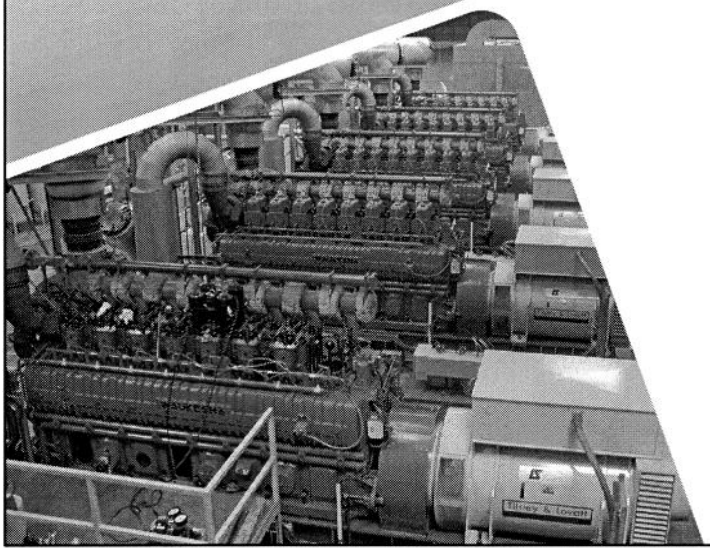
Energy
Dr Elise Cartmell



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Lecture content

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- Carbon and water
- Energy use in water and wastewater
- Renewable energy generation
  - CHP
  - Hydro
  - Wind
  - Co-firing
  - New initiatives

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Lecture aims

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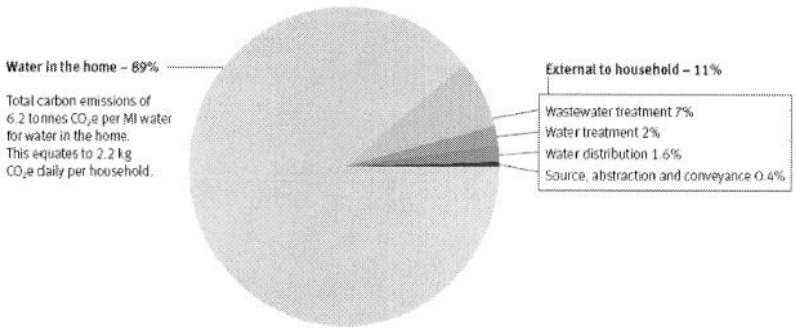
- Appreciate where energy is used in water and wastewater treatment
- Understand some of the main routes to renewable energy generation in the water sector

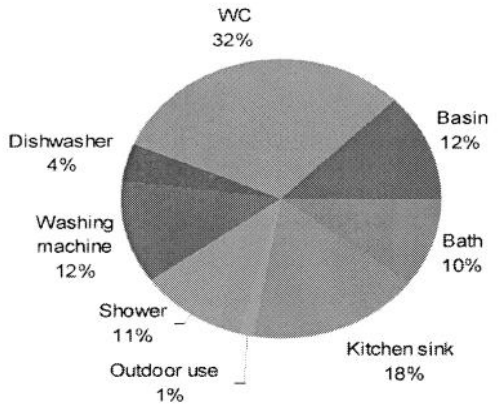
Where is the carbon in water?



Environment Agency

energy saving trust

Water use in the (older) home



About 150 litres/person/day total

Environment Agency

energy saving trust

Water company sector contributes

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- 2-3 % of net UK electricity (eighth most energy intensive sector in the UK)
- 0.8 % of UK greenhouse gas (GHG) emissions per annum
- 4.93 million tonnes of GHG emission (carbon dioxide CO_2 equivalent)
- 39% due to water supply
- 56% due to wastewater
- 5% company admin and transport

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Role of energy - Energy use

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- Energy use in water sector is ....
  - electricity 95 %
  - gas < 2%
  - fuel oil < 5 %

.... it's not rising significantly BUT it's not going down either!

But energy use set to increase by 60 – 240% within 15 years

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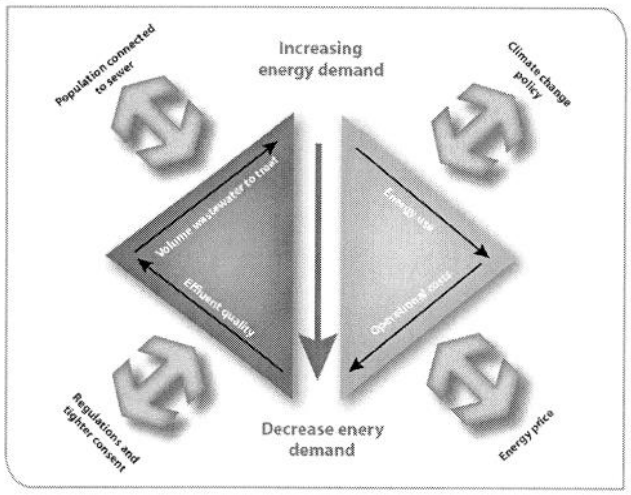

Environmental KTN

Total energy used UK water sector

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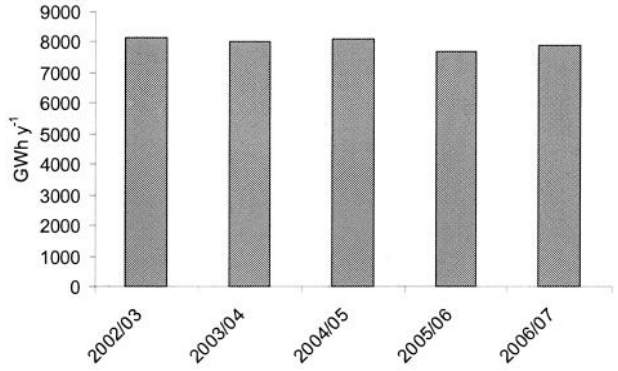
http://www.water.org.uk/home/policy/reports/sustainability/sustindicators06-07



Small changes in total energy used.
Energy efficiencies measures mitigating increases due to growth and water quality challenges

Energy – a major slice of the cake!

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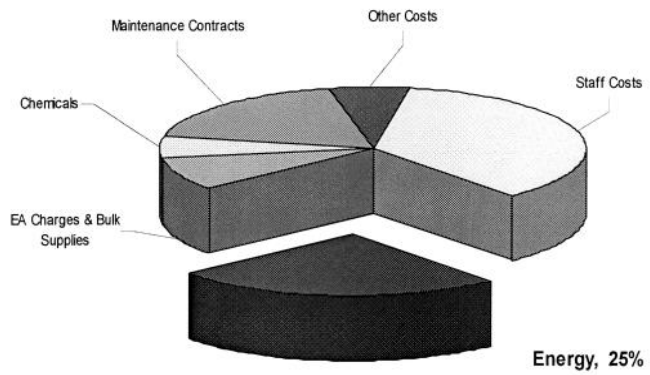

Yorkshire Water

Cost related with wastewater treatment (£m in 2006)

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Water Industry in the UK	A	B	C	%
Employment costs	**17.9**	**5**	**11.9**	30
Power	**14.5**	**10.1**	**7.8**	28
Hired and contracted services	**8.3**	**9.1**	**2.6**	17
Service charges	**5.3**	**3.7**	**6.1**	13
Materials & consumables	**6.2**	**1**	**3.1**	9
Other costs	**1**	**1.3**	**0.4**	2

Energy where it's used water

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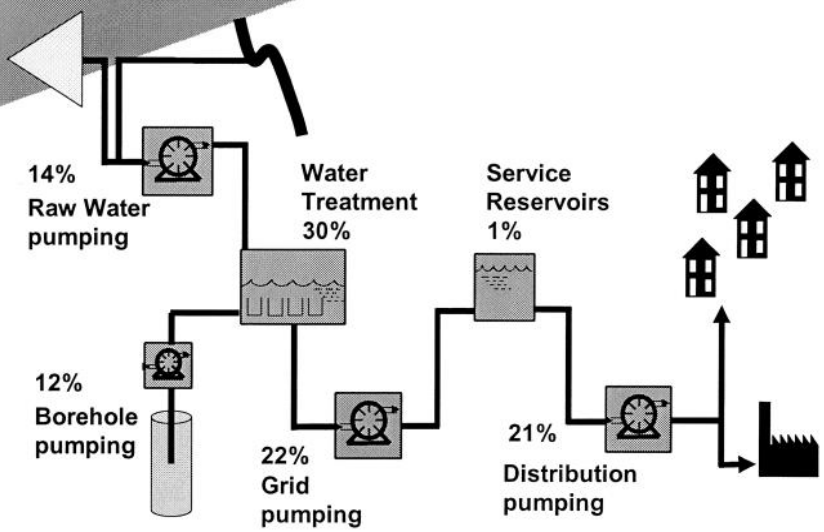
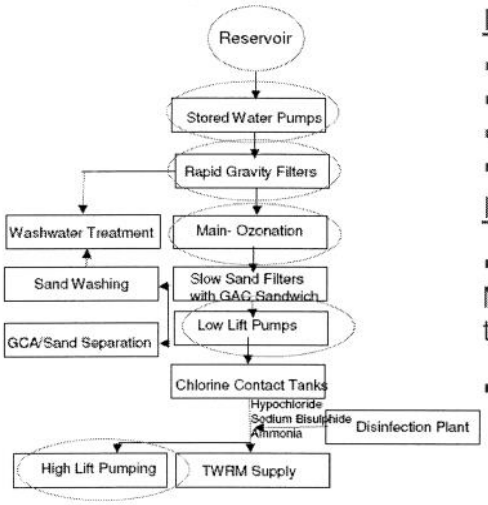


Water Treatment and Distribution

Example: Large London Works



Large Power requirements

- Pumping
- RGF backwashing
- Ozonation
- Distribution

Initiatives

- Performance Management of energy through KPIs/benchmarks
- Electrical submetering

Energy where it's used wastewater

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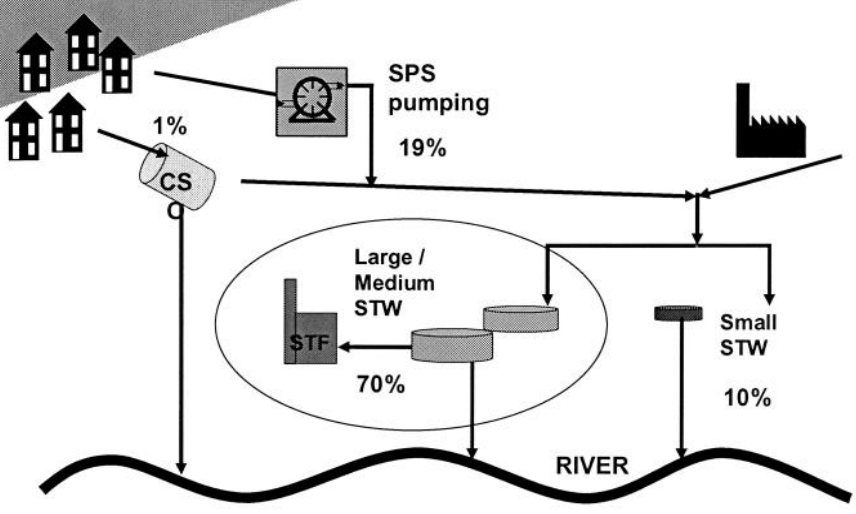

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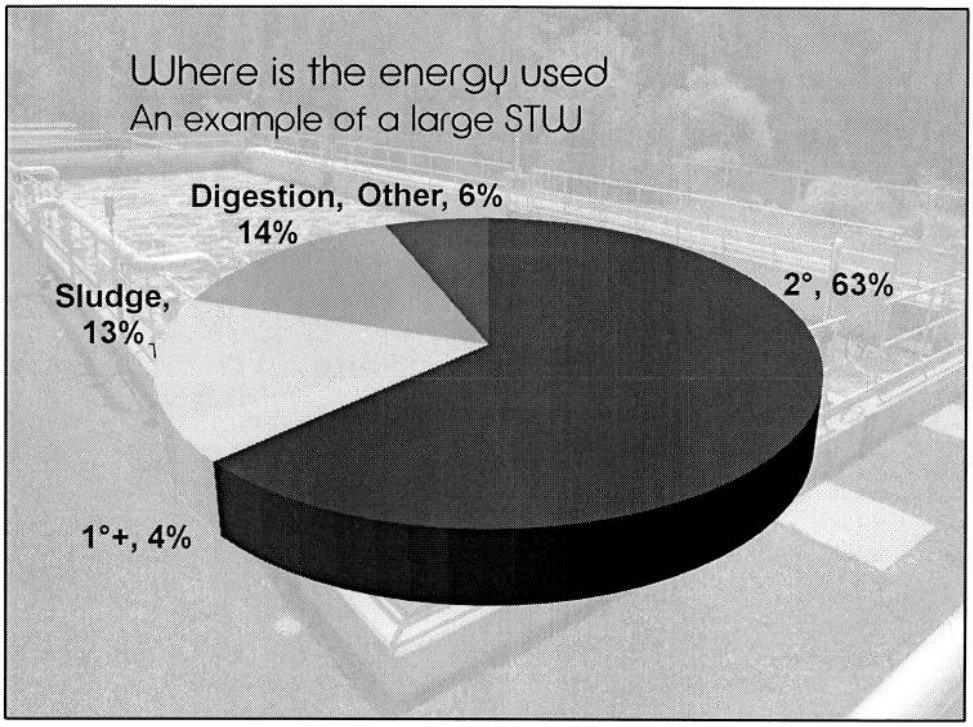
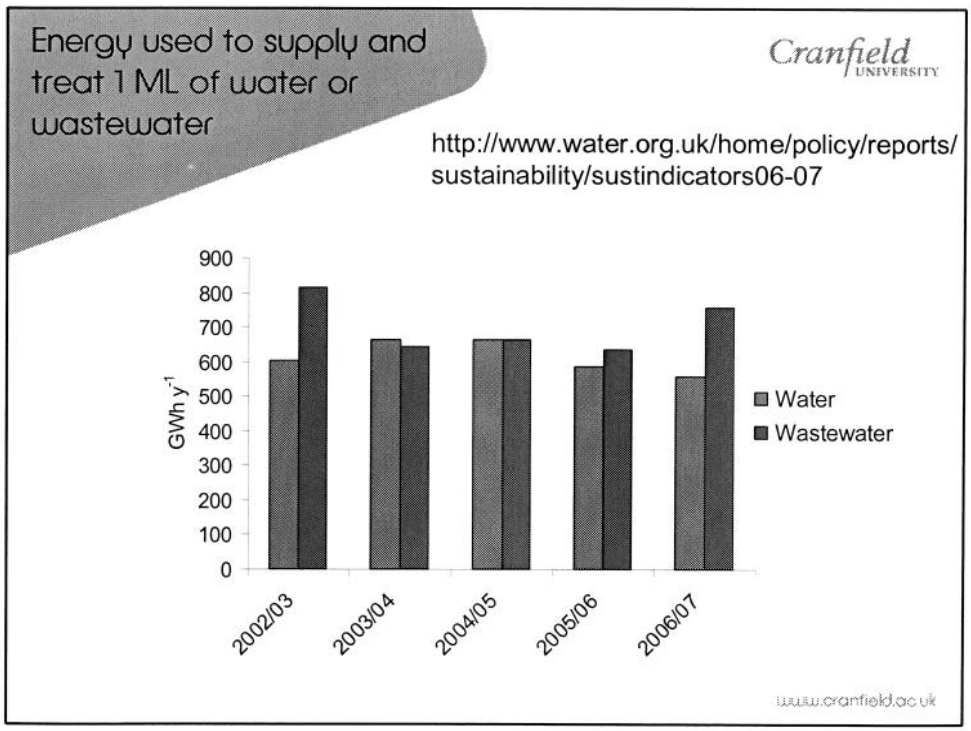

Where is the energy used
An example of a large STW
Digestion, 14%
Other, 6%
Sludge, 13%
2°, 63%
1°+, 4%


Energy used to supply and treat 1 ML of water or wastewater
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http://www.water.org.uk/home/policy/reports/sustainability/sustindicators06-07
GWh y-1
900
800
700
600
500
400
300
200
100
0
2002/03
2003/04
2004/05
2005/06
2006/07
Water
Wastewater
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GHG emissions

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Core Indicator[1,2]	Total	Performance compared to 06/07
Total greenhouse gas emissions (from water supply, wastewater treatment, offices and transport)	4.93 Million tonnes CO_2e	New Indicator
Greenhouse gas emissions from supplying water (CO_2e per Ml of water supplied)	0.276 tonnes CO_2e / Ml	New Indicator
Greenhouse gas emissions from wastewater treatment (CO_2e per Ml of waste water treated)	0.693 tonnes CO_2e / Ml	New Indicator

http://www.water.org.uk/home/news/press-releases/sustainable-water/sustainability2008.pdf

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GHG emissions

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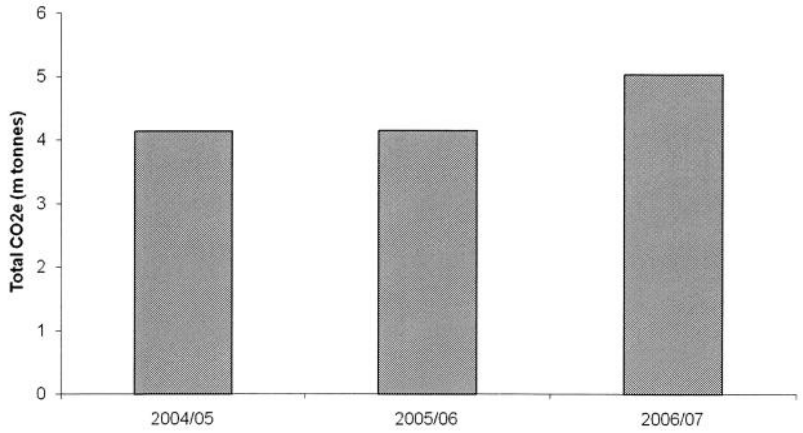
http://www.water.org.uk/home/policy/reports/sustainability/sustindicators06-07



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GHG in more detail .... United Utilities

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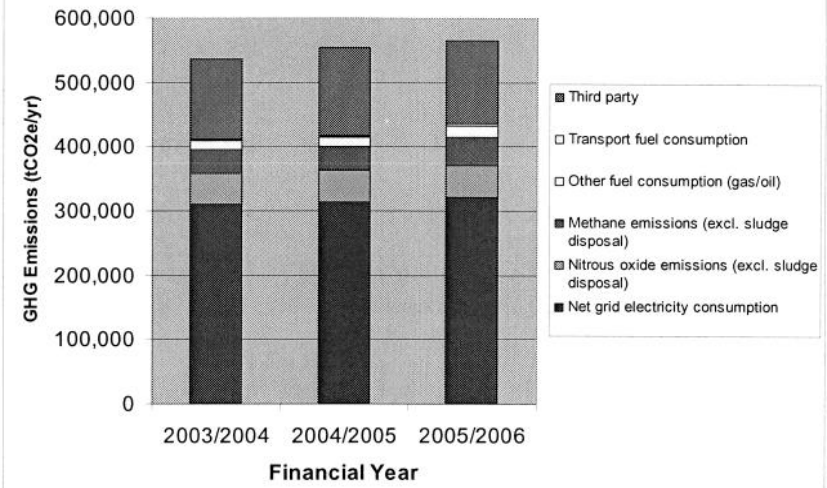
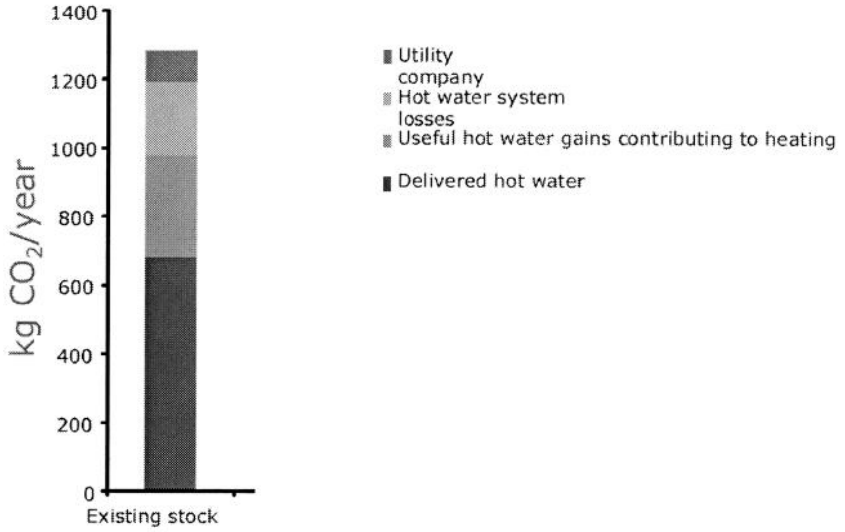


CO2 emissions from water use in existing houses



Not just CO_2
N_2O produced from ...

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- Use of ozone
- Secondary treatment of wastewater, especially off-gas from the activated sludge process
- Spreading of biosolids onto land, as part of agricultural recycling.

- 0.004 gN_2O-N/gNH_3-N entering secondary treatment
- 0.0125 kg N_2O-N/kg N in sludge applied to soil
- 1.1×10^{-4} kg N_2O per m^3 of potable water treated by ozonation

Not just CO_2
CH_4 produced from ...

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- Temporary storage i.e. balancing tanks etc.
- Gravity thickening
- Anaerobic digestion
  - emissions from leaks and annular spaces around floating roofs,
  - incomplete combustion, from flare stacks during down-time
  - from secondary digestion
- Land application of sludge

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Energy – what has been happening

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- Manage Cost
- Manage Consumption
- Optimise and develop self generation

What's going to happen

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- 80% reduction from 1990 level of GHG emissions by 2050 – UK Government targets
- From April 2010 UK emission trading scheme the Carbon Reduction Commitment (CRC)

How to achieve this?

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- Metering household water use
  - Increase metering to 33% reduce emissions by 1.1-1.6 Mt CO_2e pa (27-40% of CRC target)
- Controlling wastewater at source, more sustainable drainage schemes, treatment processes optimisation to reduce emissions, redeveloping wastewater treatment (anaerobic)
- More renewable energy generation

Renewable Energy Generation

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Why generate energy?

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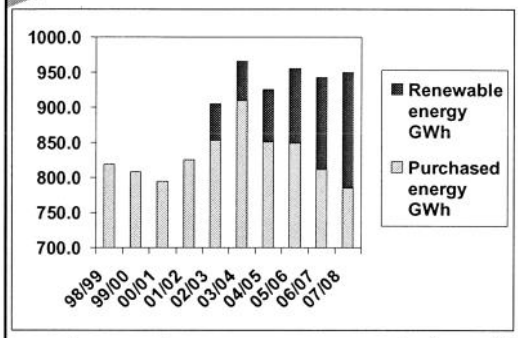
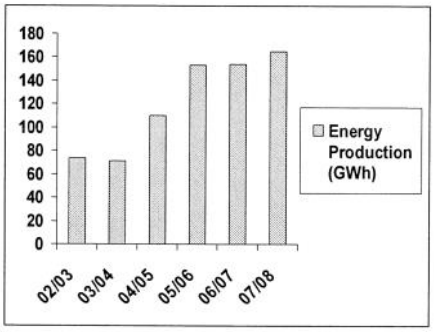
Energy use /production profile





- Increasing energy usage being offset by our renewable generation

What's happening

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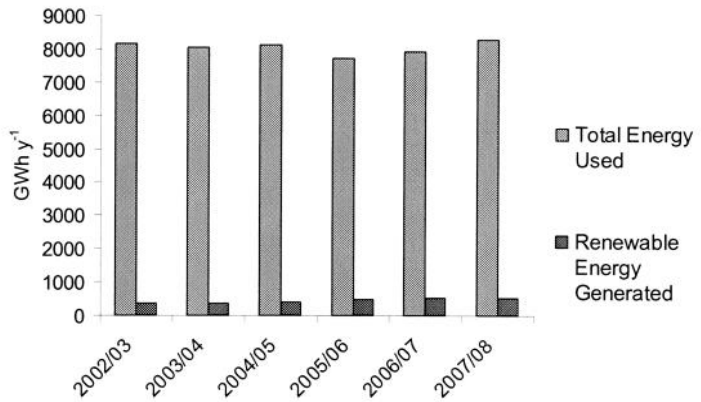
http://www.water.org.uk
Sustainability Indicators



Value of energy generation

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- **Power**
  - Traded in the wholesale electricity market for Great Britain
  - Price varies depending on predictability, time generated etc.
- **Renewable Obligation Certificate (ROC)**
  - Awarded to qualifying generation required by suppliers to demonstrate compliance with the Renewables Obligation
- **Levy Exempt Certificate (LEC)**
  - For generation qualifying for CCL exemption
- **Embedded benefits**
  - Arising from savings in costs of transmission for generation connected to the distribution network

Renewable energy What's it worth?

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For 2007 / 2008

• Electricity	c.4.0 - ? p/kWh
• ROC	c.3.2 - ? p/kWh
• ROC Bonus	c.1.1p/kWh
• LEC exports	c.0.4p/kWh
Total Value	**c.8.7p/kWh – 13p/kWh**

Combined Heat and Power

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Combined Heat and Power

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not a new concept

Strongford CHP c. 1950s

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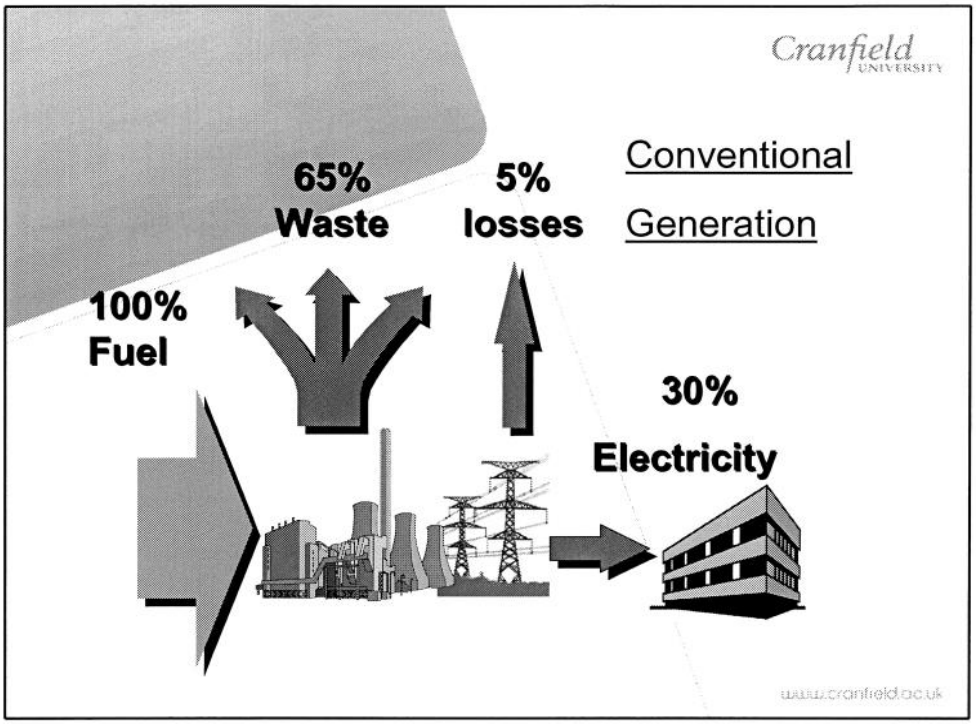
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Conventional Generation
65% Waste
5% losses
100% Fuel
30% Electricity
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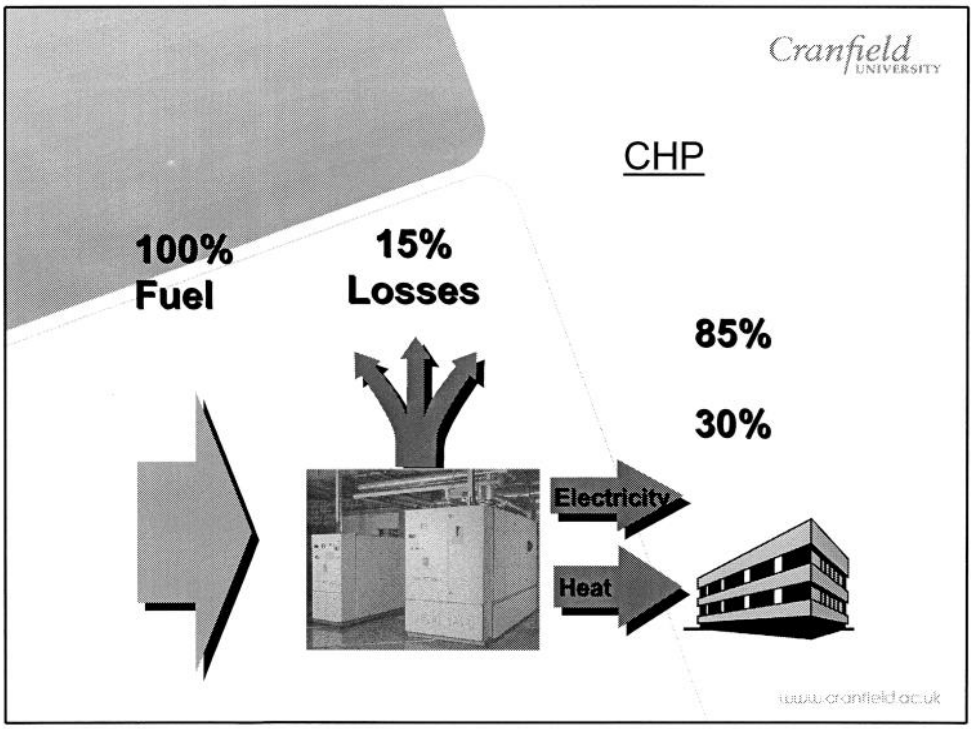
Cranfield UNIVERSITY
CHP
100% Fuel
15% Losses
85%
30%
Electricity
Heat
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CO_2 Emission reduction with CHP

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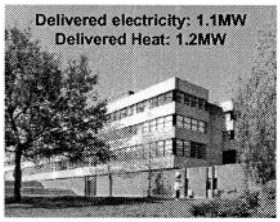
0.43 $kgCO_2/kWh_e$ + 0.24 $kgCO_2/kWh_{th}$

27.8% CO_2 saving
=1683 tonnes saved per annum

0.49 $kgCO_2/kWh_e$ + 0.00 $kgCO_2/kWh_{th}$

UK Electricity Generation

Boiler (typical 80% efficient)



CHP Plant

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Integration of biogas CHP

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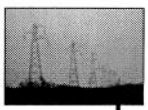
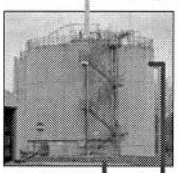


Self Supply & Export

"Excess" Gas Flarestack

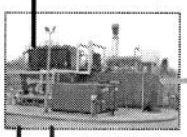
Biogas

Electricity



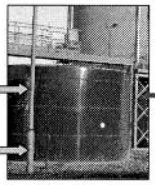
Digester 35 °c

Gas Holder



CHP Unit

Sludge at 35 °c



Imported Sludge

Indigenous Sludge

Balancing Tank 12°c

Heat Exchanger

Hot water at 70 °c

"Backup" Hot Water Boiler

from Severn Trent

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Gas quality management

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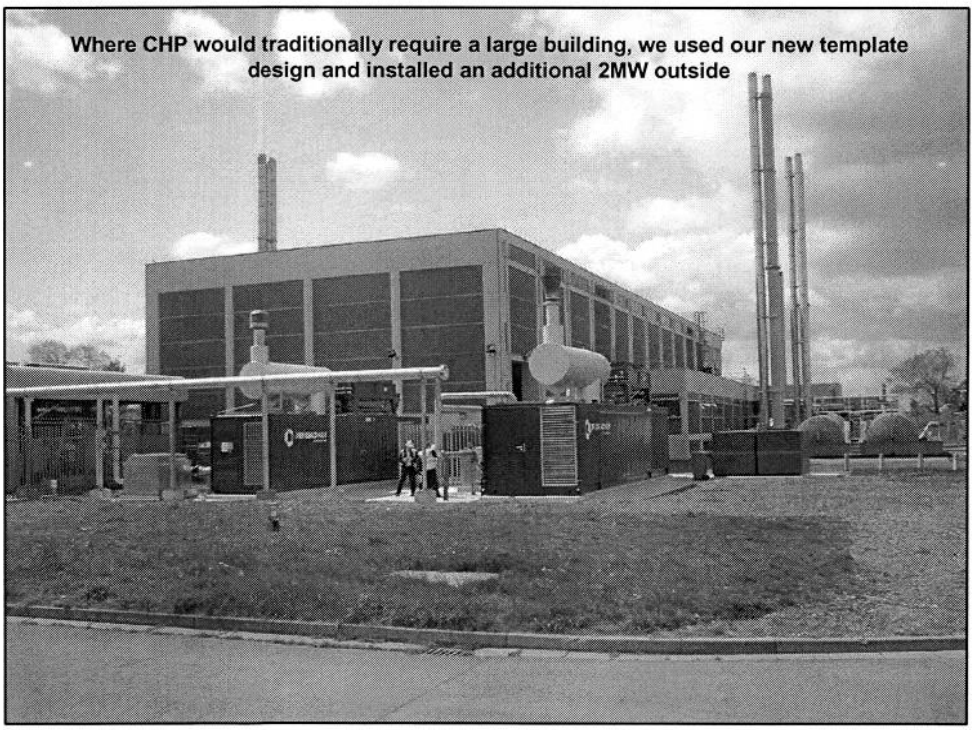
Methane (CH_4) Content

CH_4 Content equates to Calorific Value (CV) of the Fuel

Natural Gas - Gross CV = 38.62 MJ / m^3 @ ~ 94% methane

Biogas (From AD of Waste Water) = 21.5 MJ / m^3 @ 60% methane

- The lower the CV, the greater the gas volume required to deliver the required energy input.



Where CHP would traditionally require a large building, we used our new template design and installed an additional 2MW outside

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100kw micro gas turbine

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Biogas upgrading

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- But CHP methane use does not utilise all the heat
- So remove CO_2 (H_2S, water, siloxanes)
- For use as:

  Vehicle fuel or injection into natural gas grid

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Upgrading of biogas to natural gas quality

Technologies:

- Water Scrubber Absorption (single pass or regenerative)
- Pressure Swing Adsorption (PSA)
- Membranes
- Chemical adsorption

Upgrading costs:

- 3-4 €c/kWh$_{upgraded\ gas}$ for small plants (<100 m^3/h$_{raw\ gas}$)
- 1-1,5 €c/kWh$_{upgraded\ gas}$ for plants in the range 200-300 m^3/h$_{raw\ gas}$)

- Electricity demand for upgrading = **3-6%** of the energy content in the upgraded gas

Potential

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Environmental: 99% GHG emission reduction

Commercial: (1) Fleet/ (2) commodity

e.g. Mercedes B170 NGT – Hybrid – Operation on NG

16kg capacity (4x4 kg tanks) / Range 185 miles

(1) UK water company: 1.43×10^8 miles supported

14,500 motorists supported (ave. 10K p.a.)

(2) Equiv. 4×10^6 UK Gallons or £20,000,000 (£1.11.L^{-1})

Based on 1/3 £1.11 NG sales = c.£6,500,000

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Hydro

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Scale of hydro power

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- Small hydro: 2 MW-5 MW
- Mini hydro: 500 kW-2 MW
- Micro hydro: < 500 kW – most common application in water industry

- Scottish Water 5-6 % energy from hydro power

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Renewable Generation: Hydro

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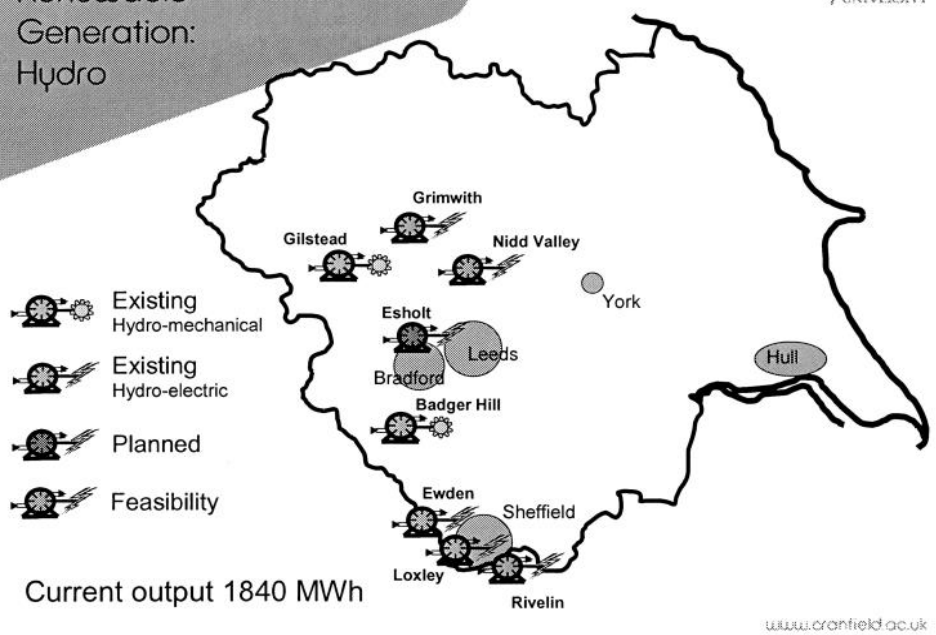

Current output 1840 MWh

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Developments

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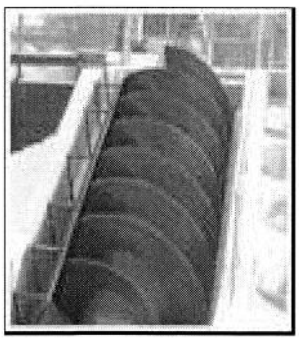
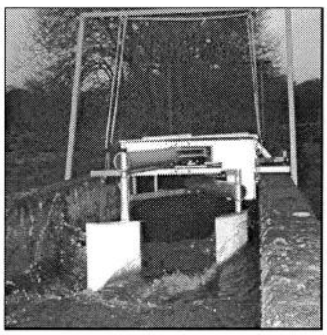
- Energy Recovery from Water Channels





- Low head hydro
- Siphonic Water pressure converted to air pressure via siphon to drive small high speed air turbine.

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Hydroturbine

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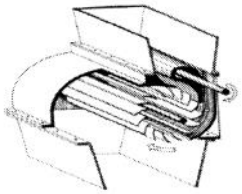
- Yorkshire Water
- 180kW from 2.3 $m^3 s^{-1}$
- 700,000 pe
- But care with ROC eligibility



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Wind

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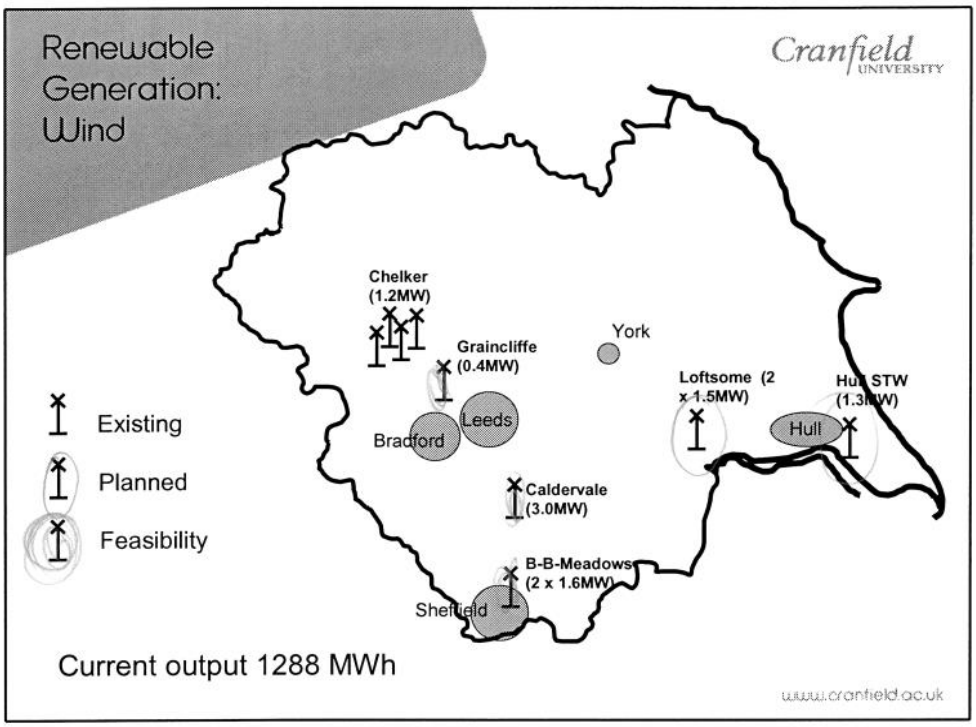
Renewable Generation: Wind
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Chelker (1.2MW)
Graincliffe (0.4MW)
York
Loftsome (2 x 1.5MW)
Hull STW (1.3MW)
Leeds
Bradford
Hull
Caldervale (3.0MW)
B-B-Meadows (2 x 1.6MW)
Sheffield
Existing
Planned
Feasibility
Current output 1288 MWh
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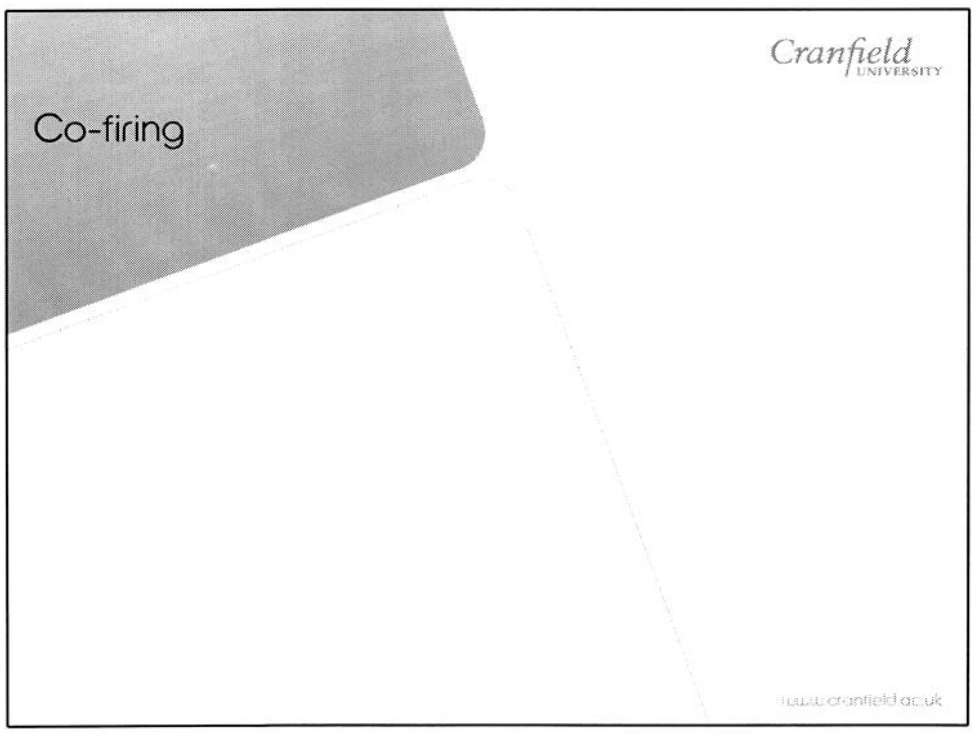
Co-firing
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Co-firing

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- Sludge combined with fossil, biomass or waste fuels to produce energy
- Can use existing facilities or purpose built co-combustion units
- Legislation, financial and perception problems but technically feasible

Issue of scale

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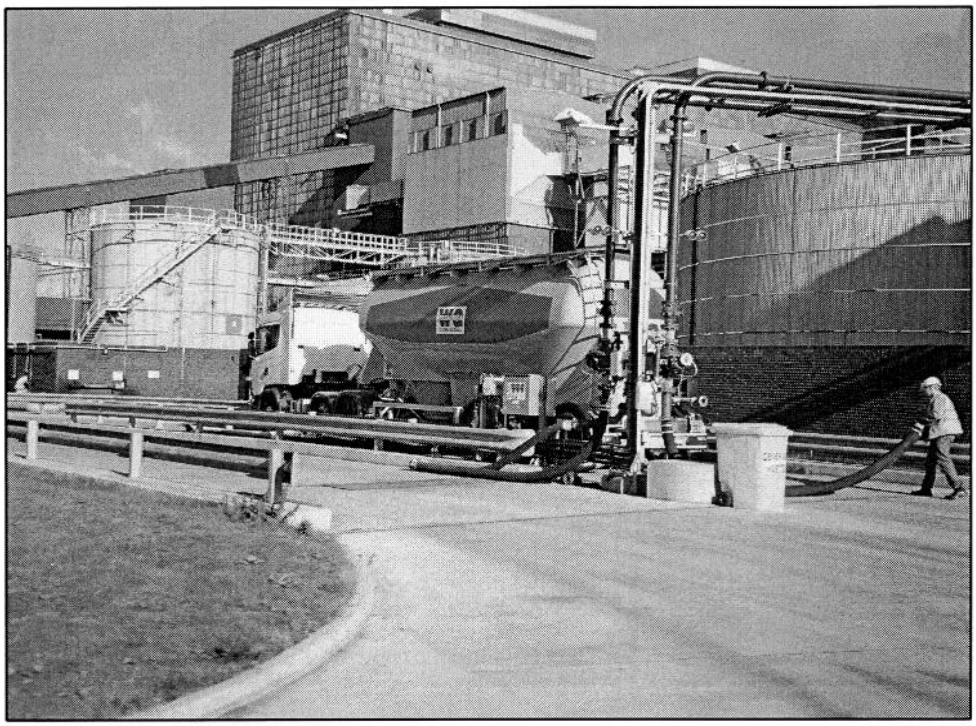
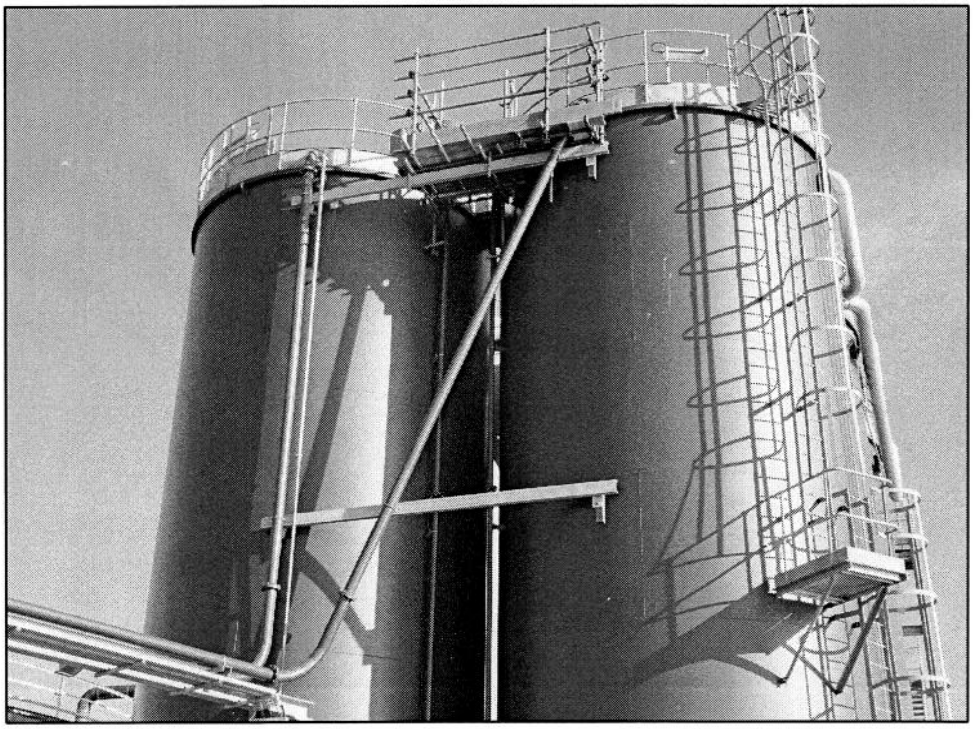
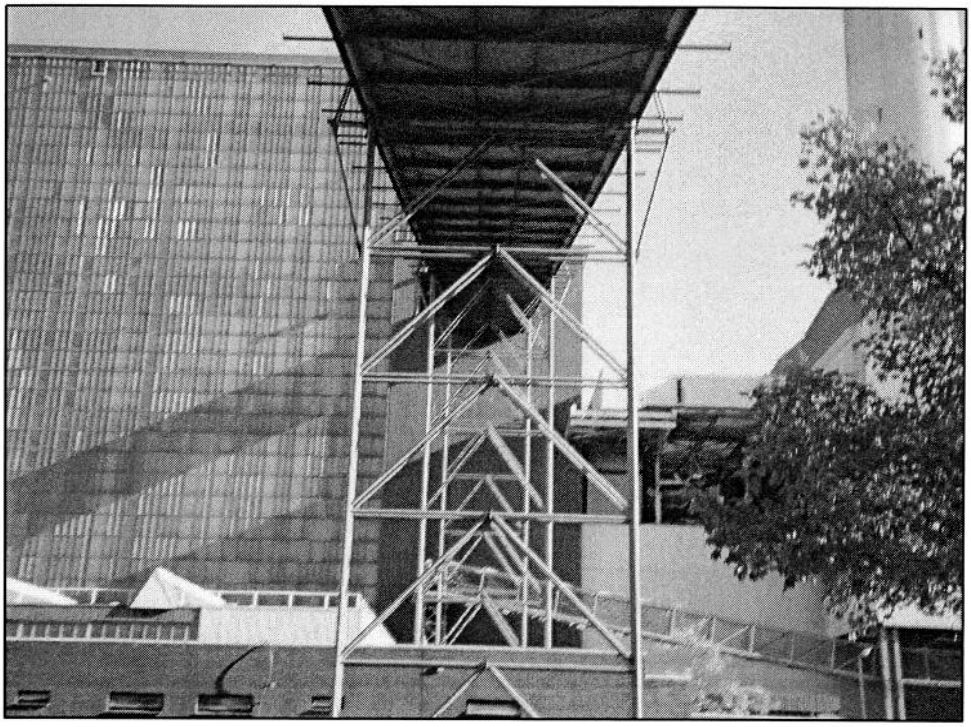
- 930 works produce < 300 tds sludge per year,
- 126 works produce > 4500 tds sludge per year
- Sludge production of 5000 tds yr^{-1} $\cong$ PE 167,000
- 15,000 tds yr^{-1} $\cong$ PE 0.5 million
- Dry sludge CV *c.* 16 MJ kg^{-1},
- So 5000 tds $\cong$ 80 TJ or *c.* 22 GWh.







Elean straw fired power station

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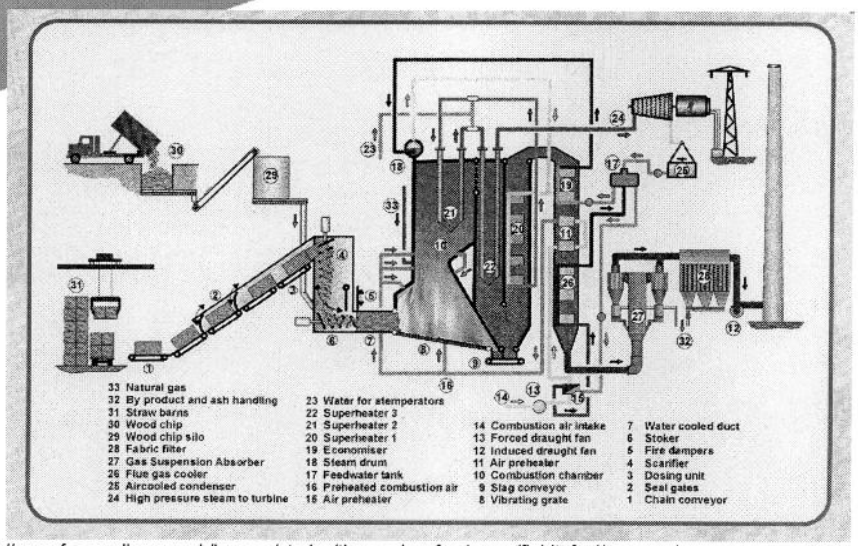

http://www.face-online.org.uk/images/stories/themes/nonfoodcrops/fieldtofuel/process.jpg www.cranfield.ac.uk

Energy Crops

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- Energy crops for biofuels
  - Biodiesel – oil seed rape
  - Bioethanol – wheat or sugar beet
- Energy crops for bioenergy
  - Miscanthus
  - Short rotation coppice

New Initiatives

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New renewables projects Energy Crop at Stoke Bardolph Farm 2MW

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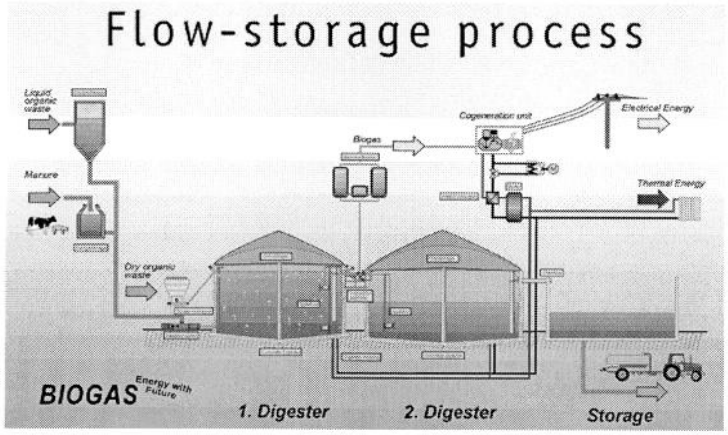

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More...

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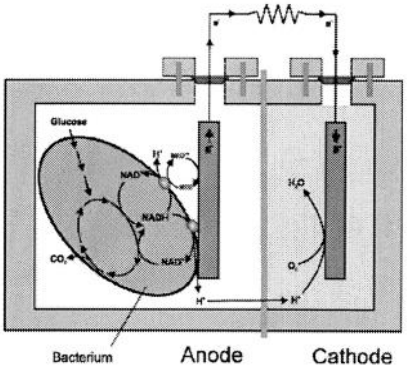
- Hydrogen
- Microbial fuel cells



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Lecture aims

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- Appreciate where energy is used in water and wastewater treatment
- Understand some of the main routes to renewable energy generation in the water sector
- Carbon neutral water and wastewater treatment