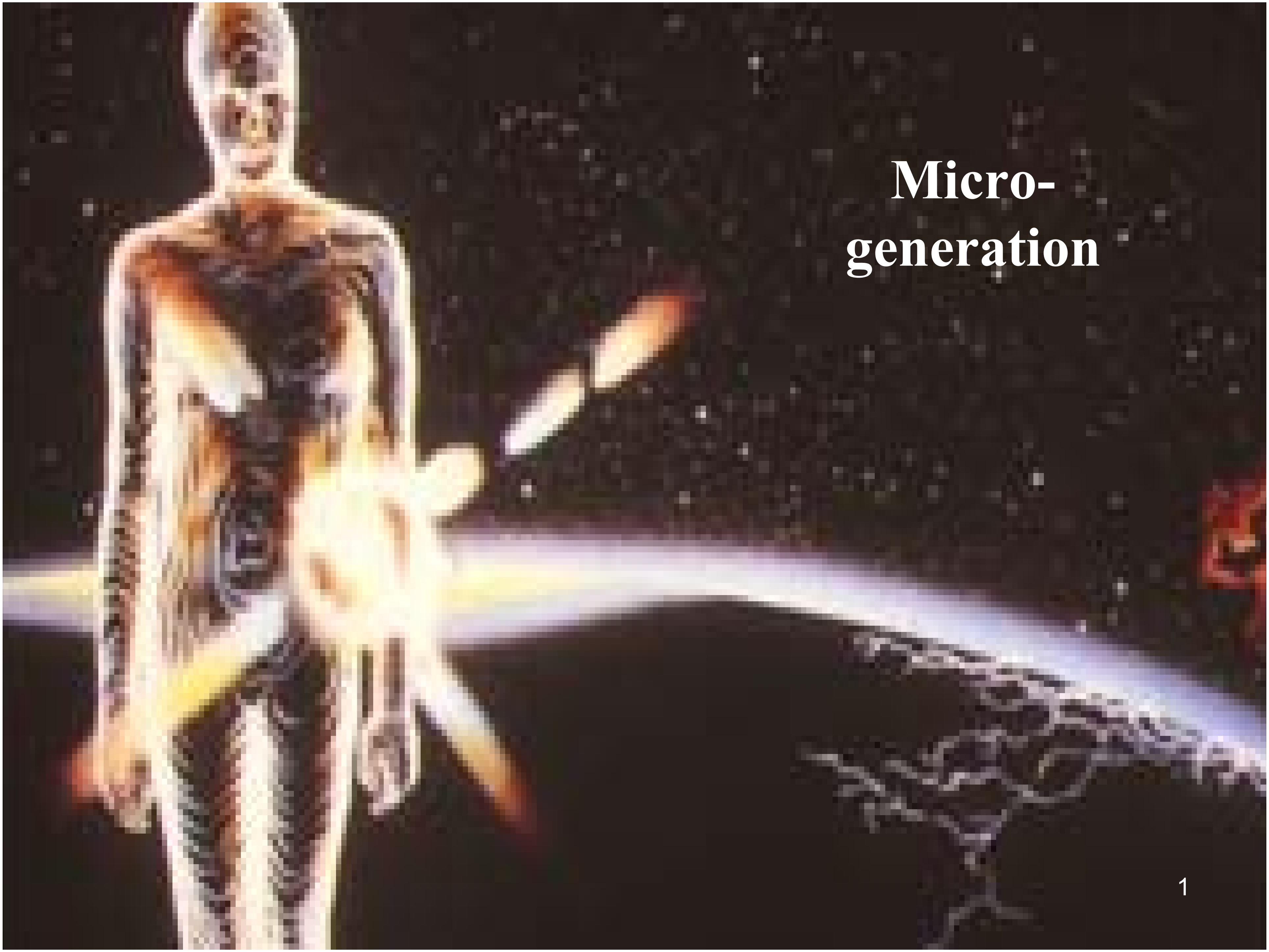
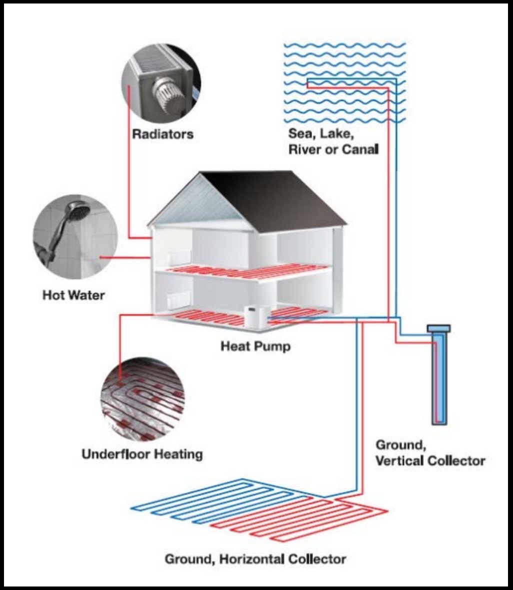
Micro-generation



Microgeneration definition

- OFGEM: “The term ‘microgeneration’ is used to refer to electricity generation equipment of the smallest capacity which covers generation of electricity up to 50 kWe.”
- DECC: Extended to renewable heat: plant fuelled or partly fuelled by renewable sources (less than 100 or 200 kW thermal output).



Types of microgeneration

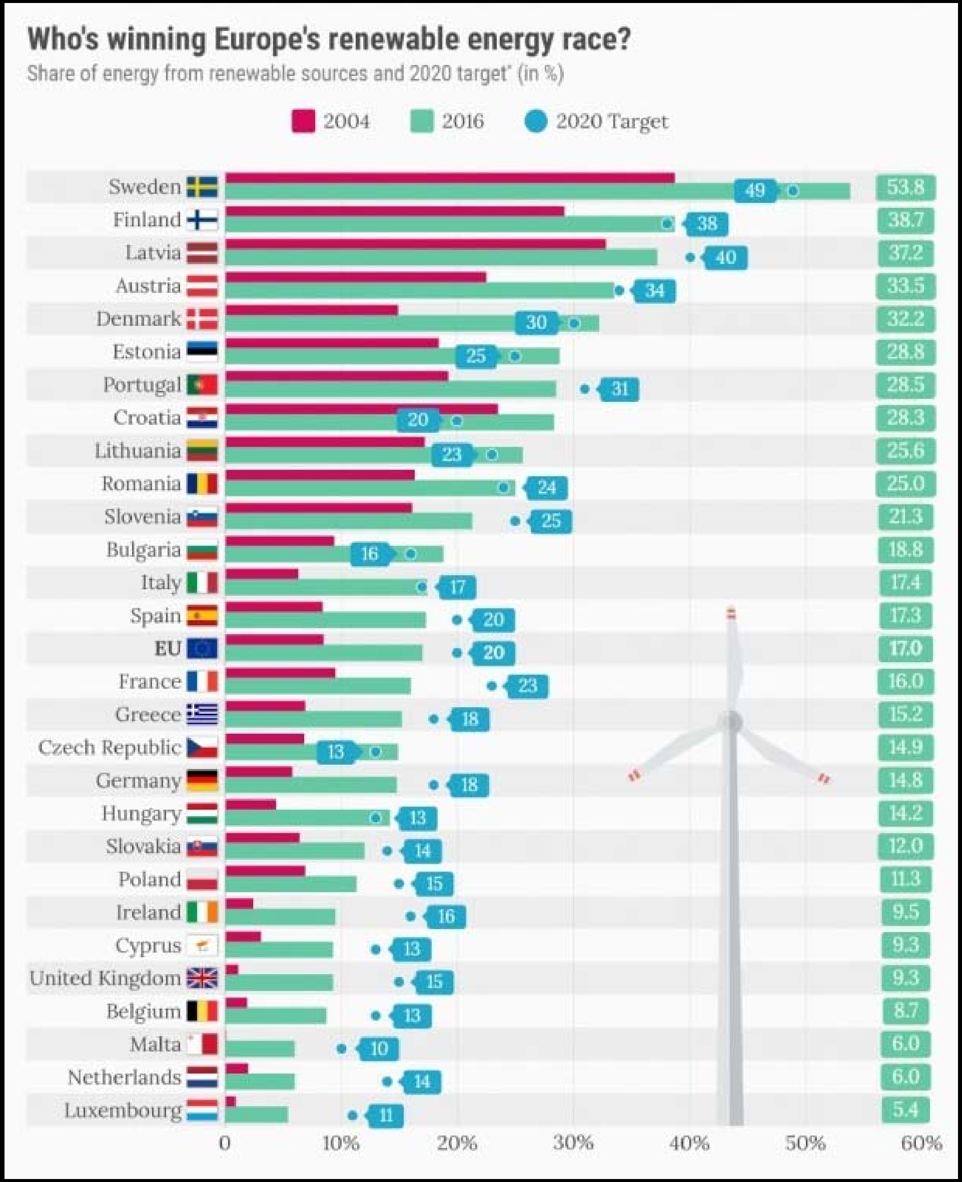
- Heat and electricity:
  - microCHP (Stirling, ICE)
  - fuel cells (SOFC, PEM)

- Heat only:
  - biomass (woodchip, biogas)
  - solar thermal (flat plate evacuated tube);
  - heat pumps (GSHP, ASHP, WSHP).

- Electricity only:
  - SWECS
  - PV
  - micro hydro

Drivers – FIT, RHI

- ❑ EU 20/20/20 target, UK 15% of total energy provision from renewables by 2020 … 9% achieved by 2016.
- ❑ To boost green energy provision the Feed-in Tariff (FIT; 2009) and the Renewable Heat Incentive (RHI; 2011) were introduced.



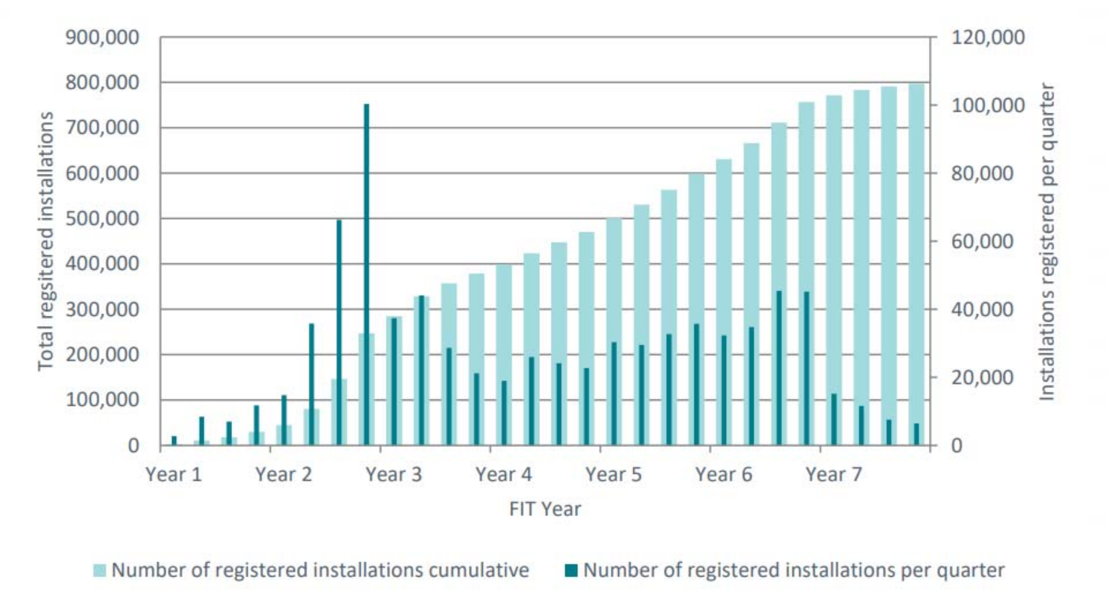
Who's winning Europe's renewable energy race?

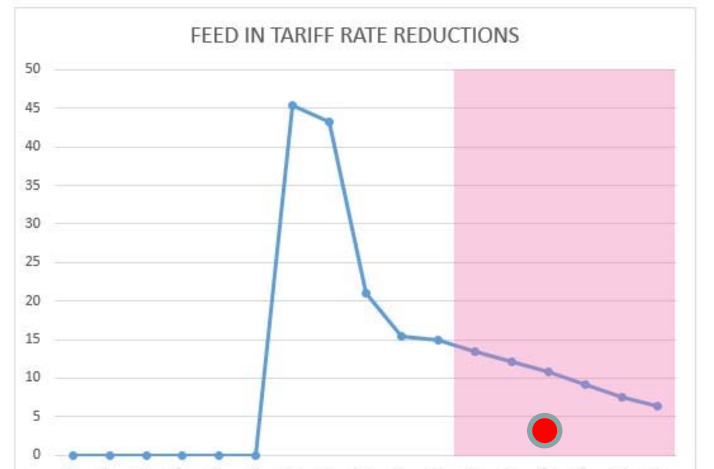
Share of energy from renewable sources and 2020 target* (in %)

Installations - electricity

- Feed in tariff – FIT – payment for renewable generated electricity (<5MW) + export payment
- FIT was wildly successful (particularly PV)
- Resulted in tariff cuts to reduce scheme costs

Technology	**Scale**	**Tariff level (p/kWh) (2017 Dec)**
Solar electricity (PV)	≤10 kW	4p
Anaerobic digestion	≤250 kW	4.99
Wind power	≤50 kW	8.26
Micro CHP	≤2kW	13.95
Hydroelectricity	≤100 kW	7.78





Source: OFGEM

Legislation - heat

- Renewable Heat Incentive (RHI) qualifying technologies:
  - air, water and ground-source heat pumps;
  - solar thermal;
  - biomass boilers;
  - renewable combined heat and power;
  - use of biogas and bioliquids;
  - injection of biomethane into the natural gas grid.
- Domestic tariffs:

Solar thermal	**10.44 p/kWh**
Biomass boiler < 200kW	**2.96 p/kWh**
ASHP	**2.61 p/kWh**
GSHP	**9.09 p/kWh**

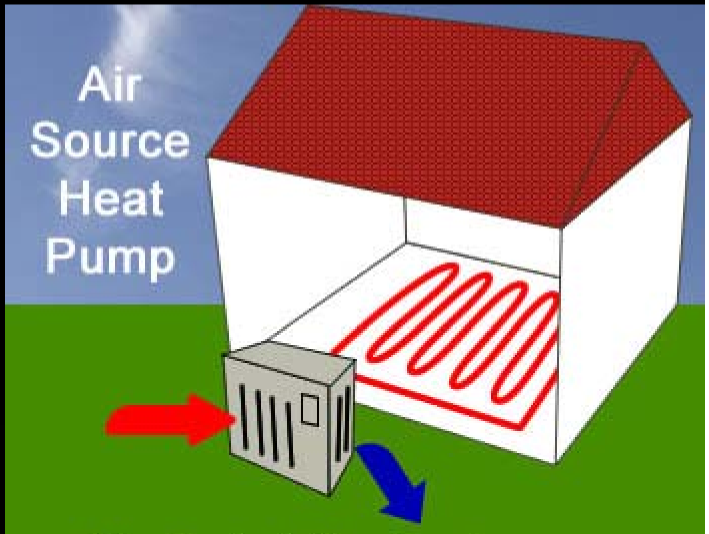
- Domestic installations must be accompanied by energy efficiency improvements.

Technologies - Heat Pumps

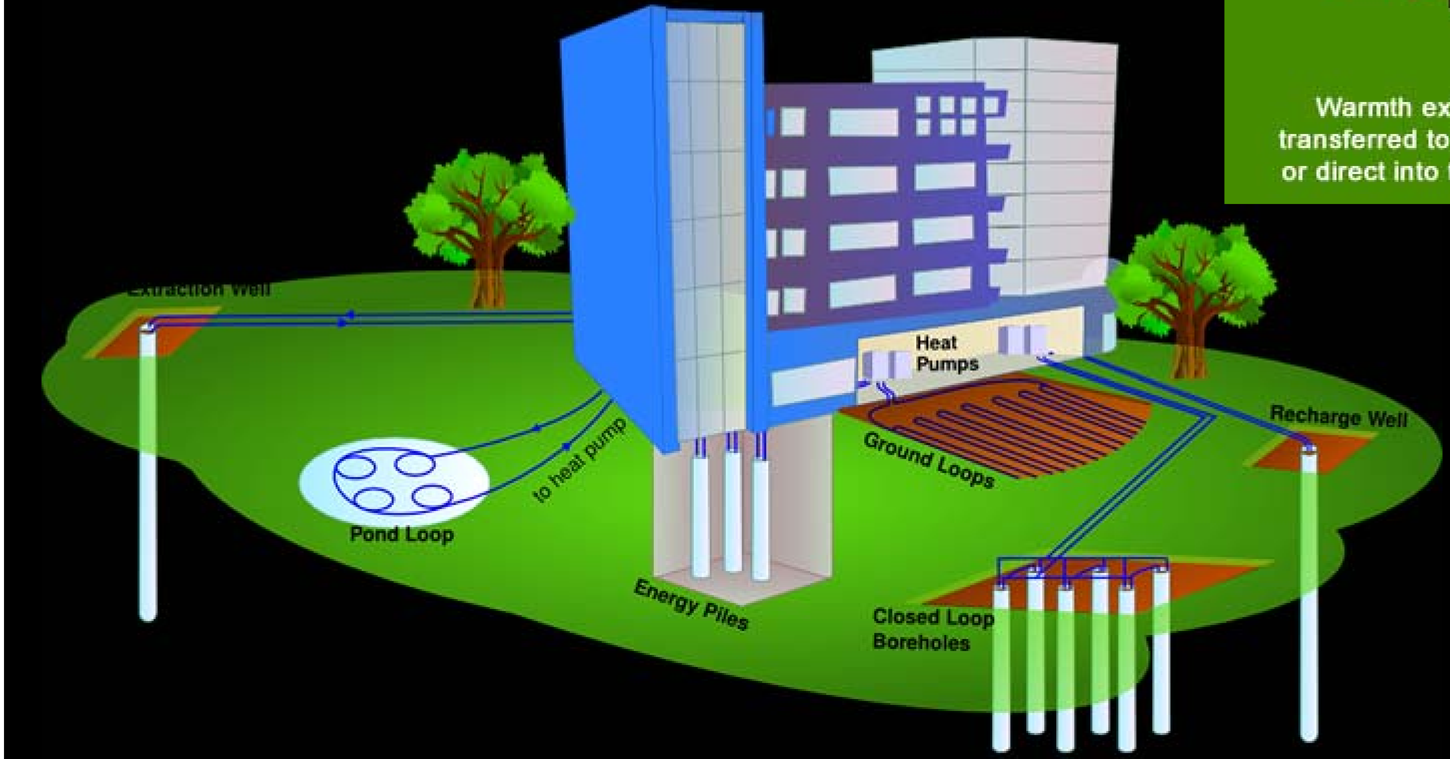
☐ Promoted via RHI.

☐ Three broad categories:

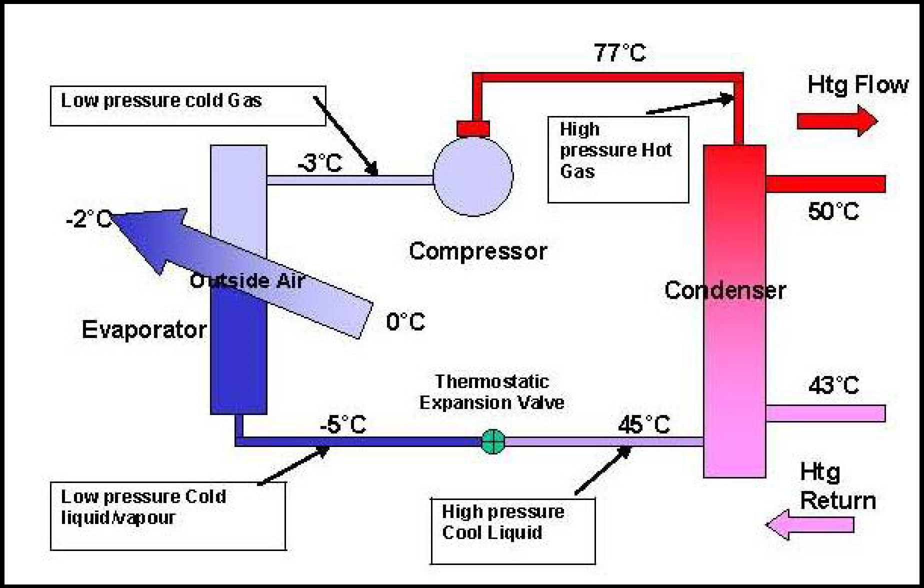
- ground source;
- water source;
- air source.



Warmth extracted from Air and transferred to the underfloor heating or direct into the air inside the home



Technologies - Heat pumps



- Performance measured by SPF – seasonal performance factor.
- For a heat pump to be considered renewable SPF > 2.5 according to EU.

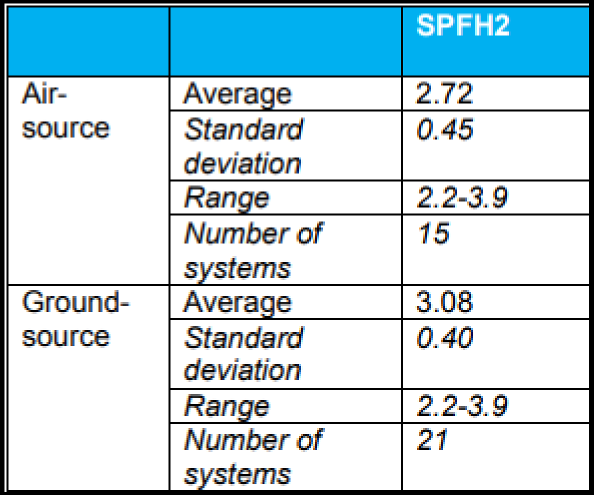
$$SPF = \frac{Q_s + Q_w}{E_e}$$

Q_s – space heat delivered (kWh)

Q_w – water heat delivered (kWh)

E_e – electrical consumption (kWh)

- Typical values from field trials (EST).



		SPFH2
Air-source	Average	2.72
	Standard deviation	*0.45*
	Range	*2.2-3.9*
	Number of systems	*15*
Ground-source	Average	3.08
	Standard deviation	*0.40*
	Range	*2.2-3.9*
	Number of systems	*21*

Technologies - Heat pumps

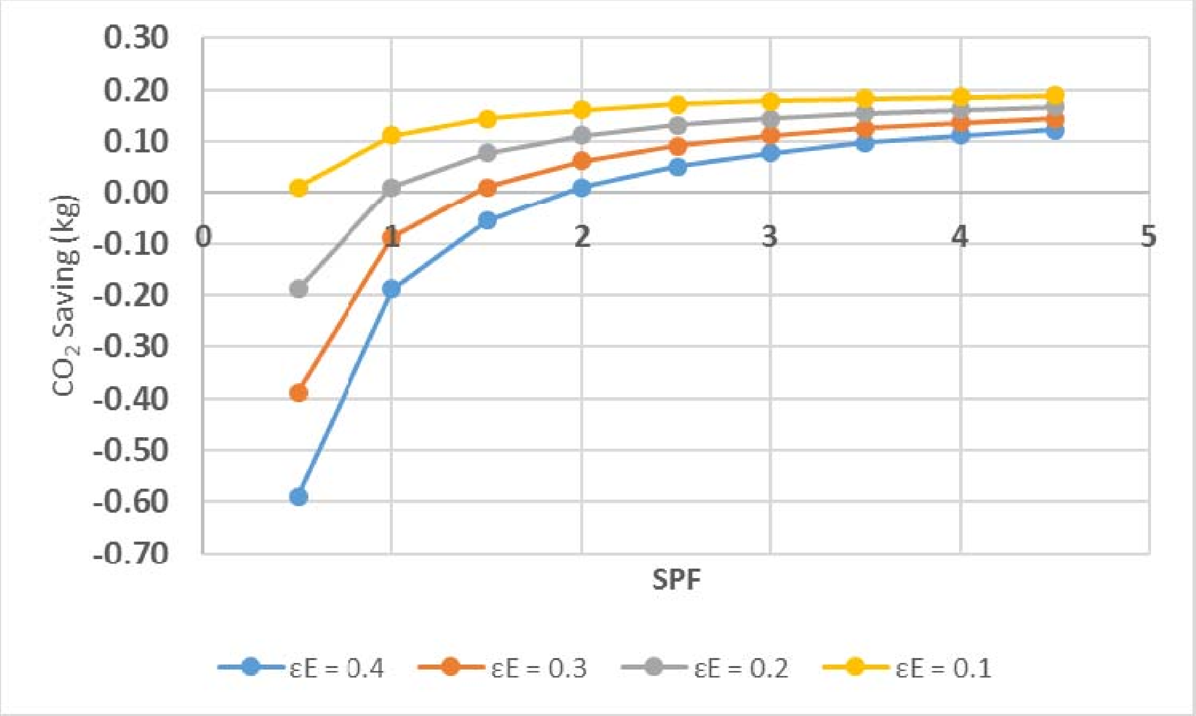
☐ CO_2 (kg) saving per kWh of heat output:

$$s = \frac{\varepsilon_G}{\eta_B} - \frac{\varepsilon_E}{SPF}$$

ε_E – carbon intensity grid electricity ($kgCO_2/kWh$)

ε_G – carbon intensity natural gas – 0.18 ($kgCO_2/kWh$)

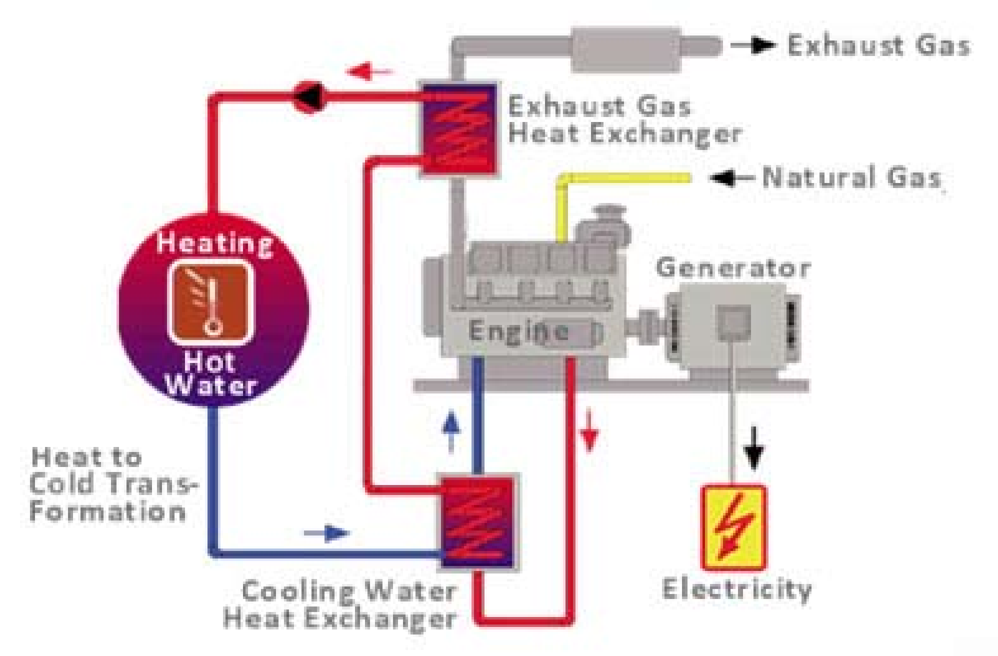
η_B – gas boiler efficiency (~0.85)



☐ 2017 intensity – 2.9 $kgCO_2/kWh$.

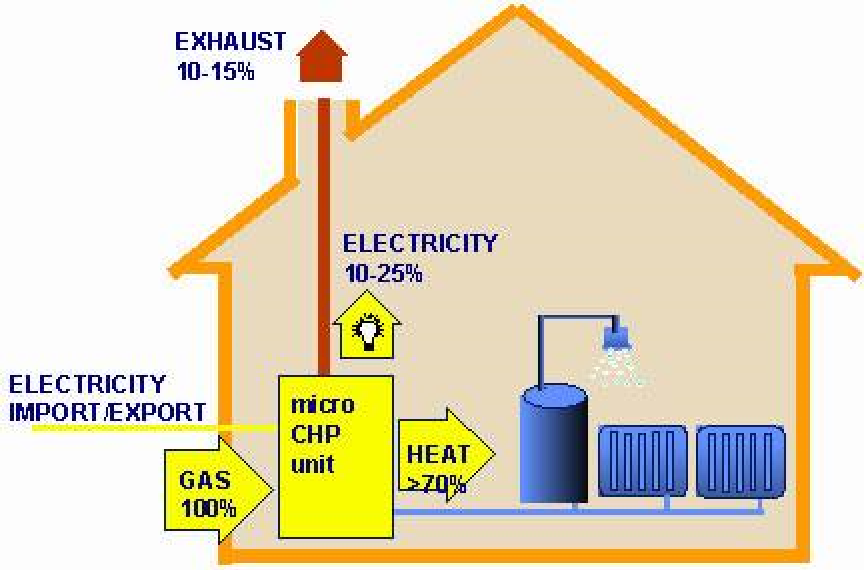
☐ Savings *improve* as grid decarbonises.

Technologies - combined heat and power (CHP)



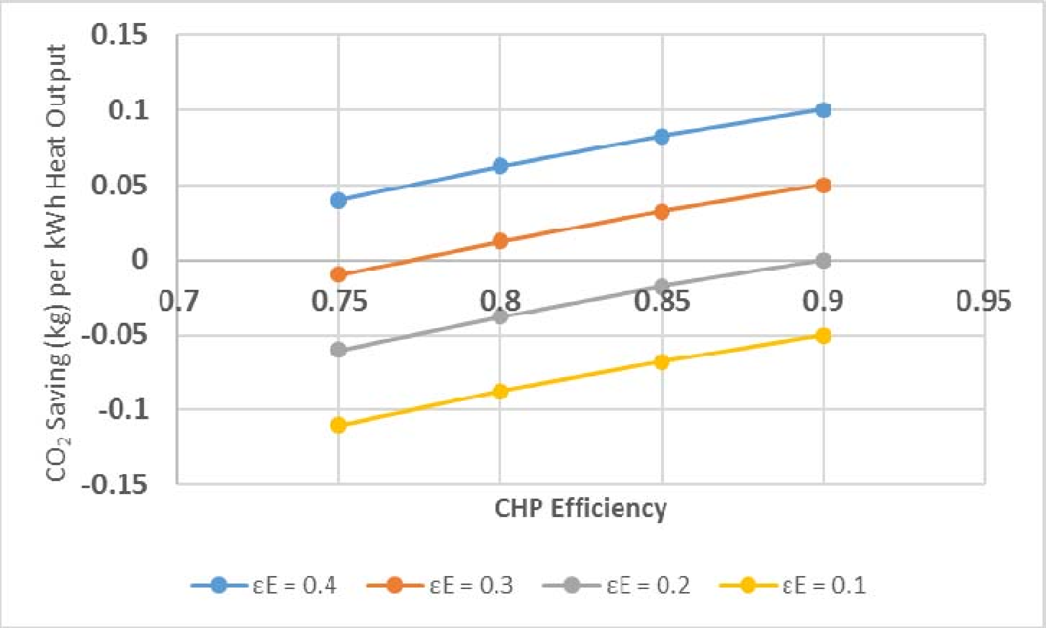
- CHP – provision of heat and power from a single fuel source
- Efficiencies of 85-90% possible
- Heat recovery from prime mover
- Wide range of scales –
  - kW (micro-small scale)
  - multi MW (industrial)

Source EST



- Promoted via FITS.
- Carbon savings compared to separate provision of heat and power.
- Limited uptake in the UK.

Technologies - combined heat and power (CHP)



- ☐ 2017 intensity – 2.9 $kgCO_2/kWh$.
- ☐ Savings *deteriorate* as grid decarbonises.

- ☐ CO_2 (kg) saving per kWh of heat output

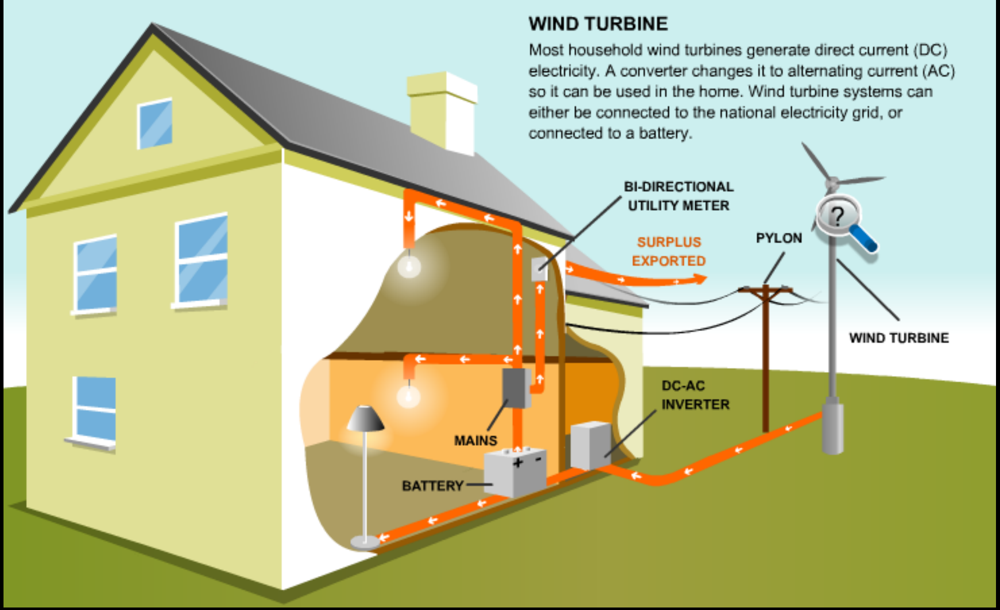
$$s = \left(\frac{1}{\eta_B} - \frac{1 + \frac{1}{HPR}}{\eta_{CHP}}\right)\varepsilon_G + \frac{\varepsilon_G}{HPR}$$

HPR - heat: power ratio

Technologies - biomass heating

- Uptake encouraged by renewable heat incentive (RHI).
- More expensive and more maintenance required than gas boiler.
- Efficiency < gas boiler.
- Substantial running cost savings compared to oil boilers or electricity in off-gas grid areas.
- Usually combined with a substantial thermal store.
- Question marks over carbon savings and air pollution.

Technologies - wind power



WIND TURBINE

Most household wind turbines generate direct current (DC) electricity. A converter changes it to alternating current (AC) so it can be used in the home. Wind turbine systems can either be connected to the national electricity grid, or connected to a battery.

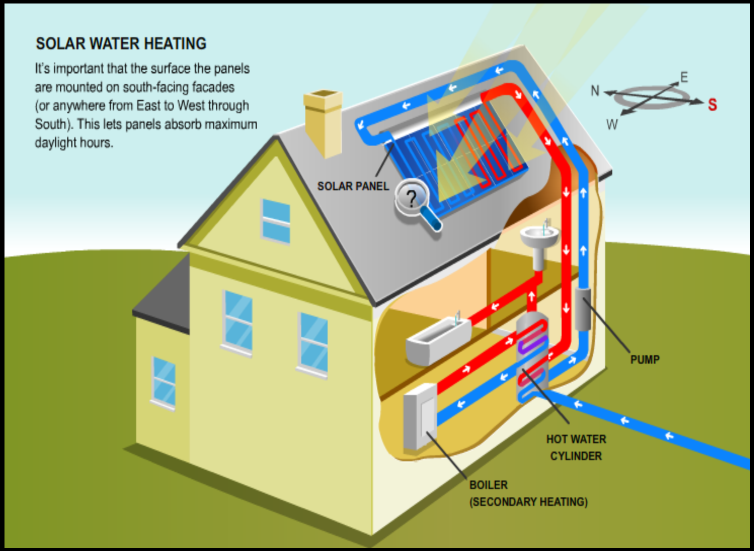
Source EST

- Uptake encouraged by FITS.

- Most small wind turbines installed in rural areas - good wind resource.

- Performance in urban areas is usually very poor.

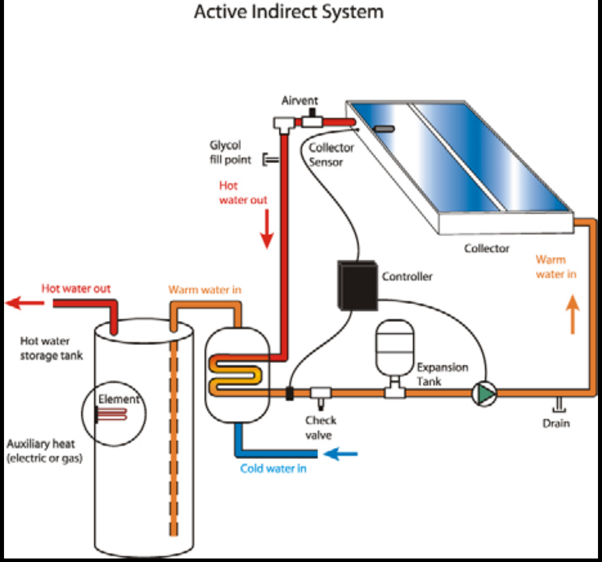
Technologies - solar thermal



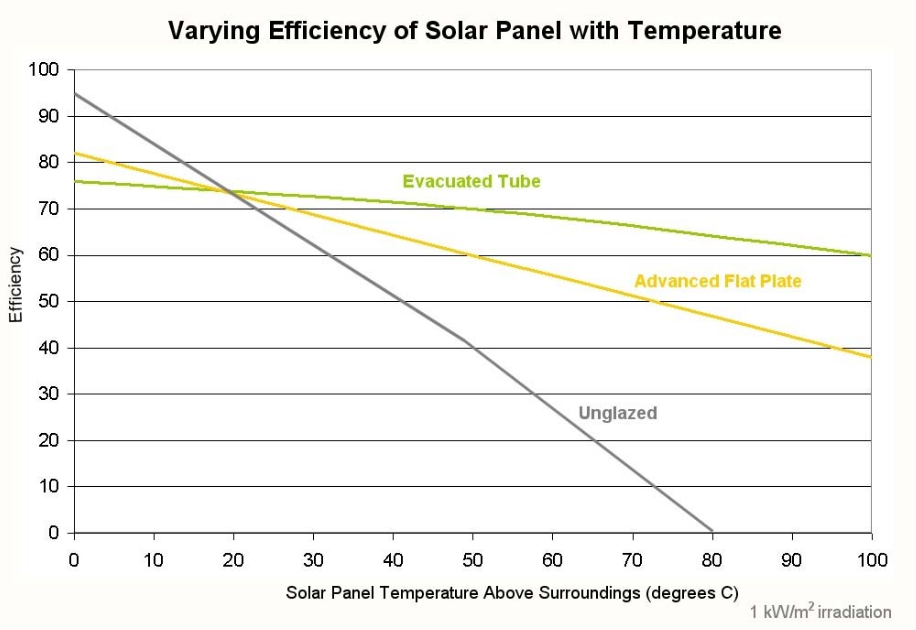
SOLAR WATER HEATING

It's important that the surface the panels are mounted on south-facing facades (or anywhere from East to West through South). This lets panels absorb maximum daylight hours.

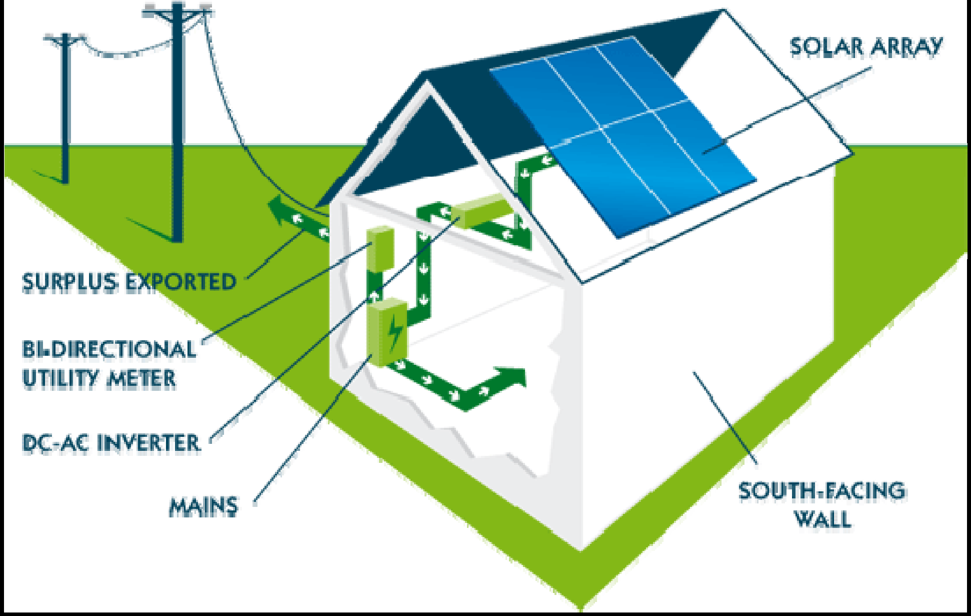
Source EST



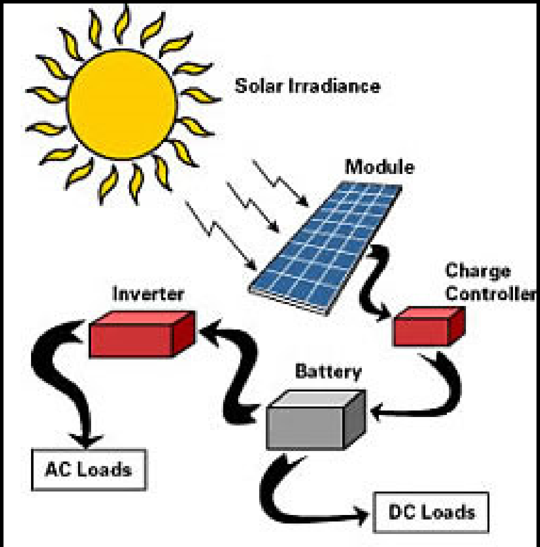
- Uptake encouraged by renewable heat incentive (RHI).
- Efficiencies ~ 70% but dependent on heating system and control as well as collector.
- Usually installed with thermal storage.
- Poor uptake in UK compared to PV.



Technologies - photovoltaics

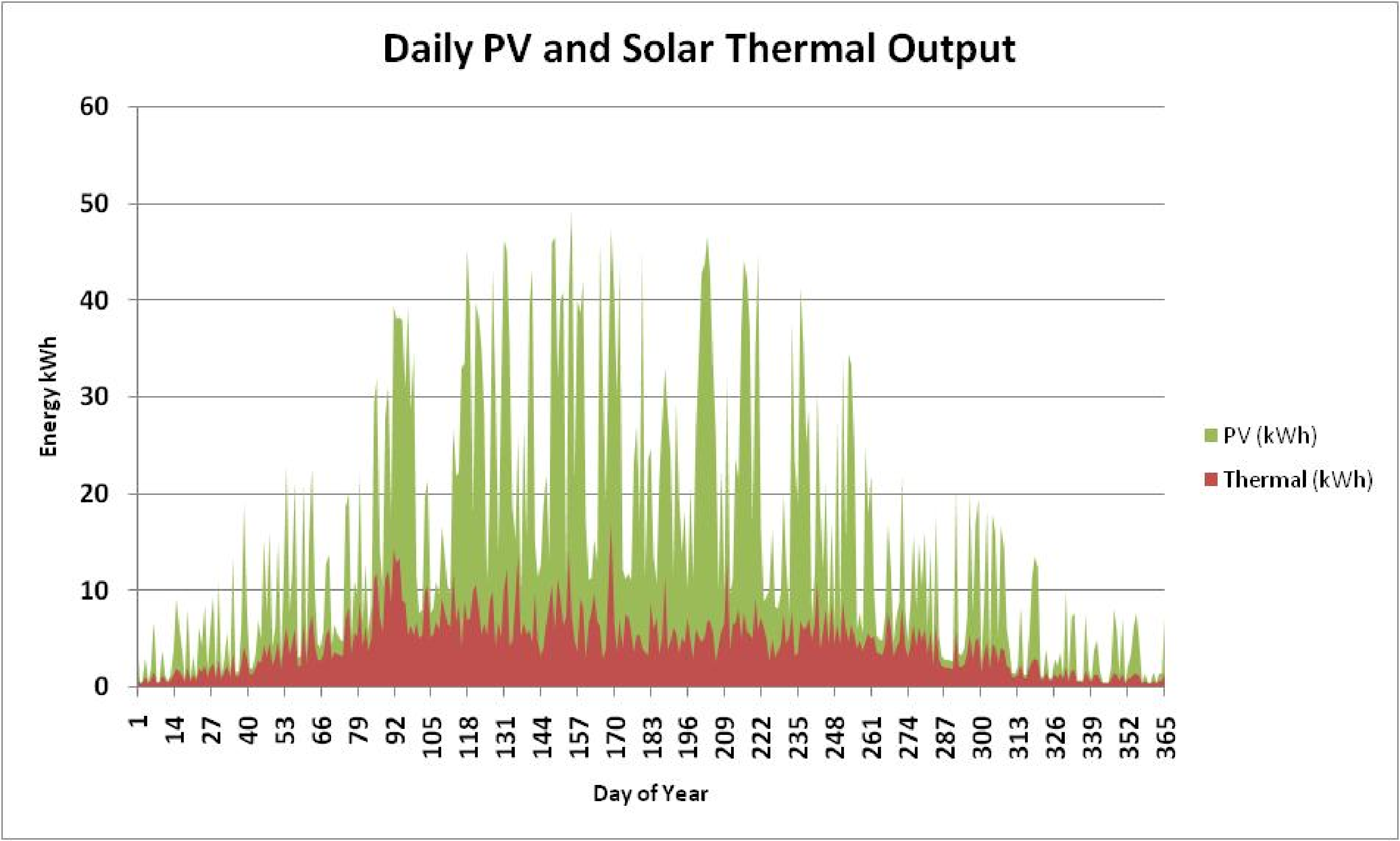


Source EST



- Explosive growth due to FITS.
- Growth in rooftop PV and PV farms.
- PV capacity was ~0 in 2009 now 12.8 GW.
- Now a significant part of the UK power generation mix.

Solar variability



- ❑ Solar thermal and solar PV vary diurnally (over the course of a day).
- ❑ Also exhibit significant seasonal variability.

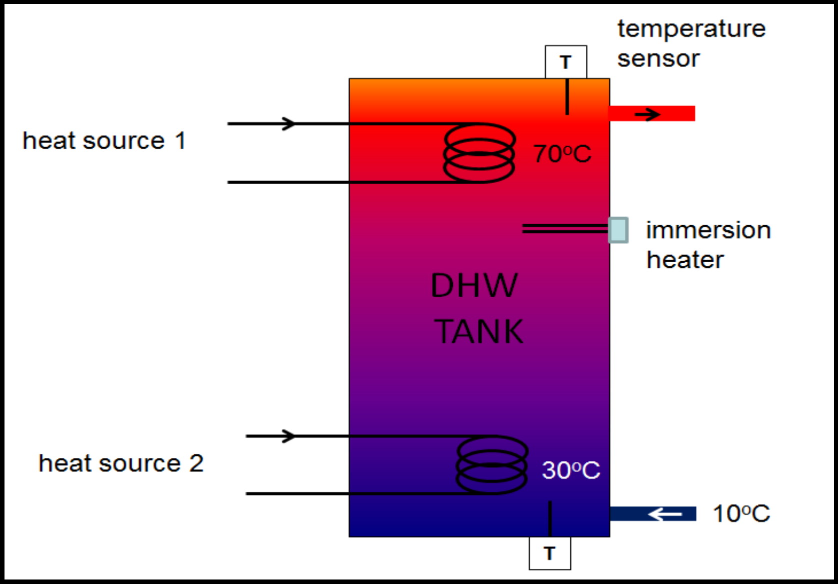
Thermal Storage

Positives:

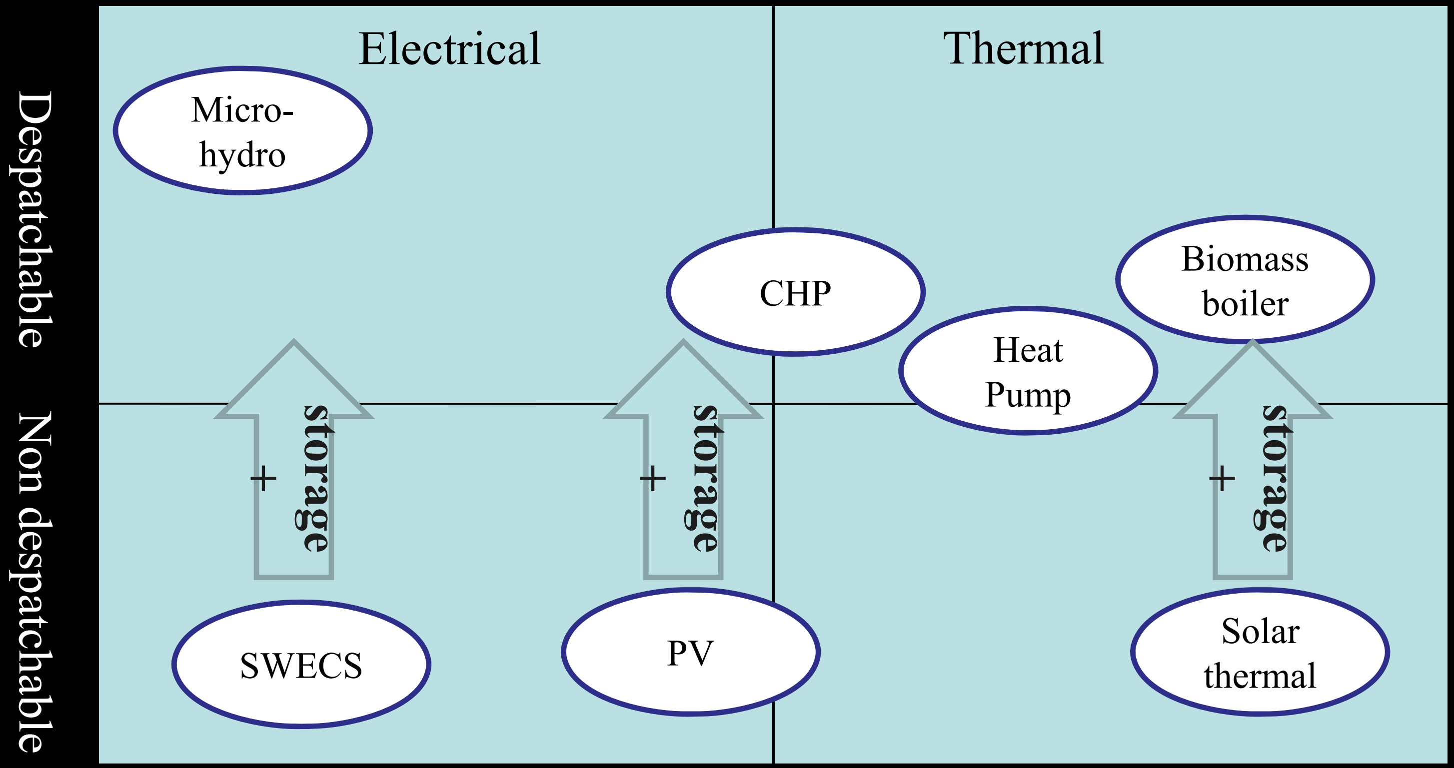
- ❑ allows intermittent supplies to meet demands;
- ❑ provides more benign operating environment for hybrid microgeneration;
- ❑ allows different temperature sources to be couple;
- ❑ facilitates load management.

Negatives:

- ❑ typically increases standby losses;
- ❑ takes up space.



Microgeneration controllability



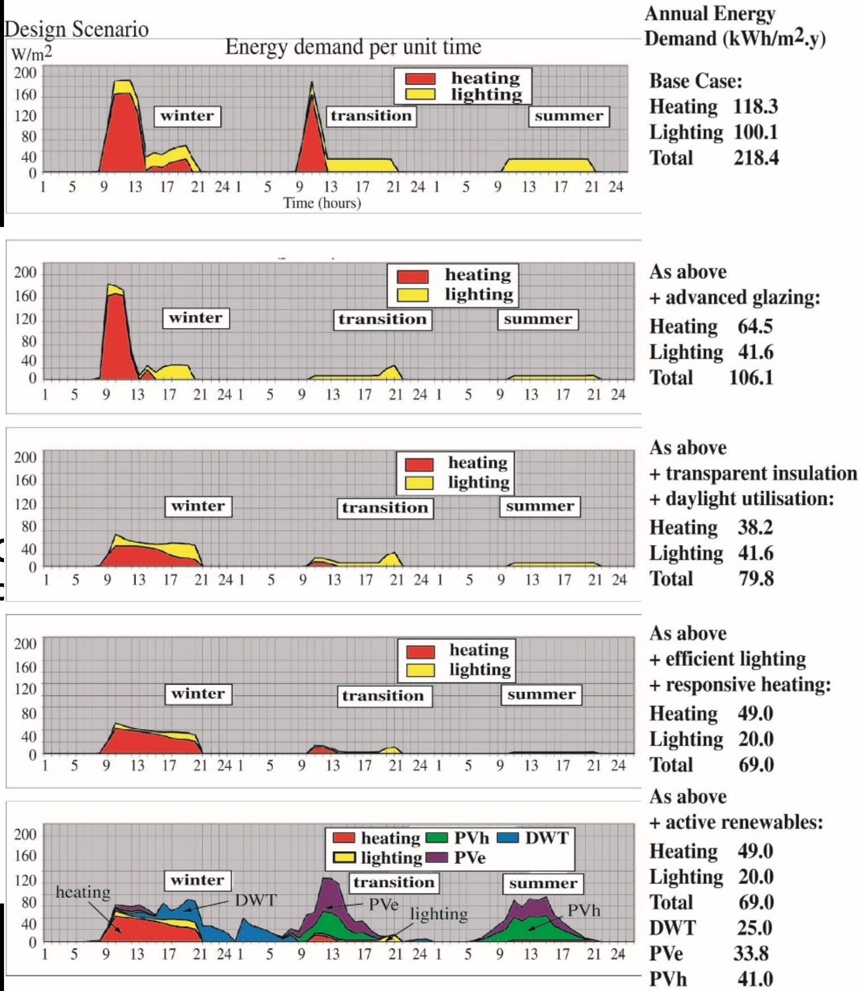
- ☐ Two broad categories:
  - *despatchable* – output can be controlled to accommodate fluctuations;
  - *non-despatchable* – output is generally variable and unpredictable.
- ☐ Energy storage can turn a non-despatchable resource into a despatchable one.

Zero energy buildings

- ☐ Microgeneration is increasingly being deployed in buildings – opening up possibility of zero energy buildings.
- ☐ *Autonomous Zero Energy Buildings* – all demand are met by on-site generation; no external network connections.
- ☐ *Net-zero site energy* – local generation completely offsets on-site demand; demand and supply are not temporally matched but balance over a year.
- ☐ *Net-zero source energy* - local generation completely offsets primary energy demands; demand and supply are not temporally matched but balance over a year.

Zero energy buildings

The Lighthouse Building, Glasgow



Annual Energy Demand (kWh/m^2.y)

Base Case:
Heating 118.3
Lighting 100.1
Total 218.4

As above
+ advanced glazing:
Heating 64.5
Lighting 41.6
Total 106.1

As above
+ transparent insulation
+ daylight utilisation:
Heating 38.2
Lighting 41.6
Total 79.8

As above
+ efficient lighting
+ responsive heating:
Heating 49.0
Lighting 20.0
Total 69.0

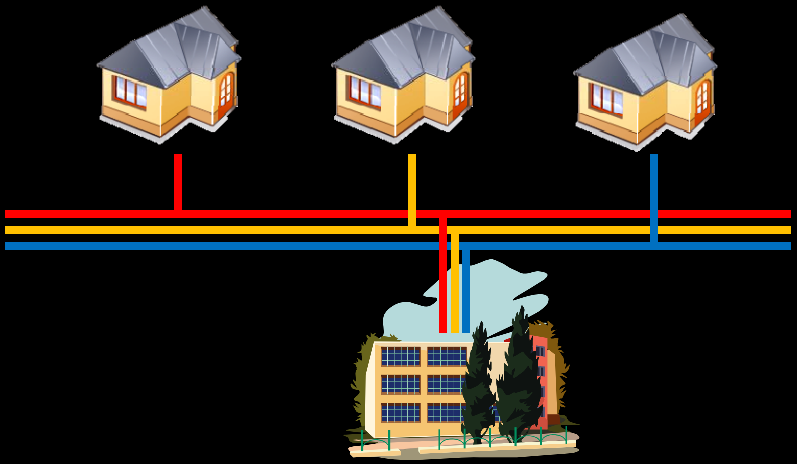
As above
+ active renewables:
Heating 49.0
Lighting 20.0
Total 69.0
DWT 25.0
PVe 33.8
PVh 41.0

Demand: 68 kWh/m^2.yr

RE supply: 98 kWh/m^2.yr

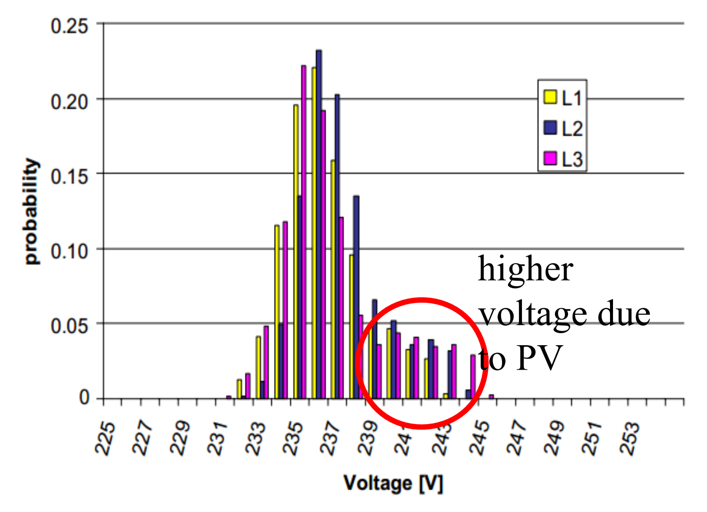
Microgeneration and the electricity network

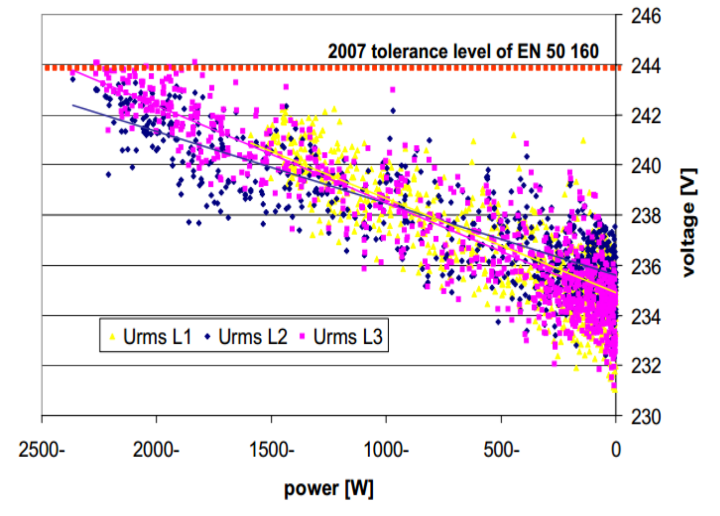
- Microgeneration power feeds into the low voltage (LV) network.
- In Europe the LV network operates at 220-250 V a.c.
- LV network couples directly to dwellings.
- So microgeneration feeding into this part of the network has a direct impact on the power supplied to dwellings.
- Microgeneration could drive the development of a highly distributed power system.
- Local power used locally … but with significant penetration power could flow back up through the voltage levels – i.e. reverse power flow.



Changes in Voltage

- ☐ Adding power into a network causes the local voltage to rise.
- ☐ Taking power from a network causes the local voltage to drop.
- ☐ A surplus of PV power in the middle of the day could result in high LV network voltage levels.
- ☐ Excessive heat pump operation in the morning/evening could cause periods of low voltage.

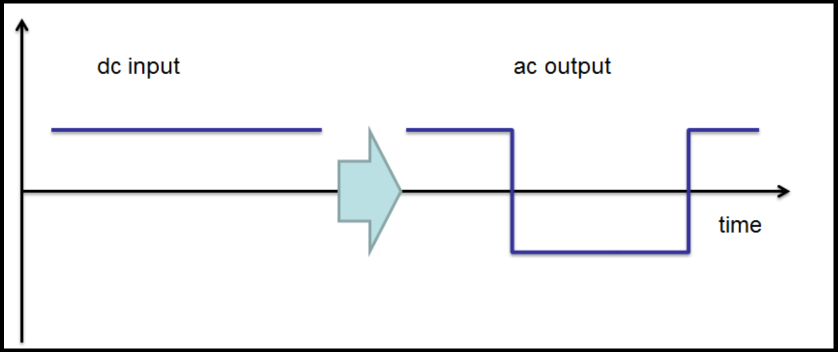


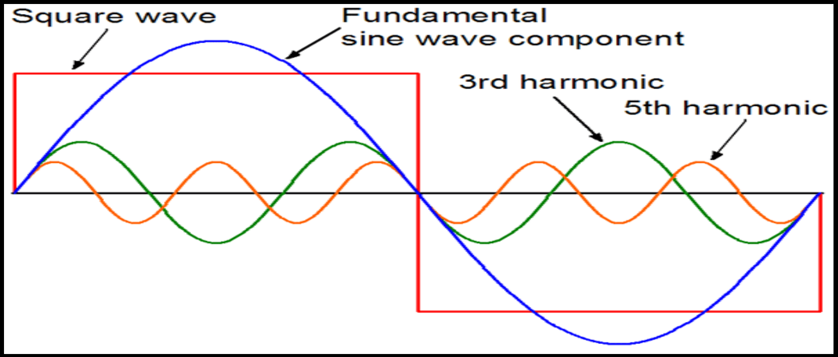


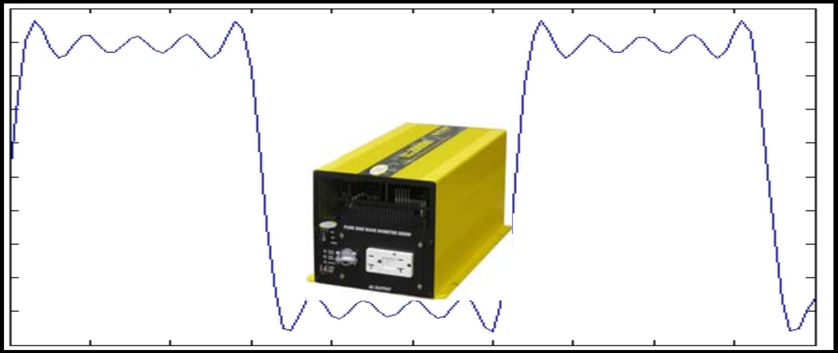
Source: Cobben *et al* PV Upscale, WP 4 Report

Harmonics and losses

- Harmonics cause increased energy losses in electricity network
- Can shorten lifespan in electrical components.
- Also having increased power flows in LV network increases I^2R losses







Source: Saribulut *et al* Electric Power Systems Research, Vol 86.

Microgeneration for network support

☐ The interaction between microgeneration and the network can be beneficial as well as causing problems.

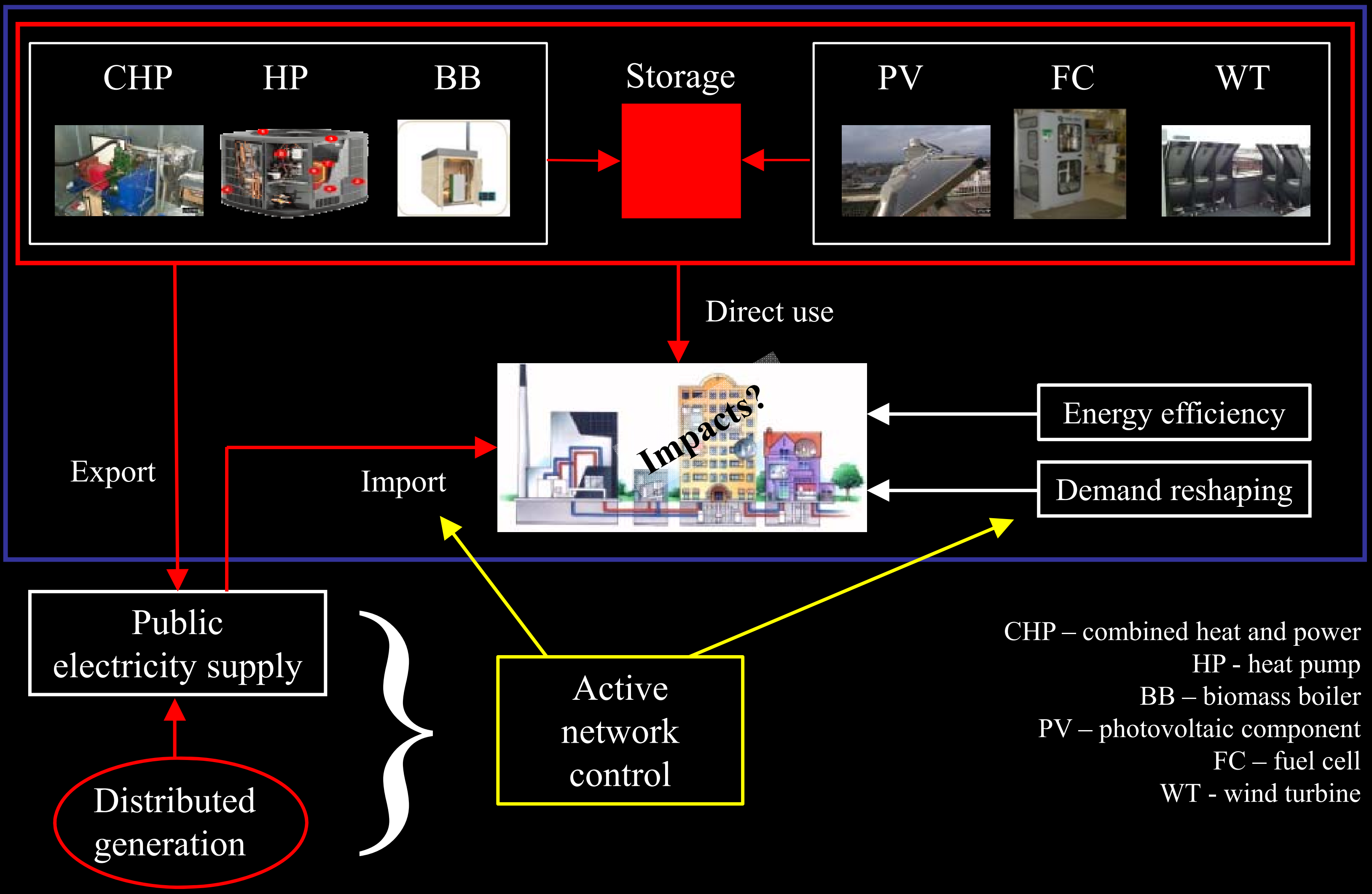
☐ Microgeneration technologies can act co-operatively with the network to improve its operation.

☐ For power producing technologies (e.g. PV):
  - provision of power when the local network is heavily loaded (positive participation);
  - stopping operation at times of low loading (negative participation).

☐ For power absorbing technologies (e.g. heat pumps):
  - absorbing power at times of high renewables/ microgeneration production;
  - stopping operation at time of heavy network loading.

☐ To provide support as described, microgeneration technologies need to be controlled and *despatchable*.

Micro-grids



CHP HP BB

Storage

PV FC WT

Direct use

Impacts?

Energy efficiency

Demand reshaping

Export

Import

Public electricity supply

Distributed generation

Active network control

CHP – combined heat and power
HP - heat pump
BB – biomass boiler
PV – photovoltaic component
FC – fuel cell
WT - wind turbine

Conclusions

- Microgeneration growing rapidly.
- Strong legislative drivers.
- Power and heat from zero low-carbon technologies.
- Patchy performance history so-far.
- Power quality and energy efficiency issues.
- Could play a part in future power supply as part of a microgrid.