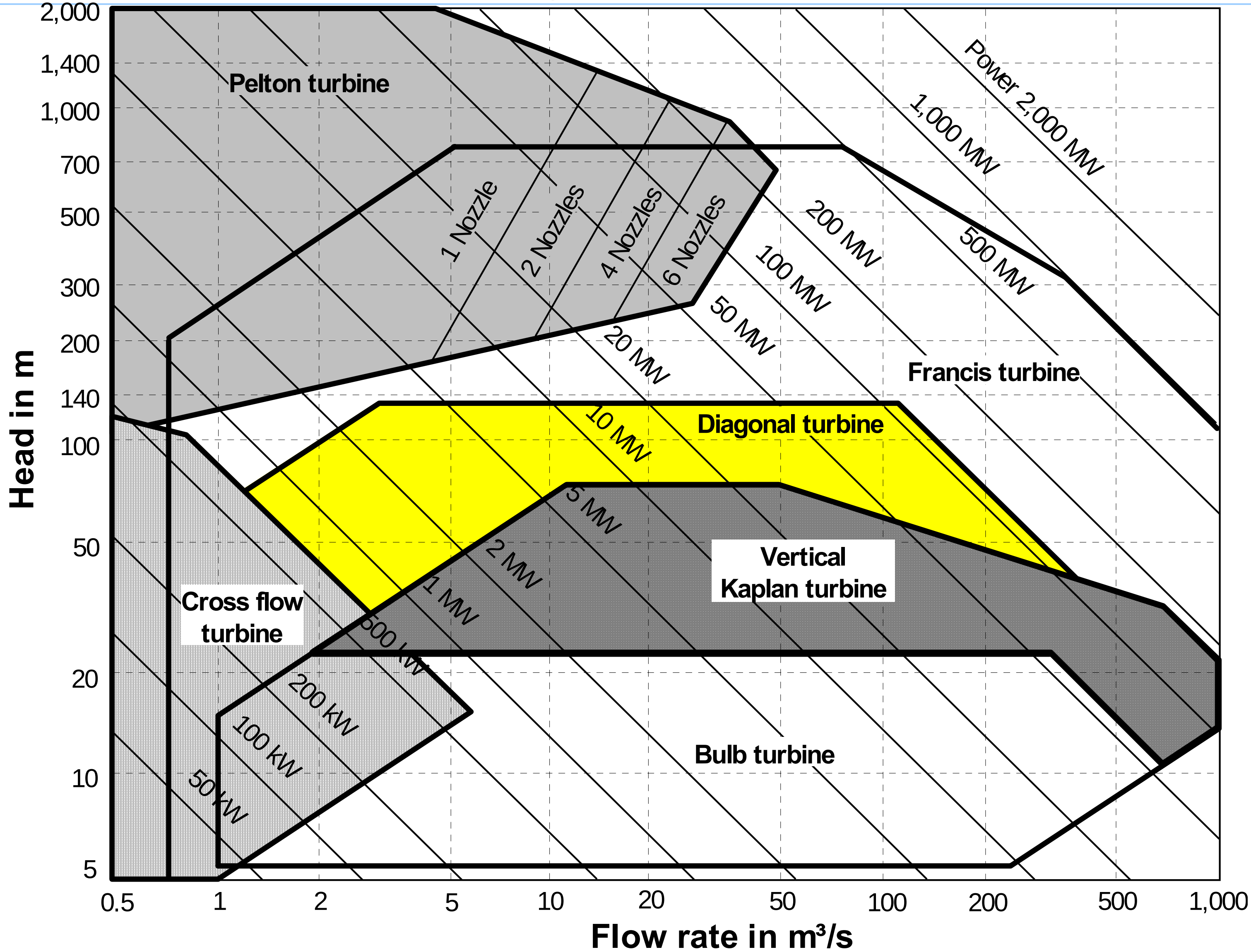
Francis Turbine



Pelton Turbine

Source: Kaltschmitt, Streicher, Wiese, Renewable Energy

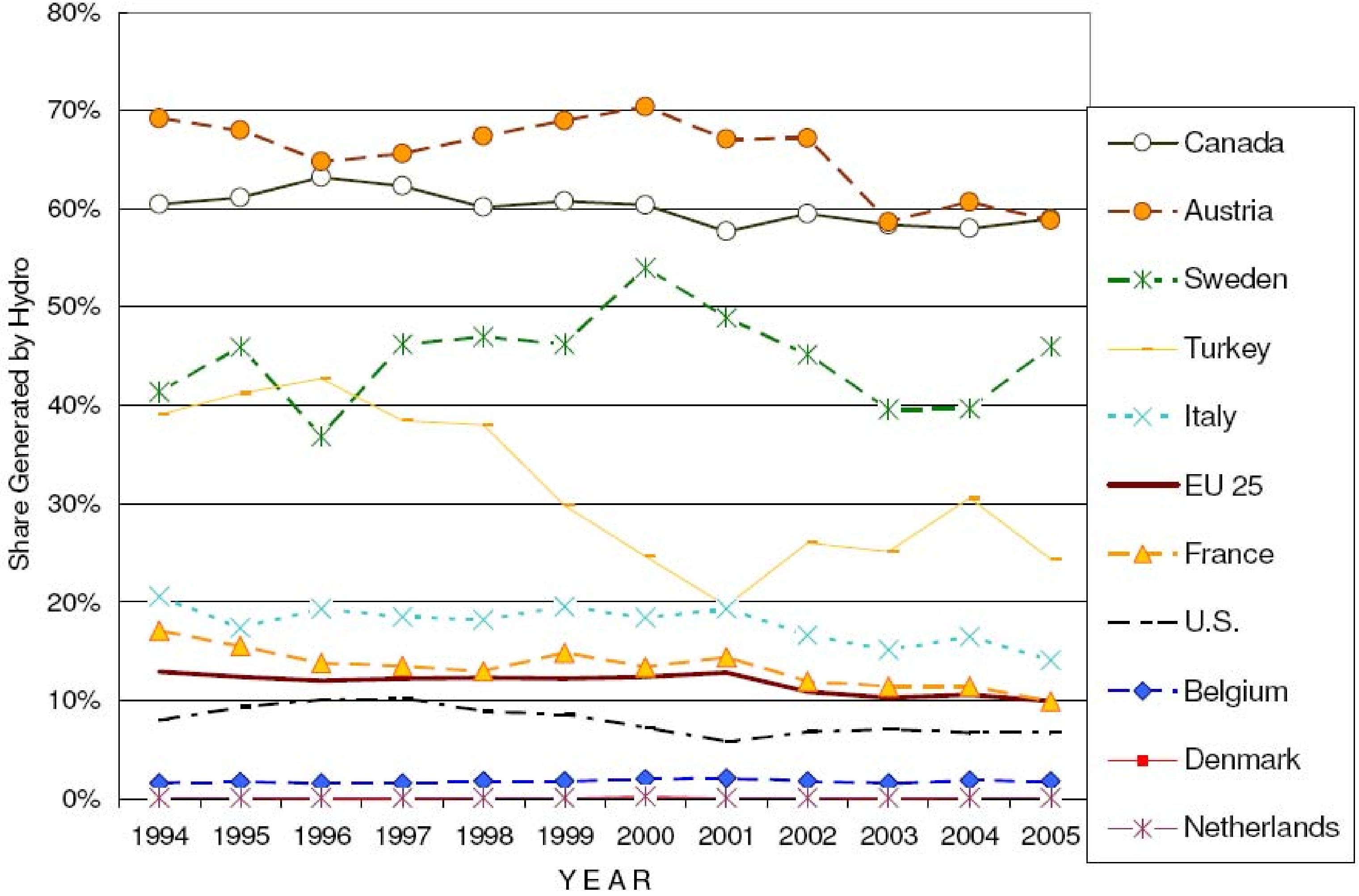
Hydro Power



Source: Kaltschmitt, Streicher, Wiese, Renewable Energy

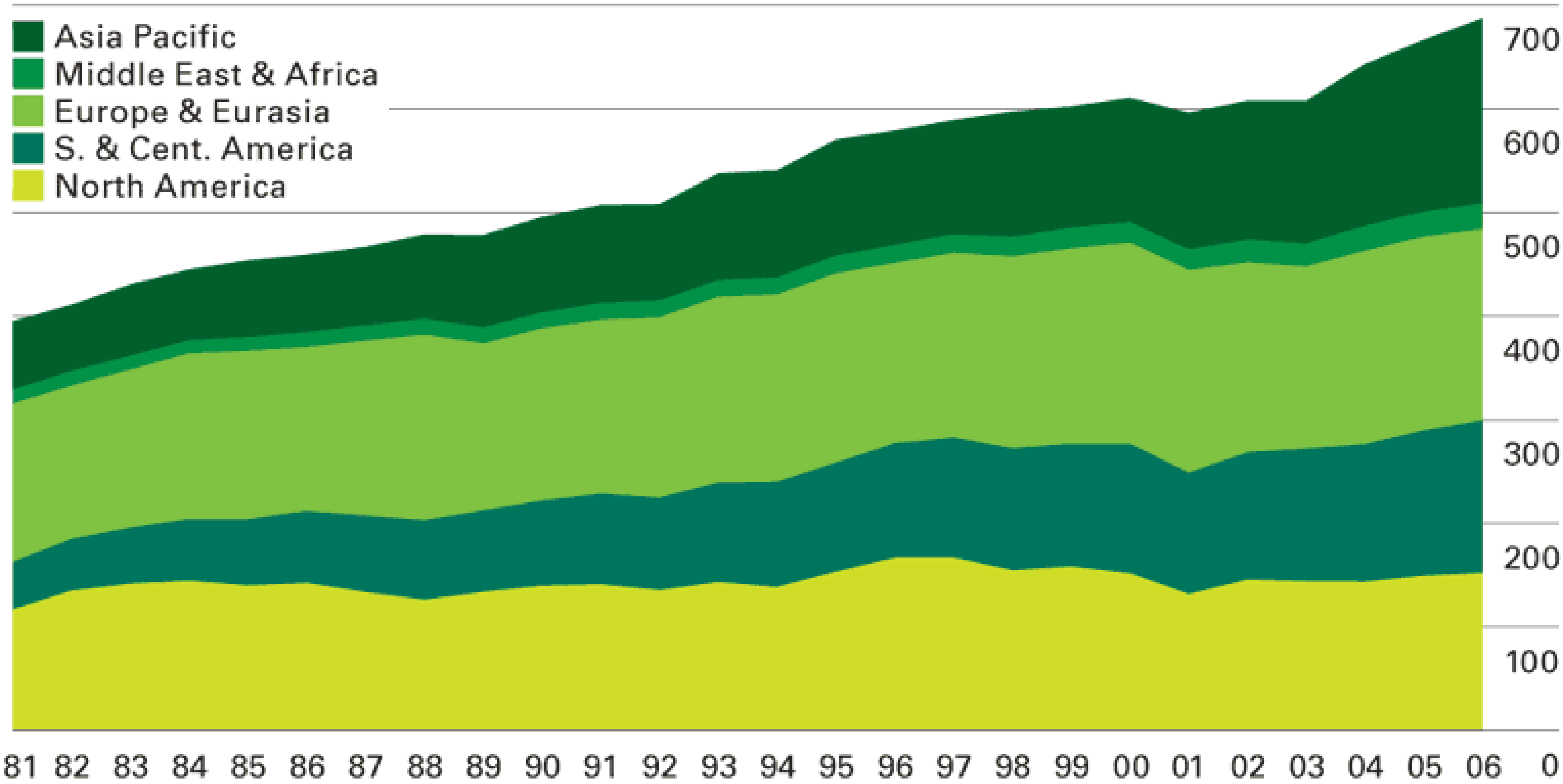
Share of hydro in electric generation

[Energy Information Administration, 2007]



Hydroelectric

Consumption by area
Million tonnes oil equivalent



Hydroelectric power generation rose by 3.2% in 2006. Increased Asia Pacific, South American and US output offset declines in Scandinavia and Canada.

BP, stat review 2007

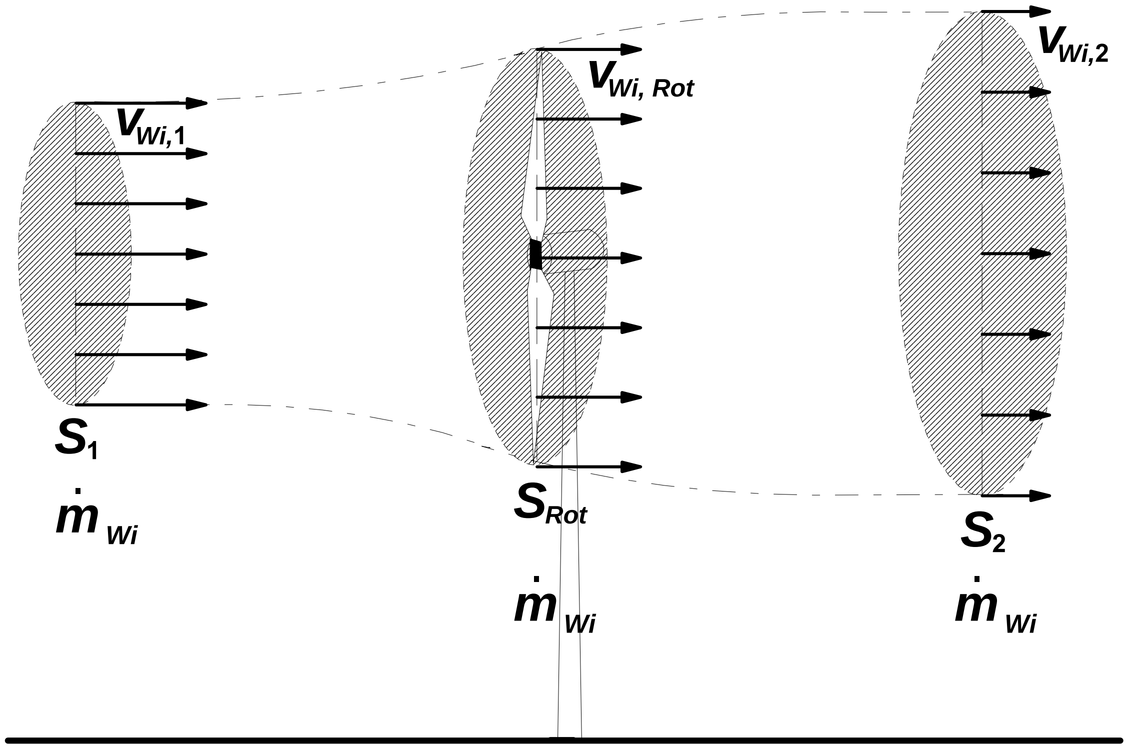
Environmental effects of Hydro Power Stations

- **Building Phase**
  - Water pollution caused by construction material or fine soils getting into the stream, release of fine particles caused by excavation, improper cleaning of building machinery, etc.
  - Oil losses due to improper handling during construction and maintenance works.
  - Oil seepage, commonly from hydraulic systems, e.g. during demolition works.
- **Operation River Dams**
  - Increase of sediments in the reservoir
  - Higher deepening of the river bed downflows due to lack of sediments (e.g. flushing of Grand Canyon)
  - Fish-barrier (fisch ladders)
  - Change of ecosystem in reservoir and downstream
  - Effect on ground-water
  - Rest-Water for diversion type power stations
  - Danger of landslide for steep coasts of river dams
- **All effects are more or less locally**

Wind Energy

Flow through an idealised wind energy converter

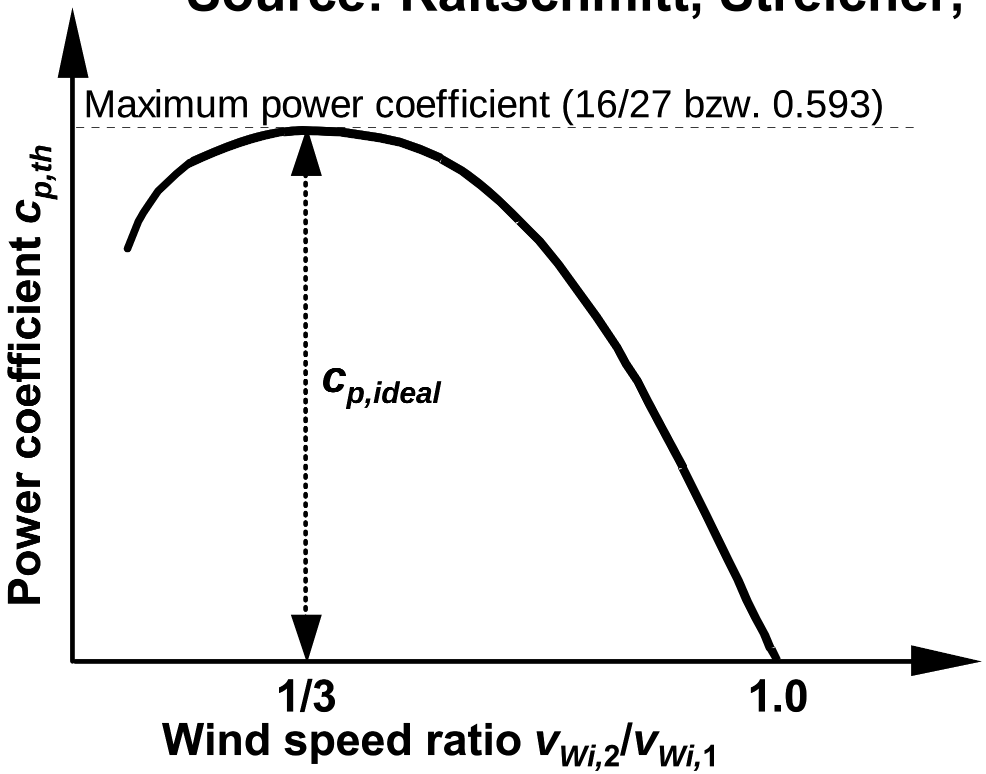
Source: Kaltschmitt, Streicher, Wiese, Renewable Energy



$$P_{Wi} = \frac{1}{2}\dot{m}_{Wi,free} v_{Wi,1}^2 = \frac{1}{2}\rho_{Wi} S_{Rot} v_{Wi,1}^3$$ with $$\dot{m}_{Wi} = \rho_{Wi} S_i v_{Wi,i} = const.$$

Flow through an idealised wind energy converter

Source: Kaltschmitt, Streicher, Wiese, Renewable Energy



tip speed ratio λ

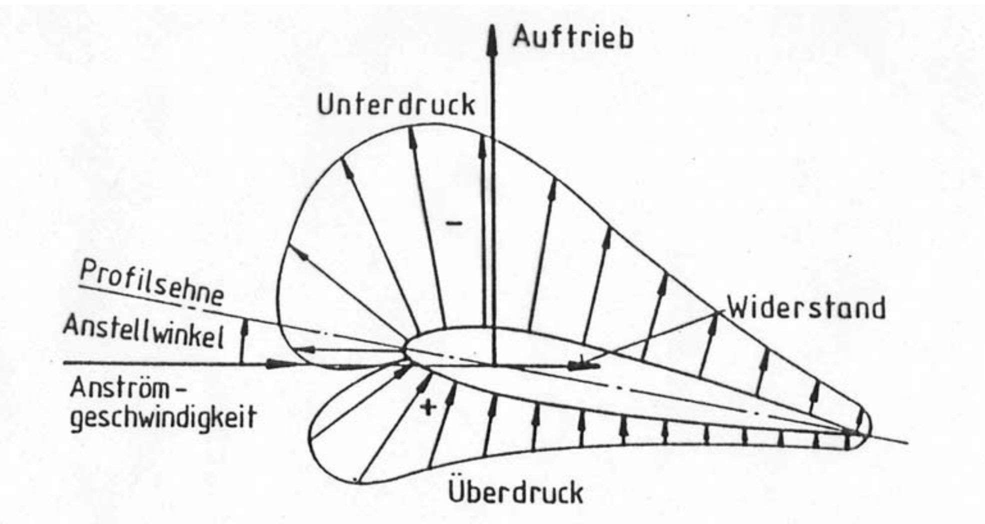
$$\lambda = \frac{v_u}{v_{Wi,Rot}}$$

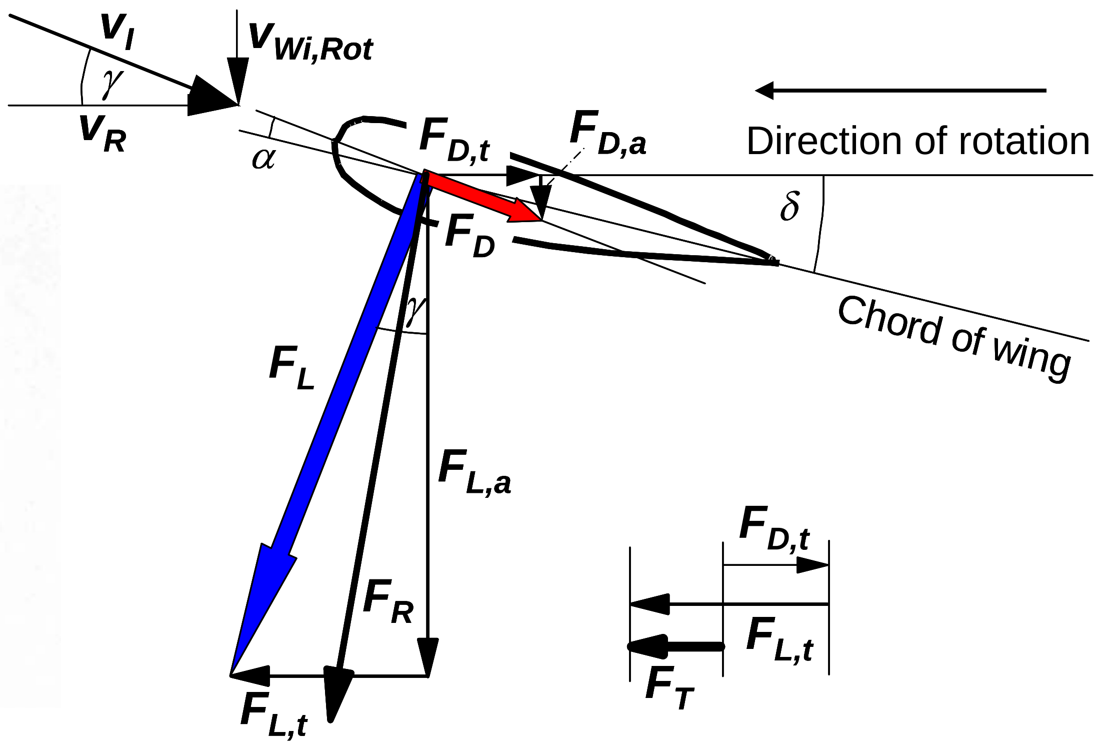
useful power of a wind power station P_{WEC}

$$P_{WEC} = c_p \eta_{mech.-elec.} P_{Wi}$$

Flow conditions and forces of the airfoil lift principle

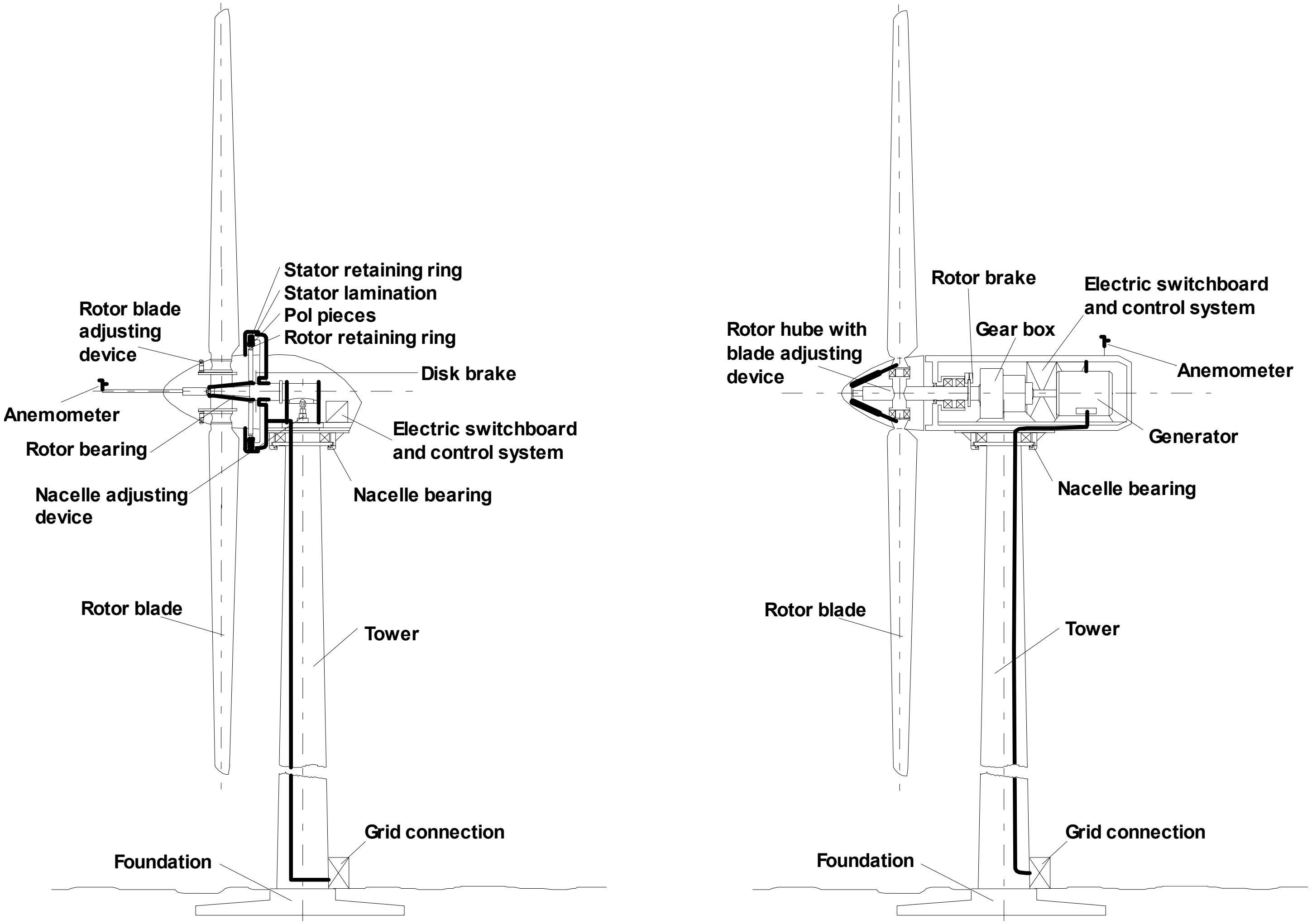
Source: Kaltschmitt, Streicher, Wiese, Renewable Energy





Schematic of horizontal axis converters equipped with gearbox (right) and gearless (left)

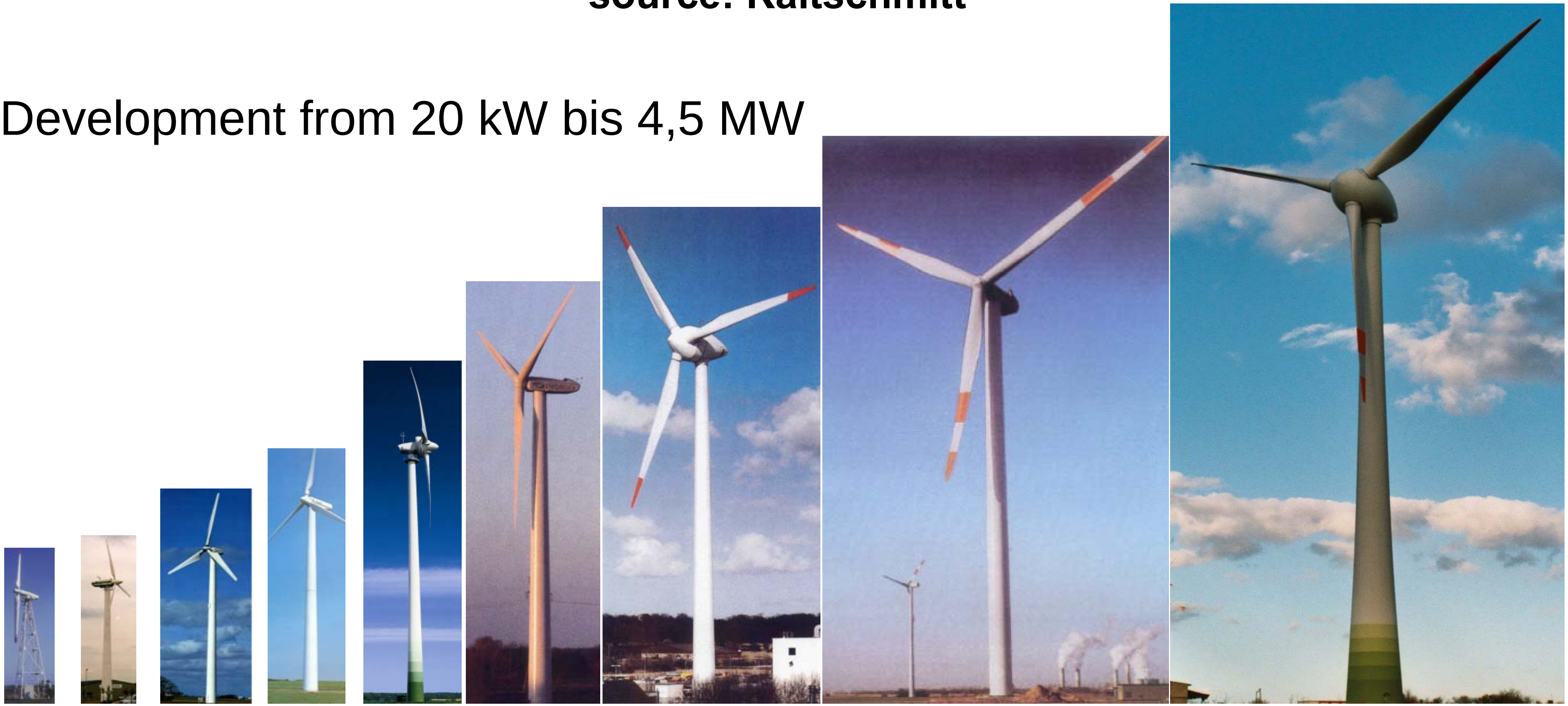
Source: Kaltschmitt, Streicher, Wiese, Renewable Energy



20 Years of Wind Energy Development

source: Kaltschmitt

Development from 20 kW bis 4,5 MW



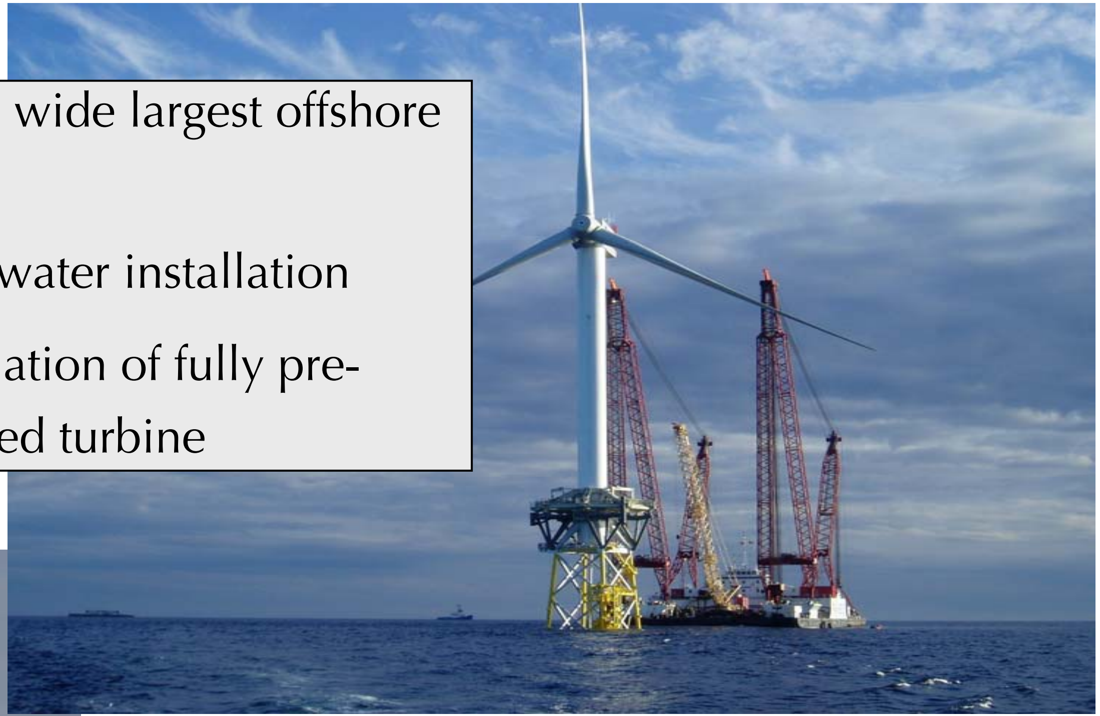
1982	1984	1986	1988	1992	1994	1996	2000	2002
Aeroman	Vestas	Nordtank	Micon	Enercon E40	Nordex N54	Enercon E66	Nordex N80	Enercon E112
20kW	55kW	150kW	250kW	500kW	1000kW	1500kW	2500kW	4500kW
Ø 11,5m	Ø 17m	Ø 25m	Ø 30m	Ø 40m	Ø 54m	Ø 66m	Ø 80m	Ø 112,8m

5 MW plant: source: Kaltschmitt

Offshore plants: source: Kaltschmitt

- ✓ world wide largest offshore turbine
- ✓ deep water installation
- ✓ installation of fully pre-assembled turbine

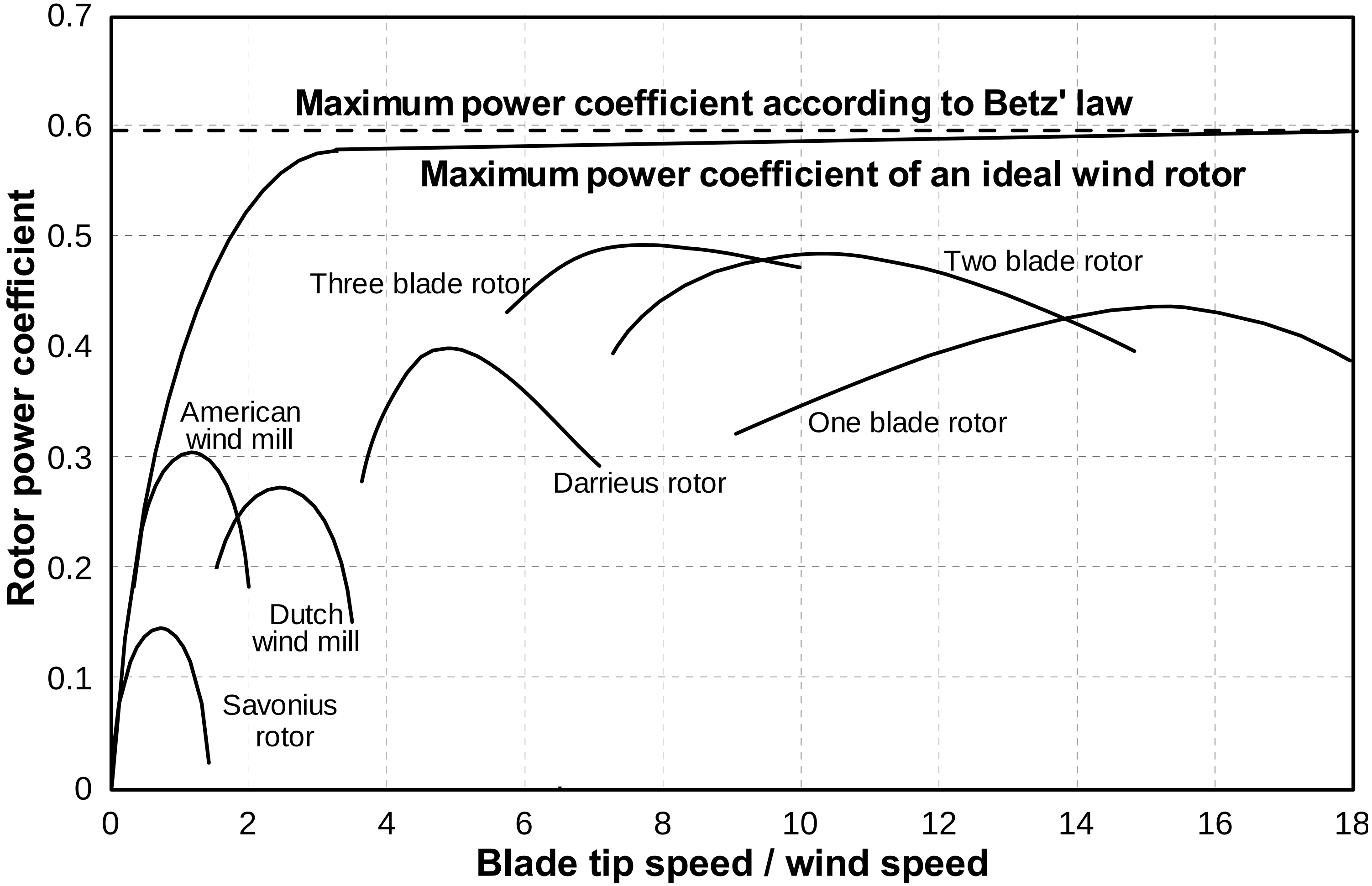
Transport



Installed

Power coefficient (cp(λ)) curve of different wind energy converter designs

Source: Kaltschmitt, Streicher, Wiese, Renewable Energy



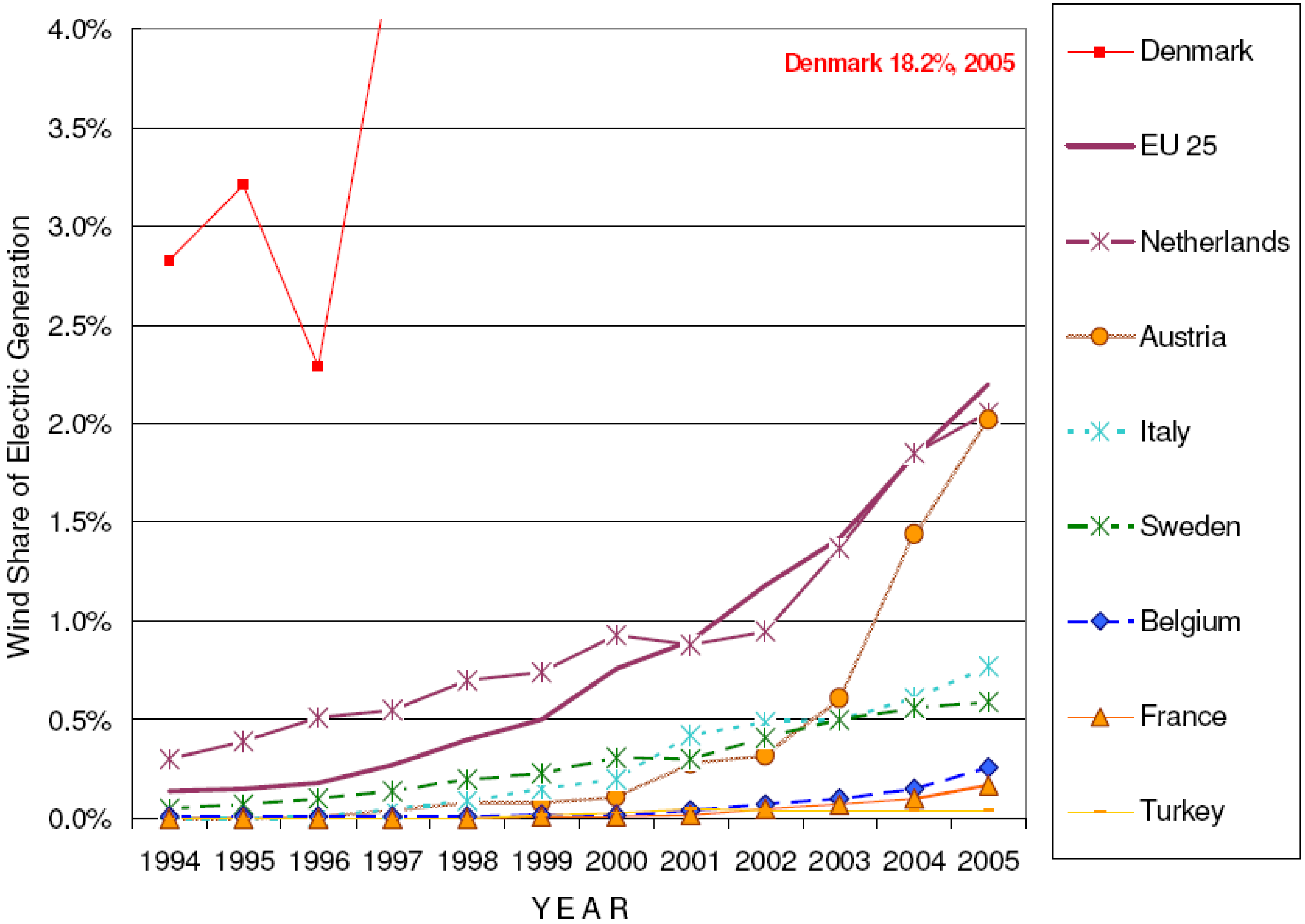
Mean investment, operation and power generation costs

Source: Kaltschmitt, Streicher, Wiese, Renewable Energy

Capacity	in kW	1,500	2,500	5,000
Investments				
Wind energy converter	in k€	1,250	2,180	4,150
Grid connection	in k€	185	200	380
Miscellaneous	in k€	205	219	418
Total	in k€	1,640	2,599	4,948
Yearly costs[a]	in k€/a	95	151	295
Power generation costs				
1,800 h/a	in €/kWh	0.082	0.078	0.075
2,500 h/a	in €/kWh	0.059	0.056	0.054
4,500 h/a	in €/kWh	0.033	0.031	0.030

[a] operation, maintenance, insurance, miscellaneous

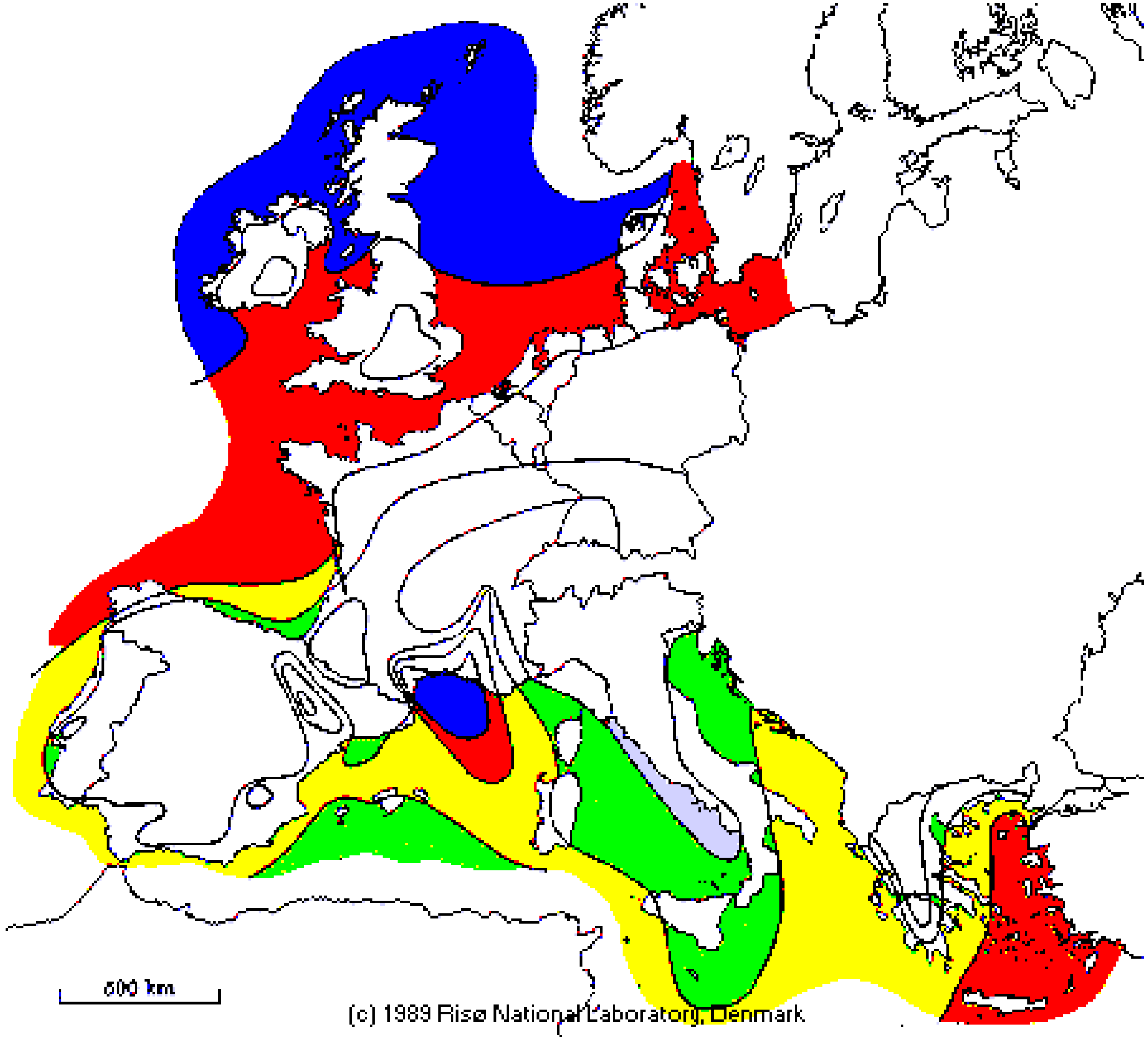
Share of European wind electric generation [European Commission, 2007]



World Wide Wind speed map

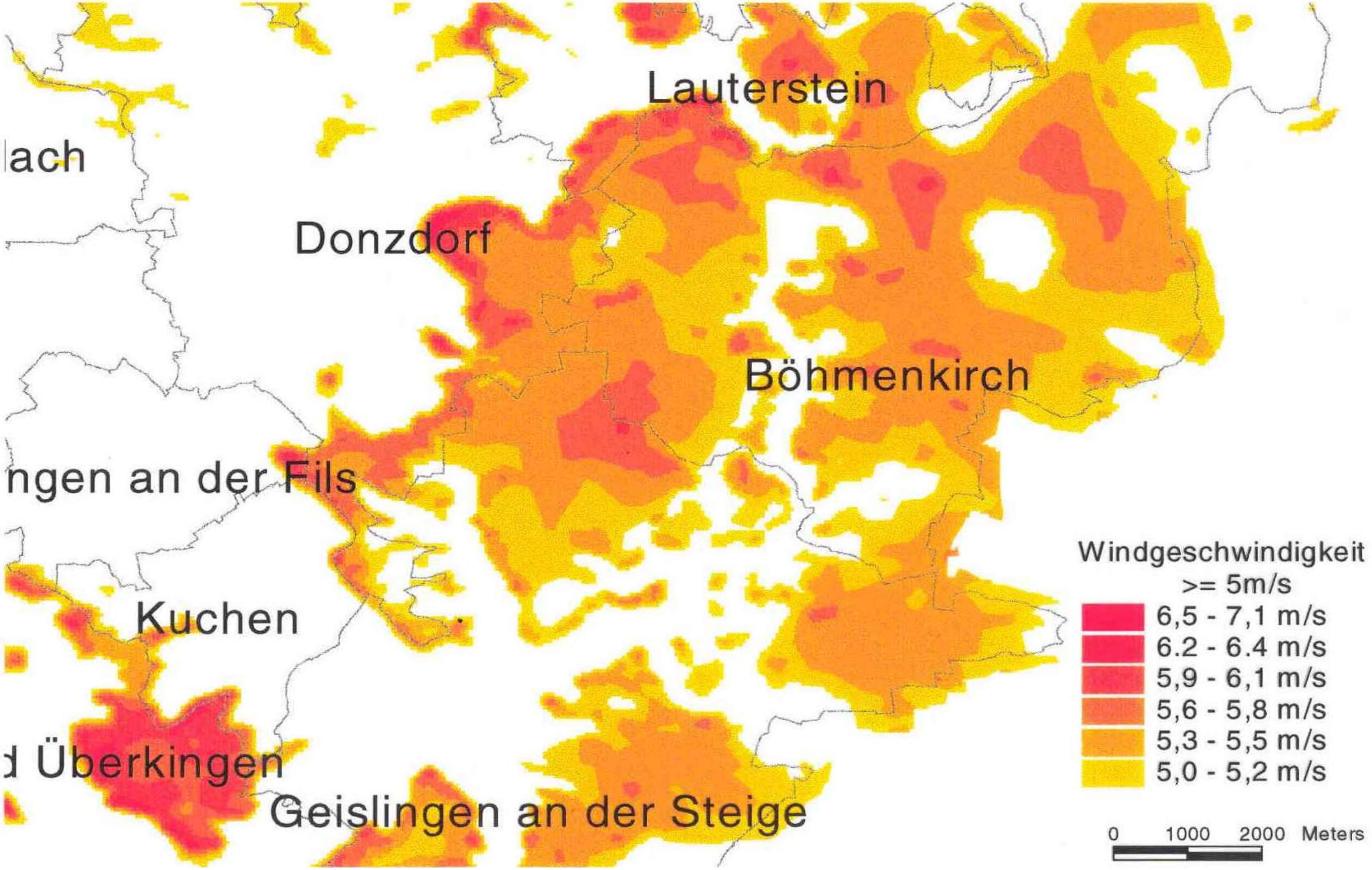
source: Kaltschmitt

	50 m ms -1	100 m ms -1
blue	> 9.0	> 10.0
red	8.0 – 9.0	8.5 – 10.0
yellow	7.0 – 8.0	7.5 – 8.5
green	5.5 – 7.0	6.0 – 7.5
light violet	< 5.5	< 6.0



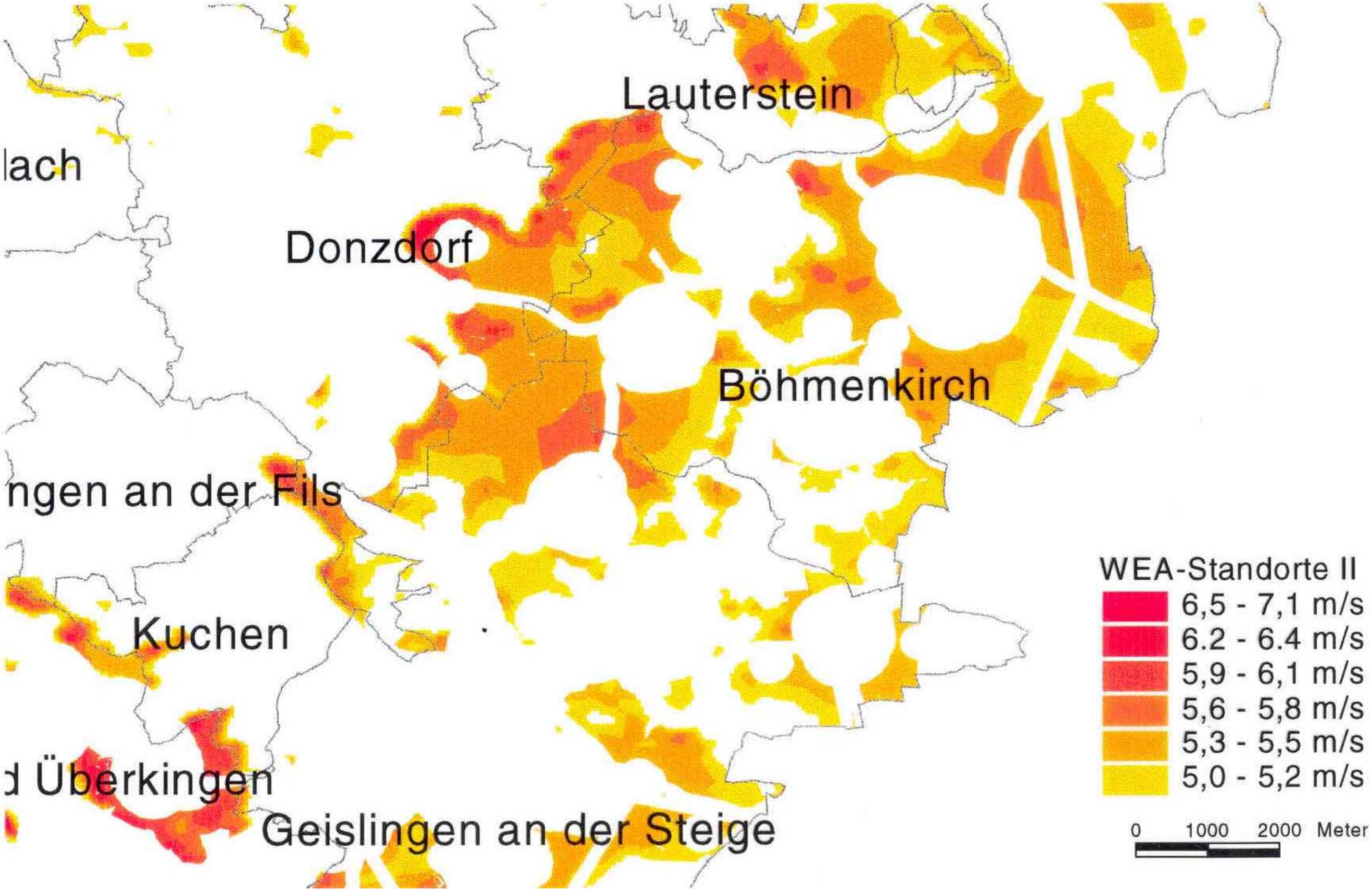
Local areas with wind speed > 5 m/s

source: Kaltschmitt



Useable local areas with wind speed > 5 m/s

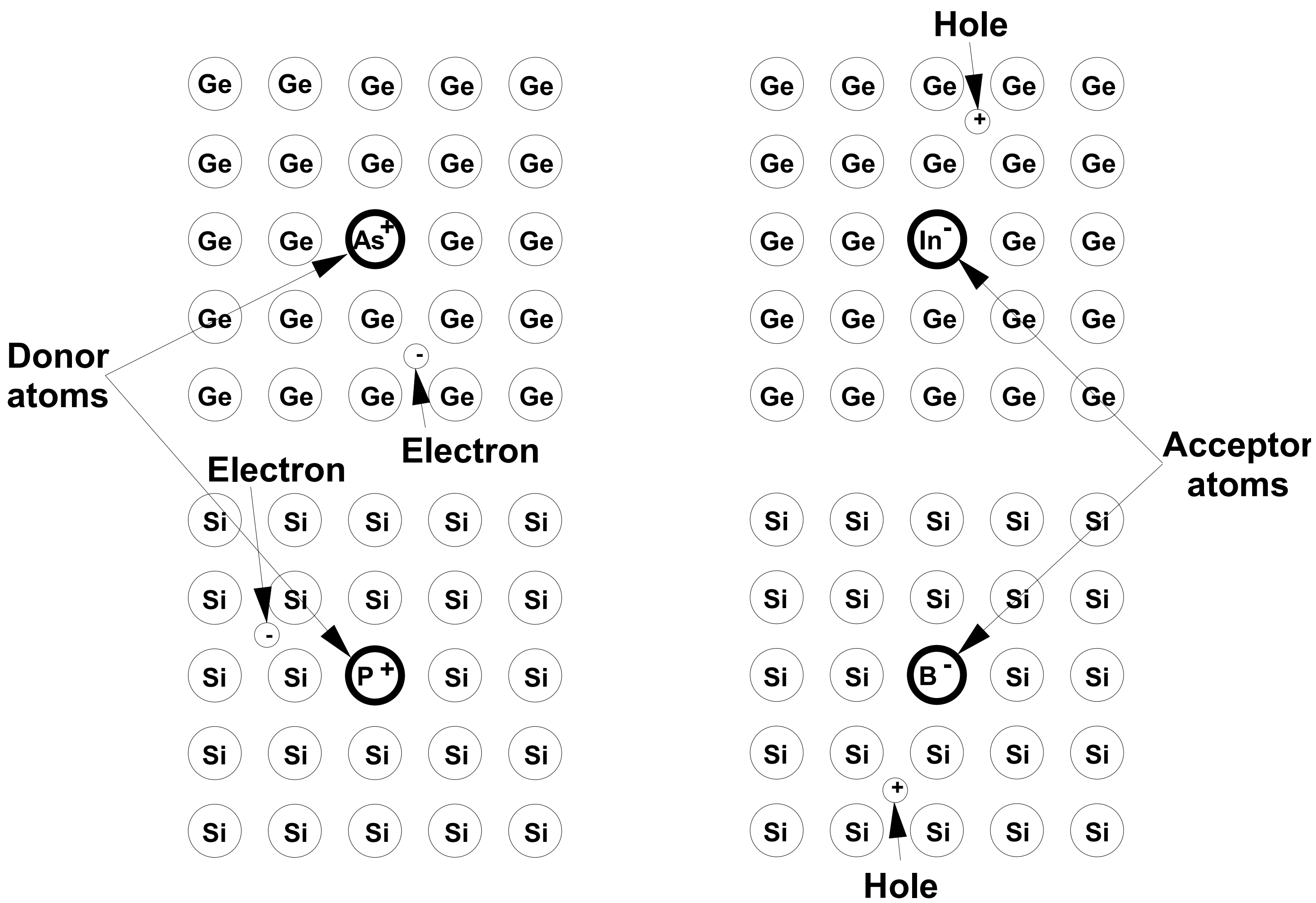
source: Kaltschmitt



Photovoltaics Energy

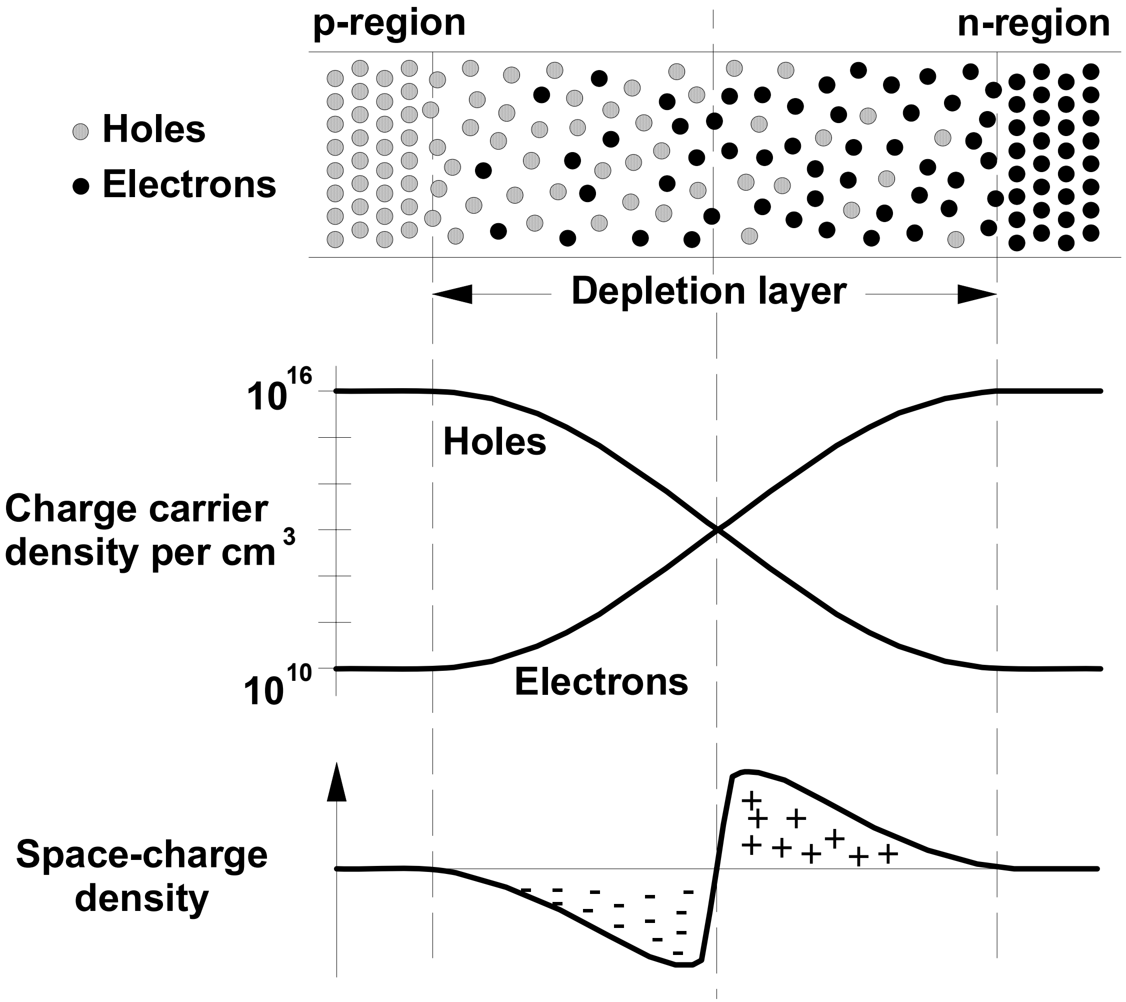
PV-Theorie: Donation of SI-Cristal

Source: Kaltschmitt, Streicher, Wiese, Renewable Energy



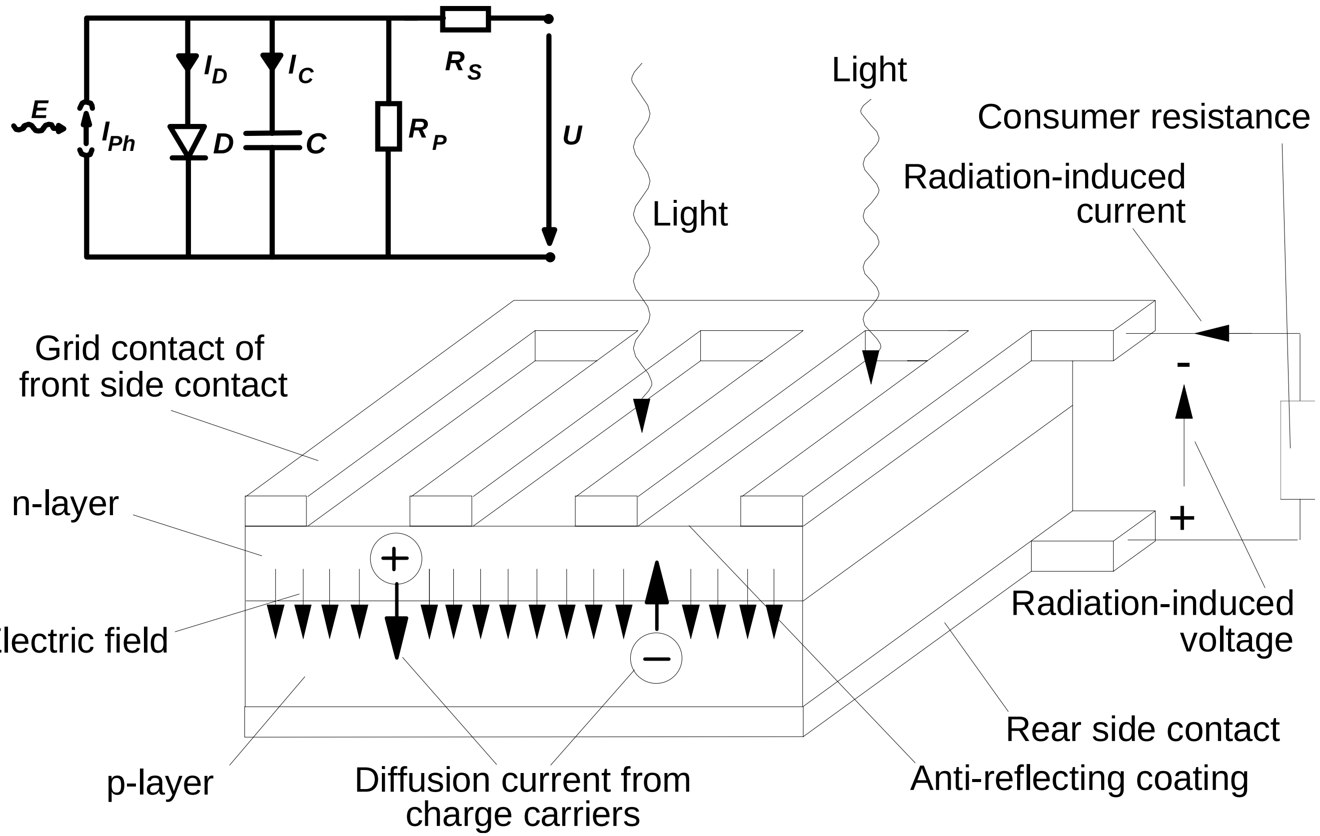
PV-Theorie: Barrier at p-n-junction

Source: Kaltschmitt, Streicher, Wiese, Renewable Energy



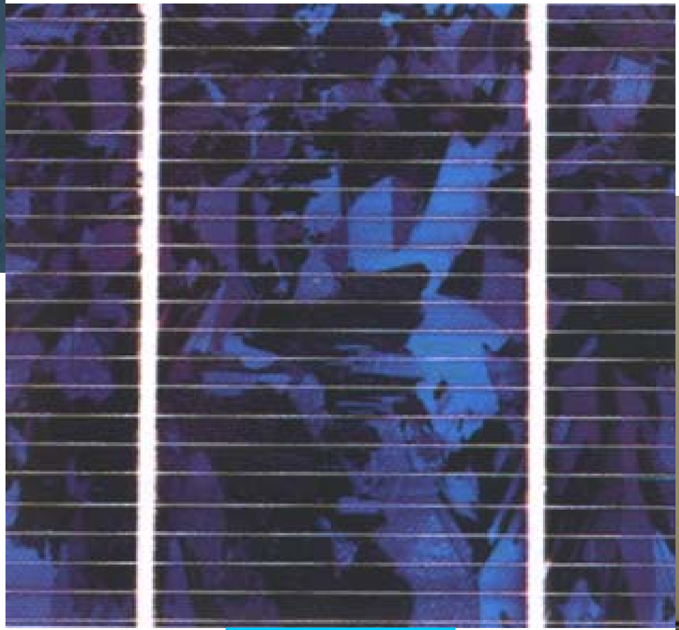
PV-Theorie: Structure of Solar Cell

Source: Kaltschmitt, Streicher, Wiese, Renewable Energy

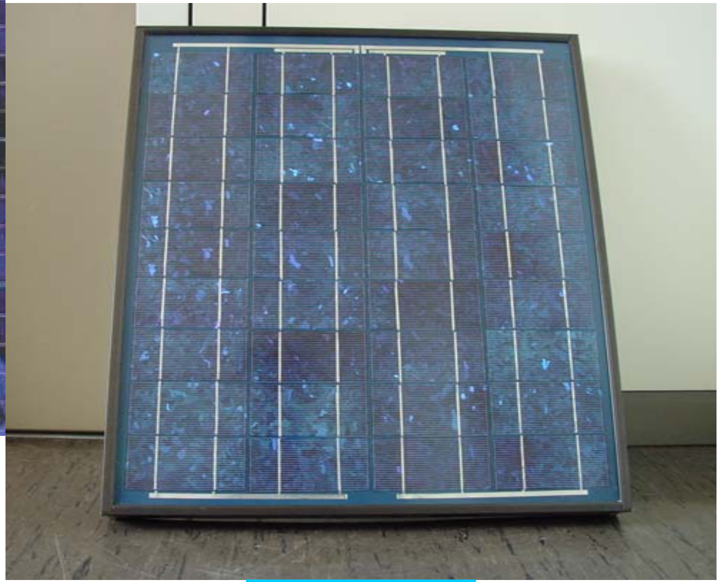


Disk, Cell, Module

Disk



Cell

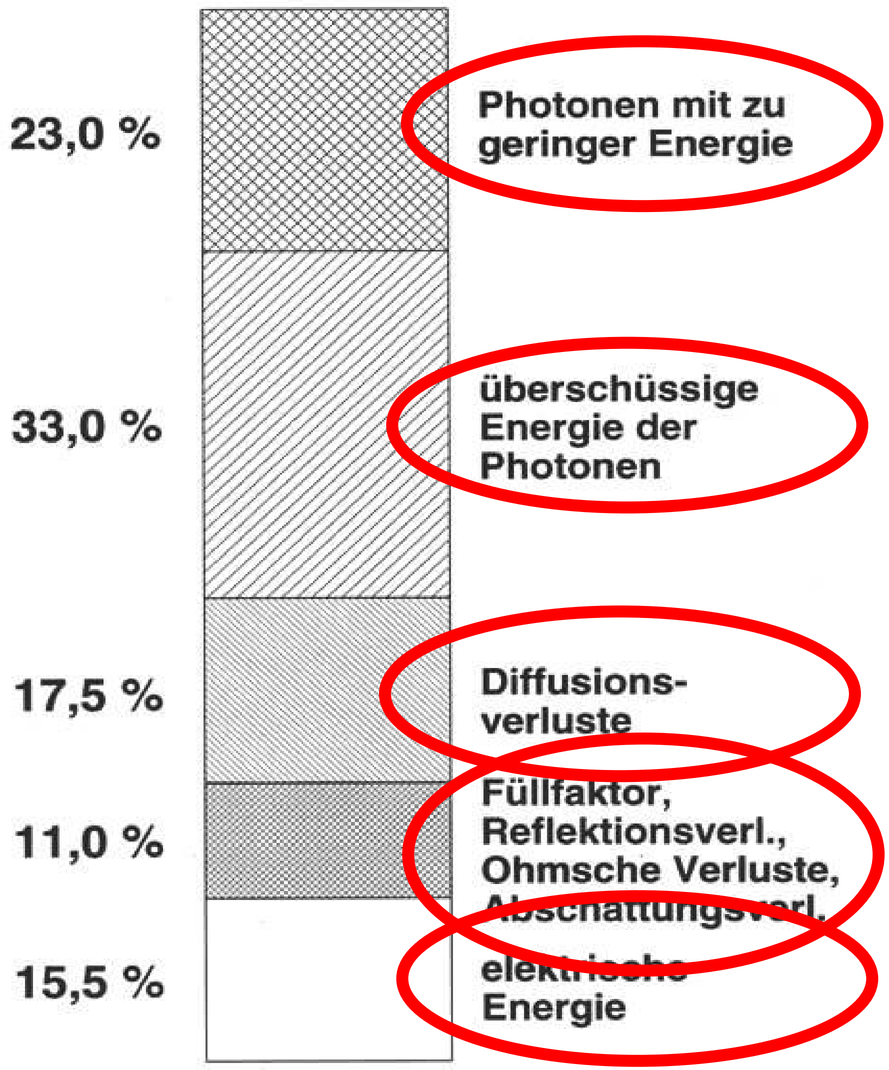


Module

source: Kaltschmitt

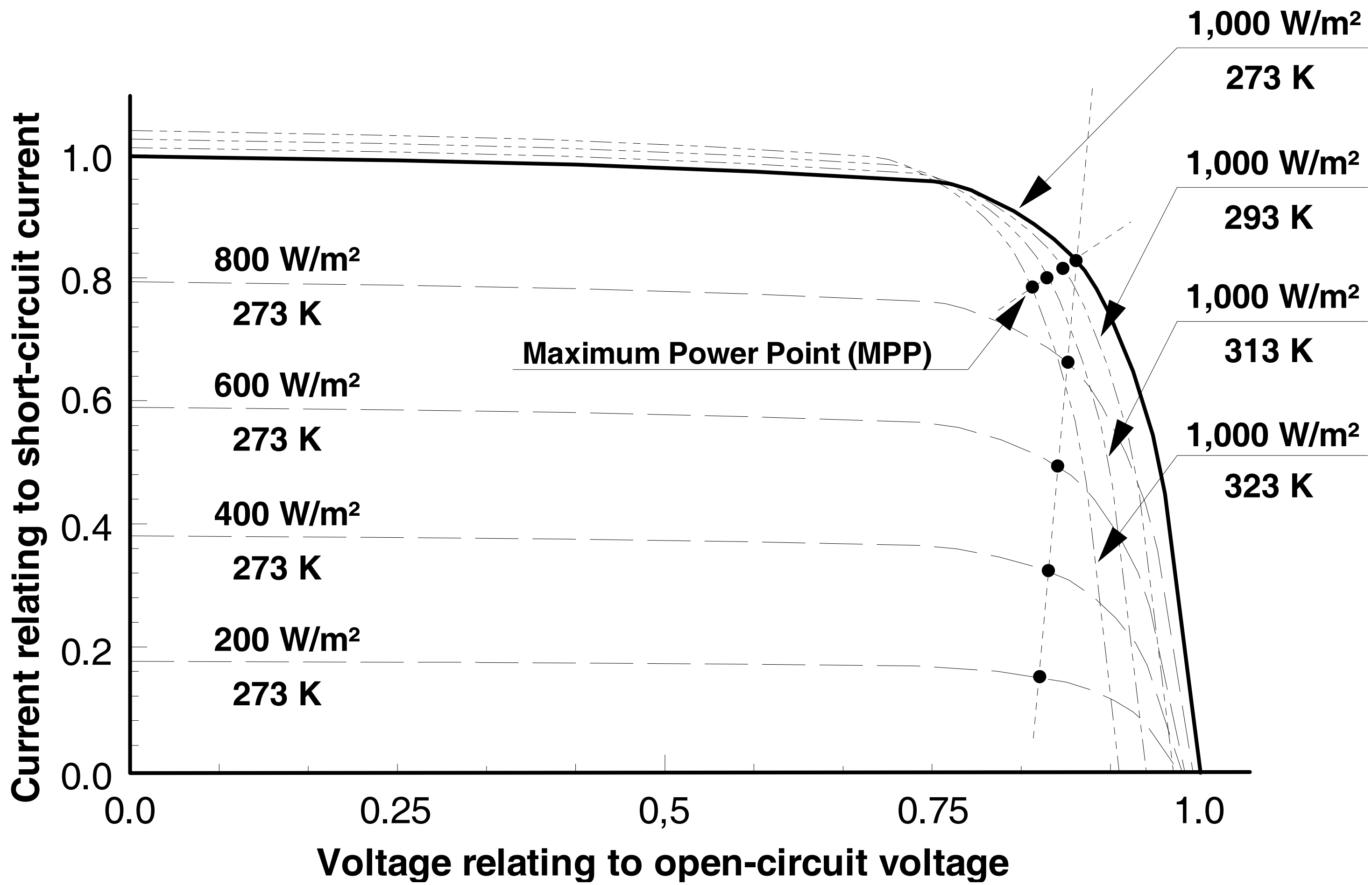
Losses of a Solar Cell (Example values)

source: Kaltschmitt



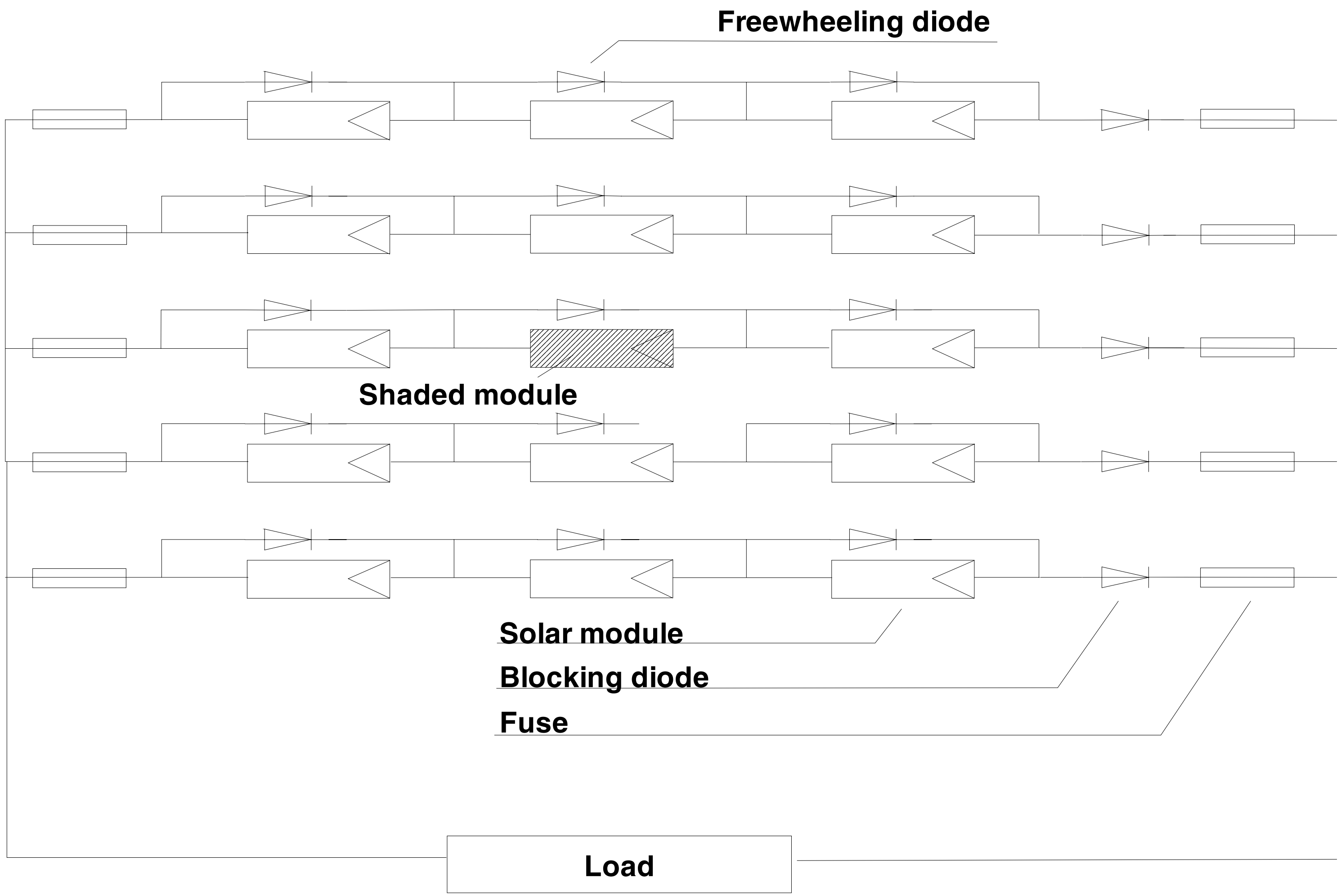
PV-Theorie: Cell charactersitic (irradation and temperature)

Source: Kaltschmitt, Streicher, Wiese, Renewable Energy



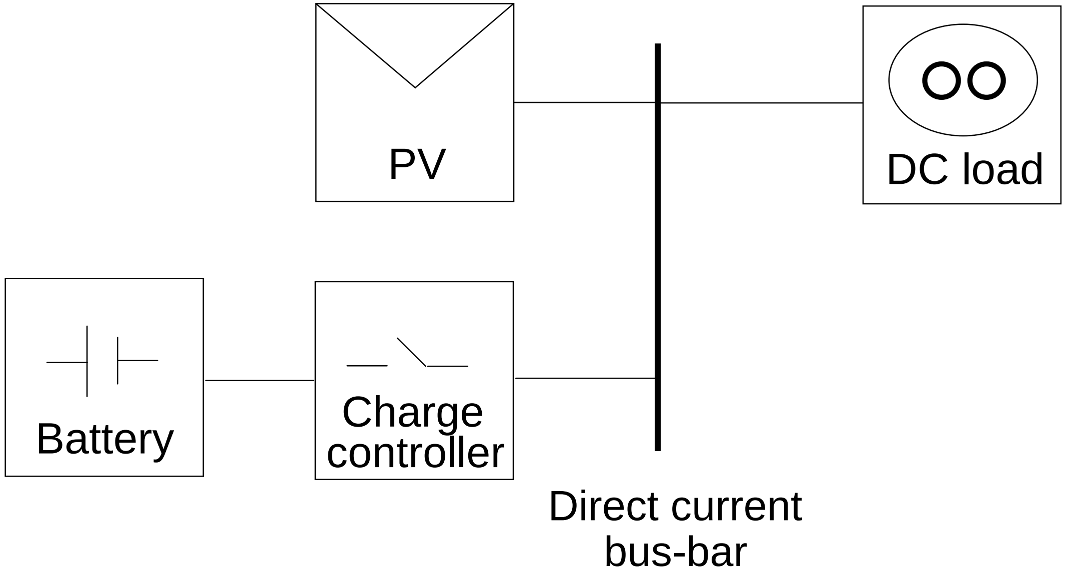
Series and parallel connection of Modules

Source: Kaltschmitt, Streicher, Wiese, Renewable Energy



Island Systems

Source: Kaltschmitt, Streicher, Wiese, Renewable Energy



Island Systems

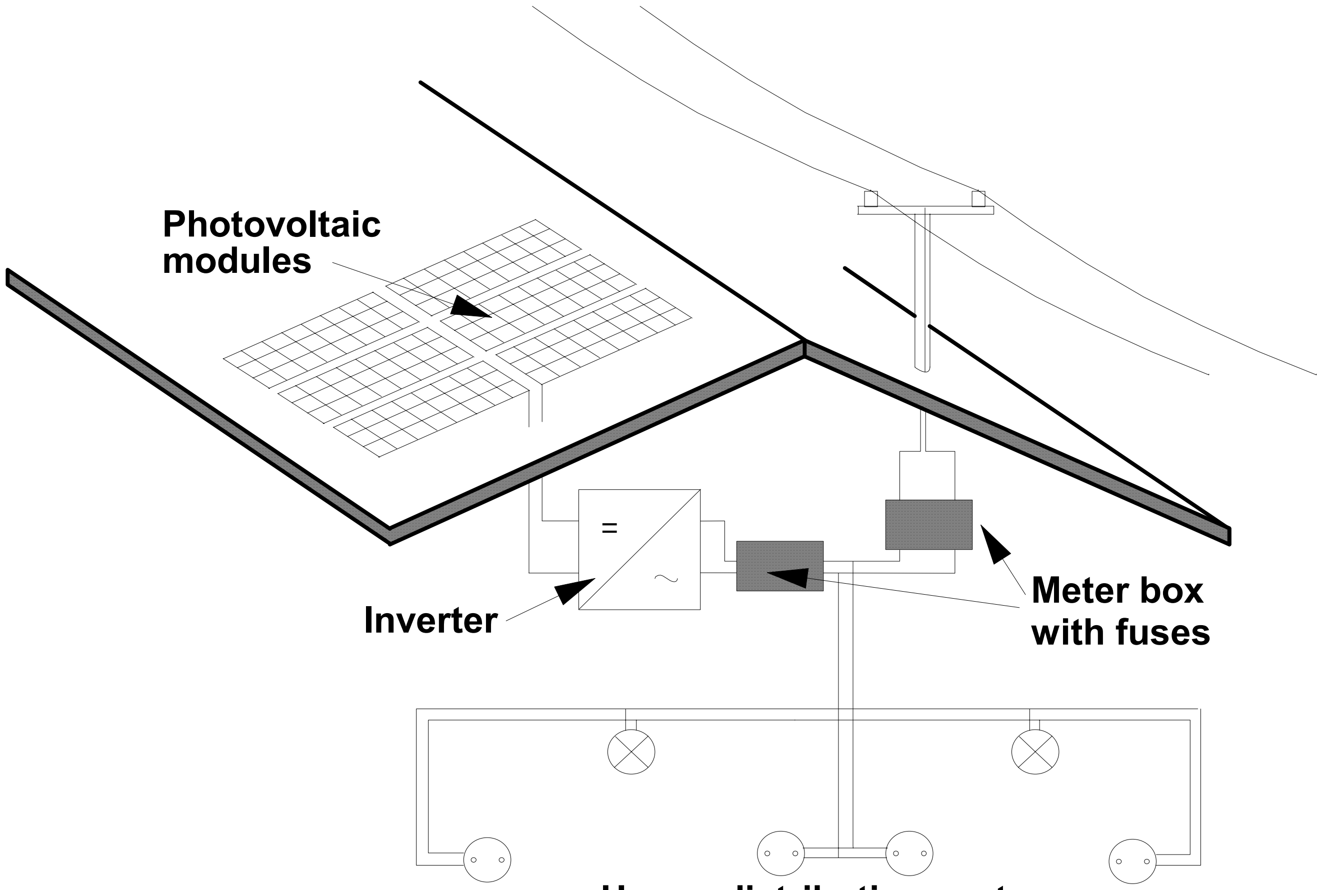
Source: Streicher

10 Year old system in Syria,

Modules Batteries ??

Grid connected Systems

Source: Kaltschmitt, Streicher, Wiese, Renewable Energy



Grid connected Systems, Costs

Source: Kaltschmitt, Streicher, Wiese, Renewable Energy r

			System I	System II	System III
Nominal system capacity		in kW	3	20	2,000
Full load hours	Site 1	in h/a	800	800	900
	Site 2	in h/a	1,000	1,000	1,100
	Site 3	in h/a	1,200	1,200	1,300
Investments					
Modules		in k€	7.8	46.3	4,134
Inverter		in k€	1.1	7.8	741
Further components		in k€	1.2	7.9	872
Miscellaneous		in k€	2.9	16.0	1,667
Total		in k€	13.0	78.0	7,414
Operating costs[a]		in k€/a	0.03	0.8	108
Power generation costs	Site 1	in €/kWh	0.42	0.41	0.36
	Site 2	in €/kWh	0.34	0.33	0.30
	Site 3	in €/kWh	0.28	0.27	0.25

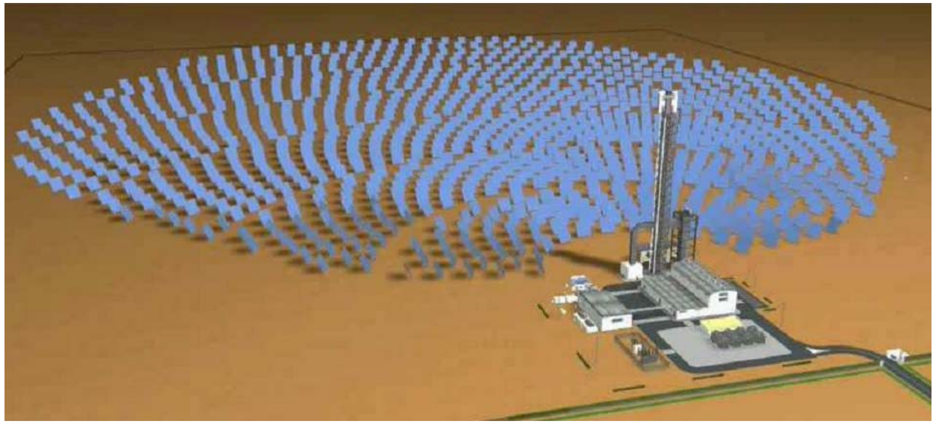
[a] operation, maintenance, miscellaneous.

Conclusion PV

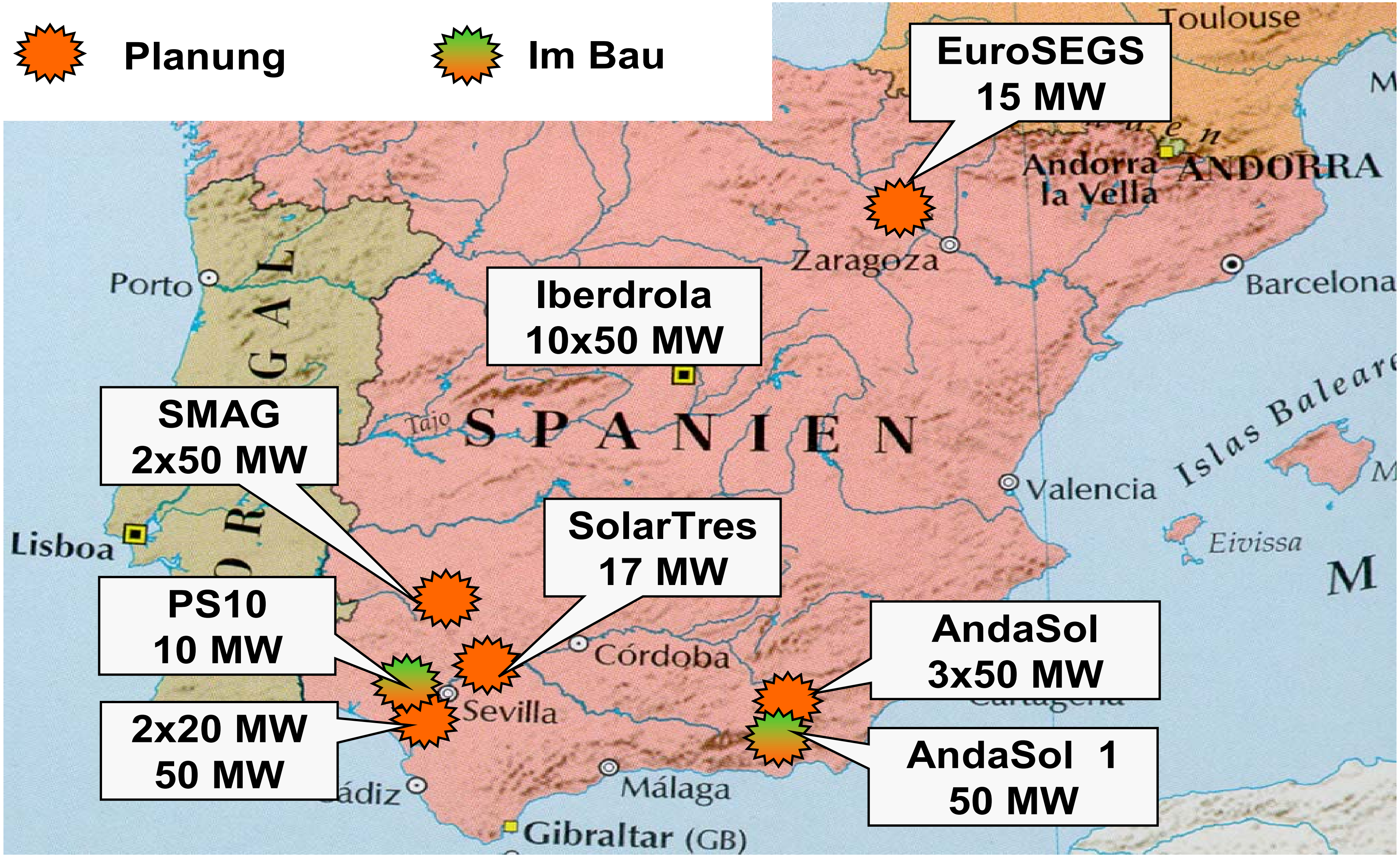
- Technology is well developed
- Annual electric efficiency is about 10 %
- Prices are slowly decreasing but still very high
- Island plants are economically feasable
- Grid connection plants are only economic with
- funding schemes
- Share of PV in the energy system is very small

Solarthermal Power Plants

Quelle: Weinrebe/SBP



Spanish Solar Thermal Power Plant Activities

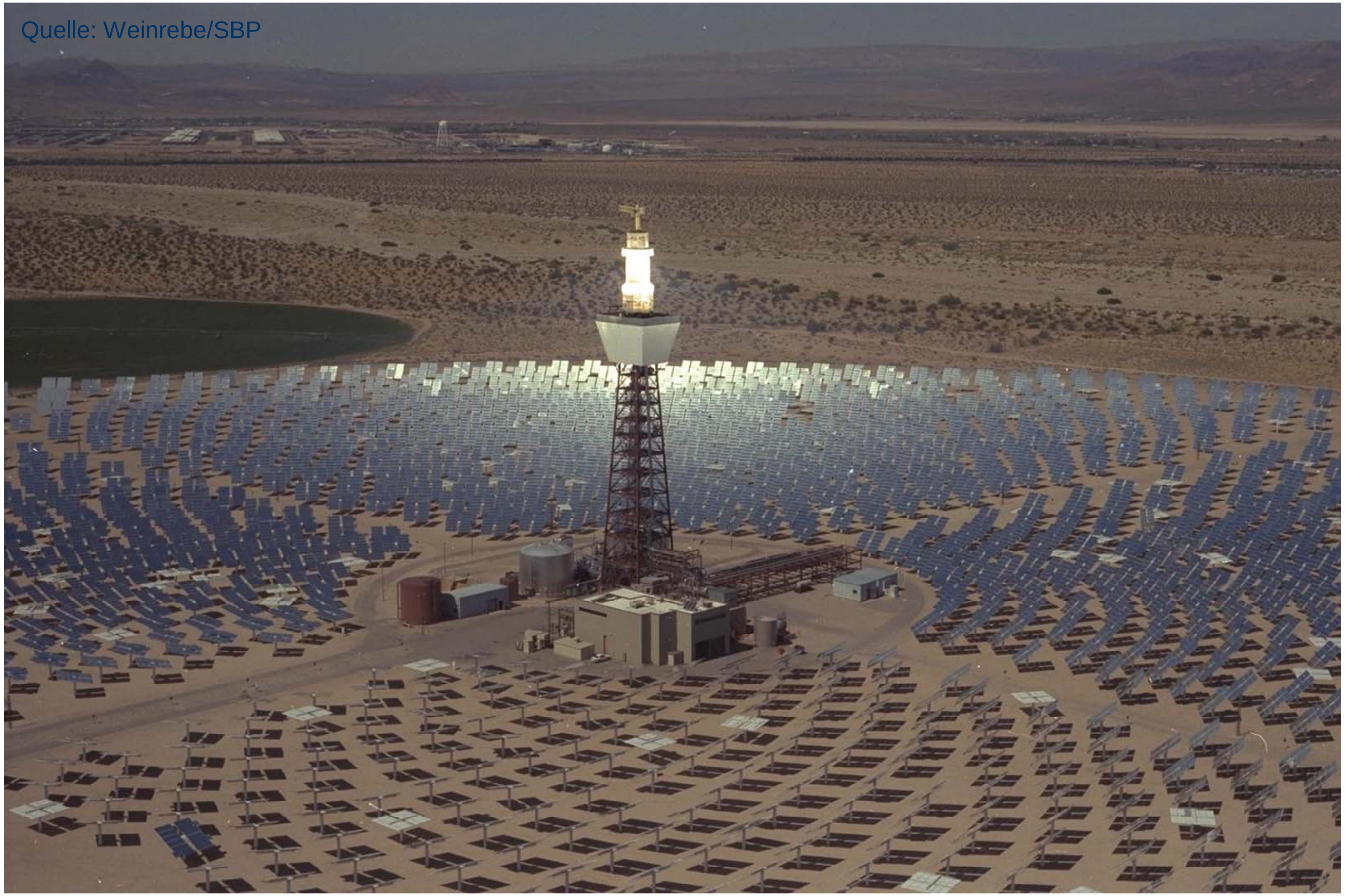


Solarthermal Power Plants
Heliostats

Quelle: Weinrebe/SBP

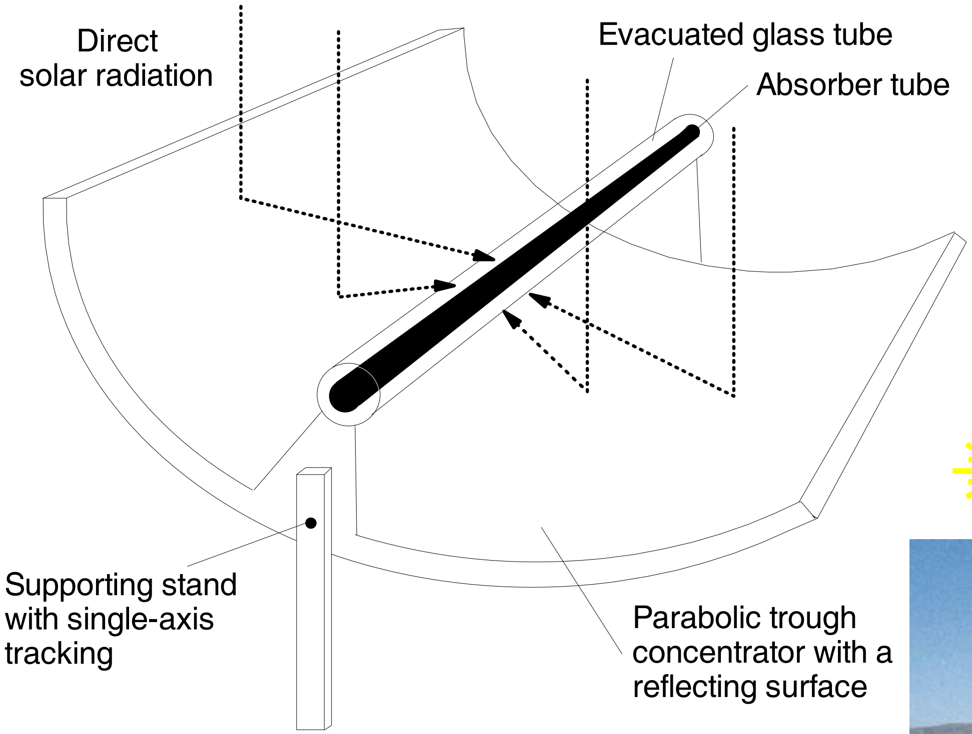
Source: Kaltschmitt

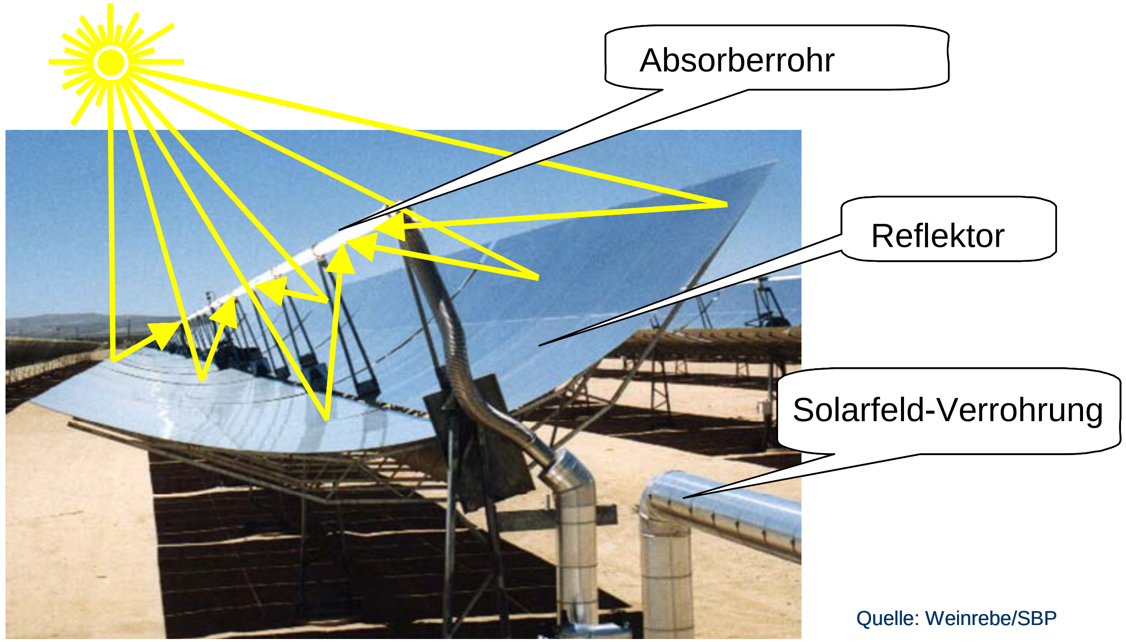
Solarthermal Power Plants
Solar Two Molten Salt



Source: Kaltschmitt

Solarthermal Power Plants
Parabolic Trough

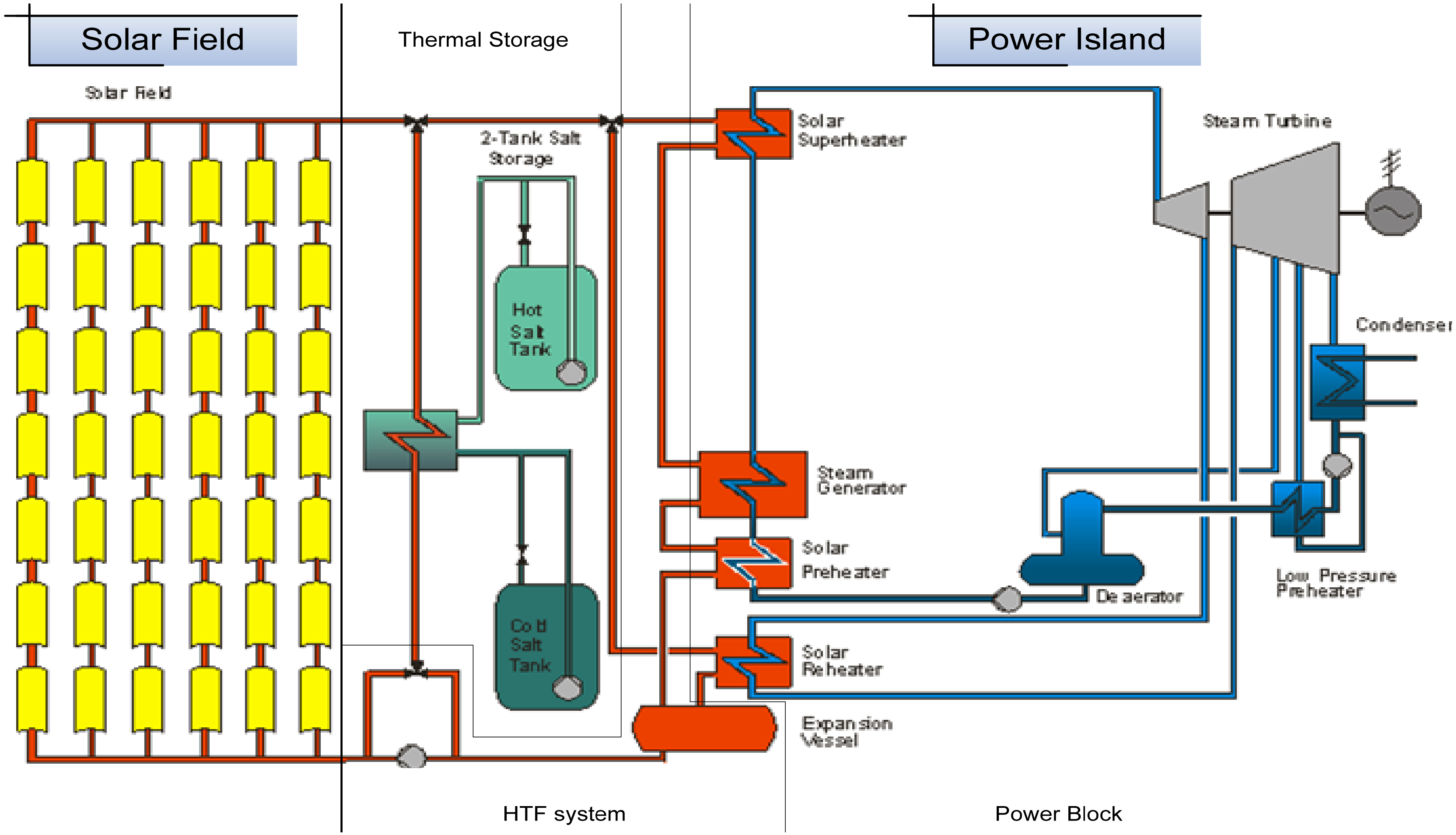




Quelle: Weinrebe/SBP

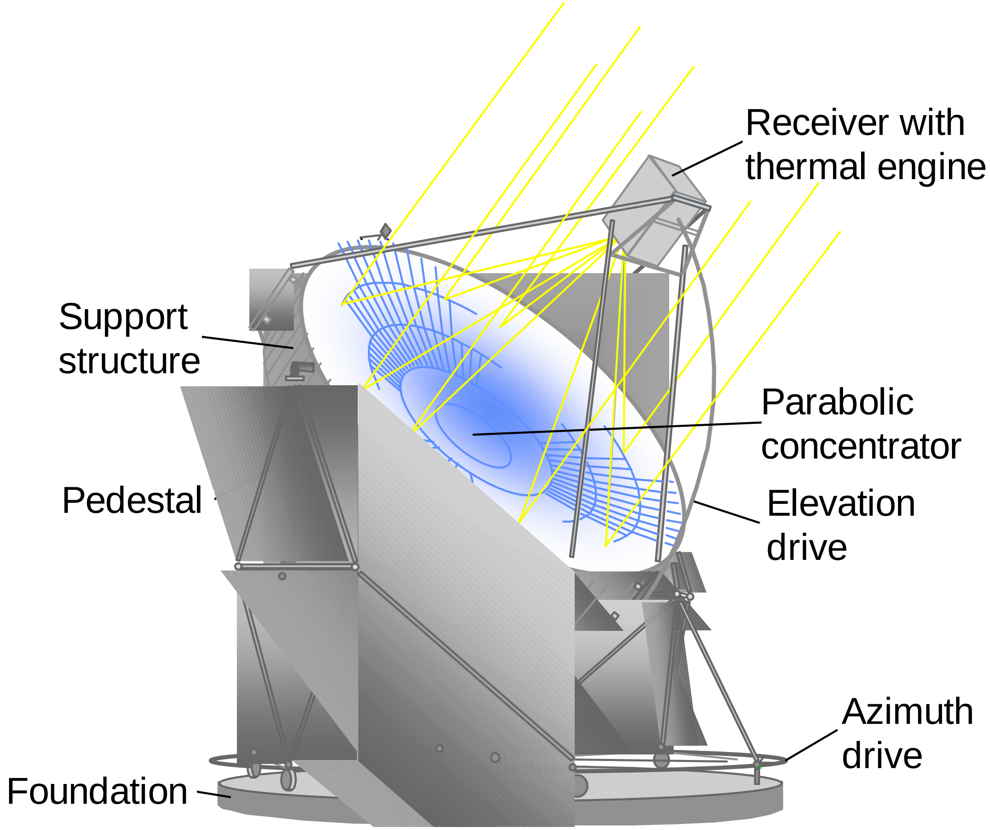
Source: Kaltschmitt

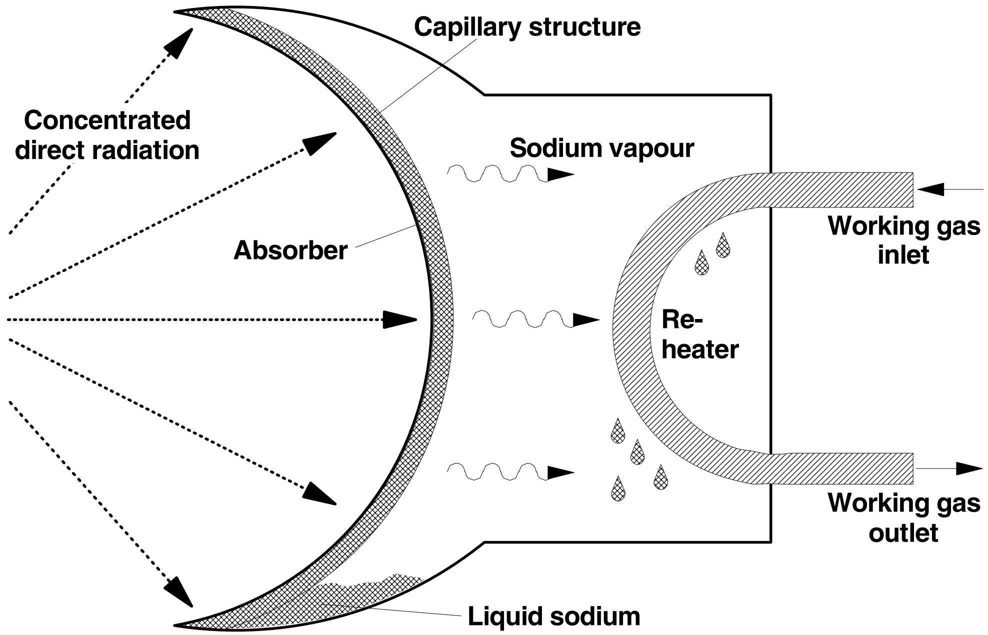
Systemlayout of the Andasol-Plant



Source: Kaltschmitt

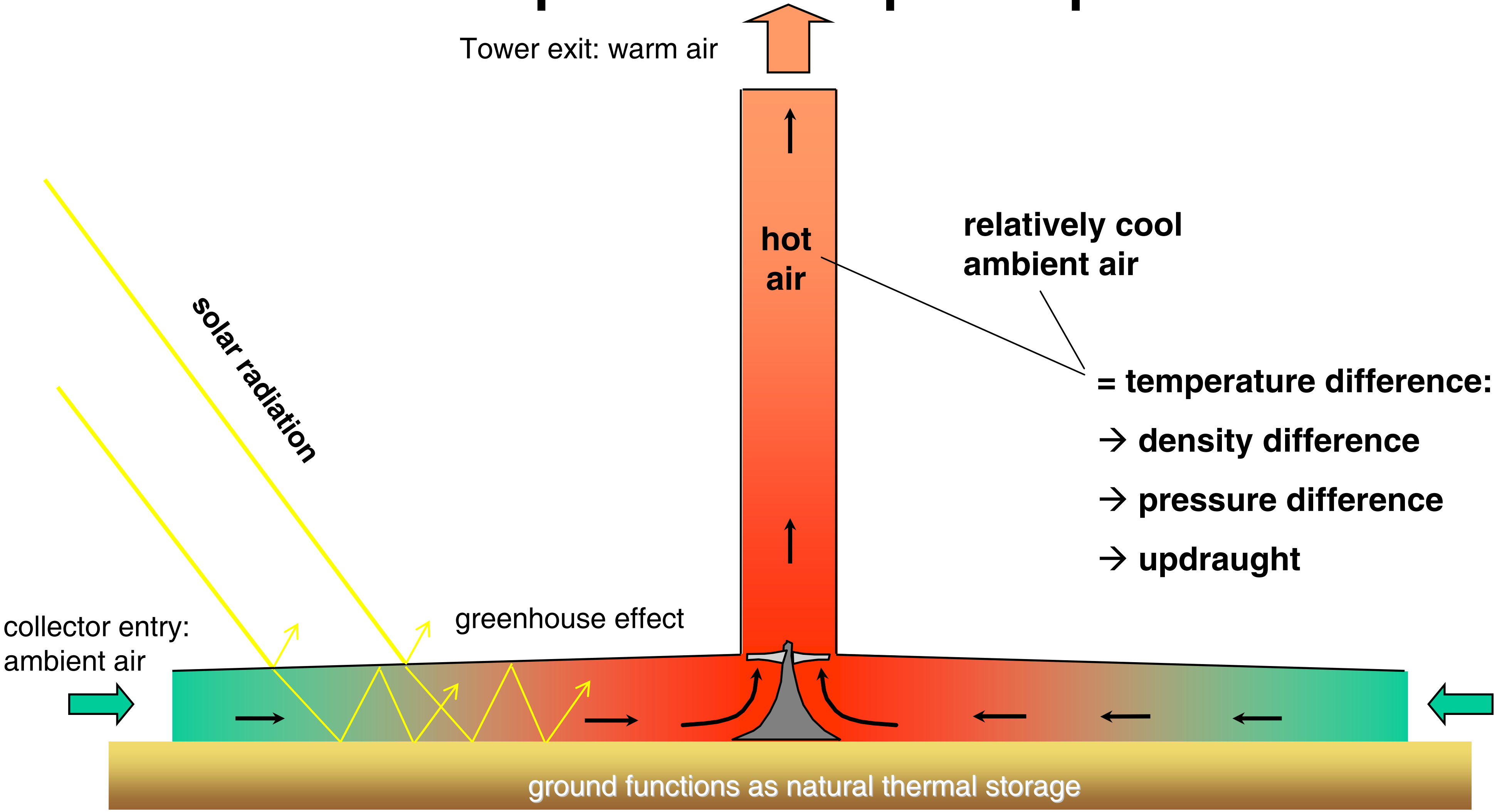
Solarthermal Power Plants
Dish Stirling Principle





Source: Kaltschmitt, Streicher, Wiese, Renewable Energy

Principle of solar updraft tower power plants



Quelle: Weinrebe/SBP

Electricity from Biomass

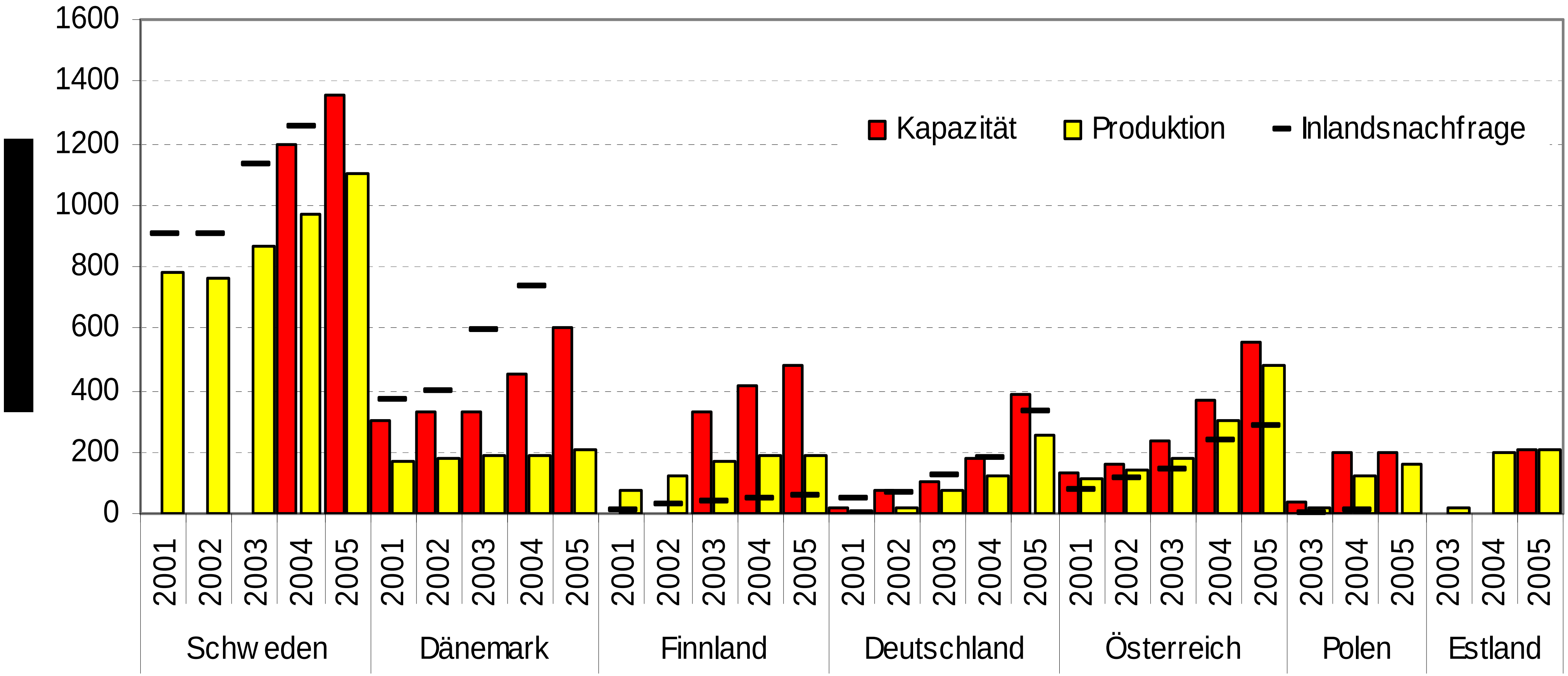
Efficiency of Plants

Wood	0.55 %
Gras land	0.30 %
Cultivated Land	0.30 %
Sweet Water	0.50 %
Ozeans	0.07 %
Intensive cultivation	
Sugar Cane	4.8 %
Corn	3.2 %
Sugar beet	5.,4 %
Theoretical Efficiency	33.5 %

source: Kaltschmitt

Biogeneous Solid Fuels
- Pellets -

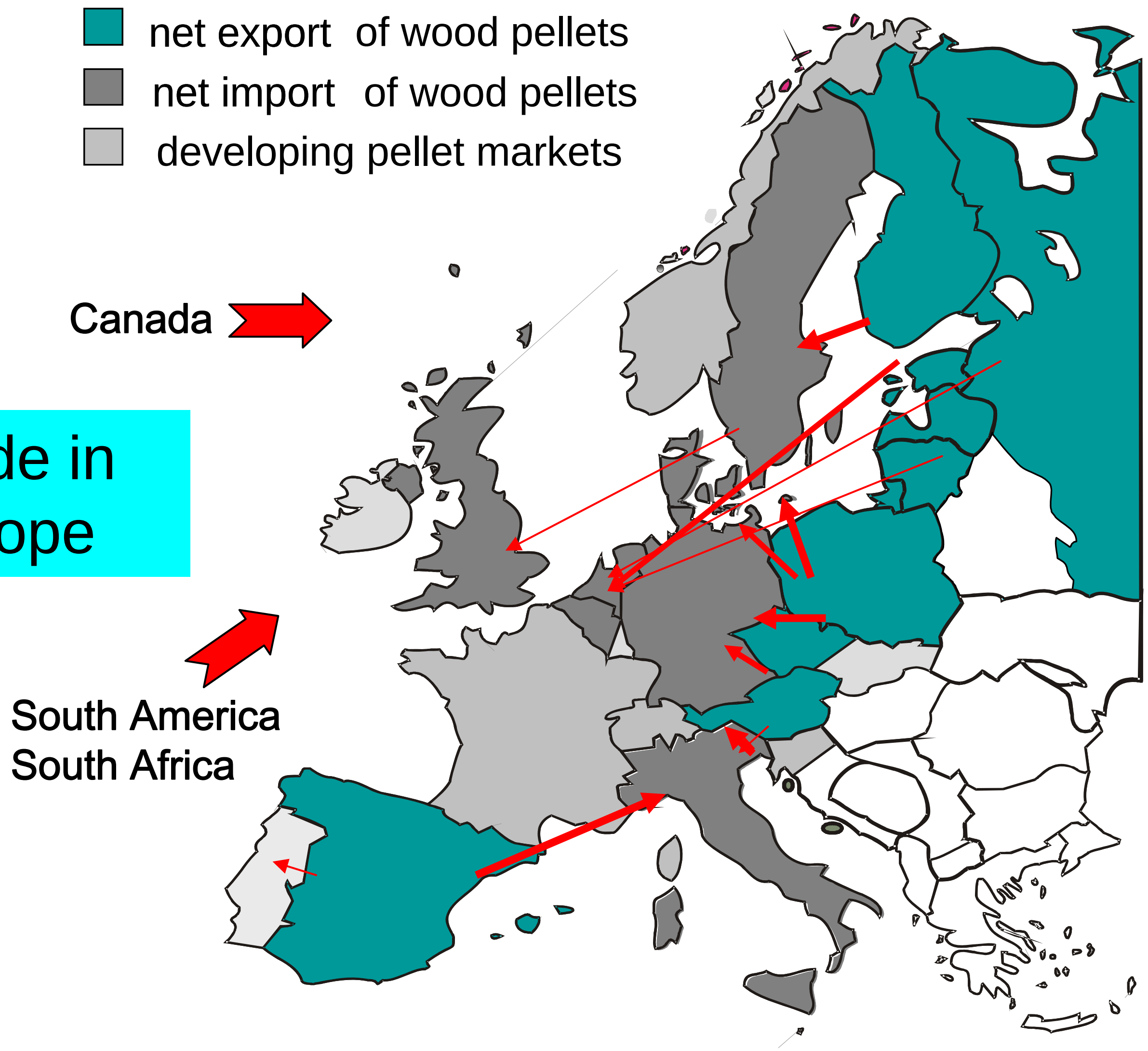
Pelletproduction,–production capacity and domestic need in various European States



source: Kaltschmitt

Biogeneous Solid Fuels

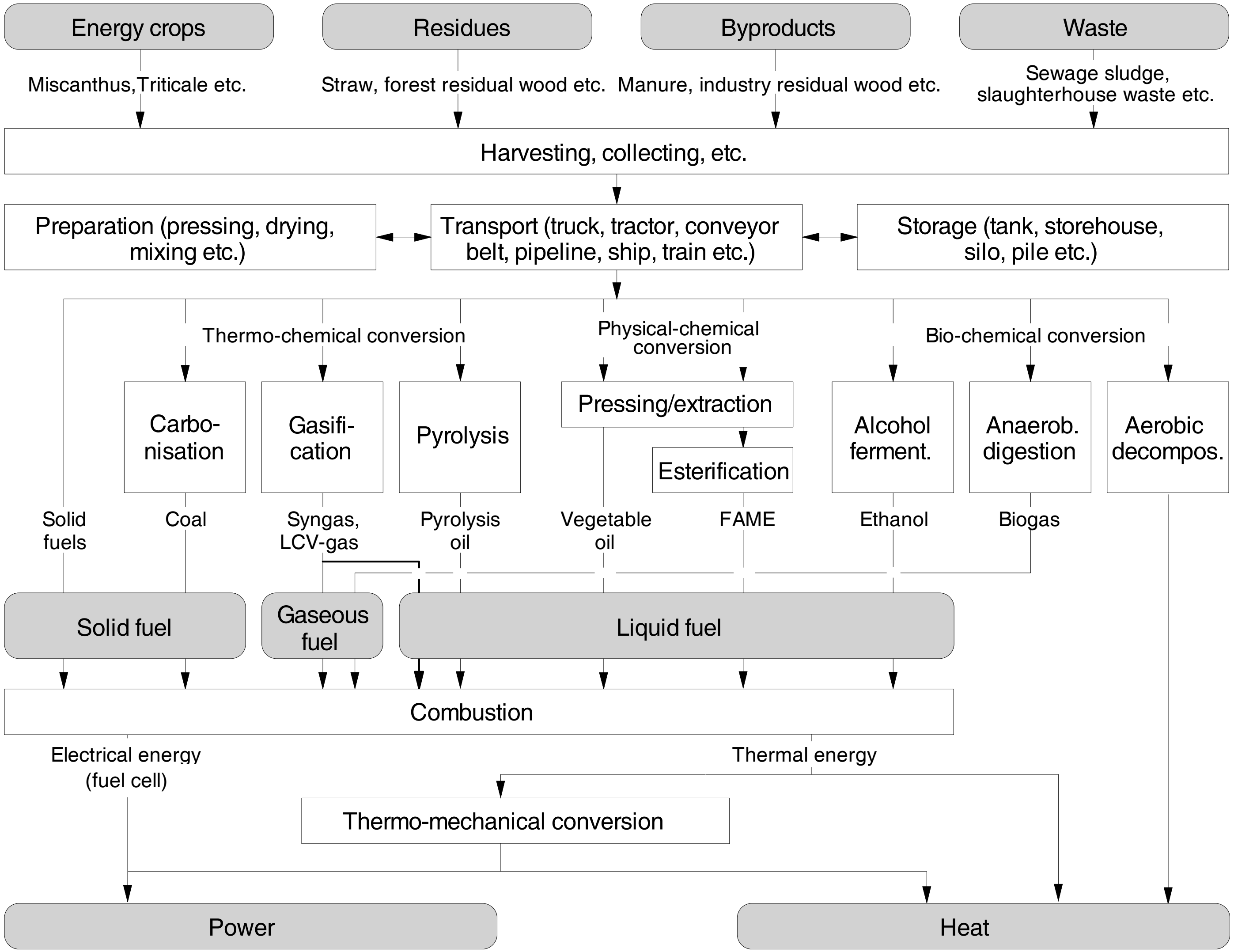
- Pellets -



Pellets Trade in and to Europe

source: Kaltschmitt

Energy from biomass



source: Kaltschmitt, Streicher, Wiese

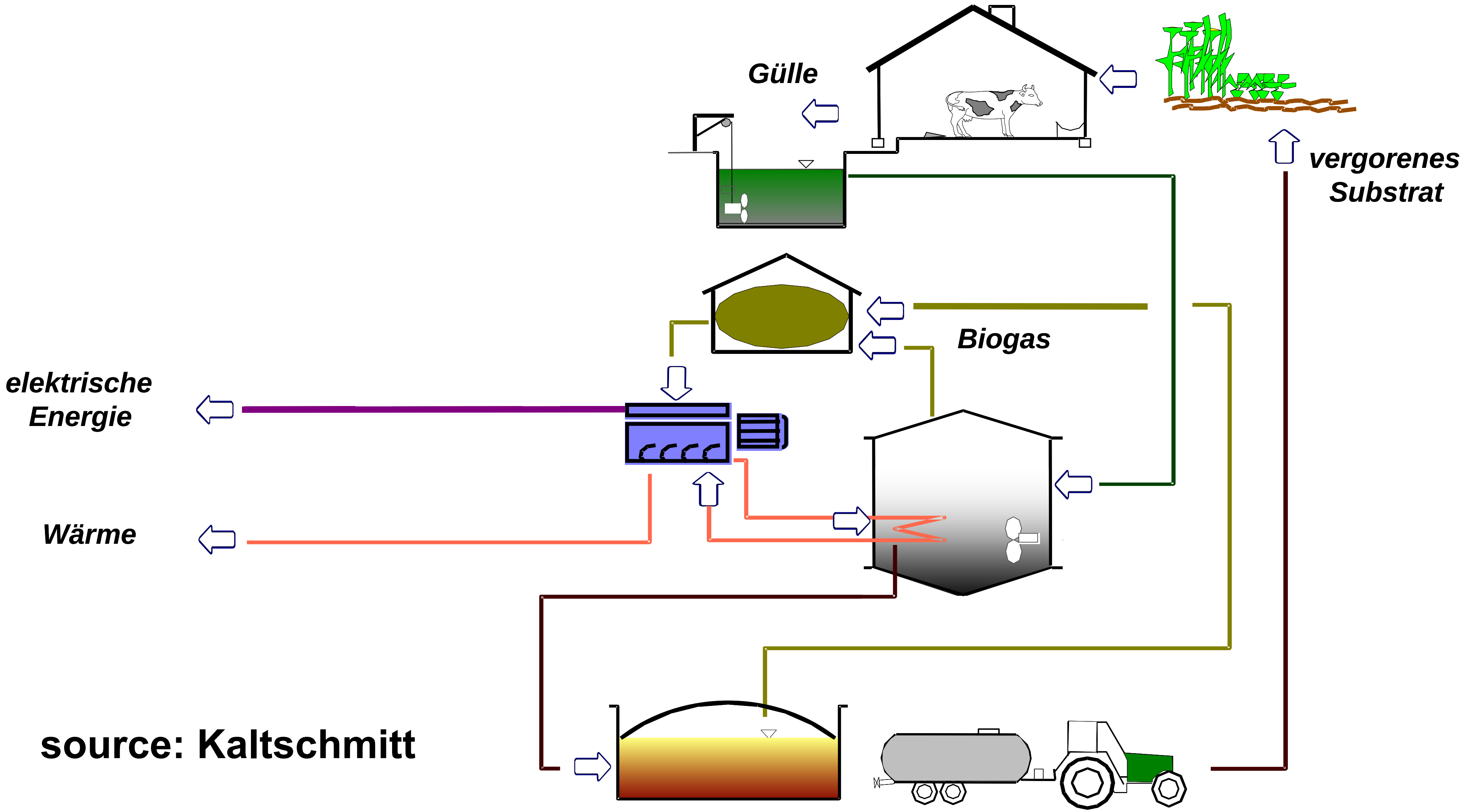
Electricity Production "Biogeneous Solid Fuels "

source: Kaltschmitt

Worldwide Electricity Production from solid Biomass

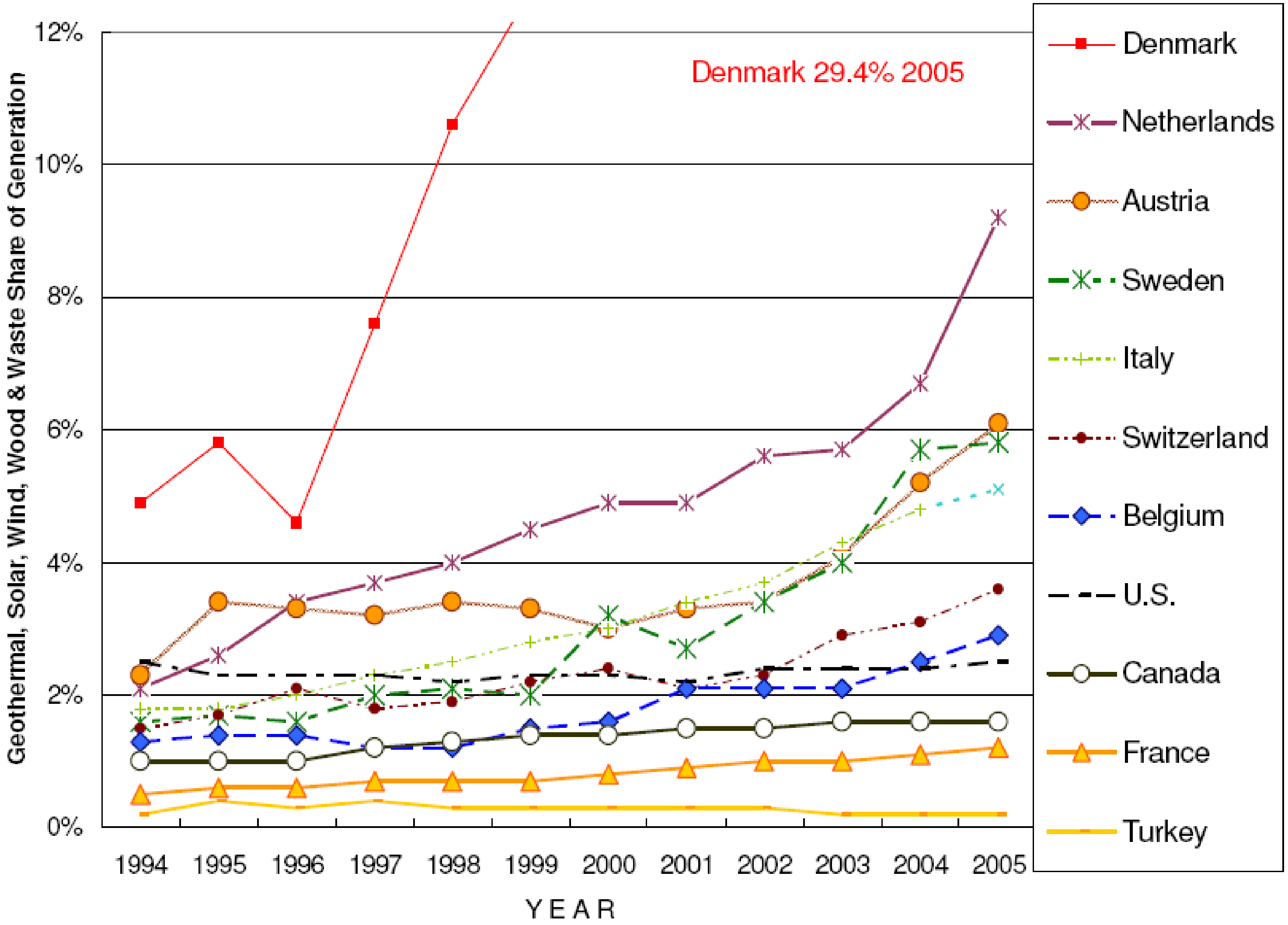
- World
  - Installed Electric Power : 37 GW (2004) (ca. 50 % OECD, 50 % not OECD)
  - Potential Electricity Production : 150 to 260 TWh/a (225 TWh) (2004) (OECD 2004: 16,1 GW bzw. 97 TWh; about 60 % from KWK)
- EU
  - Installed Electric Power : 6,2 GW (2004)
  - Potential Electricity Production : 35 TWh (2004) (+23 % ggb. 03)
- (Org. Waste Fraktion)
  - (OECD-States: Installed Electric Power : 7,6 GW
    Potential Electricity Production : 21 TWh (rund 1/3 aus KWK))
  - (EU-15: Installed Electric Power : 3,3 GW
    Potential Electricity Production : 10 TWh)

Electricity Production
"Biogas"

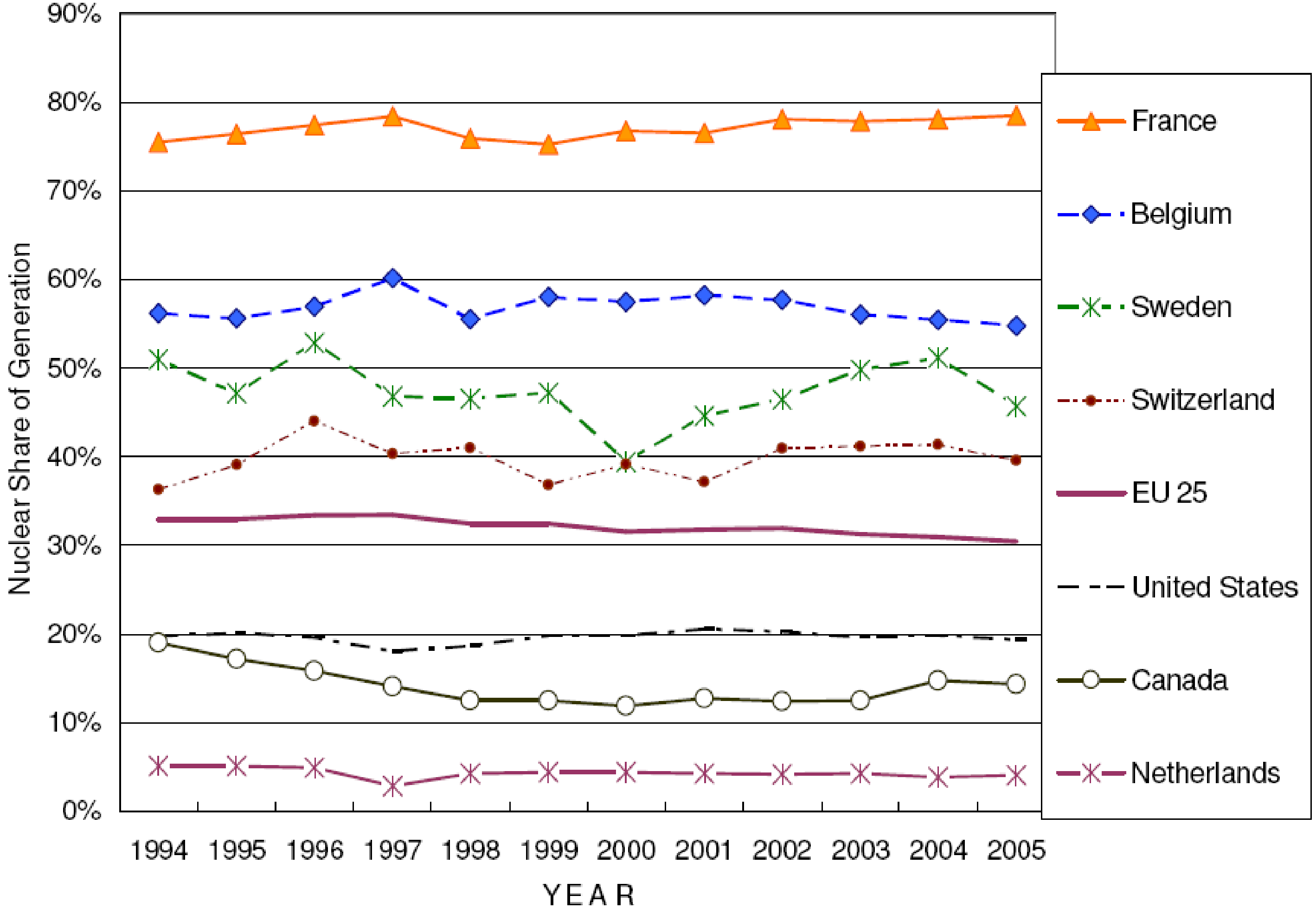


source: Kaltschmitt

Share non-hydro renewables in power generation [Energy Information Administration, '07]



Share of Nuclear in power generation [Energy Information Administration, '07]



Energy and Environment

Technical Solutions to use Renewable Energy Carriers

Part C: Transportation

IWT TU Graz
Institut für Wärmetechnik

Emissions of Transportation

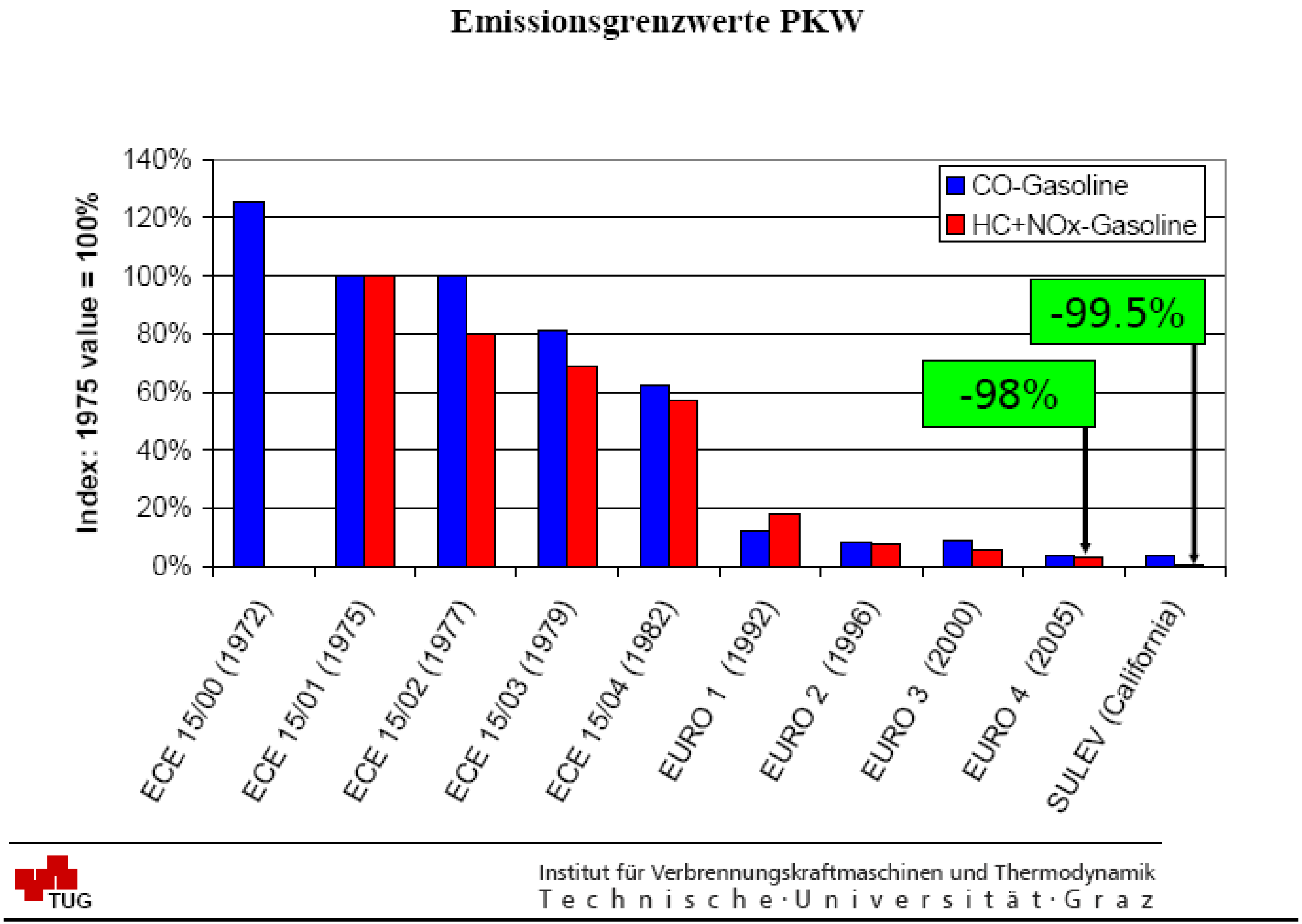
TU Graz
Graz University of Technology

Source: Riahi 2007

	Horses	Cars (ca. 1920)	Cars (1995)
Engine efficiency, %	4	10	20
Wastes			
Solid	400	–	–
Liquid	200	–	–
Gaseous,			
including:			
Carbon (CO_2)[d]	170	120	70
Carbon (CO)	–	90	2
Nitrogen (NO_x)	–	4	0.2
Hydrocarbons	2[e]	15	0.2

d Total carbon content of fuel
e Methane

Emissions- limits Pasenger-Cars Europe



Possibilities for CO2-Emission Reductions

Effective but „psycholgically problematic“ solutions

- Less Mobility (Internet Conferences etc.)
- Shift to public transportation, bicycle, walking
- Smaller cars (3-l/100 km car was already on the market, VW-Lupo)
- Only cars with maximum speed of 130 km/h

More common solutions

- More efficient engines
- Gas engines (but gas is less efficient and has therefore only little less CO2 emissions)
- Biofuels (problematic with food production)
- Hydrogen (where does it come from), Fuel cell ??
- Electric vehicels (range, batteries??)

Existing Low Energy Vehicles

Some newer examples of efficient commercially available internal combustion-propelled vehicles:

- Audi A2 (3l) 1.16 MJ/km (3.0 l Diesel/100 km / 94 mpg UK / 78 mpg US) (discontinued)
- VW Lupo (3l) 1.16 MJ/km (3.0 l Diesel/100km / 94 mpg UK / 78 mpg US) (discontinued)
- VW Polo BlueMotion 3,(8–4,0 l/100 km Diesel (RL80/1268/EWG) 99–104 g/km 1,4 l; 59 kW)
- Kia Eco C'eed 3,9 l/100 km Diesel (2009) 4seater
- Citroën C1 HDi55 (4,1 l/100 km Diesel (RL80/1268/EWG) 109 g/km 1,4 l; 40 kW)
- Toyota Prius 1.45 MJ/km (Hybrid) (4.2 l/100 km / 67 mpg UK / 56 mpg US)
- Honda Insight 1.49 MJ/km Hybrid vehicle (4.3 l/100 km / 65 mpg UK / 54 mpg US) (discontinued)
- Honda Civic Hybrid 1.59 MJ/km (4.6 l/100 km / 55 mpg UK / 46 mpg US)
- Citroen C3 1.94 MJ/km Stop & Start (5.0 l Diesel/100 km / 56 mpg UK / 47 mpg US)

Electric Vehicles

Source: Wikipedia,
Indian Vehicle REVA

Current Problems of Electric Vehicles

- Only a few important European car producers offer affordable EVs in selected markets, but at prices that are higher than those for comparable conventional vehicles.
- European manufacturers are designing better internal combustion engine vehicles with enhanced power trains and gasoline direct-injection (GDI) and turbo direct-injection (TDI) drives, which offer energy efficiency and high performance.
- Attractive EVs from Japanese producers are available only in very selected markets and in small numbers.
- Car dealers around the world are not motivated to offer or sell EVs.
- New vehicle and technology concepts, such as "3-litre cars" in Europe (80 mpg) or fuel cell vehicles make potential customers uncertain as to the current state of EVs and induce them to put off the buying decision.

Current EV Market

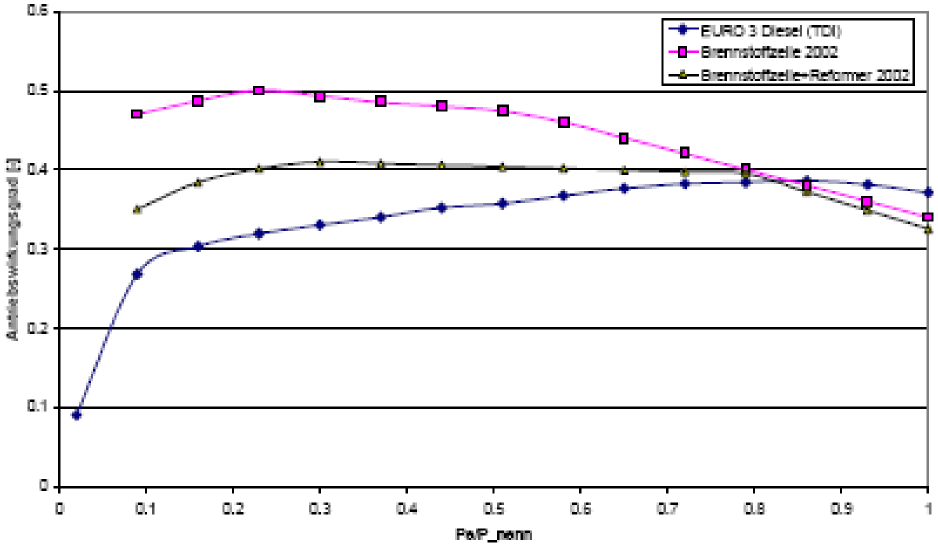
Source IEA, IA Electric and Hybrid Vehicles

Year	2004		2005		2006		2007 thru Oct. 1	
Vehicle Type	**EV[1]**	**HEV**	**EV[1]**	**HEV**	**EV[1]**	**HEV**	**EV[1]**	**HEV**
Austria	515	0	517	75	1,300	75	NA[2]	NA
Belgium	60	131	50[3]	602	50[3]	1,493	0	2,665
Canada[4]								
Denmark	5,300	15	5,650	35	5,650	60	10,650[3]	100
France	11,013	650	~11,000	3,650[3]	~11,000	10,000[3]	NA	NA
Italy	113,201	720	132,491	1,110	NA	2,179	NA	2,295
Netherlands[3]	500	2,000	500	3,000	500	7,500	NA	NA
Sweden	400	1,355	360	3,300	335	6,100	324	9,500
Switzerland	10,780	1,057	13,140	2,469	17,590	4,722	23,500[3]	7,760
Turkey[2]								
United States	55,852	196,293	68,000	404,400	76,200	656,300	120,000[3]	975,000
IA-HEV Members Total	**197,621**	**202,221**	**231,708**	**418,641**	**112,625**	**688,429**	**154,474**	**997,320**
China[3]	13,000,000	NA	23,000,000	NA	33,000,000	NA	45,000,000[3]	NA
Japan[3]	NA	120,000	NA	150,000	NA	260,000	NA	NA
Taiwan[3]	75,000	NA	94,000	NA	100,000	NA	106,000[3]	NA
GRAND TOTAL	**13,272,621**	**322,221**	**23,325,708**	**568,641**	**33,212,625**	**948,429**	**45,260,474**	**997,320**

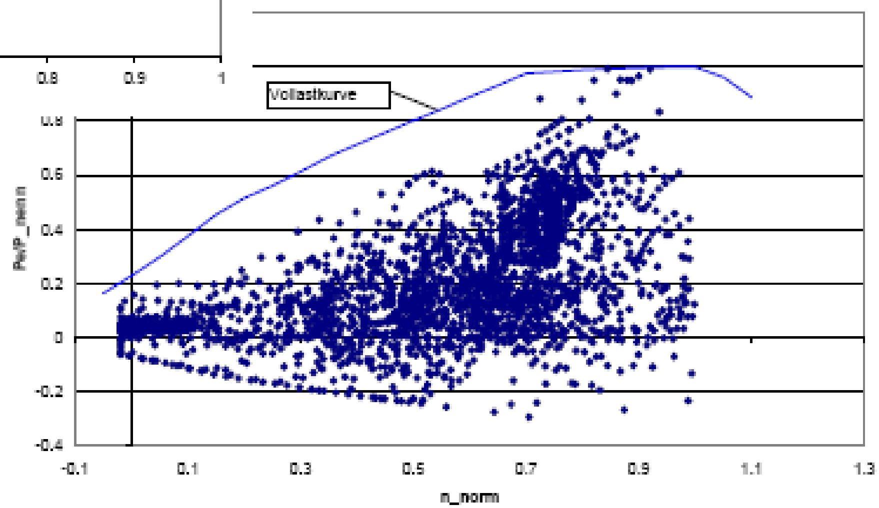
[1]Includes e-bikes and e-scooters, where data available
[2] NA = not available

Fuell cell versus Diesel

Wirkungsgradvergleich

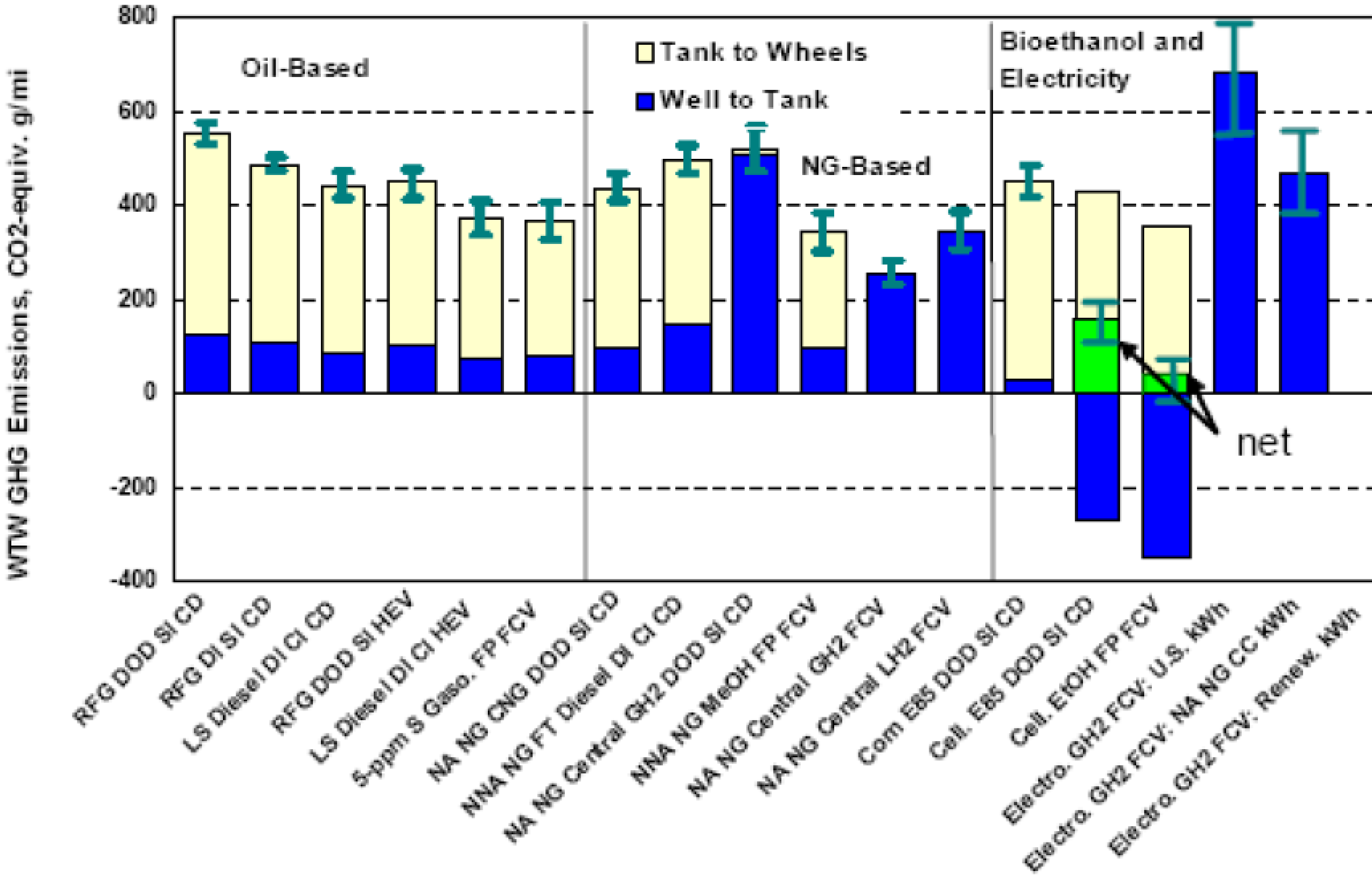


Motorbelastung, Golf in realem Fahren



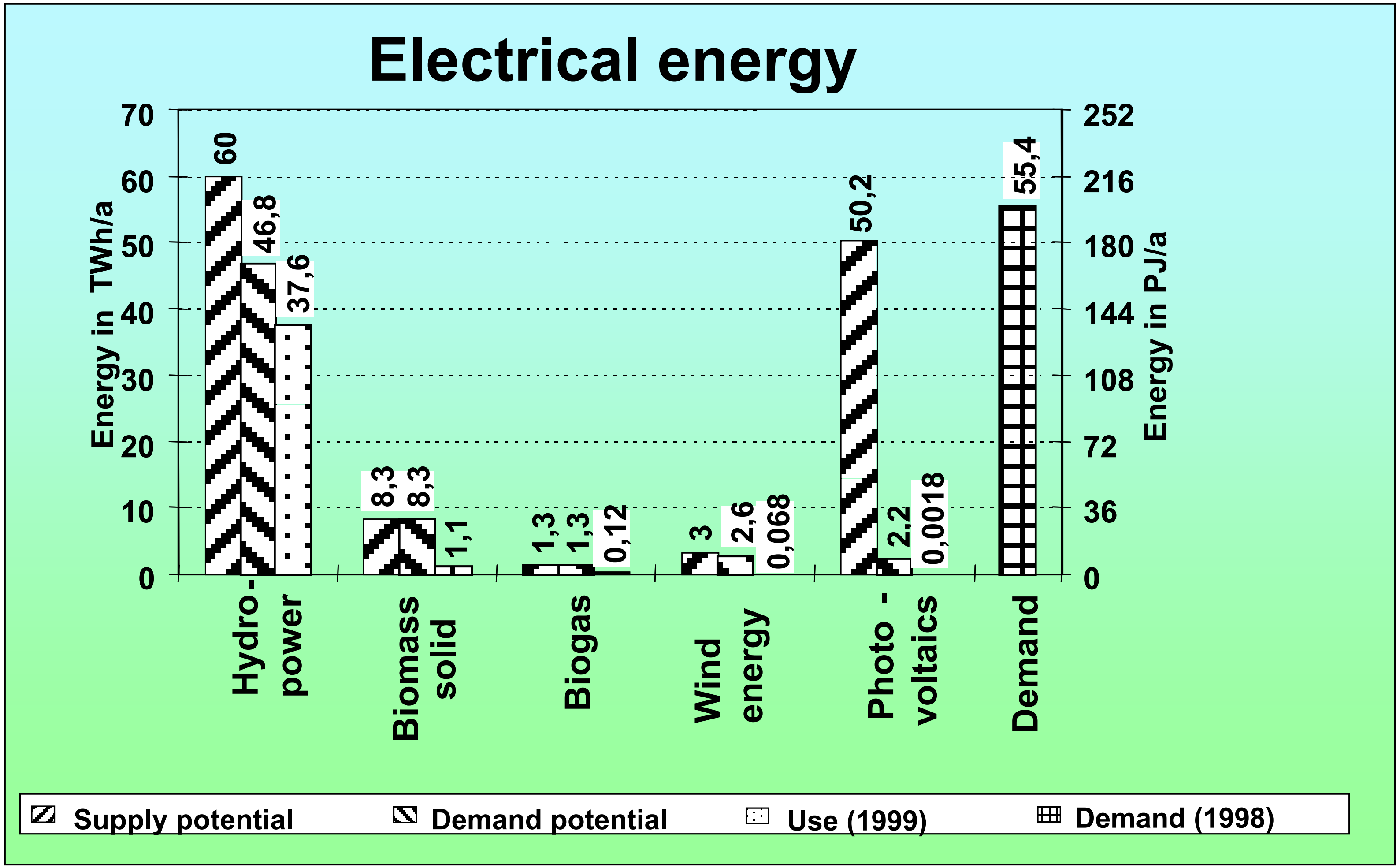
Diesel: n=12%

2005 GHG emissions comparisons for advanced powertrains and alternative fuels [Brinkman et al, 2005]



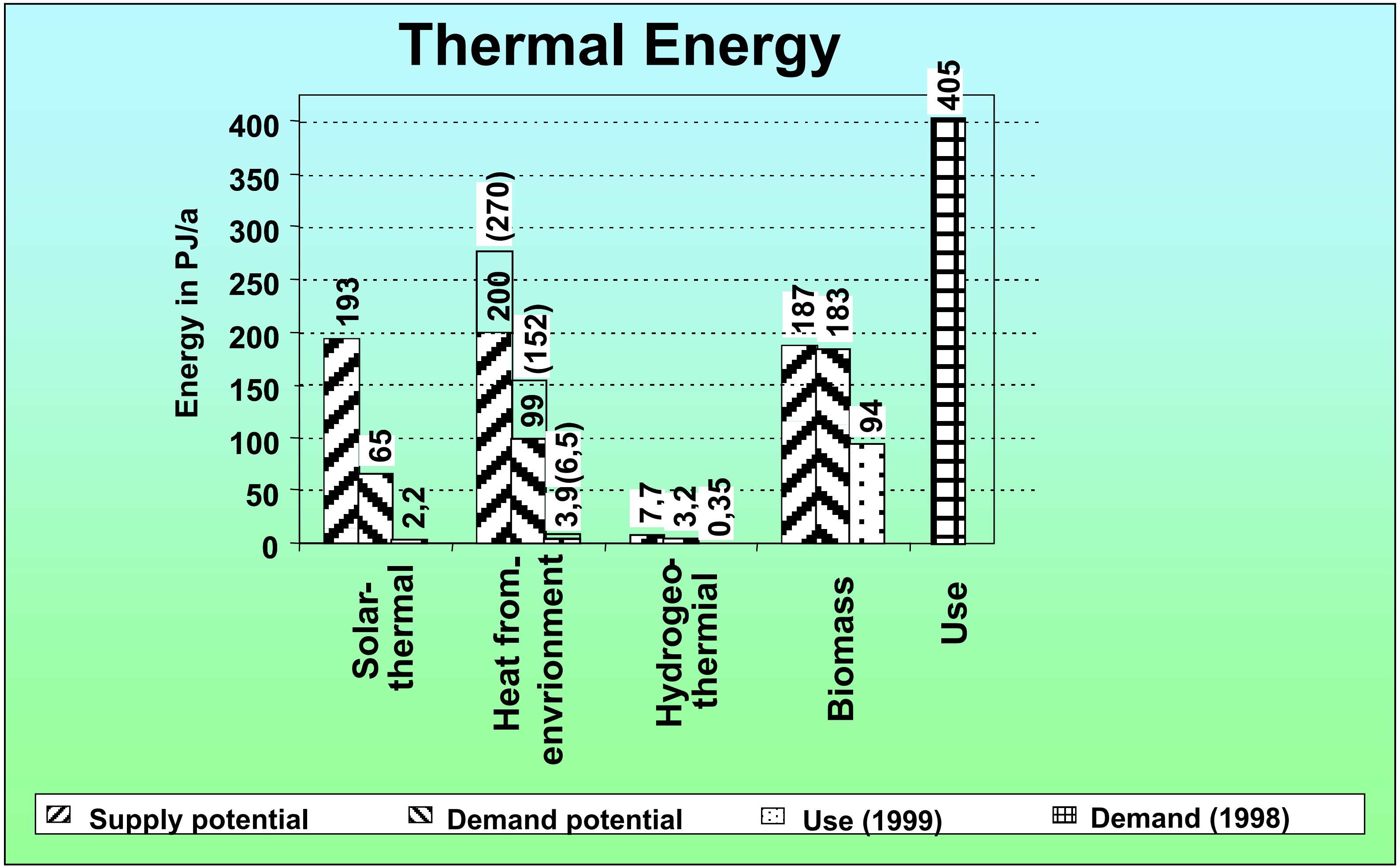
Potentials of renewables for electricity production in Austria

(from Neubart, J., Kaltschmitt, M. 2000)



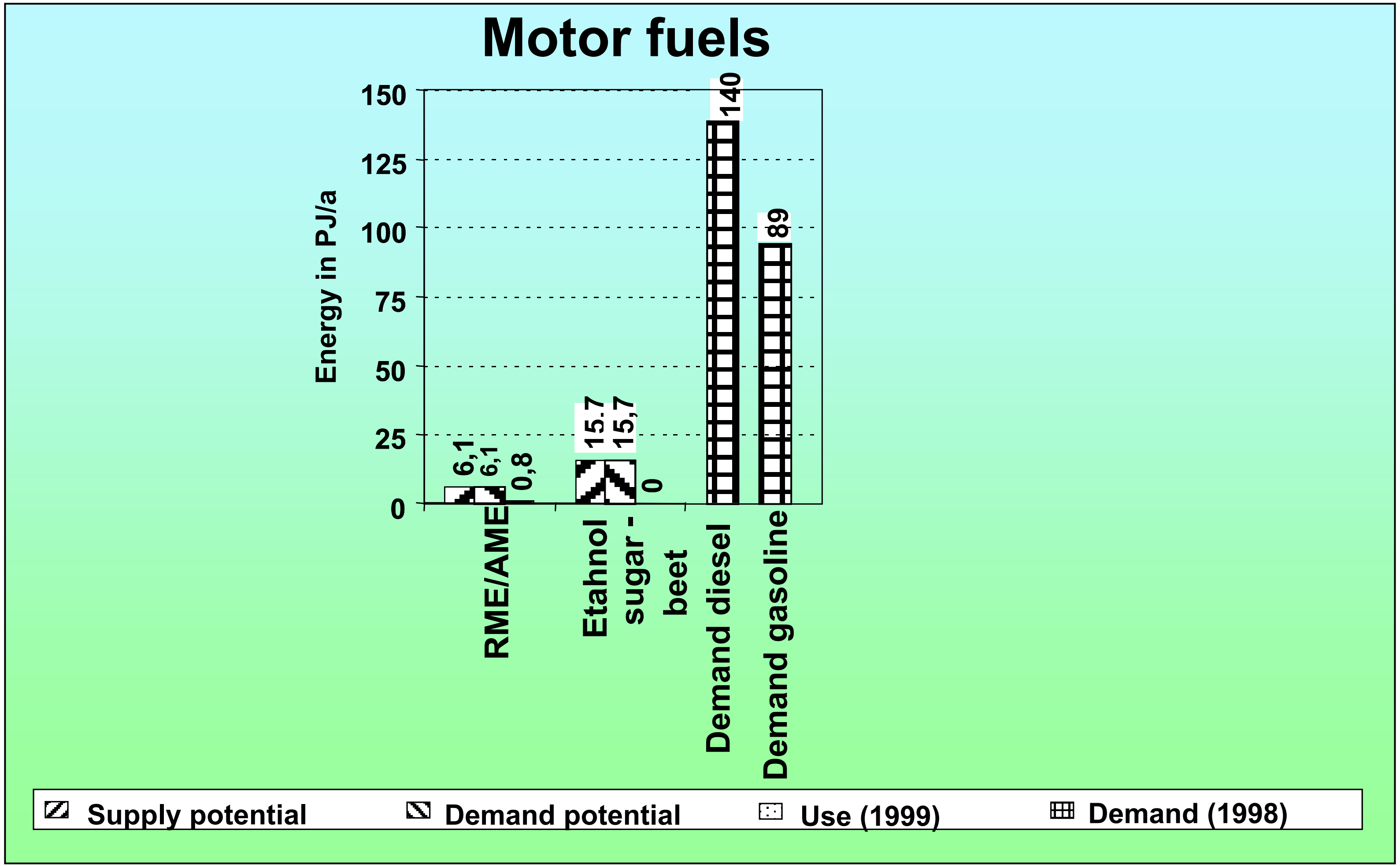
Potentials of renewables for heat use in Austria

(from Neubart, J., Kaltschmitt, M. 2000)



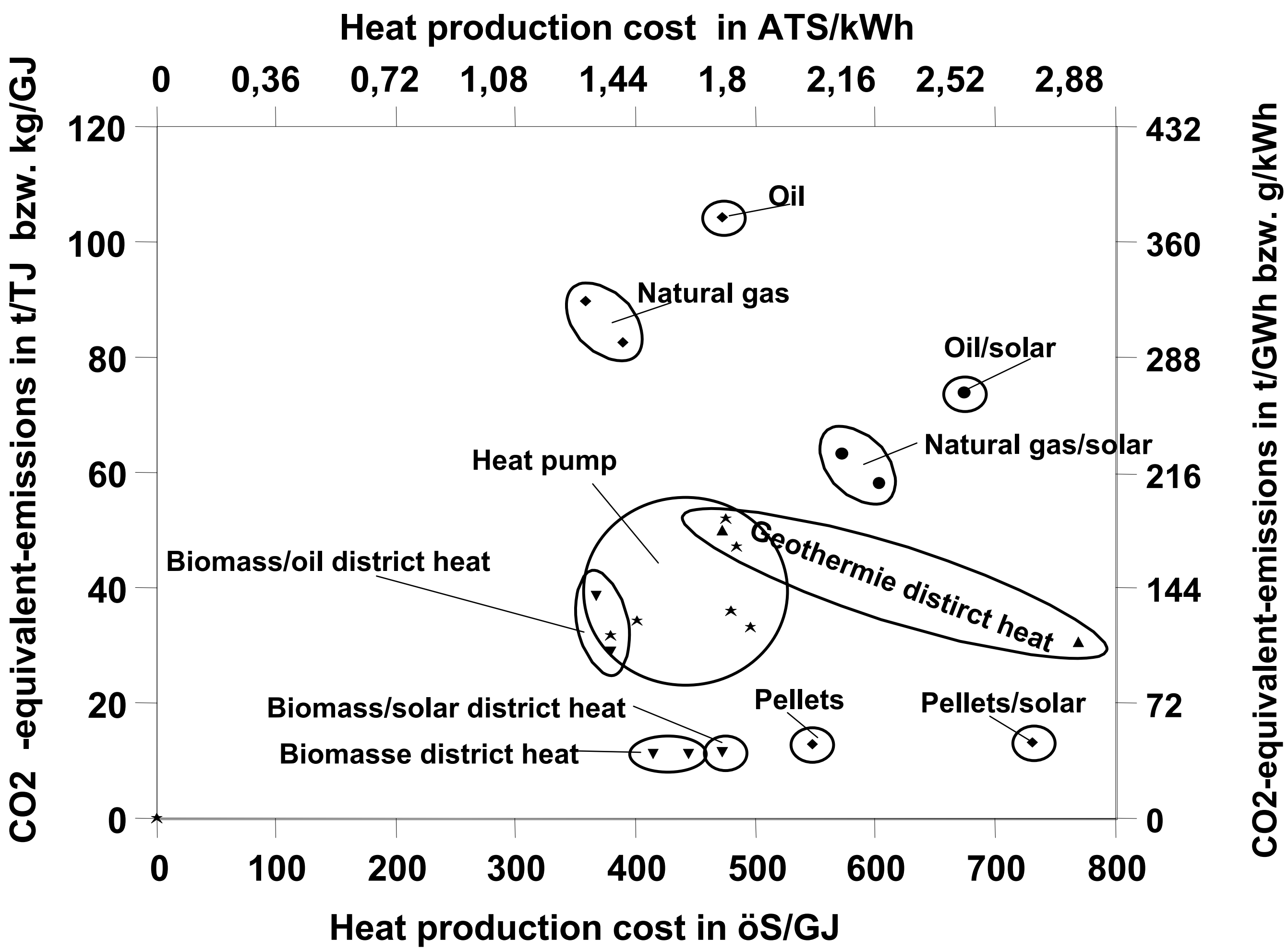
Potentials of renewables for motor fuels in Austria

(from Neubart, J., Kaltschmitt, M. 2000)



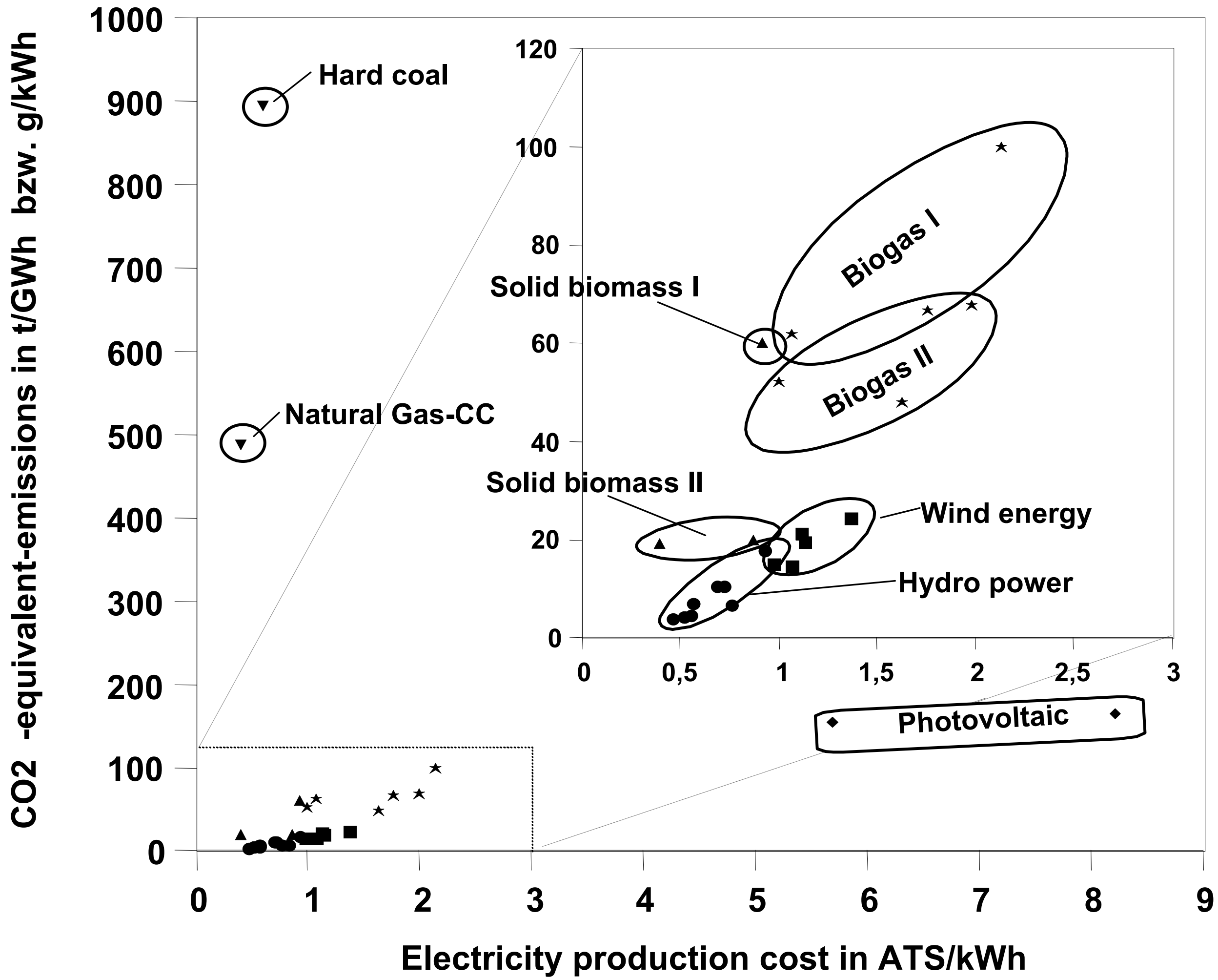
Costs and equivalent CO2-emissions heat production, EFH-II

(from Neubart, J., Kaltschmitt, M. 2000)



Costs and equivalent CO2-emissions of electricity production

(nach Neubart, J., Kaltschmitt, M. 2000)



Costs and equivalent CO2-emissions of motor-fuels

(from Neubart, J., Kaltschmitt, M. 2000)