Commercial and Research Opportunities for Sustainable Technology to Mitigate Climate Change

Presentation by Prof John Twidell,, IoP/FAPESP, San Paulo Feb 26-28 2009

Governing bodies worldwide accept that anthropogenic climate change is a reality and that the principle cause is mankind's use of fossil-fuels. There is also general recognition that mitigation is essential, which includes the rapid increase of renewable energy supplies together with improved efficiency of energy use. In the last 30 years, scientists and engineers have produced a wide range of proven technological options for supplying heat, electricity and fuels from renewable resources. The application and further development of these technologies requires supportive institutional frameworks from governments, from local to global scale. The presentation will review these technologies, outline the institutional situation and illustrate commercial developments. Delivery can only be by commerce. Therefore, the revolution in energy supply and use necessary in the text 20 years implies research development and commercial opportunity on a huge scale.

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Presentation by Prof John Twidell
AMSET Centre
amset@onetel.com

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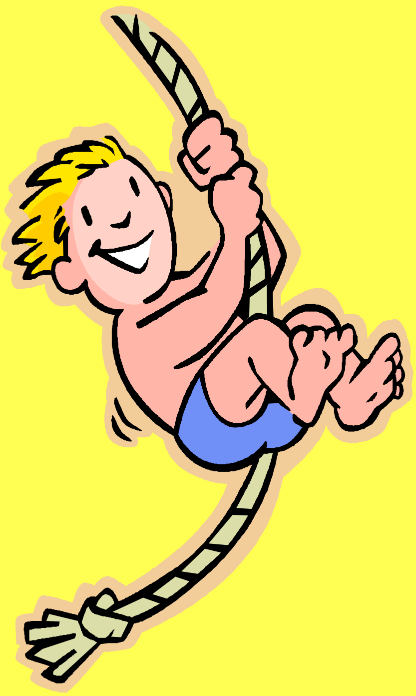
The context is <u>Sustainability</u>

the continuation and enrichment of human society by:

- ecological integration
- improving quality of life and wealth for all
- safeguarding future generations

The key strands of the Climate Change problem: (on which our grandchildren depend)

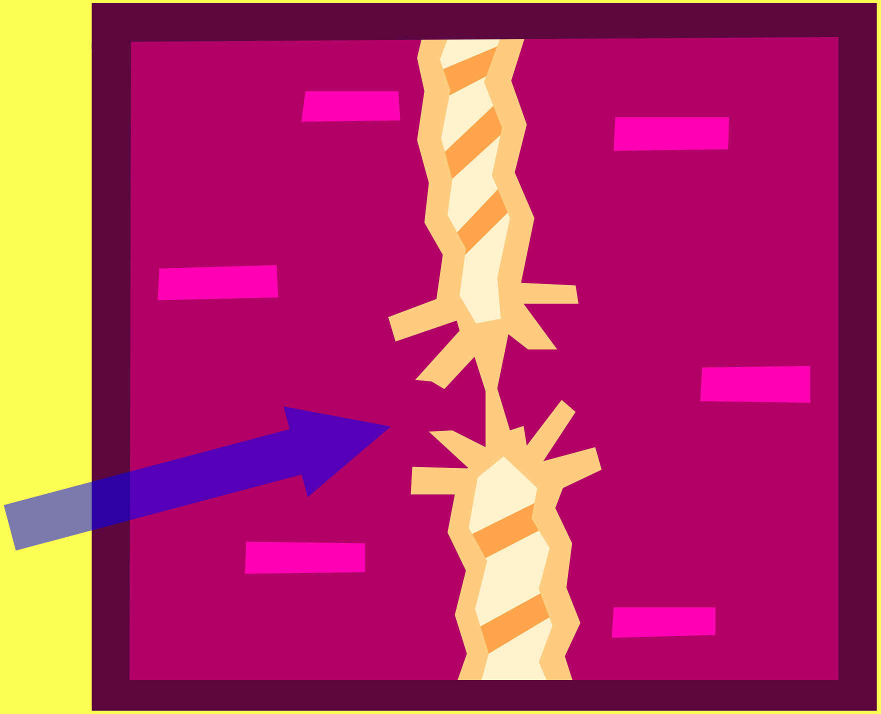
- Population increase?
- Quality of life expectations?
- Failure to cooperate internationally?
- Old-fashioned technology?
- Not living ecologically?
- Scientific uncertainty?
- Moral selfishness?



Solve the problem with Ocam's razor

Occam's razor: William of Occam, 14th century UK philosopher.

"If there are several explanations for observed phenomena, carefully cut out complex strands until the basic explanation remains"



What is this explanation for Climate Change?

Occam's explanation

- Fossil-fuels must remain underground
- How? By using non-fossil energy supplies

Non-fossil energy supplies that significantly reduce CO_2

Nuclear fission

(electricity only, finite, polluting) X

- Nuclear fusion

(inoperative as yet) X

- Solar

(unstoppable, so ‘renewable’) yes

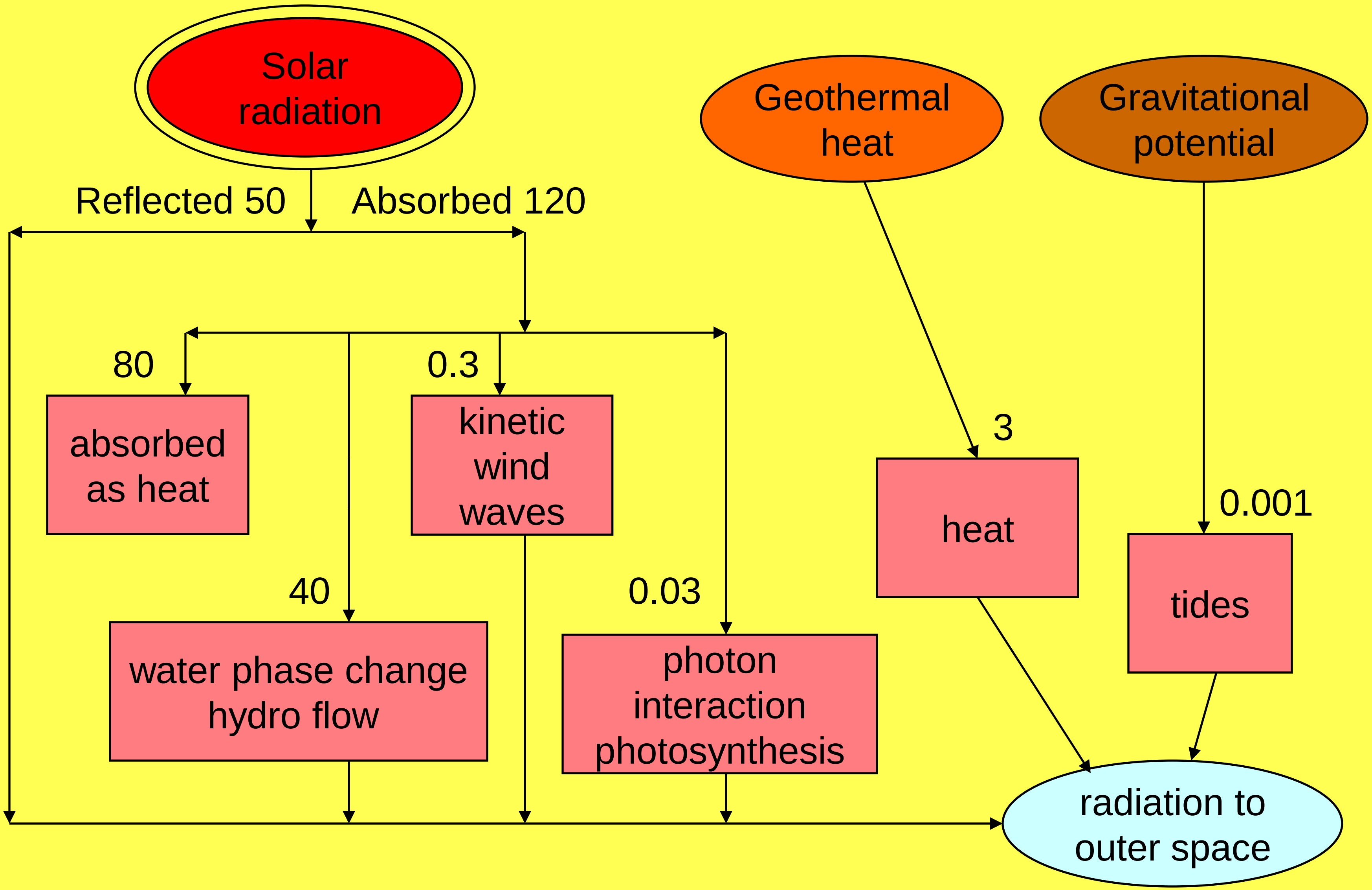
Renewables definition

- **Renewable Energy is energy obtained from the natural and persistent currents of energy in the environment**
- e.g. sunshine, wind, rainfall

- considered “Green Energy”
- intrinsically non-polluting

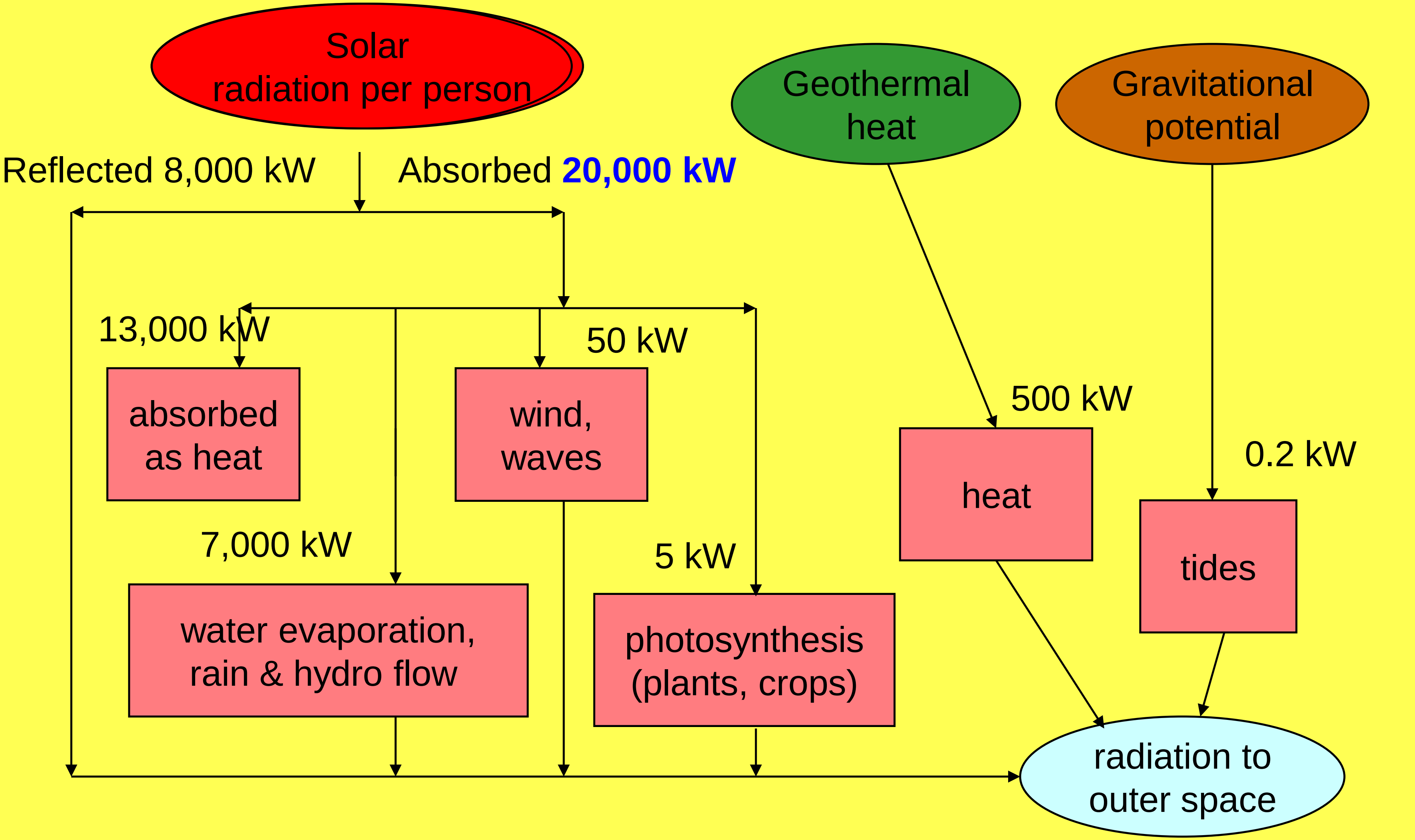
- “Direct” RE from natural environment
- “Indirect” RE from society’s wastes

Total renewable energy flows through the biosphere: unit 10^{15} W (10^{9} megawatt)

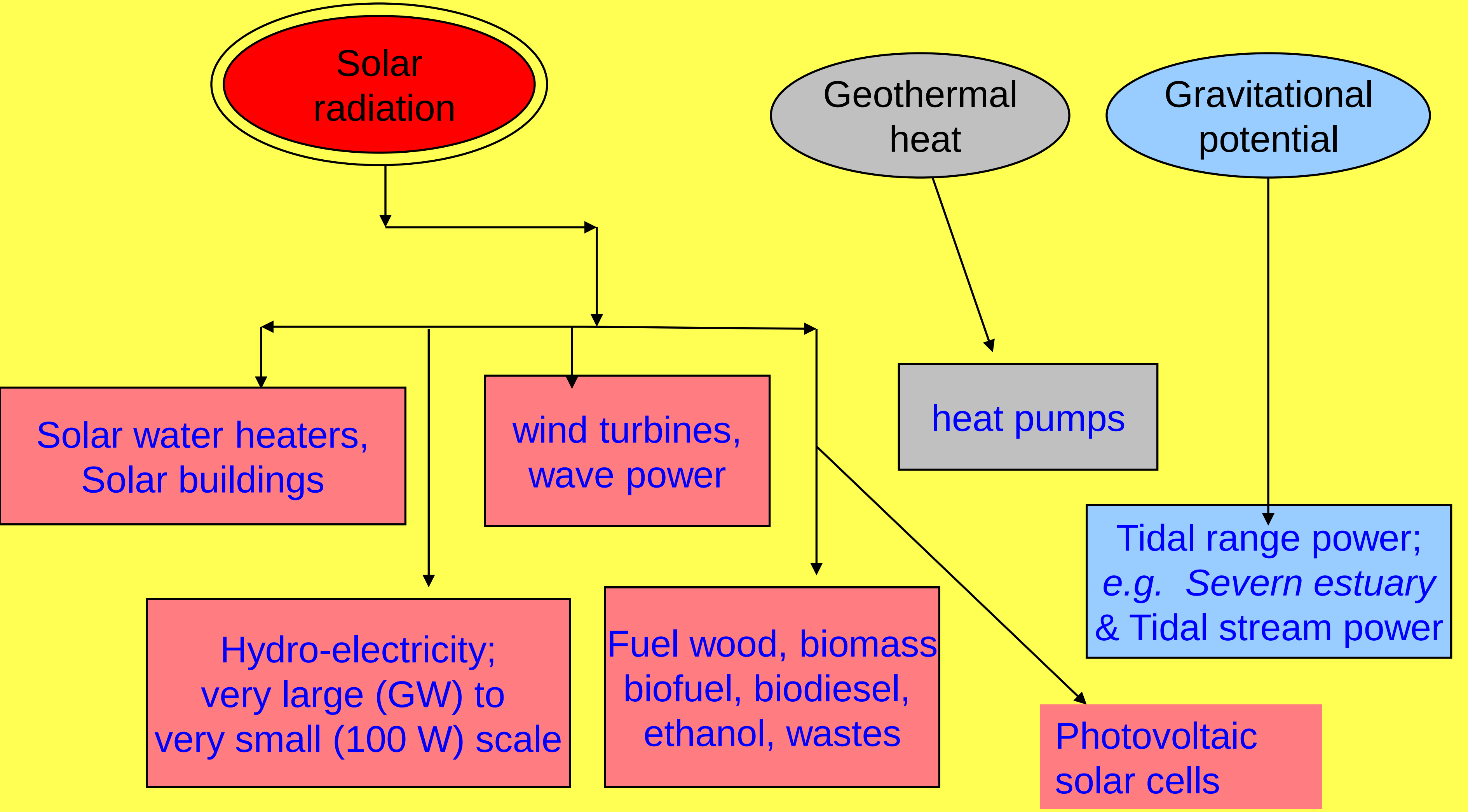


Per capita Renewable energy: kilowatt per person on Earth

i.e. solar is equivalent of 20,000 one-bar electric heaters for <u>each</u> man, woman and child



Renewable energy technologies



Renewable energy technologies for heat, electricity, transport fuels

- solar buildings
- solar water heating
- solar thermal electricity
- solar cell photovoltaic electricity
- solar driers
- solar refrigeration
- hydroelectricity
- micro-hydro
- wind turbines
- wave power
- photosynthesis
- biomass crops
- pyrolysis
- biofuel oils
- biogas
- sewage gas
- urban waste
- geothermal heat
- tidal range
- tidal stream power
- fuel cells

Energy supply is essential for biological and economic life. Therefore, it is the duty of governments to encourage sustainable energy supplies and the efficient use of energy by:

- **Research, development, demonstration R, D & D**
- **Manufacturing grants**
- **Regulations**
- **Obligated (compulsory) markets and quotas**
    - **Competitive (lower prices, but less manufacture)**
    - **Open (‘feed laws’ at higher price, much manufacture)**
- **Planning policy**
- **Taxation policy**
- **Pollution abatement credits**
- **Etc**

These are all happening

Legally required actions in Europe

- By 2020, 20% of EU total energy (fuels, heat and electricity) from renewables
- So each EU country must have ~10 x more renewables than now
- UK, all new buildings zero-carbon by 2020, staged from now
- UK electricity target 15% from renewables by 2020, now ~5%. Requires huge increase in onshore and offshore wind power, plus efficient use of energy.
- UK Climate Change Bill (2009: the first in the world), UK Government is legally required to have reduction of C.C. emissions by 80% by 2050
- Note: President Obama wants USA CO_2 reduced by 80% by 2050.
- Market value of such green products globally ~ $US400 bn *(Stern & Grantham Institute Feb 2009)*

but always,
energy efficiency is essential

- FOSSIL-FUEL The best way to keep fossil-fuels underground is to use less by more efficient generation and use.
- RENEWABLE PLANT is capital expensive (the fuel is free!). The capital cost is less if less energy is needed. So efficient use of the energy is essential.
- Energy suppliers seldom make money from promoting consumer efficiency, so they encourage excessive use. Government Legislation and its Regulators (judges) have to enforce standards of efficiency, e.g. labelling, tariff structure.
- Energy efficiency requires strict legislation and compulsory standards, user understanding, education, promotion of best available technology.

Consider the technologies

Buildings consume ~ 50% of every nation’s energy supply:

- ‘Essential’ electricity for lighting, communications, microwave ovens, motor drives, heat pumps (cooling and heating)
- ‘Inessential’ electricity for heating water and space
- Fuels for cooking and heating

An example: Low-energy, solar residences, University of Strathclyde, Glasgow, Scotland

Opportunities with low-energy solar buildings:

aim for > 80% energy reductions and ~50% energy generation on site

- **Building design: passive** orientation, shading, large thermal mass, wall insulation, thermally resistive glazing, ventilation (mostly natural), specialist design methods and software, demonstration, user education.
- **Building design: active** as many passive features as possible, (thermal mass may be small, implying much control) plus forced ventilation, appliances combining heating and cooling, heat exchangers with ventilation, shared district heating and cooling.
- **Measure and monitor:** user-friendly methods, user education, friendly billing, smart-meters [~10% saving guaranteed].
- **Microgeneration: electricity:** solar photovoltaics (frequent opportunity), wind power (occasional opportunity), hydro (rare, excellent if possible), biomass gasifier or biogas engine (specialist opportunity).
- **Microgeneration: heat & cooling:** solar water heating, ground (perhaps air)-sourced heat-pump cooling and heating, biomass (e.g. pellets) heating and cooking.

our home: wood fuel, domestic heating

cooking

pellet stove

dry wood store

enclosed wood-stove

house boiler for radiators, heating & hot water

you are all invited

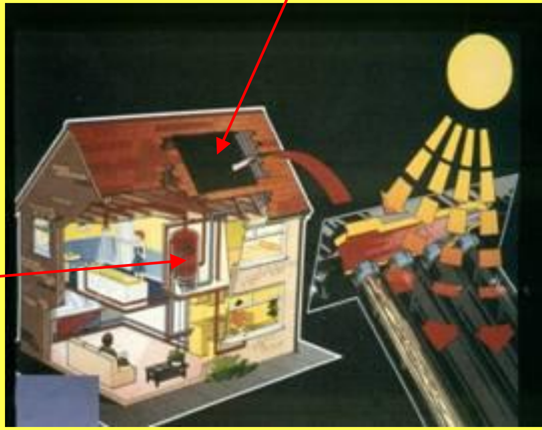
Solar energy chez John and Mary Twidell, midland UK.
Annual production ~ 50% electricity and ~ 50% hot water
Solar water heater installed 1997, payback by 2005. PV installed 2003, payback ~2040

Solar photovoltaics

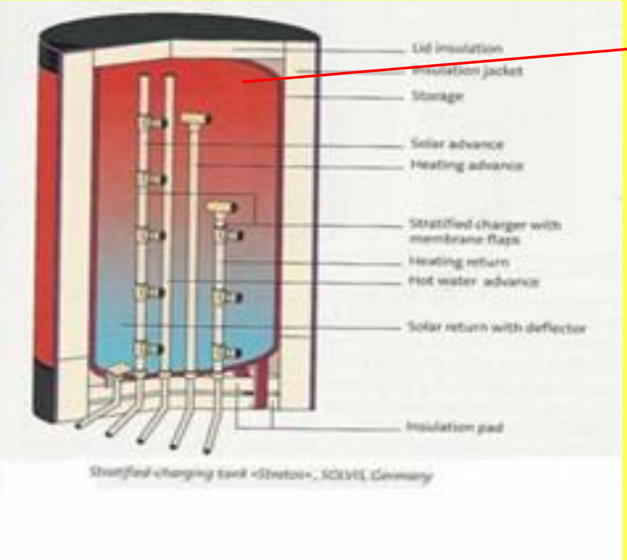
- minimal visual impact
  (often positive)
- no moving parts for electricity supply
- no noise
- no to little maintenance
- charge batteries
  (life 6 y; chemicals)
- invert to grid export
  (90 to 95% efficient)

Solar water heating

- **world ‘capacity’ 2008, ~30,000,000 m^2**
- **equiv at ~100 W/m^2, 3000 MW thermal**
- **manufacture ~ 3,300,000 m^2/y**
- **cost of household 2 m^2 unit with tank c.£3,500 in UK (produces 50% need) c.£2,000 in Israel & Greece (75% need)**
- **UK payback versus electricity, 8 y**



Vacuum tube collectors, selective surfaces, heat pipes



Stratified tank for efficiency

Efficient appliances:

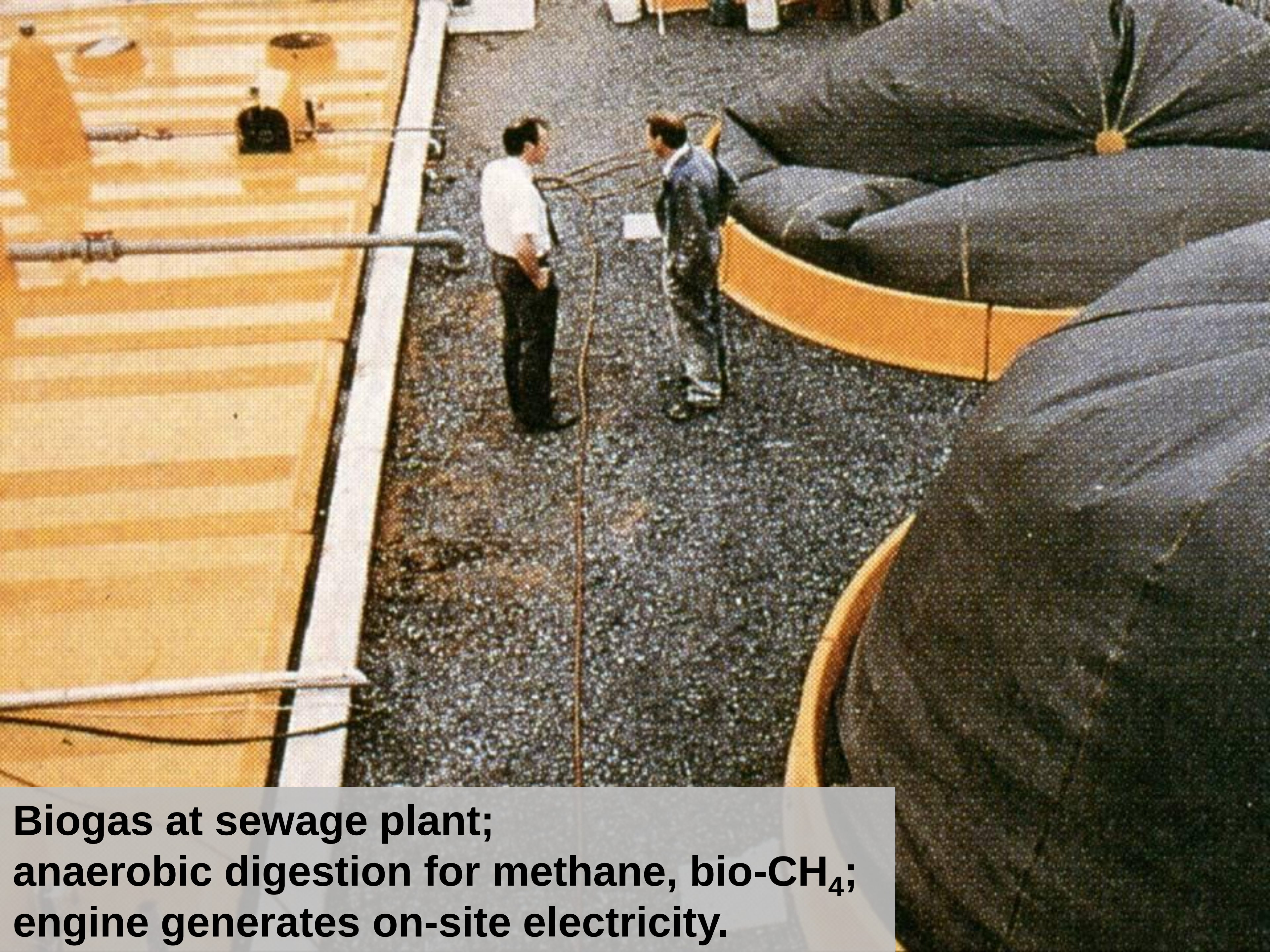
aim for >60% energy reductions

- **Lighting:** compact fluorescent (~ 10 W, save $75 per lamp over lifetime), LED (light emitting diodes GaN, ~2W per light-assembly, solid-state function), controls
- **Refrigeration:** thick &/or novel insulation (aerogels, vacuum panels), location, combined with heat-pump heating, sealed doors
- **TV, computers, electronics:** easy and permanent off-switching, standby power reduction, passive cooling, low-energy chip design, smaller scale, no vacuum tubes)
- **Pumps and motors:** efficient induction motors, controls

Grid **electricity** supply: main renewables options

In order of new capacity contribution. Established large hydro not included.

- **Biomass thermal** (including mixed with coal) and combined heat and power (*moderate growth*)
- **Landfill gas** to turbine (*slow growth now, most UK*)
- **Wind power**: proven technology onshore and rapid installation once having planning permission, most Spain, Germany, Portugal. (*rapid growth ~30%/y*)
- **Offshore wind**: initial windfarms completed (~ 10 now in EU, most UK), expensive, many more in planning (*growth ~ 15%/y*)
- **Solar photovoltaics**: buildings integrated and large self-standing plant (*growth ~ 25 %/y*)
- **Small hydro** (e.g. Scotland) (*growth ~ 10%/y*)
- **Solar thermal electricity** (concentrated beam by orientated mirrors, 'steam' turbine *(~ 2 major development plants Spain*)
- **Wave** (*developmental projects*, mostly Scottish manufacture, e.g. off Portugal, test stations northern Scotland, Orkney)
- **Tidal current** (*developmental*, e.g. Northern Ireland)



Biogas at sewage plant;
anaerobic digestion for methane, bio-CH_4;
engine generates on-site electricity.


~300 kW wind turbine R&D,
smoke trail shows the wake

Wind grid-electricity costs

- costs decreasing steadily
- sells wholesale for about ~ 5p/kWh Scotland (cf old-nuclear ~4, coal ~3, gas ~ 4)
- capital cost ~£900 / kW (decreasing as machines made larger)
- usual capacity 2 to 4 MW per machine
- rotor diameter ~100m, hub height ~100m
- latest development - offshore turbines


Copenhagen harbour
Middlegrunen offshore wind farm

Wind energy capacity installed by end 2008

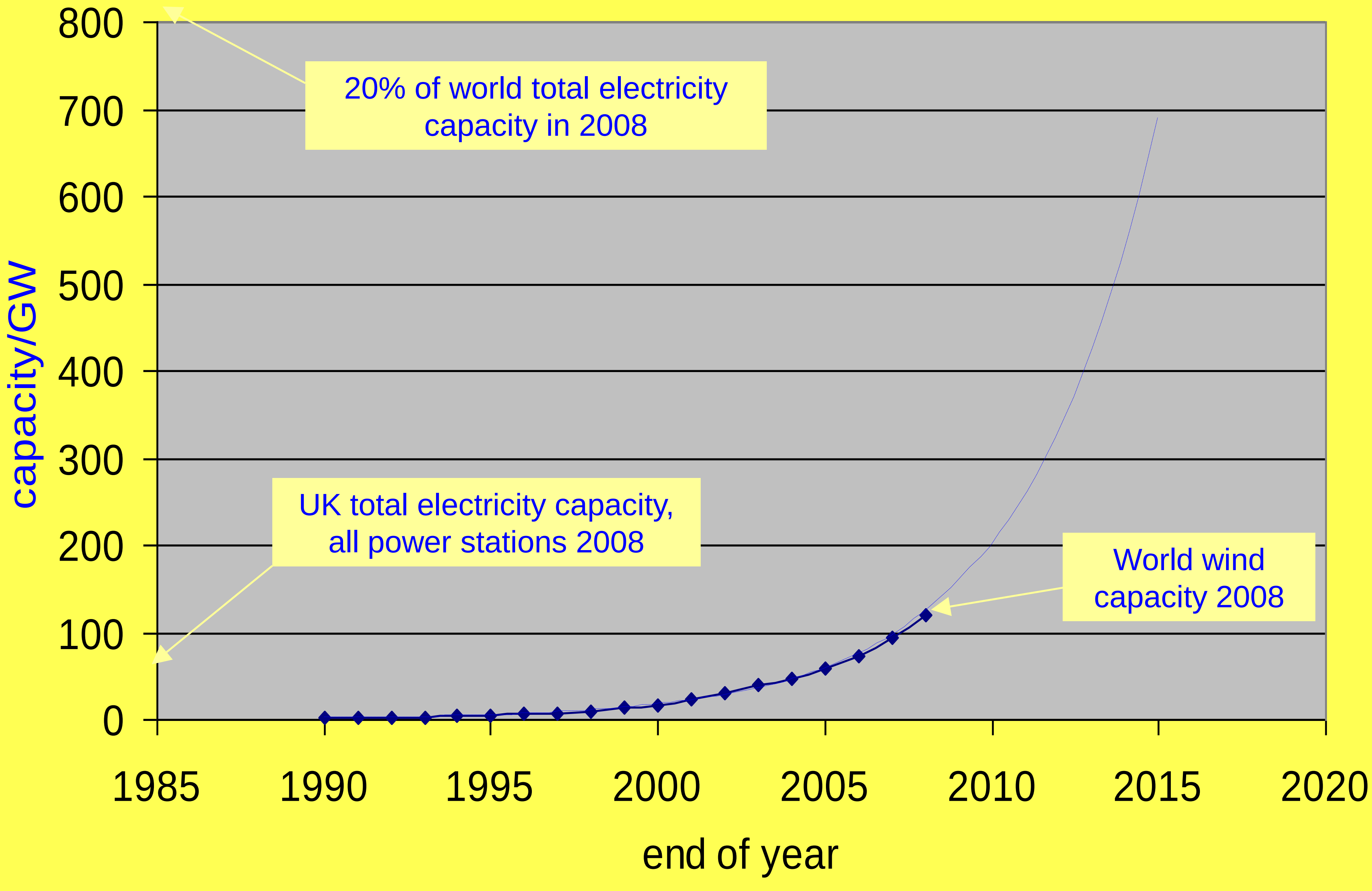
(N.B. conventional thermal power station 1000 MW electricity)

- World Dec 2008: 120,000 MW total (15W/caput)

  (of which 50% from Danish-based companies)
- *2002 to 2008 av. ~25%/y annual growth*

	total capacity	*capacity per person*
USA	25,000 MW	90 W/cap (4)
Germany	24,000 MW	300 W/cap (3)
Spain	15,000 MW	350 W/cap (2)
China	12,000 MW	12 W/cap (7)
India	8,000 MW	8 W/cap (6)
Denmark	3,500 MW	650 W/cap (1)
UK	3,300 MW	55 W/cap (5)

Global installed wind power capacity/GW
actual to end 2008: logarithmic extrapolation



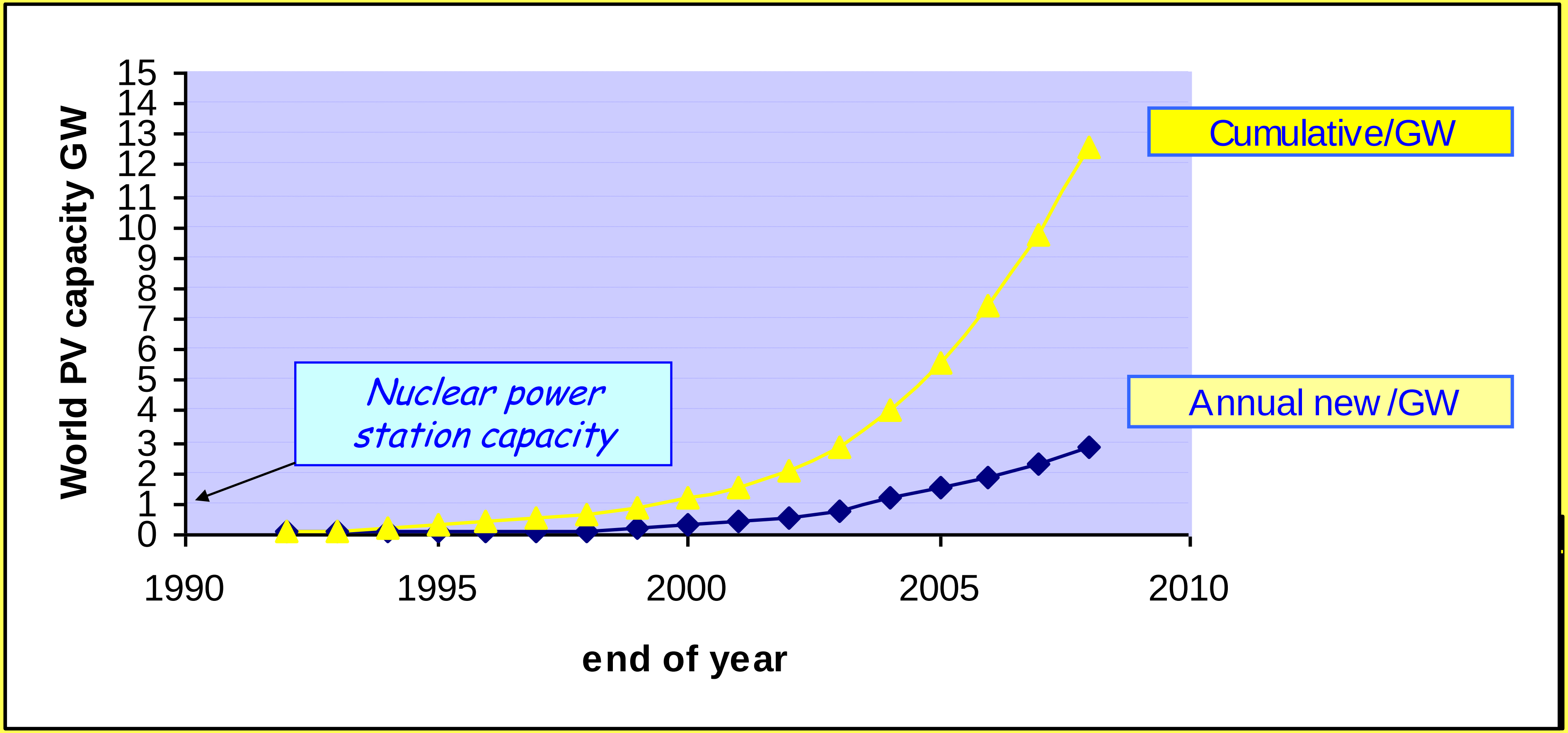
Wind turbine impacts

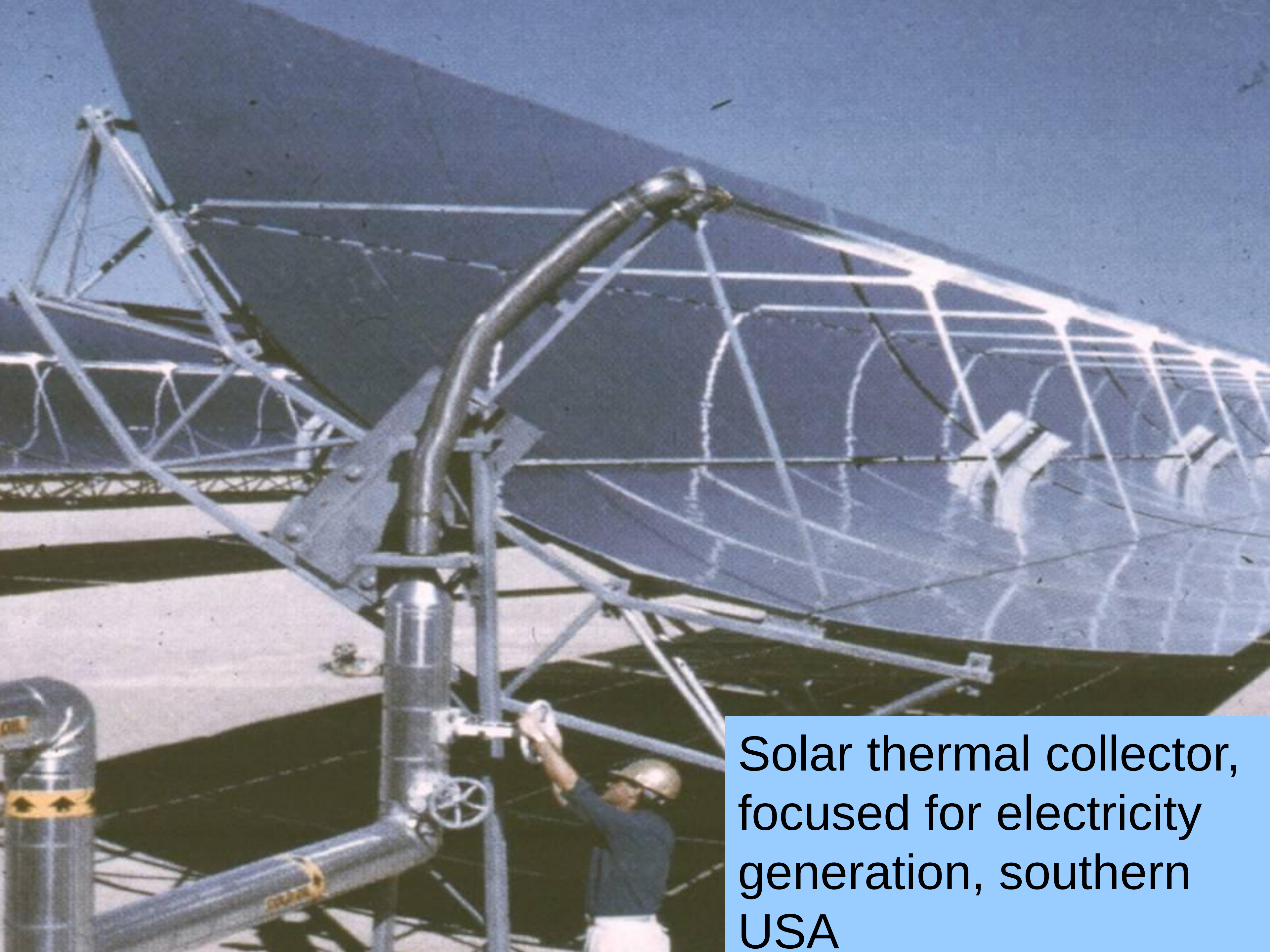
- visual (no hiding place!)
- larger diameter, slower rotation
- noise from machinery, blade tips, tower passing (=40 bBA at 250 m; sleepable)
- birds very seldom (< house windows)
- grid limitations for exportable power

Solar photovoltaic power station

World installed photovoltaic solar power

Installed capacity about 8 years behind wind power, but growth marginally faster





Solar thermal collector, focused for electricity generation, southern USA

UK Wavegen system with Wells turbine, installed on Scottish island, Islay; developmental ~ 300 kW

Scottish ‘Pelamis’ wave power, now operating 5 km off Portugal ~ 2.3 MW peak

750 kW generators, hydraulic pressure at each of 3 hinges

Tidal-current and major-river turbine for electricity

(photo Northern Ireland from BWEA.co.uk)

Tidal-range power, La Rance, France:

240 MW, installed 1966

(UK actively considering River Severn barrage, ~1,600 MW)

Non-fossil-fuel transport; renewables fuel and appropriate vehicle

- Bioethanol (spark ignition engine)
  — Brazil outstanding, but there more export potential?
- Biodiesel (esters) (diesel compression engine)
  - from cooking oil (very common, but limited);

  - from oil-seed crops (EU requires 5% mix, increasing annually); but often crops use fossil-fuels for fertilizers, harvesting etc, also substitutes for food; so not straightforward)
- Electric cars (electricity from renewables)
- Hybrid (biofuel and plug-in electric battery)
- Hydrogen (spark ignition, hydrogen from renewables)

Major changes since President Obama encouraged institutional support mechanisms, e.g. in California.

Cane sugar, Malawi: self-energised refinery

for sugar, molasses & ethanol fuel (spark ignition engines).

The carbon involved is ecological ‘bio-Carbon’, so OK

Sunflower oil;

for food & biofuel (e.g. for diesel engines);

Combustion is to bio-CO_2


De Montfort University
Leicester

Hydrogen fuel; transport (spark ignition engine), cooking, electricity from fuel cell.

N.B. Hydrogen production from renewables is C free

NASA high altitude, unmanned, monitoring plane

Energy strategy

- Renewables **potential = 20,000 kW** / *capita (abundant)*
- energy target: '*contract and converge*' all nations < **2 kW per capita** *(requires best technology and new products)*
- Energy efficiency vital *(obligated & market driven)*
- Introduce renewables wholeheartedly *(obligated targets)*
- Technology, business & lifestyle change *(economic growth)*
- Hence renewables adequate and affordable
- So…. sustainability possible

So, for renewables……………………...

- potential very large and sufficient
- free (no cost) in the environment
- but dispersed and variable
- need to capture, deliver, utilize and store
- encourages local enterprise & cash flow
- manufacturing growth from environmental push and commercial pull

- *but*….RE plant is relatively large
- *so*…..RE plant is capital intensive

Conclusions: renewables …

- proven technologies, constantly developing
- most are in the market place
- credit for environmental and sustainable benefits
- favoured by world, European, national & local policies
- *Considerable market opportunities*