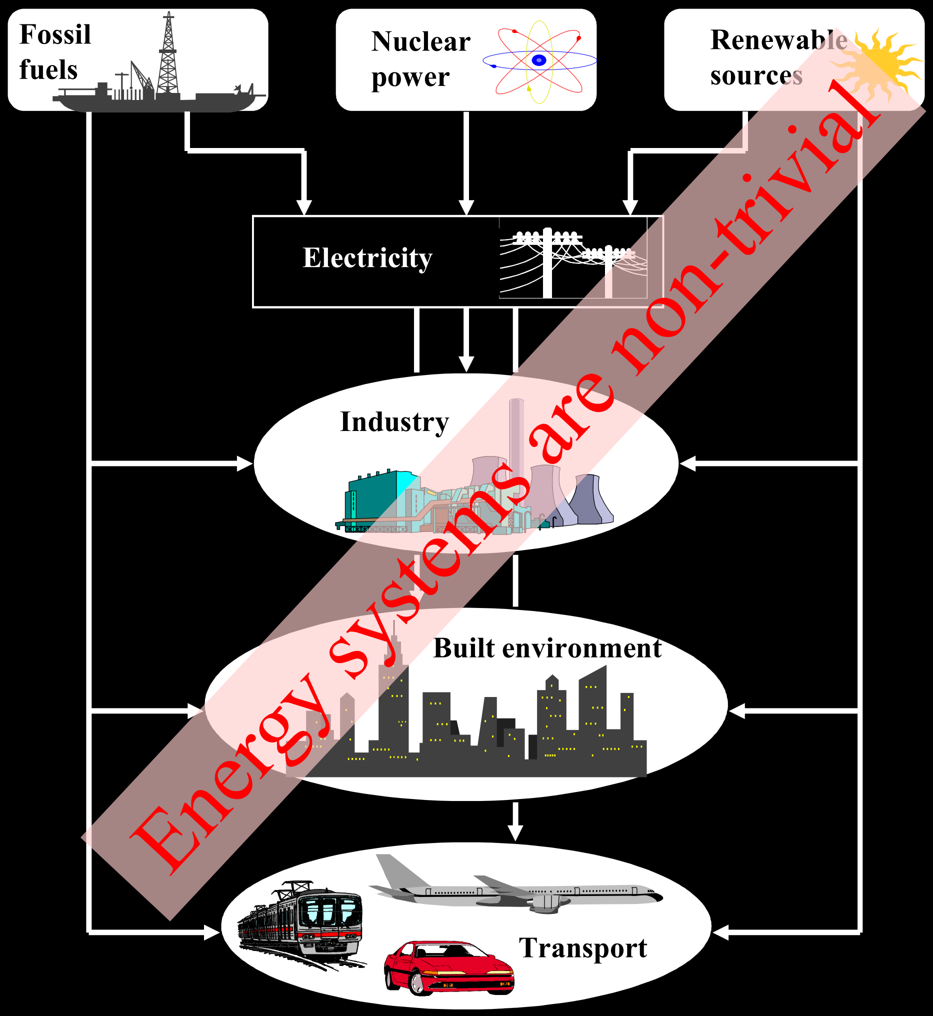
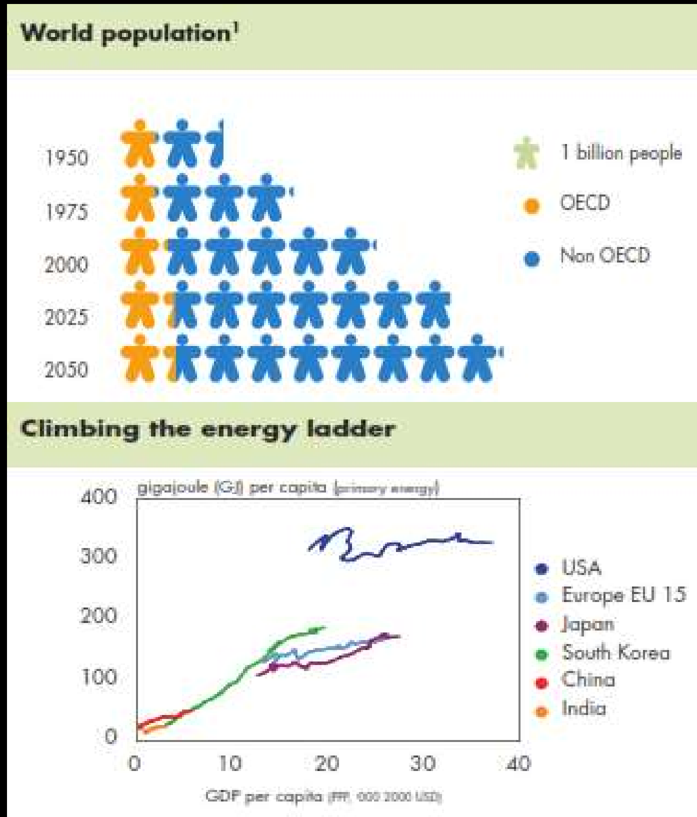
Energy Challenges and Opportunities

Energy production, conversion and distribution

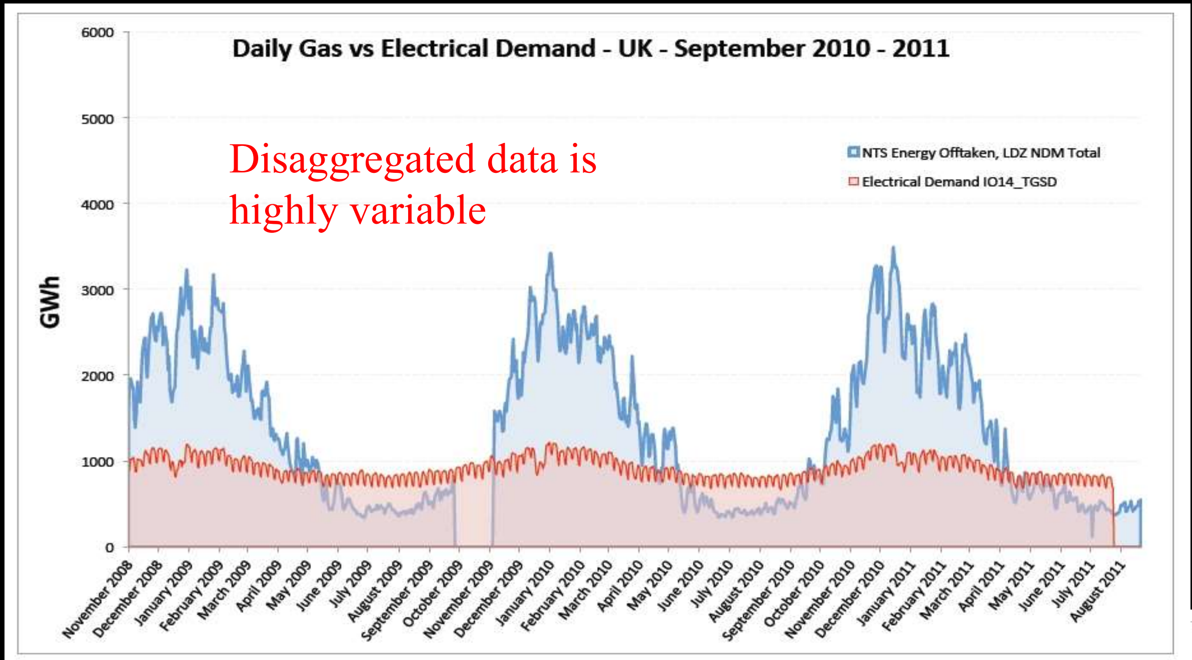


Step-change in energy use.
Supply struggling to meet demand.
Environmental stresses increasing.

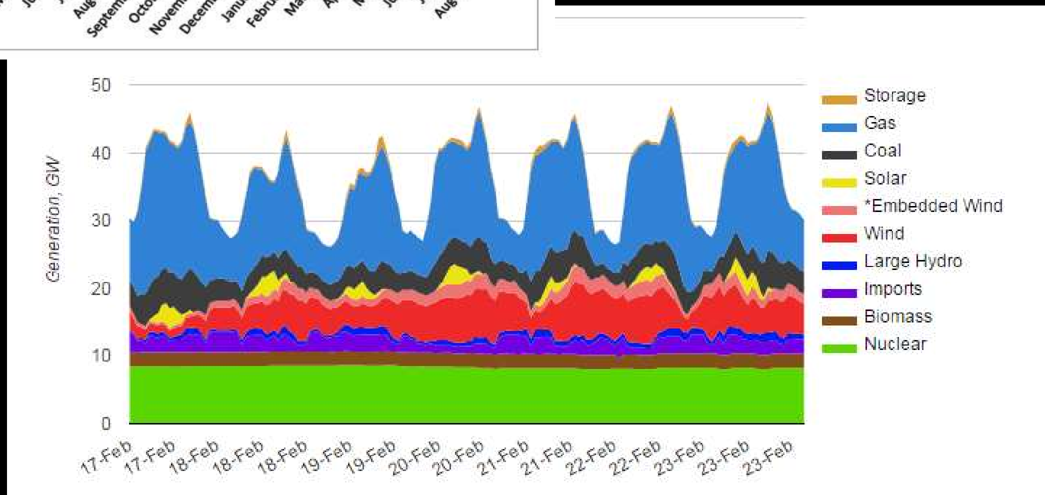


Shell Global Scenarios to 2050
(www.shell.com/scenarios)

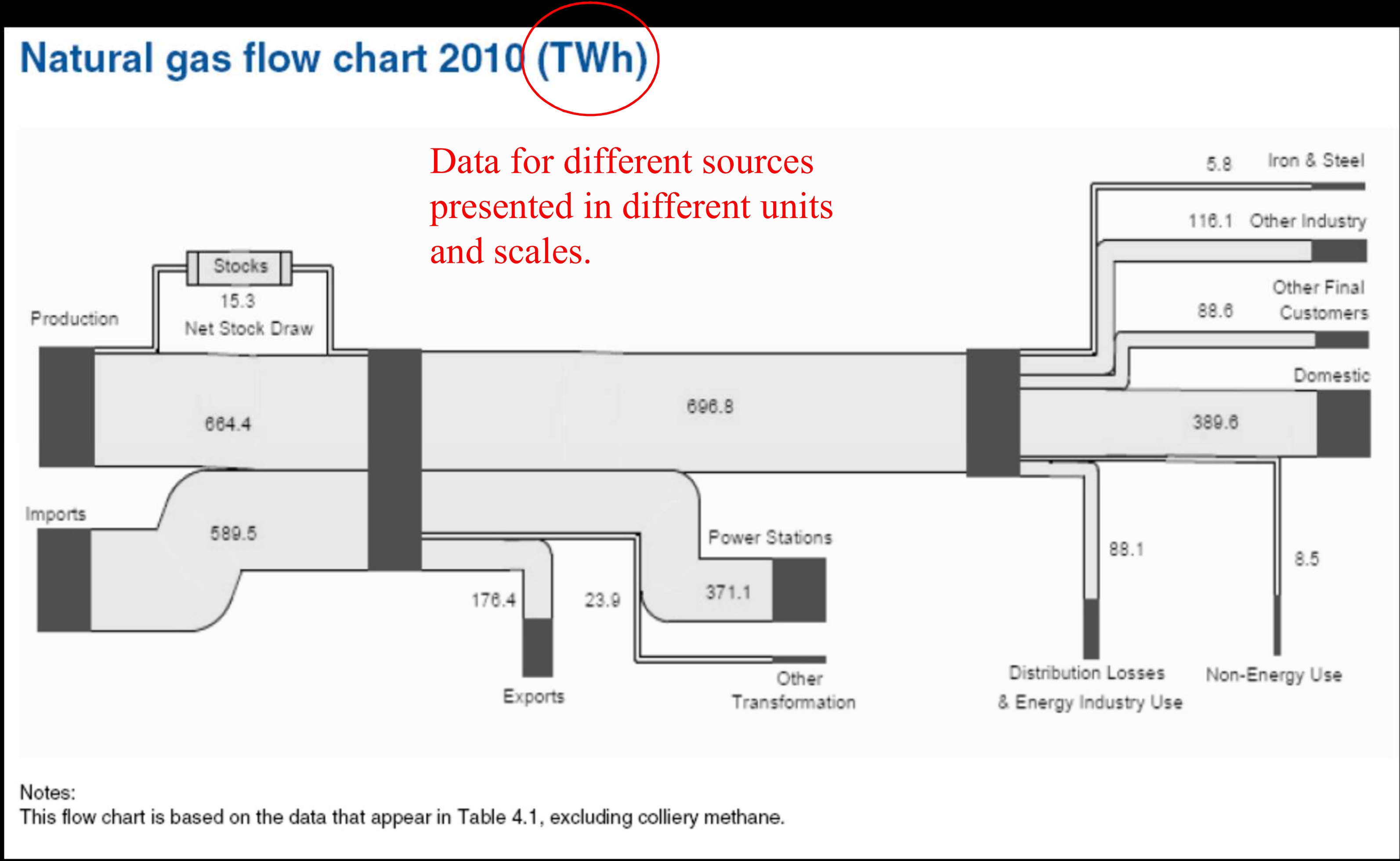
National energy demand



National Grid

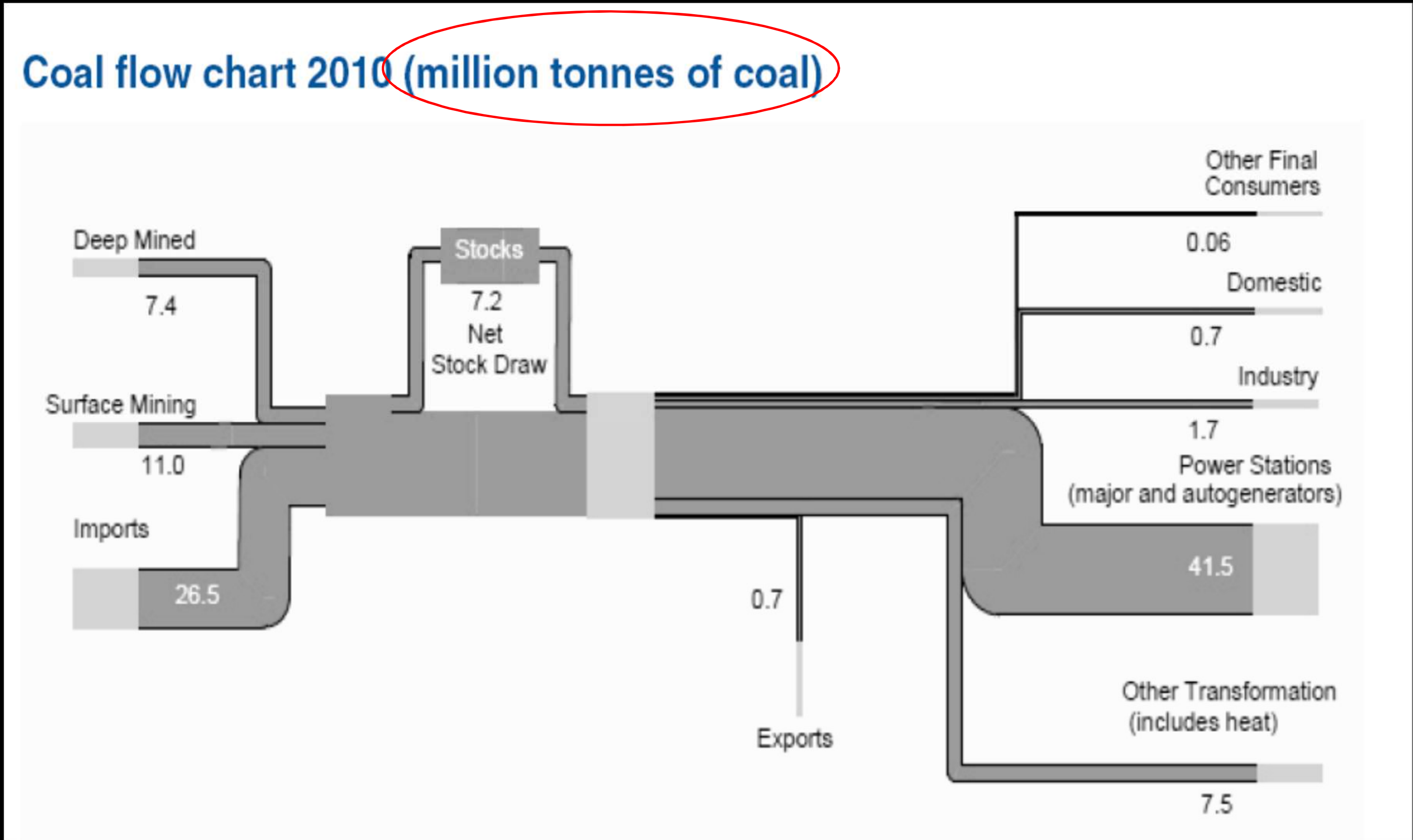


UK gas balance



DUKES

UK coal balance



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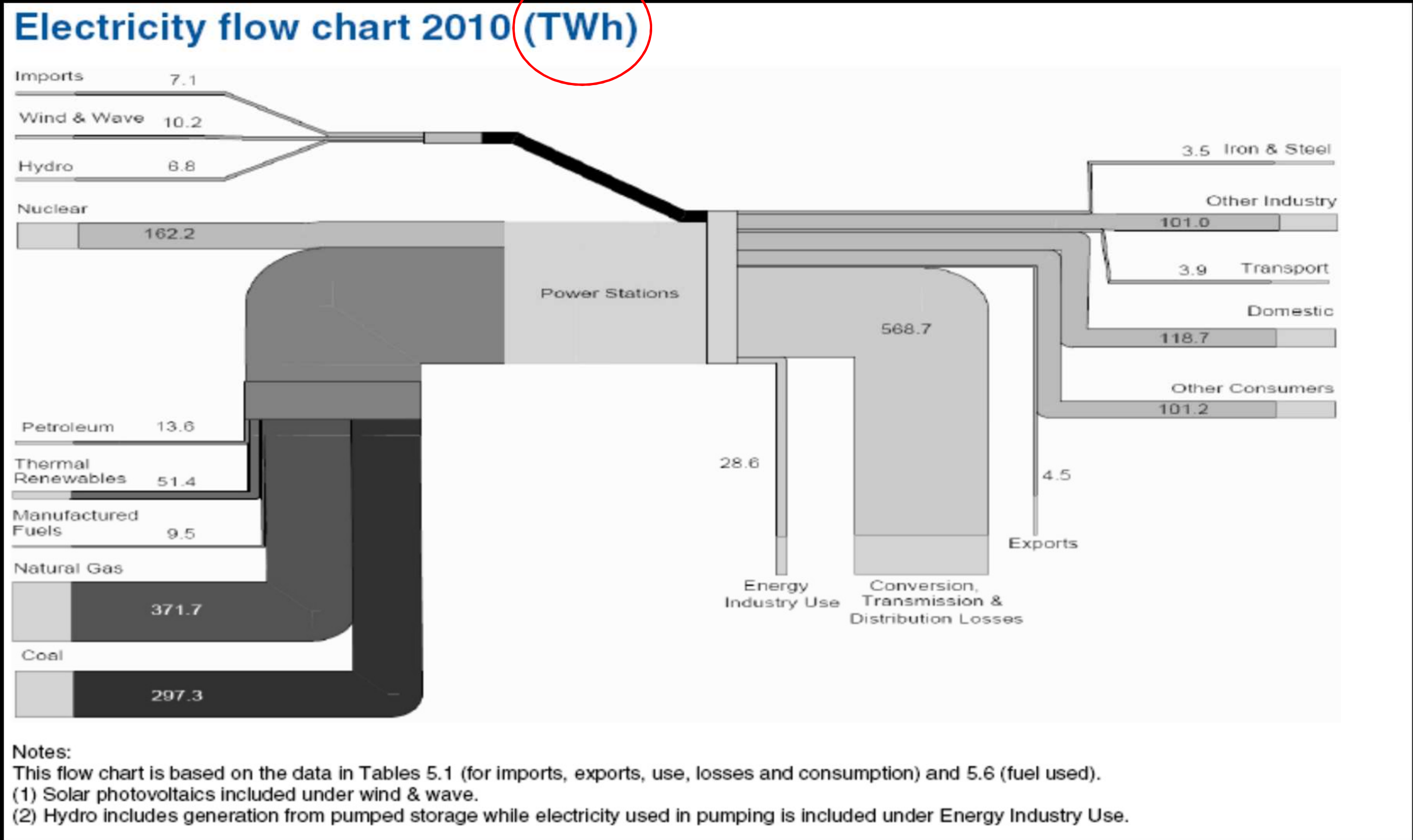
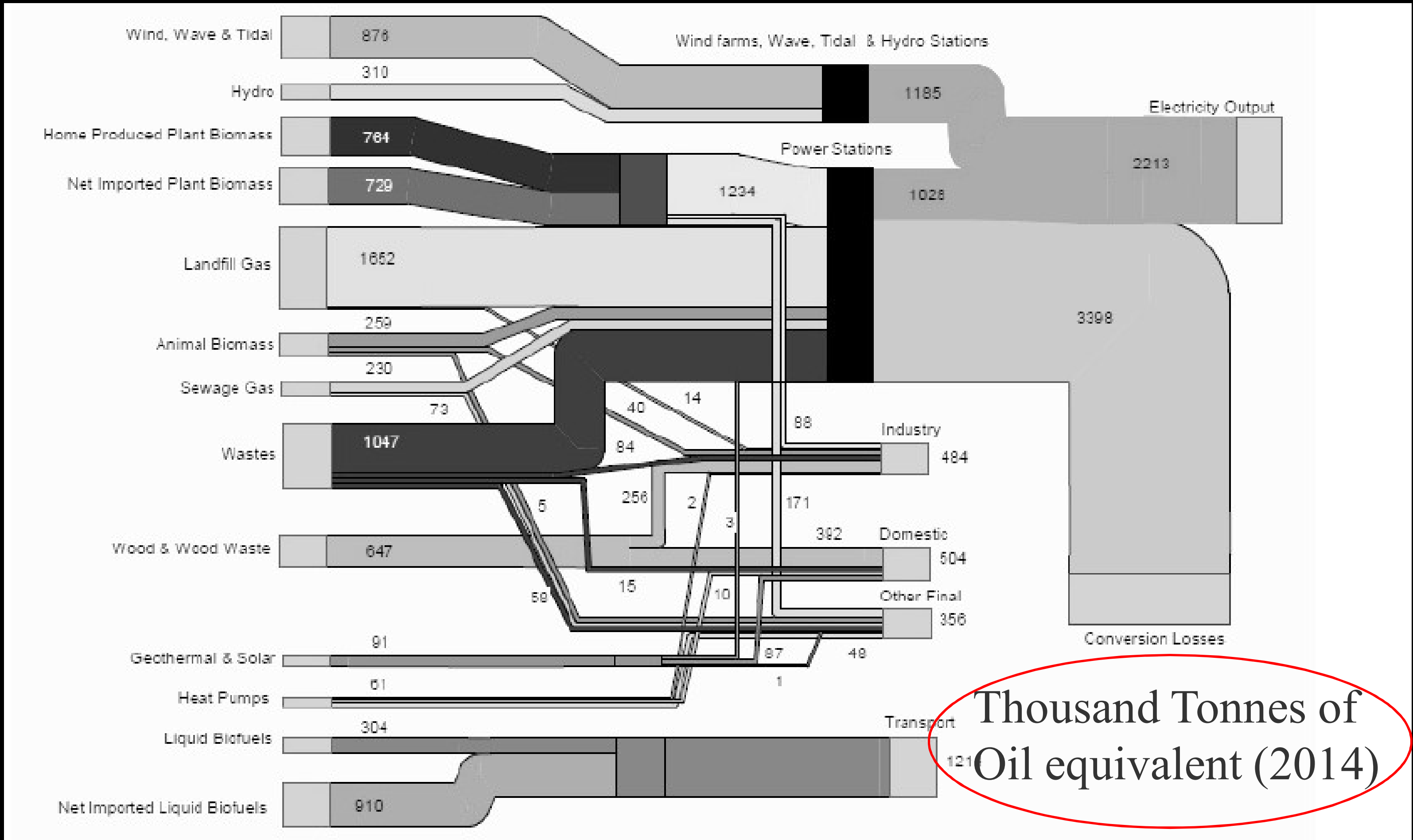
UK electricity balance



DUKES

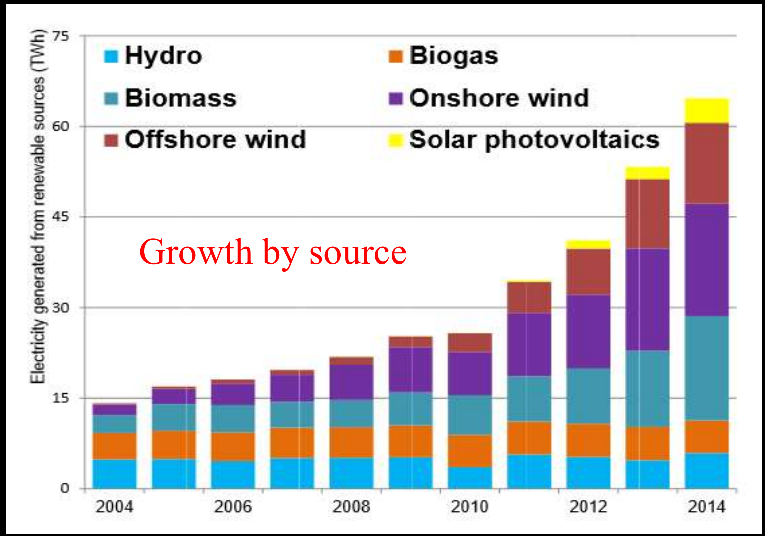
UK renewables balance

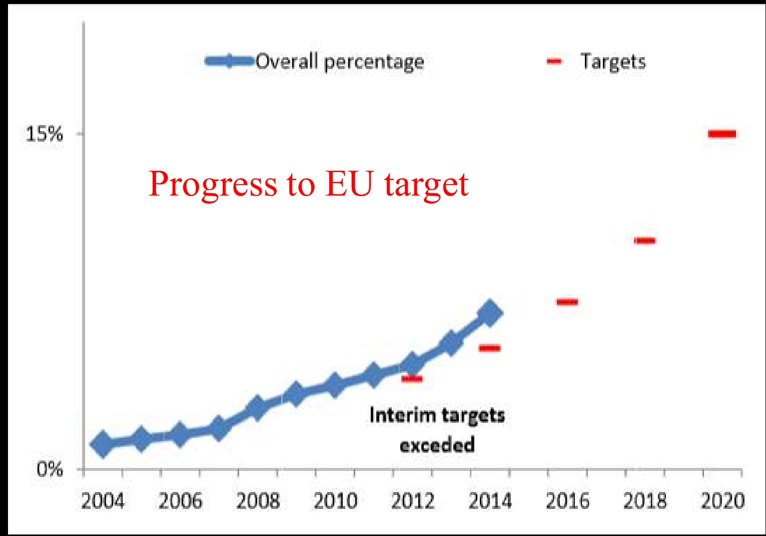


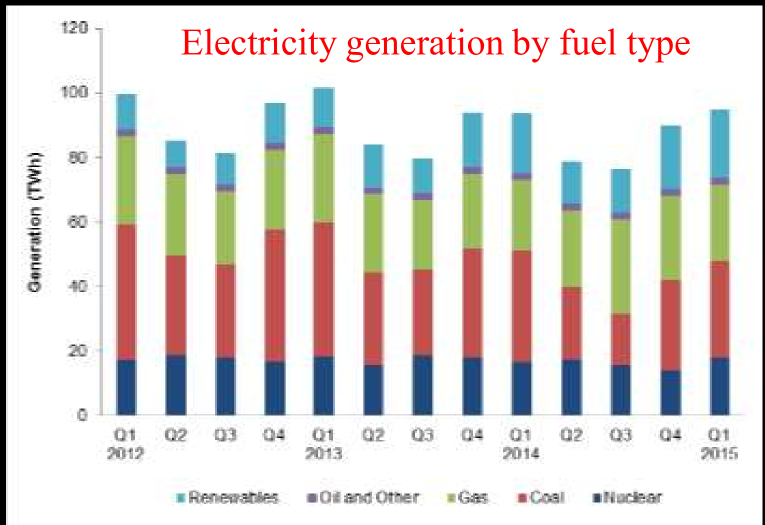
DUKES

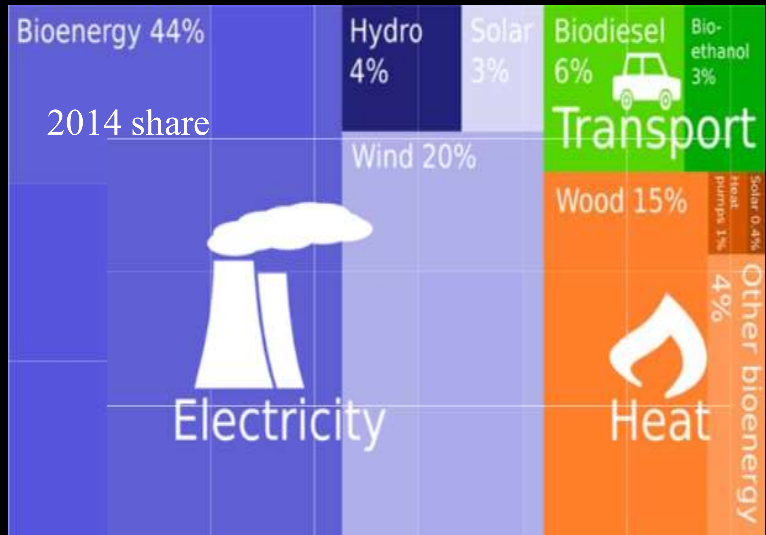
Challenge: moving towards a wider variety of low-carbon energy resources reduces reliance on specific energy types but greatly increases the complexity of the energy system.

UK renewable energy





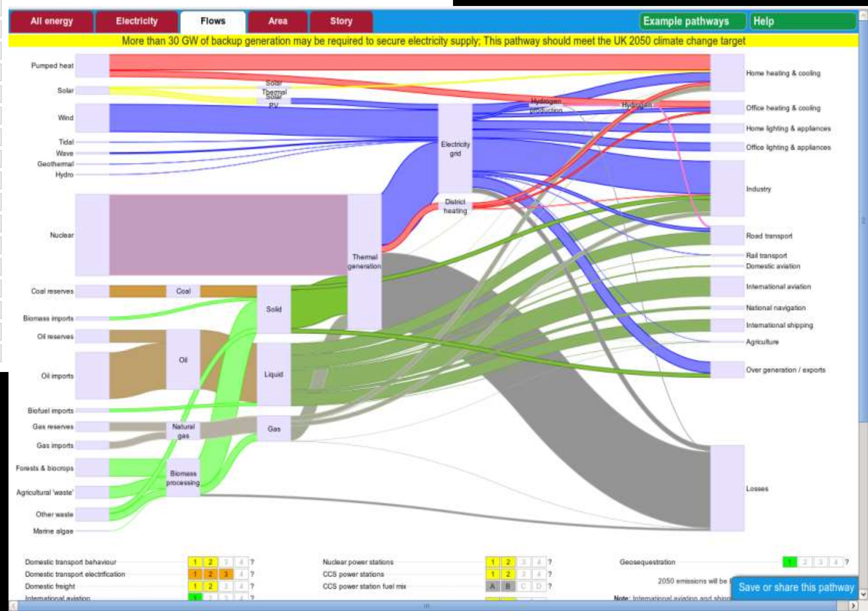




DUKES

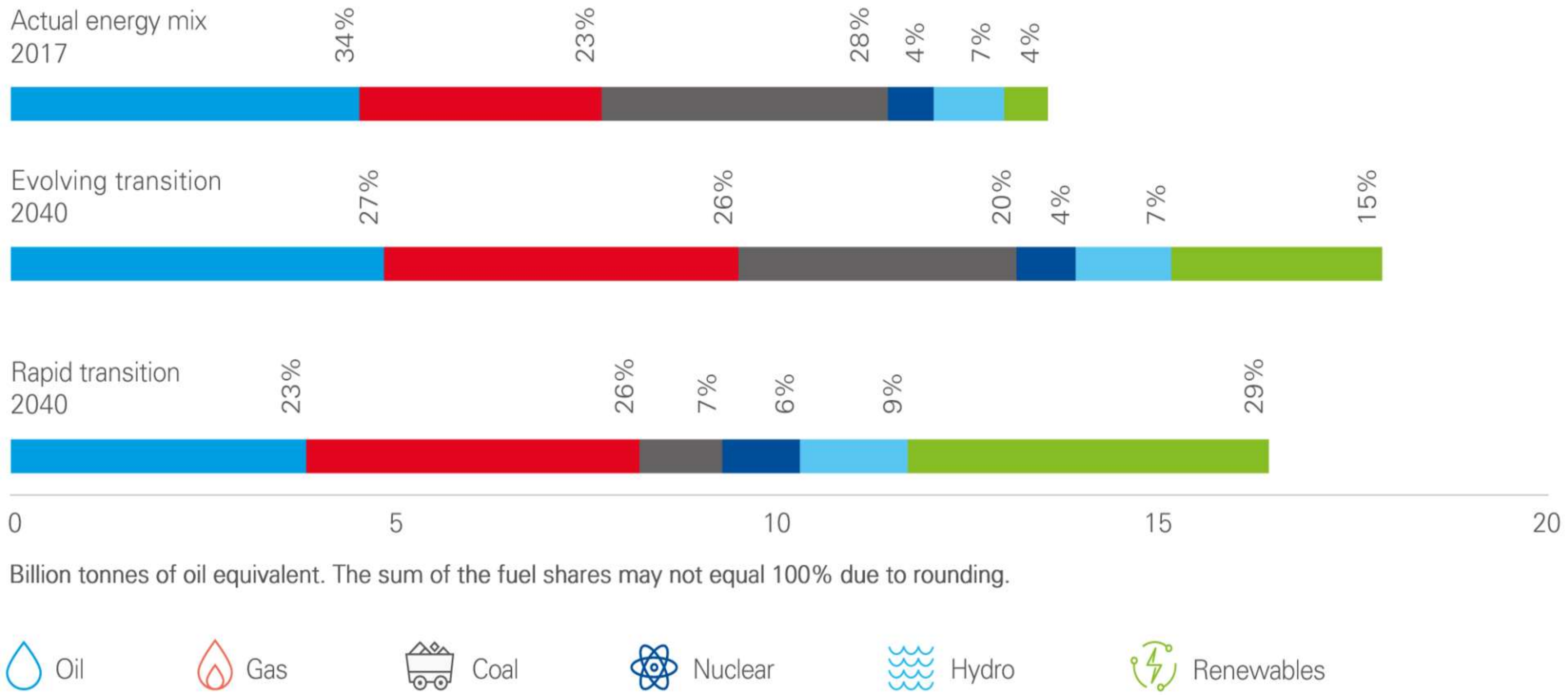
DECC: 2050 calculator

Used to indicate the outcome of different supply type mixed and demand reduction interventions.



http://withouthotair.blogspot.com/2010/07/2050-calculator-tool-at-decc.html

World energy outlook



BP Energy Outlook, 2019 Edition

World energy outlook

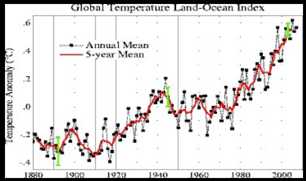
Shell Global Scenarios to 2050 (www.shell.com/scenarios)

Examples of a volatile industry

- UK:
  - North Sea oil price drops to ~$50/barrel (2015)
  - Wind capacity growth slows (2015).
  - Government cuts subsidies for new onshore wind farms, ends small scale solar subsidies and ceases funding for the Green Deal (2015).
  - Lancashire County Council rejects planning application for shale gas exploration (2015).
  - Hydraulic Fracturing Consent for shale gas operator Cuadrilla Bowland Ltd (2018).
  - The 400th anaerobic digestion plant is commissioned (2015).
  - ‘Contracts-for-difference’ scheme, which subsidises large-scale renewable energy projects, given go-ahead by European Commission (2015).
  - UK to phase out coal-power by 2025 (2018).
  - UK aims to have 16 GWe of new nuclear capacity operating by 2030 (2018).

- International:
  - The largest MW capacity for a tidal power plant in 2011 is located at Sihwa Lake and rated at 254 kW.
  - 200 MW tidal stream site planned for the Incheon site in Korea (2015).
  - World coal consumption reduces for the first time in 15 years (2015).
  - Japanese government provides an annual investment fund of $4 billion to support coal-fired power plant worldwide (2015).

Viewpoints and options



Viewpoints:

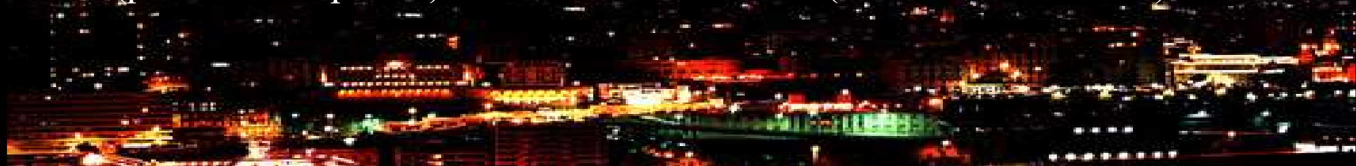
- ❑ human well-being (moral obligation)
- ❑ climate change mitigation (save the planet)
- ❑ environment protection (biodiversity)
- ❑ fossil fuel prolongation (sustain economic growth)
- ❑ fossil fuel replacement (pollution reduction)
- ❑ security of supply (political autonomy)

Reduce/reshape energy demand:

- ❑ population control (not an option)
- ❑ lifestyle change (do little, save little)
- ❑ apt technologies (plethora of options)

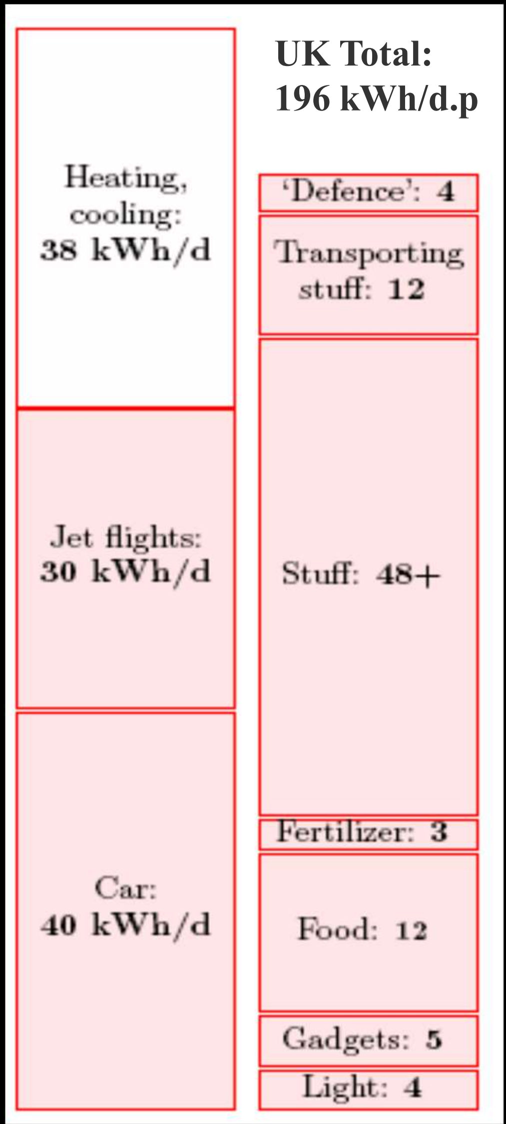
Deploy clean energy sources:

- ❑ clean fossil fuels (cost increase)
- ❑ nuclear fission (public acceptance)
- ❑ renewable energy (needs infrastructure)



Challenges: accommodate disparate views, negotiate non-optimal solutions, design and operate hybrid systems, obtain investment capital, keep costs down and taking the long view politically.

Lifestyle change



MacKay, www.withouthotair.com

'Simple' actions	Possible saving (kWh/d.p)
Frugal heating system use	20
Switch off appliances at home/work	4
Stop flying	35
Efficient transport	20
Don't replace gadgets	4
Use CFL or LED	4
Avoid clutter	20
Become vegetarian	10
Sub-total	117
'Difficult' actions	
Eliminate draughts	5
Double glazing	10
Improve insulation	10
Solar hot water panels	8
Photovoltaic panels	5
Replace old building with new	35
Electric heat pump for heating	10
Sub-total	83

Challenge: small lifestyle changes are unlikely to result in substantial energy demand reduction.

Apt technologies

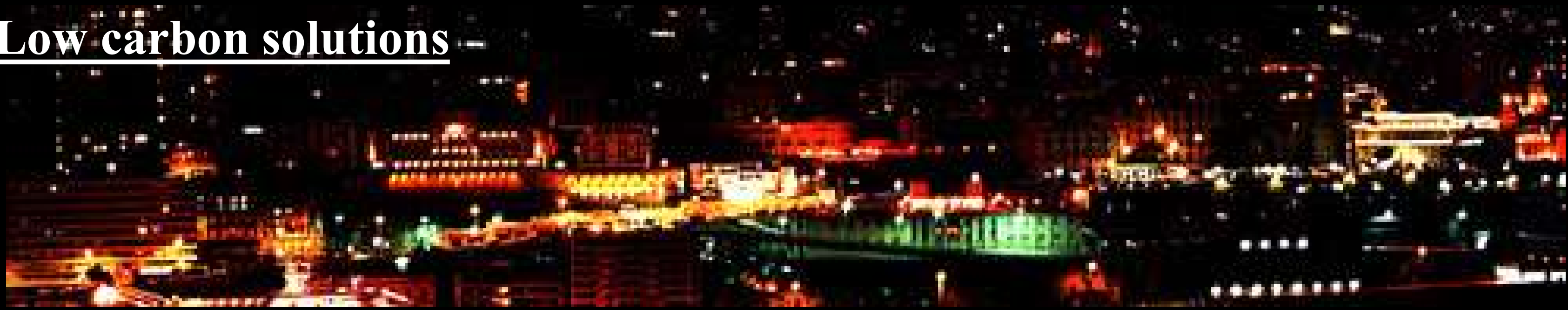
Challenge: how to identify the best deployment combination.

Transport (25-65%):
- journey curbing
- efficient engines
- alternate fuels
- fuel cells
- hybrid engines

Buildings (30-85%):
- frugal living
- fabric & ventilation
- efficient systems
- passive solar
- embed renewables

Industry (15-75%):
- produce less
- efficient plant
- heat recovery
- smart control
- new materials

Low carbon solutions



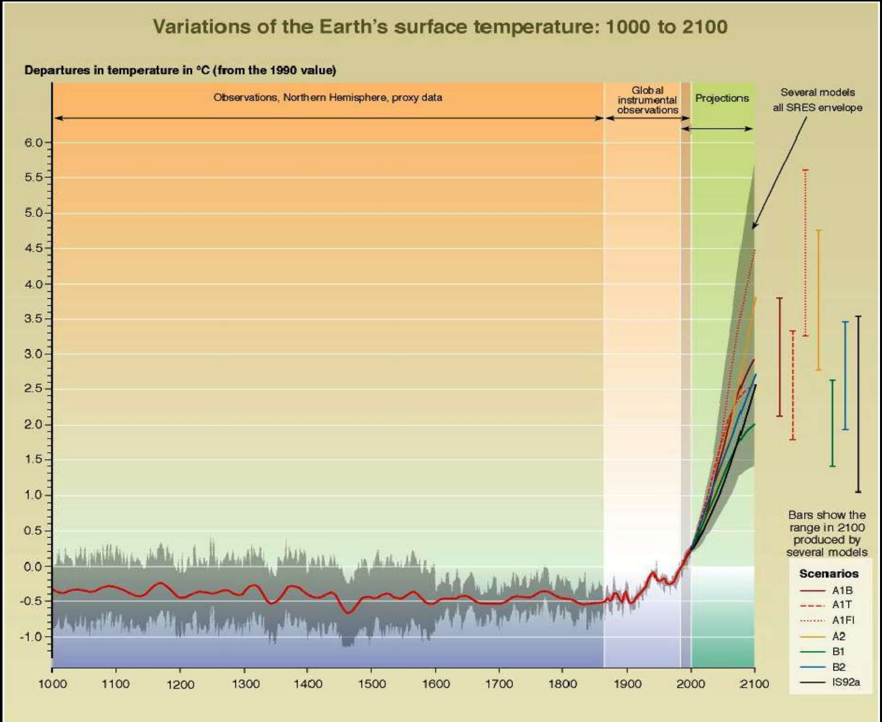
Demand-side:
- Daylight utilisation
- Smart control
- Smart zoning
- Passive solar devices
- Heat recovery
- Solar ventilation pre-heat
- Switchable glazings
- Selective films
- Transparent insulation
- Moveable devices
- Breathable walls
- Phase change material
- Demand management
- Smart meters & grids
- Electric vehicles

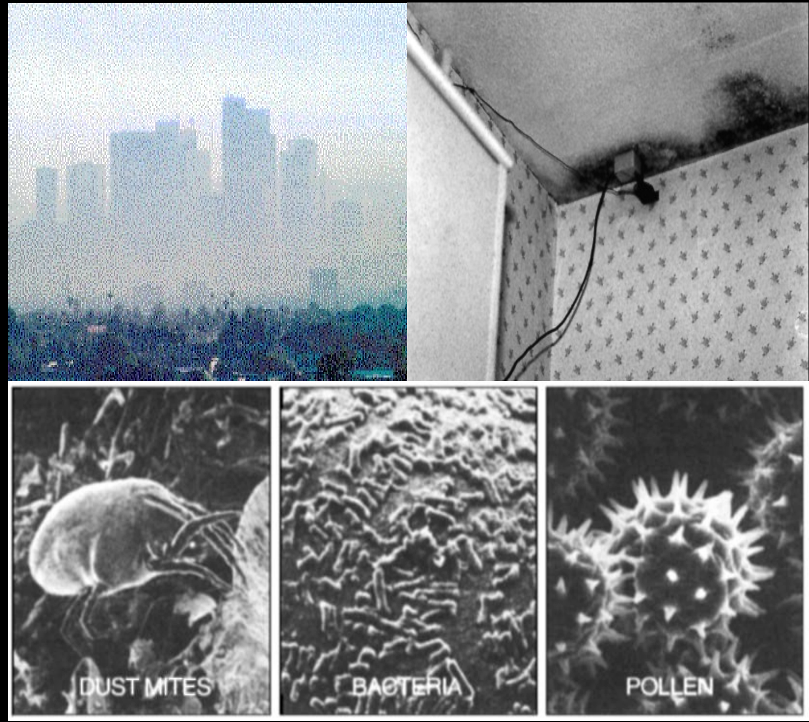
Supply-side:
- Condensing boiler
- Heat pump
- Combined heat and power
- Tri-generation
- Photovoltaics
- Desiccant cooling
- Evaporative cooling
- Electricity to heat
- Smart space/water heating
- Wind power
- Biomass/biofuel heating
- Culvert heating/cooling
- District heating/cooling
- Energy storage
- Fuel cells

Energy systems' characteristics:
- ❑ dynamic - processes vary at different rates;
- ❑ non-linear - defining parameters depend on system state;
- ❑ systemic: system comprises many sub-systems;
- ❑ stochastic – some inputs vary randomly.

Challenges: performance in practice; hybrid systems design; robustness; user understanding; cost shifts; unintentional impacts; impact on network loads.

Typical Problems





Caution!:

- ❑ energy efficiency measures may exacerbate poor indoor air quality;
- ❑ decentralised power production reduces global emissions but moves them to the breathing zone;
- ❑ increased system complexity may increase capital, operating and maintenance costs.

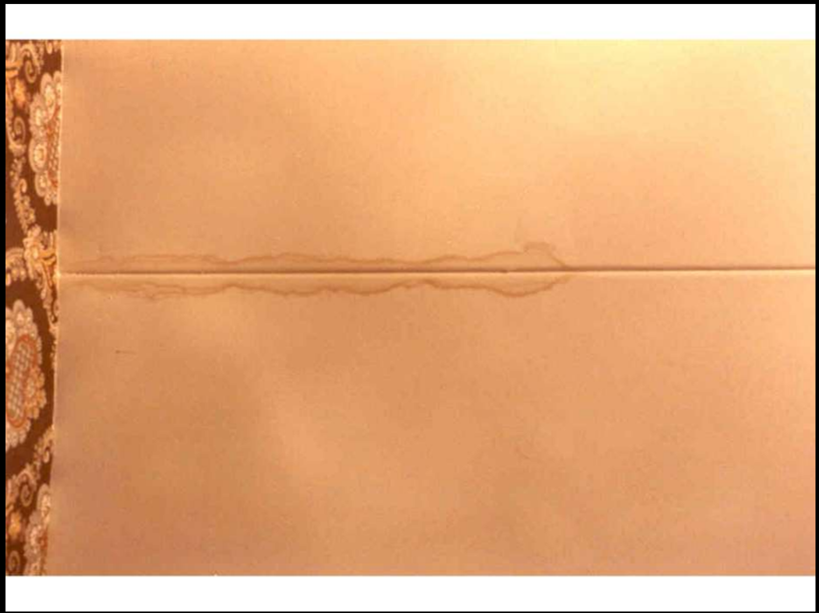
Typical problems

- Systems do not perform as well as expected.
- Products/ components not robust and performance degrades over time.
- Controls often don’t.
- Upgrades create unexpected problems, e.g.
  - Constructional moisture problems
    - derive from inadequate heating/ventilation, construction failure and/or inappropriate user behaviour;
    - moisture flow is a function of rain penetration and temperature/pressure gradients;
    - epidemiological evidence suggests that mould infestation in buildings can have health implications for vulnerable individuals.
- The devil is in the detail, e.g. building insulation and ventilation:

Surface condensation on glass

Hugo.Hens@bwk.kuleuven.be

Interstitial condensation



Insulated pitched roof, condensation against the corrugated fibre cement sheet roof cover by air leakage, dripping moisture wetting the gypsum board internal lining.

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Natatorium with low slope timber roof

Insulation with vapour decompressing layer below the insulation, interstitial condensation in that layer wetting the timber floor causing rot.

Concrete deck with no vapour retarder. Interstitial condensation wetting the insulation.

View of the decompressing layer and what is left of the insulation after wetting by interstitial condensation.

Hugo.Hens@bwk.kuleuven.be

Insulated cavity wall

Rain penetration around windows

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Post-filled cavity wall

Cavity tray wrongly detailed.

Hugo.Hens@bwk.kuleuven.be

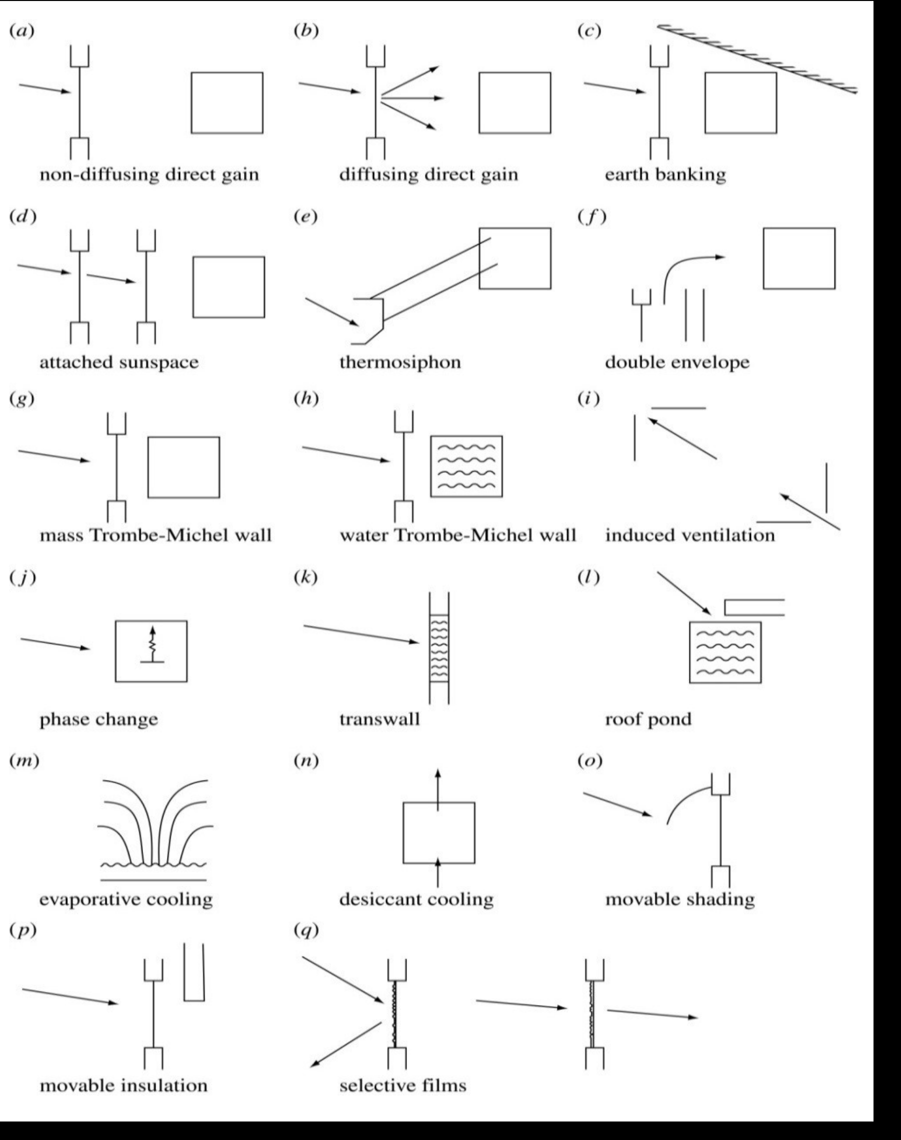
Rain penetrating the veneer wall and running off between insulation and veneer, wetting the underside of the inside leaf and the ground floor screed.

Built environment issues

- ❑ Passive solar (user control)
- ❑ Heat recovery (heat sink matching)
- ❑ Fabric upgrades (moisture problems)
- ❑ Efficient systems (cost implications)
- ❑ Daylight utilisation (glare avoidance)
- ❑ Smart control (commissioning)
- ❑ Local heat/power generation (demand matching)

Challenges: balancing energy, emissions, air quality, comfort, cost, controllability, robustness, job creation *etc*.

Passive solar features



Insulated low slope steel deck

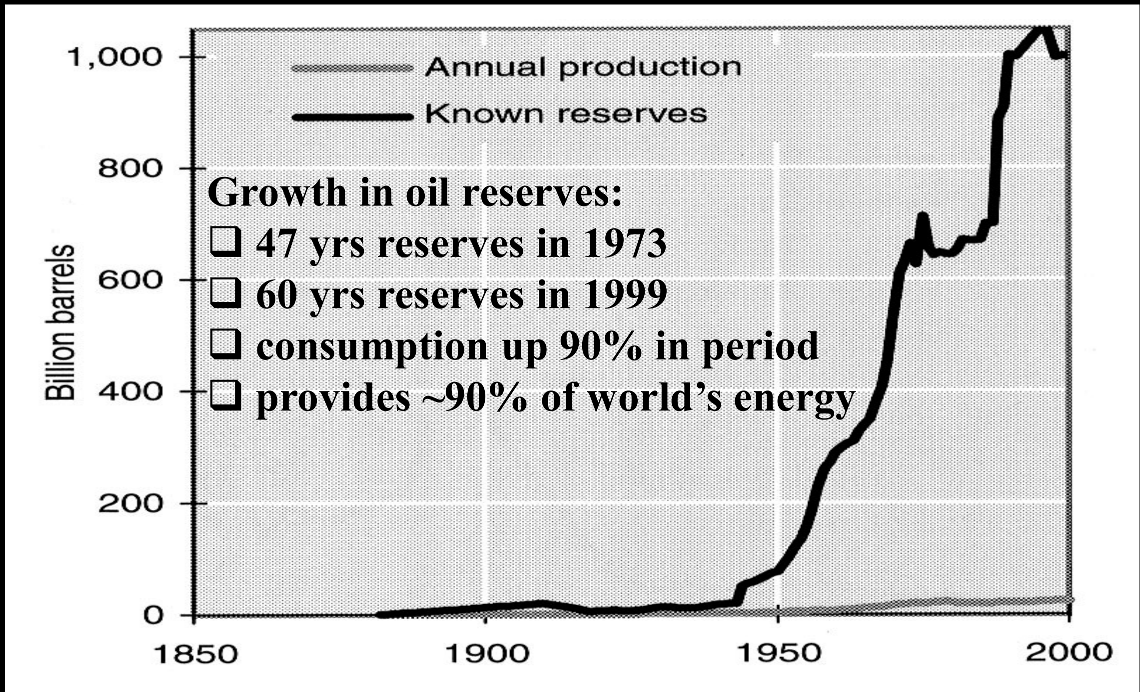
Corroding deck due to solar driven condensation of moisture below the membrane in winter.

Source: Hugo.Hens@bwk.kuleuven.be

Mould on thermal bridges

Hugo.Hens@bwk.kuleuven.be

Fossil fuels



Reserves:

- ❑ Coal 230-1500 yrs;
- ❑ Oil 40-250 yrs;
- ❑ Gas 60 yrs.

Outlook:

- ❑ global energy spend <2% of GDP;
- ❑ UK spend 6% of GDP (£75b/y; c.f. £10b/y spent on discarded food);
- ❑ will dominate the world economy for 30 years or more.

Challenges:

- ❑ refine exploration techniques;
- ❑ make less 'polluting' (e.g. decarbonise);
- ❑ enhanced extraction (e.g. sequestrate C);
- ❑ new resources (e.g. coal bed methane, oil shale, tar sand);
- ❑ new uses (e.g. methanol production).

Nuclear

Fission:

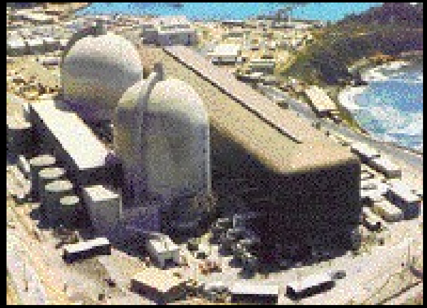
- ~6% of global energy production;
- more expensive than fossil-based power generation but less expensive than most renewables;
- radioactive waste is a problem (transmutation initiatives);
- 100 years of $U_{235;}$
- 14,000 years of U_{238} but security problematic.

Challenges:

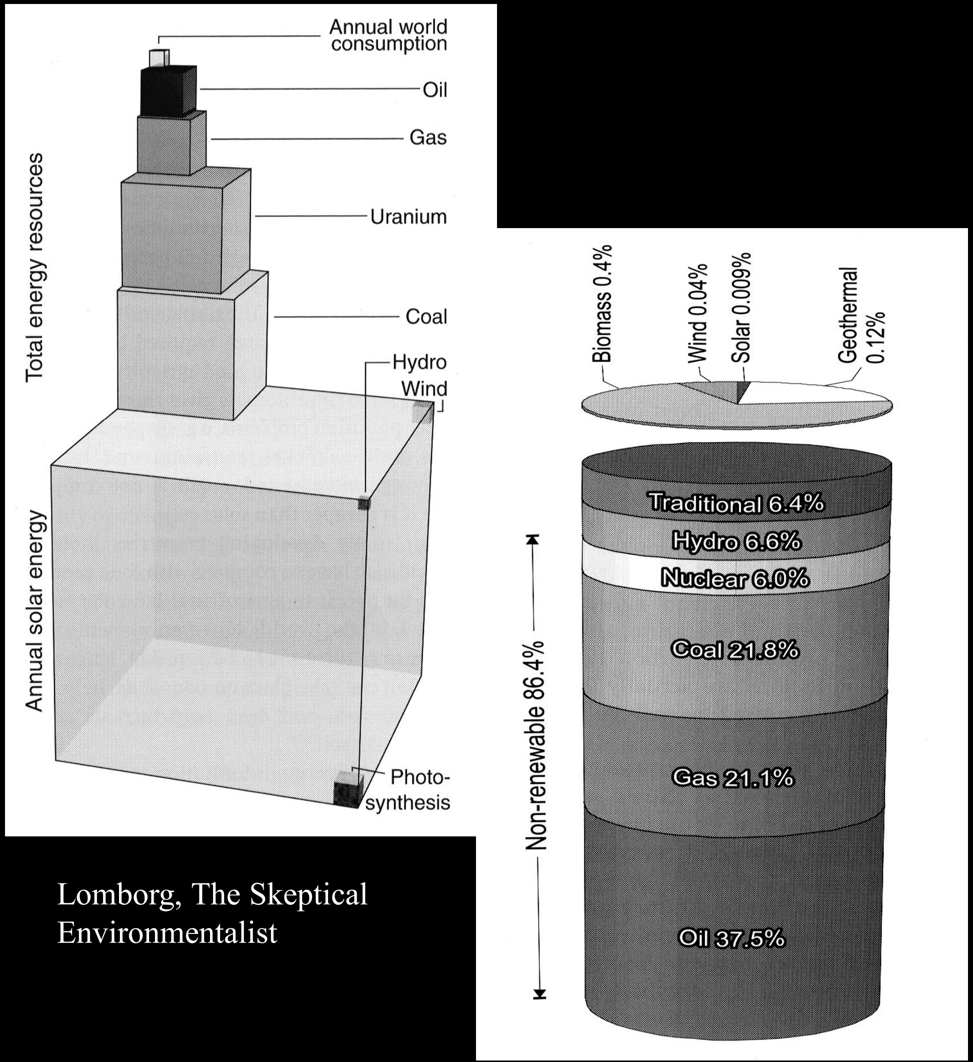
- new build;
- waste disposal;
- public acceptance;
- life cycle costs.

Fusion:

- abundant fuel supply (sea water);
- 1g equivalent to 45 barrels of oil;
- little radioactive waste;
- astronomical temperatures required;
- commercial by 22nd century?

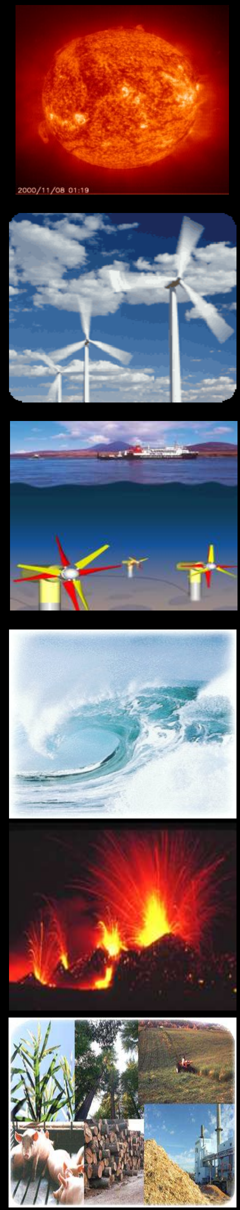


Strategic renewable energy



Lomborg, The Skeptical Environmentalist

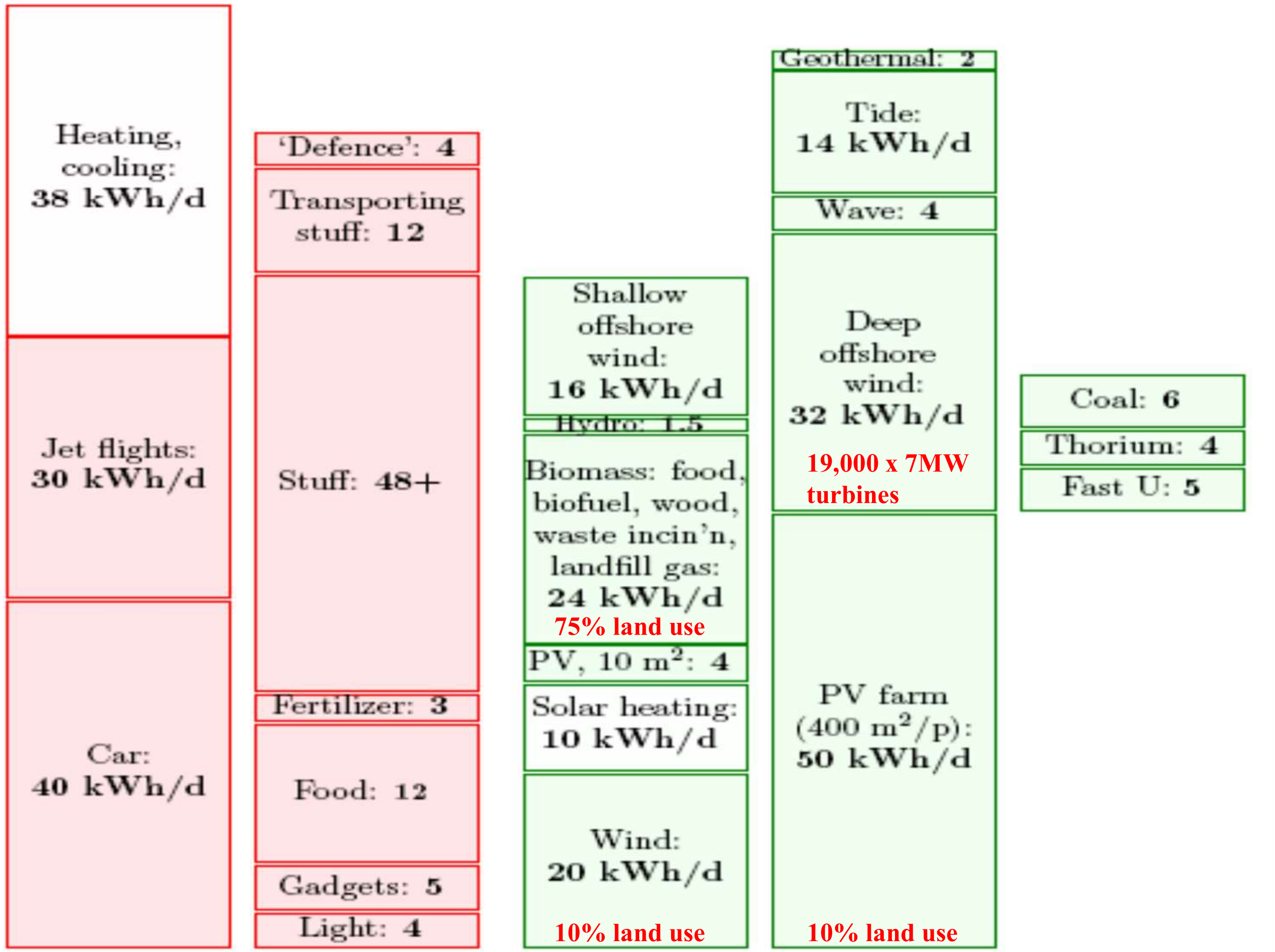
- To avoid problems with fault clearance, network balancing and power quality, distributed RE systems with limited control possibility should be restricted to ~25% of network capacity.
- High capture levels require:
  - increased transmission network capacity;
  - active distribution network management;
  - energy storage and/or standby capacity.
- Practical resource not vast relative to total demand.



Renewable energy: supply/demand match

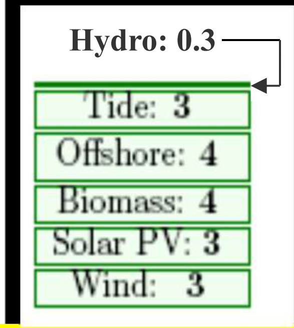
UK energy consumption ------ (196 kWh/d.p) ------

Maximum conceivable UK sustainable production -------------------- (174 kWh/d.p) ----------------------



Caution: Matching energy demand from renewable sources requires the industrialisation of the environment on a vast scale.

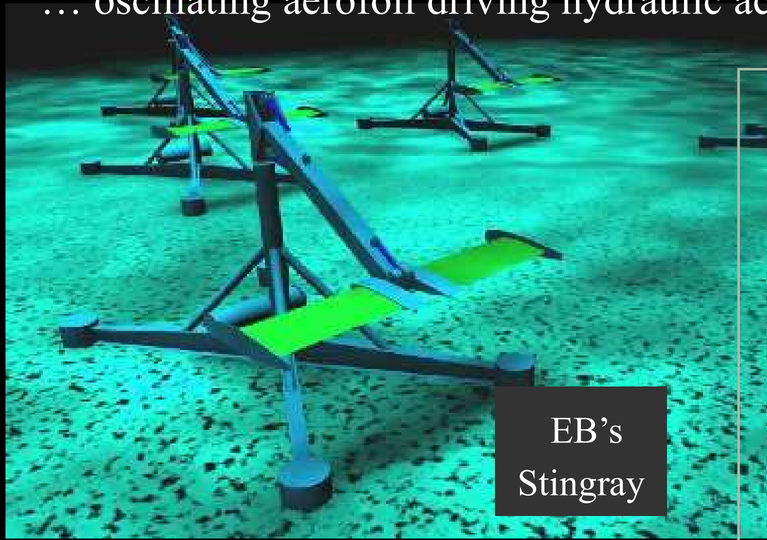
Likely resource (17 kWh/d.p)



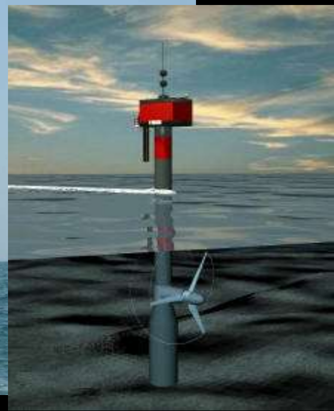
MacKay, www.withouthotair.com

Future concept: marine tidal current

… oscillating aerofoil driving hydraulic accumulators



… horizontal axis turbine evolved from wind technology

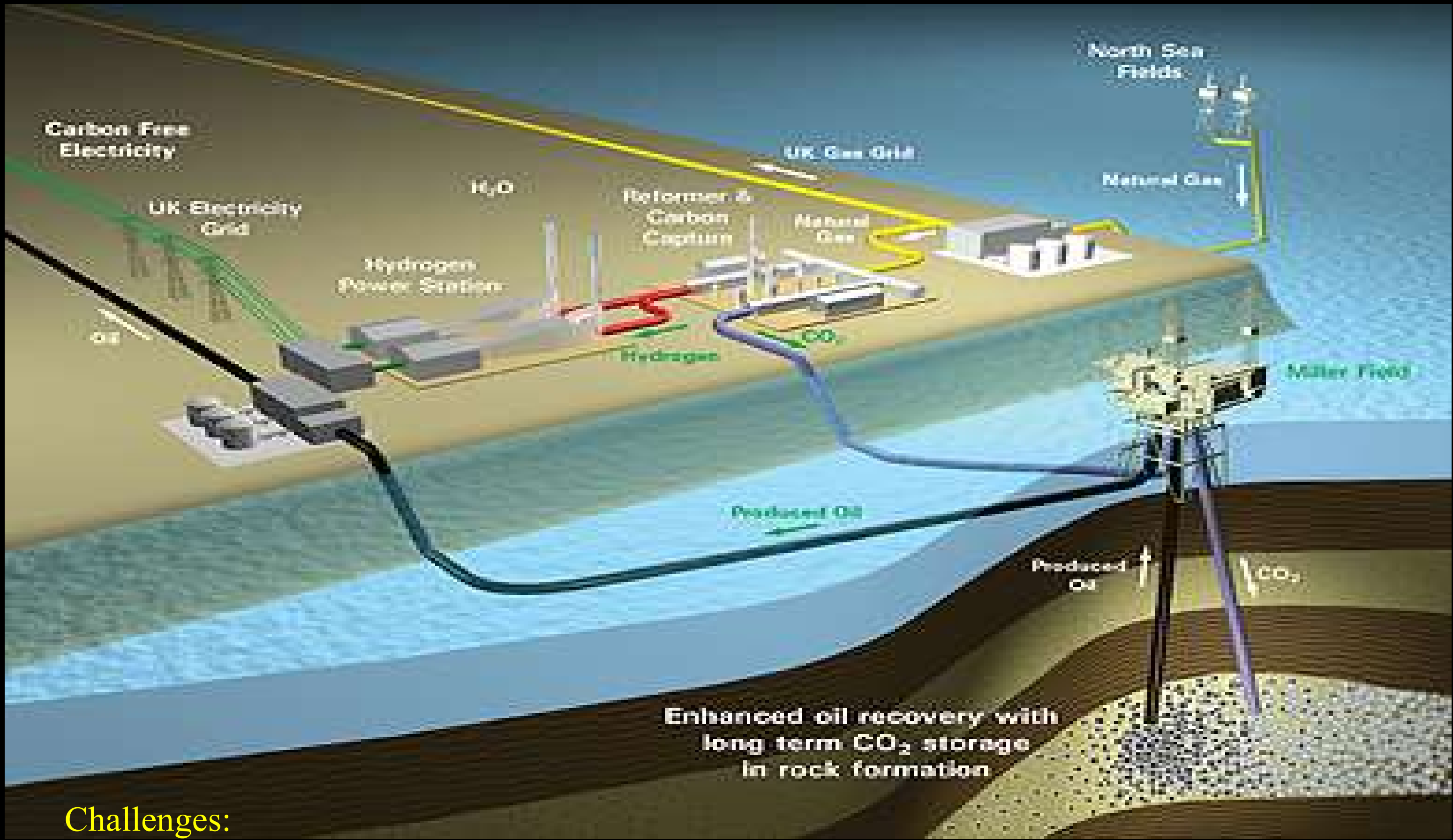


… contra-rotation

Challenges:

- reduce cost;
- limit corrosion and abrasion;
- new maintenance and safety issues;
- power take-off at low rotation speed;
- gearing reduction/ elimination;
- grid access/ power transmission;
- land access and use;
- phased operation of different sites;
- maritime & aquaculture impact;
- new business models.

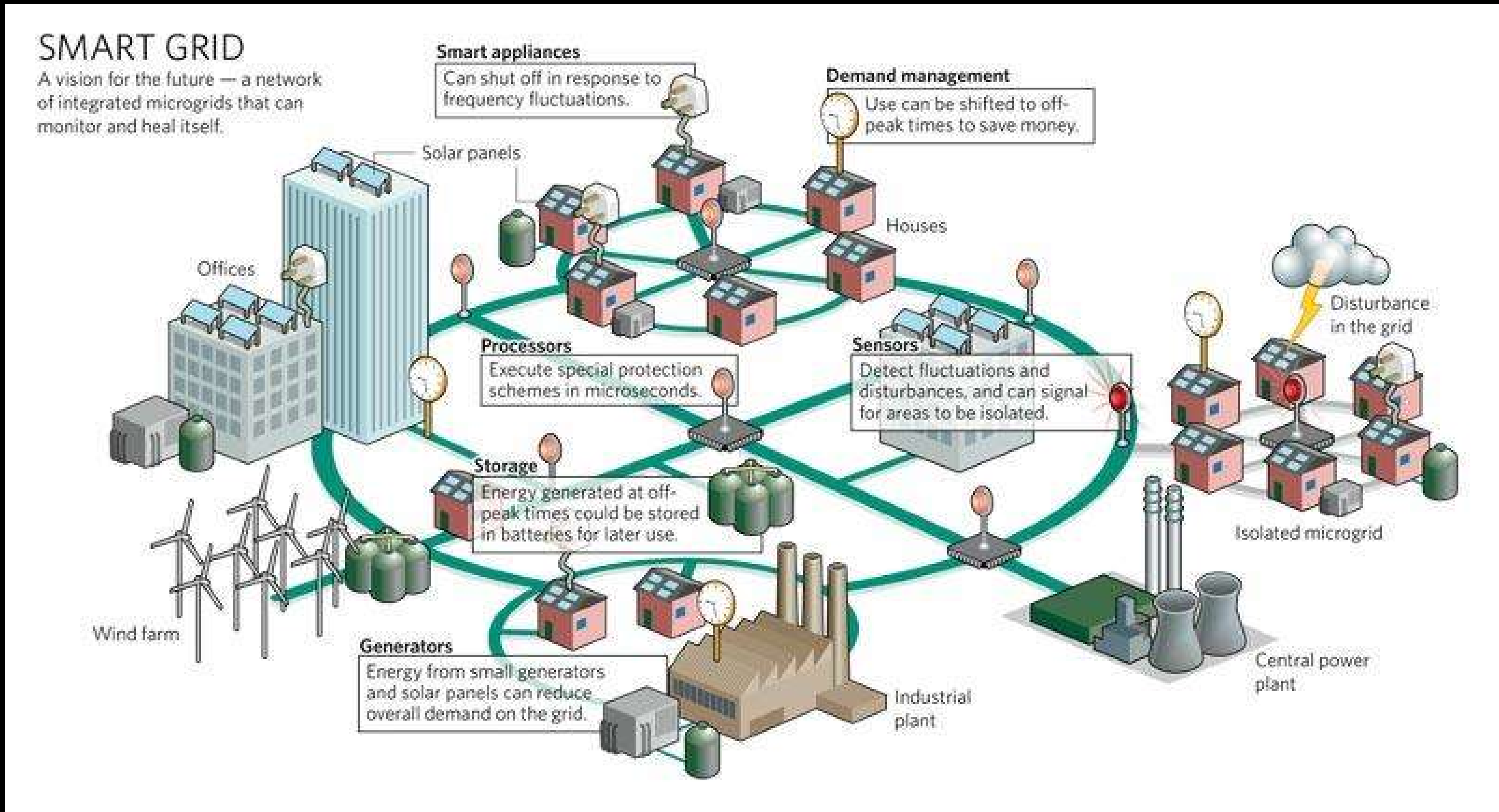
Future concept: H_2 production with CO_2 capture and storage



Challenges:

- large capital investment;
- geological issues;
- gas and electricity grid access;
- new distribution infrastructure;
- market transformation;;
- new business models.

Future concept: smart grids



https://smartgridtech.wordpress.com/smart-grid/

Challenges:

- ❑ market transformation;
- ❑ policy & legislation;
- ❑ new business models;
- ❑ large capital investment;

- ❑ market transformation;
- ❑ policy & legislation;
- ❑ new business models.

Micro-generation and micro-grids

Embedding supply within a community

CHP HP BB

energy storage

PV FC DWT

Network connected

Building integrated

Public supply connection

Demand reshaping measures

Distributed generation

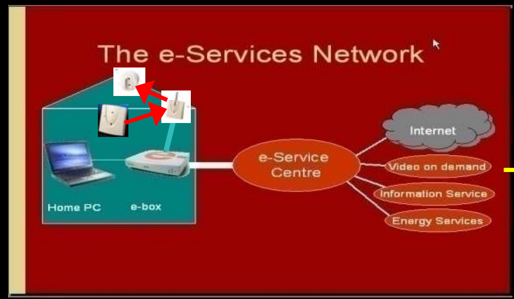
Micro-grid trading

Power station ………… 1 @ 2000 MW
Wind ……. ………… 100 @ 20 MW
Marine …………… 4,000 @ 0.5 MW
CHP …………… 40,000 @ 0.05 MW
Urban RE ……… 200,000 @ 0.01 MW

Renewable energy systems 3-5 times larger if the requirement is to match energy production.

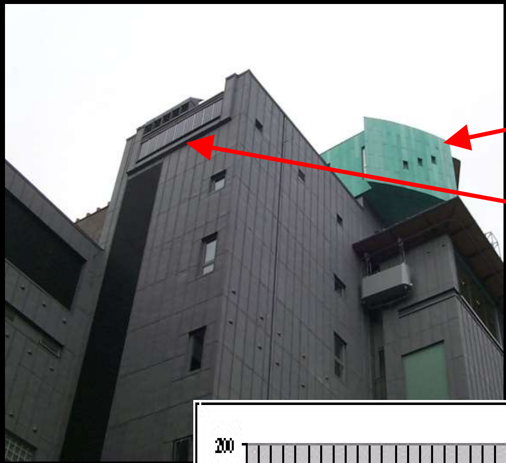
Challenges: hybrid systems sizing; smart control, pervasive sensing, 'e-service' delivery.

Internet-enabled energy services



New energy-related services:
- ❑ environmental monitoring;
- ❑ smart metering;
- ❑ local & aggregate control;
- ❑ demand-side management;
- ❑ information for citizens.

Building-integrated micro-generation

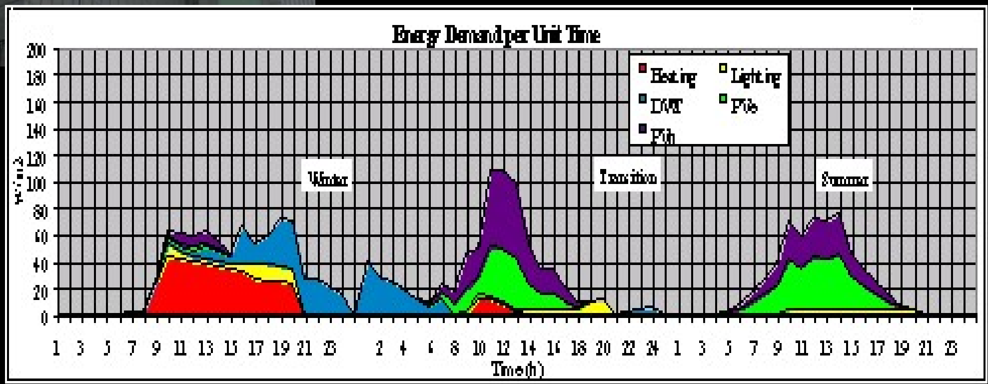


Demand reduction through transparent insulation, advanced glazing and smart control.

PV: 0.7 kW_e

DWT: 0.6 kW_e

PV hybrid: 0.8 kW_e / 1.5 kW_h



total demand: 68 $kWh/m^2.yr$

total RE supply: 98 $kWh/m^2.yr$

Challenges:

- ❑ accommodate the grade, variability and unpredictability of energy sources/demands;
- ❑ hybrid systems design;
- ❑ strategies for co-operative control of stochastic demand and supply;
- ❑ network balancing, fault handling and power quality maintenance.

How best to stimulate development and assess proposals?

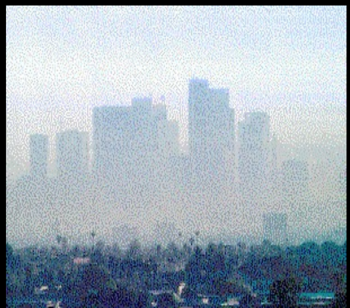
- With so many options, how do we identify the optimum deployment combinations?
  - Feasibility (technical, social acceptability) – requires modelling tools.
  - Economics (in the conventional sense).
  - Energy/carbon economics:
    - energy efficiency rating;
    - net CO_2 per unit of useful energy produced;
    - embodied energy in life cycle of products.
  - Environmental impact:
    - consumption of valuable resources (actual and potential).
  - Social impact (jobs).

- UK policy framework:
  - Mostly financial instruments.
  - 2020 targets (limited agreement on means to attain them):
    - EU target: 20% of <u>energy requirements</u> to be met from renewable resources;
    - Scotland: 100% <u>renewable electricity</u>;
    - UK: 15% of <u>energy consumption</u> from renewable sources (2009 Renewable Energy Directive);
    - Carbon Emissions Reduction Target (CERT).

"The real need is to leave future generations with knowledge and capital, such that they can obtain a quality of life at least as good as ours, all in all."

Nobel Laureate, Robert Shaw

Environmental quality and energy efficiency



Fossil fuel prolongation

New and renewable energy system deployment