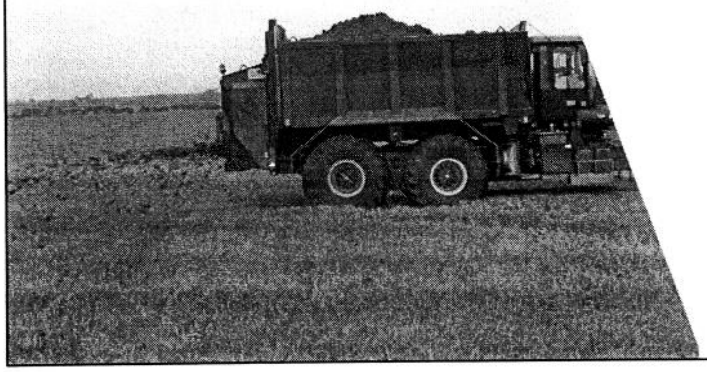
Sludge Re-Use

Dr Elise Cartmell



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Sludge is it a ...

PROBLEM OR RESOURCE ?

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Where does it go?

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Agriculture *c.* 77 %

Land reclamation *c.* 6 %

Where does it go?

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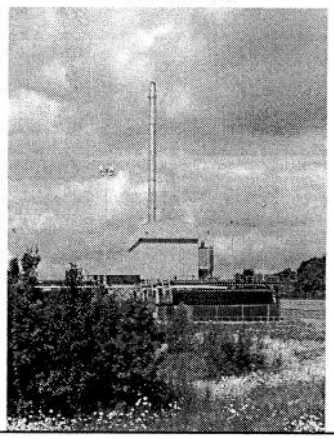
- Incineration (with energy recovery in some situations) *c.* 16 %



Where does it go?

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- Landfill (only in a minority of cases – 1.3%)

Dumping at sea banned from 1998

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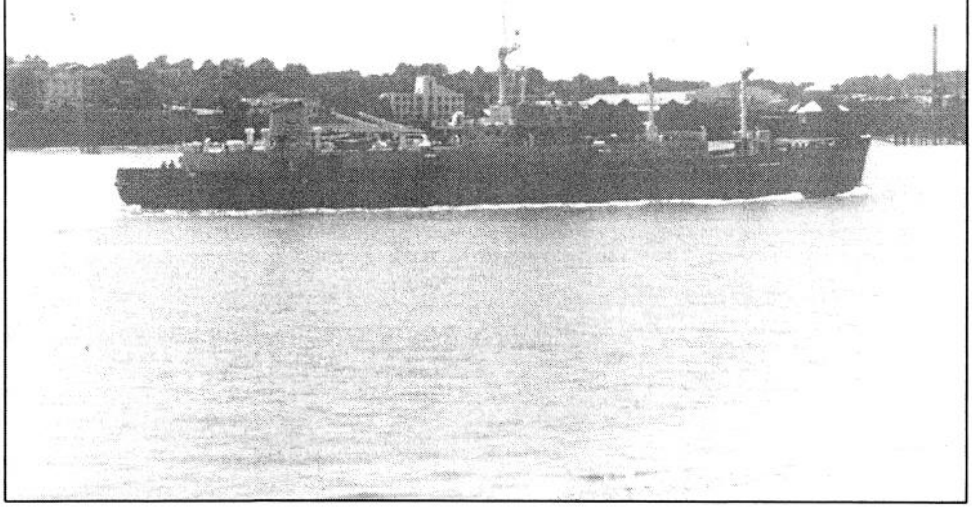

What will be covered in the lecture

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- Regulatory Framework
- Sludge Quality - PTE, Nutrients, Pathogens
- Utilisation Routes
  - Agriculture
  - Energy recovery

Lecture aims

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- To be appreciate the regulatory framework for sludge re-use
- To be aware of the main sludge re-use options

Why Regulate?

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- To ensure bonafide recovery – not cheap disposal
- To ensure that harm to the environment is prevented
- To provide an assurance that regulations are complied with

Regulatory Framework

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General

- EC Urban Waste Water Treatment Directive
- Landfill Directive
- Waste Incineration Directive
- Waste Directive
- IPPC
- Odour and public health issues - local authority Environmental Health legislation
- Water pollution - Water Resources Act
- Waste enforcement legislation where Controlled Waste
- Sludge Use in Agriculture Regulations

Regulatory Framework

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Biosolids recycling

- EC Use of Sludge in Agriculture Directive, 1986
- UK Sludge (Use in Agriculture) Regulations 1989, 1990 Amendment Regulations
- DoE Code of Practice for Agricultural Use of Sewage Sludge, 1996
- MAFF Codes of Good Agricultural Practice for the Protection of Water, 1998 also Air and Soil
- BRC 'Safe Sludge Matrix'
- Revised Regulations

Common sense points

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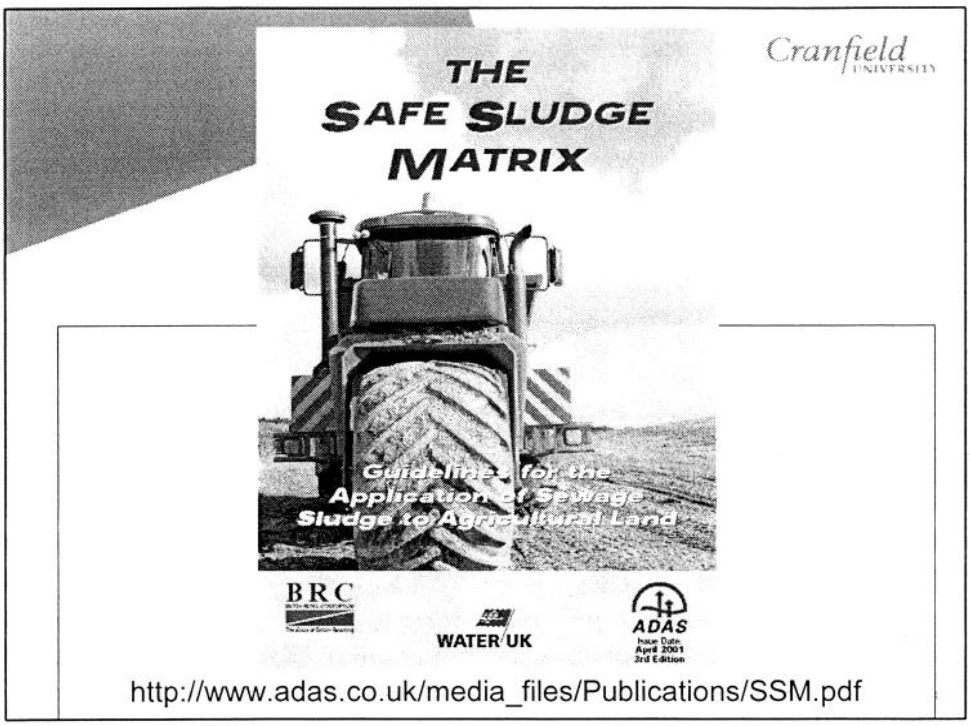
- Soils sampled before sludge application
- Keep under soil metal limits
- Don't apply sludge for soils under pH 5
- Take account of crop fertiliser needs
- Don't pollute ground or surface waters



CROP GROUP	UNTREATED SLUDGES	CONVENTIONALLY TREATED SLUDGES	ENHANCED TREATED SLUDGES
FRUIT	✗	✗	✓ (10 month harvest interval applies)
SALADS	✗	✗ (30 month harvest interval applies)	✓ (10 month harvest interval applies)
VEGETABLES	✗	✗ (12 month harvest interval applies)	✓ (10 month harvest interval applies)
HORTICULTURE	✗	✗	✓ (10 month harvest interval applies)
COMBINABLE & ANIMAL FEED CROPS	✗	✓	✓
GRASS & FORAGE - *GRAZED*	✗	✗ (Deep injected or ploughed down only) (3 week no grazing and harvest interval applies)	✓ (3 week no grazing and harvest interval applies)
GRASS & FORAGE - *HARVESTED*	✗	✓ (No grazing in season of application) (3 week no grazing and harvest interval applies)	✓ (3 week no grazing and harvest interval applies)

NOTE : ✓ *All applications must comply with the Sludge (Use in Agriculture) Regulations and DETR Code of Practice for Agricultural Use of Sewage Sludge (to be revised during 2001).*

✗ *Applications not allowed (except where stated conditions apply)*

Soil Metal Limits

Environment Agency

PTE	Maximum permissible concentration of PTE in soil (mg/kg dry solids)				Maximum permissible average annual rate of PTE addition over a 10 year period (kg/ha)[1]
	pH 5.0<5.5	pH 5.5<6.0	pH 6.0-7.0	pH[2] >7.0	
Statutory:					
Zinc	200	200	200	300	15
Copper	80	100	135	200	7.5
Nickel	50	60	75	110	3
	For pH 5.0 and above				
Cadmium	3				0.15
Lead	200				15
Mercury	1				0.1
Non-statutory:					
*Chromium	400				15
*Molybdenum[3]	4				0.2
*Selenium	3				0.15
*Arsenic	50				0.7
*Fluoride	500				20

Policy directions

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?

Europe

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- Technical Document April 2000
- Soil Thematic Strategy - due Spring?
- Thematic Strategy on Waste Prevention and Recycling

- Revision to Sludge Directive?

Landbank competition

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- Composts
  - Local authority targets
  - Landfill Directive

- Defra project - organic materials to land

Landbank pressures

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- Water Framework Directive
  - River Basement Characterisation
  - Programme of Measures
- Nitrate Vulnerable Zones (NVZs)
- CAP Reform - Cross compliance
  - Good Agricultural and Environmental condition
  - Sludge Use in Agriculture
  - NVZ

To summarise

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- Beneficial provided controlled appropriately
- Highly controlled complies with
  - Sewage Sludge Directive
  - UWWTD
  - Waste Directive
- New Regulations and Directive
- Other materials and policy drivers effecting the sludge route

Sludge quality

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Wastewater Sludge production

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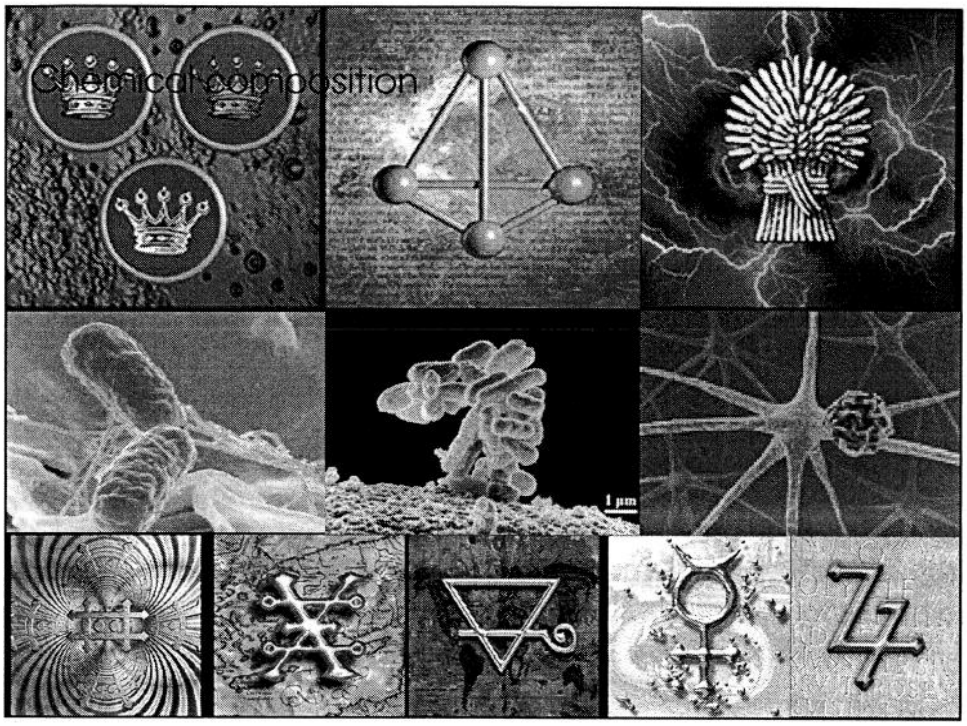
	Source	DS (%)	Yield (kg/kgBOD)	Notes
1°	Faecal solids	2-6	-	Many contain Coagulants
SAS	Biomass (organisms)	0.5-2	0.5-0.8	Poor settling
Humus	Biofilm (organisms)	2-6	0.25-0.5	Seasonal
Tertiary	Residual solids	0.5-4	-	Depends on process
Digested	Digested solids	3-4		Main treatment



Sludge quality - positives

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- N
- P
- Organic Matter
- Trace Elements
- Calorific Value

Sludge quality - negatives

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- Potentially Toxic Elements (PTEs)
- Persistant Organic Pollutants (POPs)
- Pathogens
- Odour

- Affected by
  - catchment size

Sludge quality analysis

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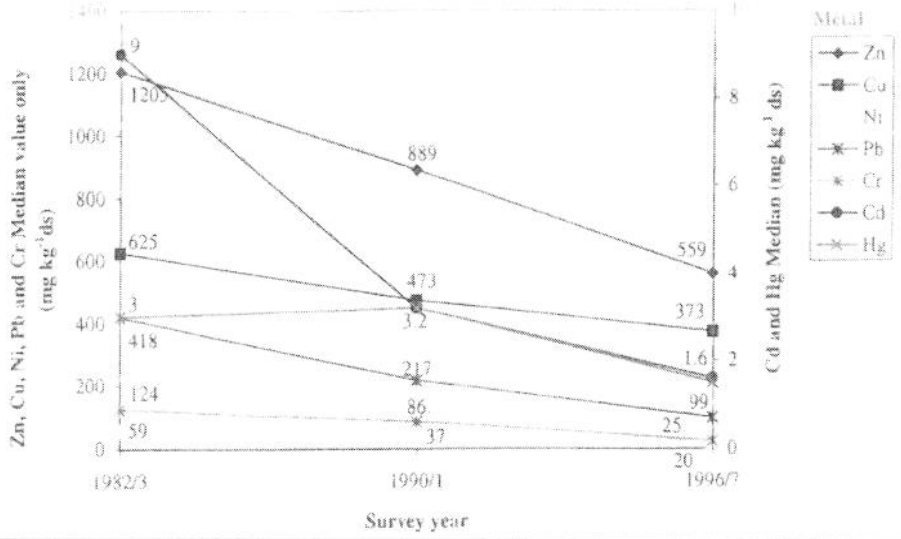
Parameter
Dry matter (%)
Organic matter (% dry solids)
pH
Nitrogen total and ammoniacal (% dry solids)
Phosphorus total (% dry solids)
Zinc, Copper, Nickel, Cadmium, Lead, Mercury, Chromium (mg kg^{-1} dry solids)
****Molybdenum, Selenium, Arsenic, Fluoride (mg kg^{-1} dry solids)***

*Parameters not subject to provisions of EC Directive 86/278/EEC

PTE Content

- 40 - 90 % of PTEs in wastewater transferred to sewage sludge during treatment
- Cd, Ni, Cr and Pb
- Little variation in PTE content of sludge in relation to end disposal outlet
- PTE content affected by catchment size

PTE sludge concentrations



Nutrient content

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Treatment	Total N	Total P
Mesophilic anearobic digestion	55,400	29,200
Anaerobic digestion and dewatering and storage	4,000	22,300
Thermophilic aerobic digestion (TAD)	35,900	47,800
TAD + dewatering + storage	51,200	14,400
Composting	40,700	18,400
Lime stabilisation	14,000	5,500
Liquid storage (3 months)	37,600	20,000
Unstabilised, dewated and stored	32,700	14,100
Thermal drying of treated sludge	36,700	38,900
Thermal drying of untreated sludge	30,800	14,800
None	42,400	21,100

Weighted average concentration (mk kg^{-1} ds) - 10,000 mg kg^{-1} ≡ 1 % of the dry solids

Pathogens of concern

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Five groups of pathogenic organisms
(Human and Animal sources)
Helminths; protozoa; fungi; viruses; and bacteria

Pathogen Levels in Unstabilised and Anaerobically Digested Sludges

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Pathogen	*Unstabilised Sludge (No./100 ml)*	*Anaerobically Digested Sludge (No./100 ml)*
Virus	2,500 – 70,000	100 – 1,000
Faecal Coliform	1,000,000,000	30,000 – 6,000,000
Salmonella	8,000	3-62
Ascaris lumbricoides - Helminth	200 – 1000	0-1,000

Utilisation Routes

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Agriculture

Agricultural Recycling

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- BPEO
- Sludge applied to 80,000 ha of land

  60 % arable ⇩ 3.5 tds ha^{-1}

  40 % pasture ⇩ 2.8 tds ha^{-1}
- Applications once every three years

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Optimising sludge use

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- Rate of sludge <= crop nutrient requirement
- Adjust fertiliser additions
- Apply recommended amounts of K (as fertiliser or farmyard manure)
- Do not exceed crop N requirement:

  Surplus N ⟶ *Excessive vegetative growth*
  ⟶ *Nitrate leaching*

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Problems

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- Public perception - health scares over salmonella, listeria, BSE, E. Coli O157
- Pathogens
- Heavy Metals (PTEs)
- Land availability
- Operational spreading difficulties
- Pollution threat to water - surface run-off
- Odour
- Storage - public nuisance and water pollution
- Transport

Potentially Toxic Elements

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- The quantities of heavy metals added depends on
  - Their concentration in the soil prior to the first application,
  - The concentration in the sludge
  - The quantity that may be added over a 10 year period
  - Soil pH is also taken into account

Heavy Metals can be divided into 2 groups

- Phytotoxic- Copper, Nickel and Zinc
- Zootoxic- Cadmium Lead and Mercury

Contamination of organic micropollutants

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- At present not regulated but concerns now exist.
  - Grazing animals take up soil as 10-15% (by weight) of their food
- Polychlorinated Biphenyls (PCBs) detected in cows milk
- Reduced fertility (sperm mobility) of pedigree rams grazed on sludge amended soil which may have been contaminated by Endocrine Disrupting Chemicals (EDCs)

Safe when controlled

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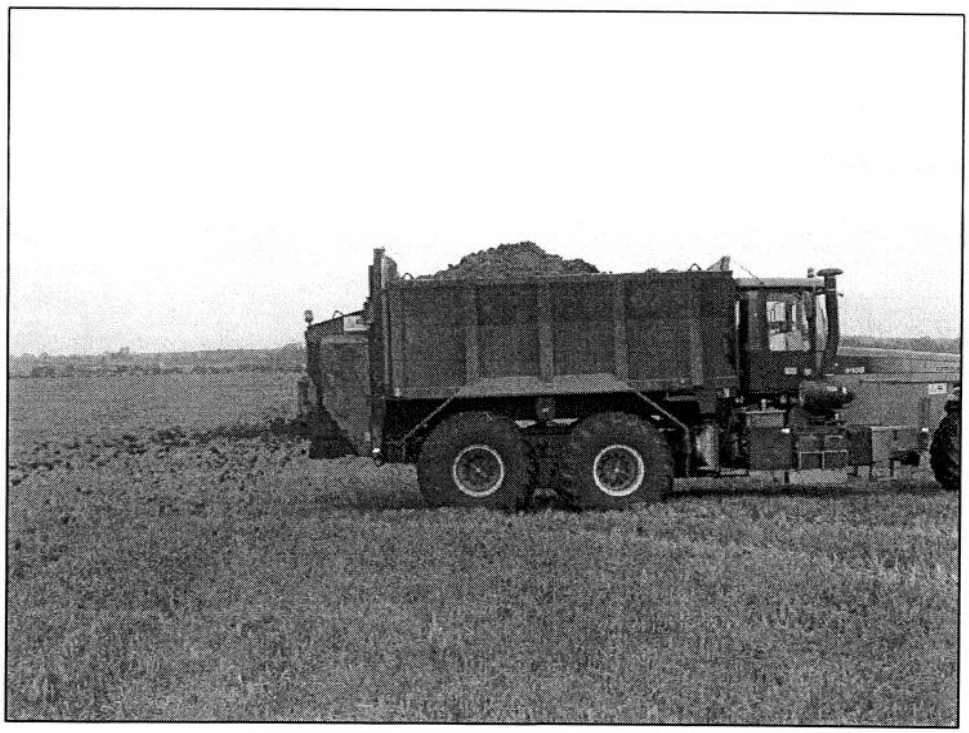
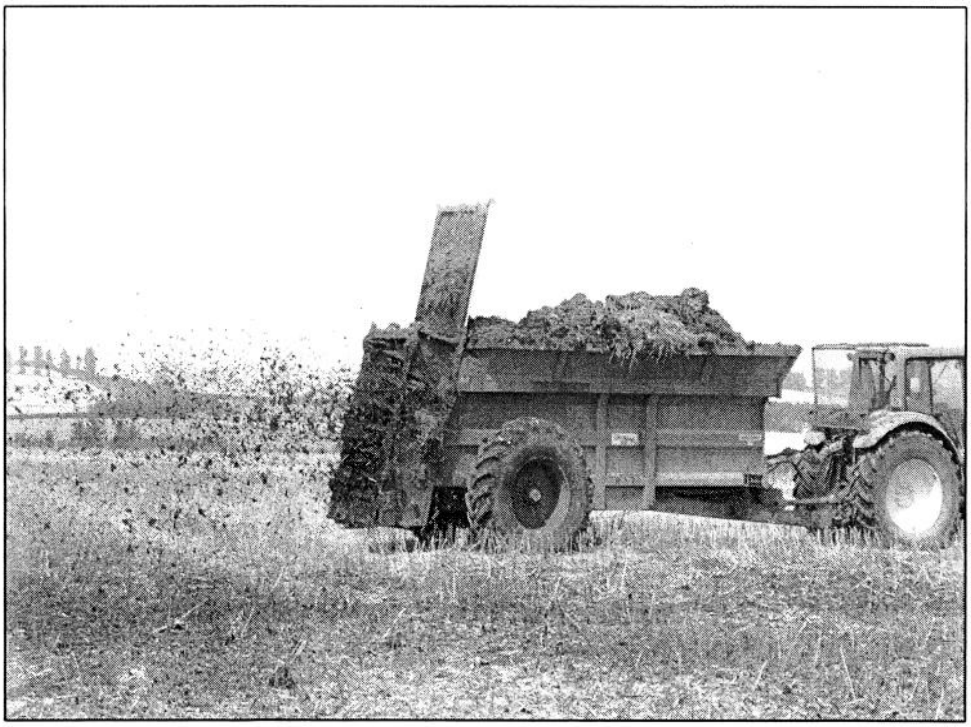
- Barriers established by regulation based on precautionary approach
- Soil is an alien and hostile environment for pathogens

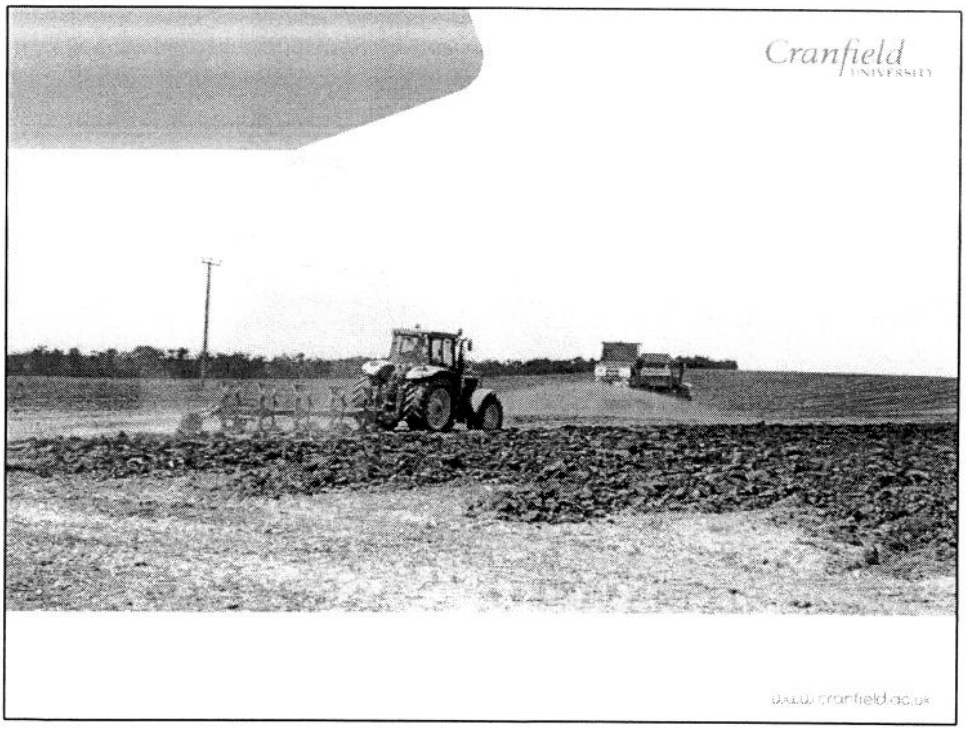
"no instances in the UK in which a link has been established between the controlled application of sludge and disease in the general population through water or food contamination" - *Royal Commission*


O&K






TERRA GATOR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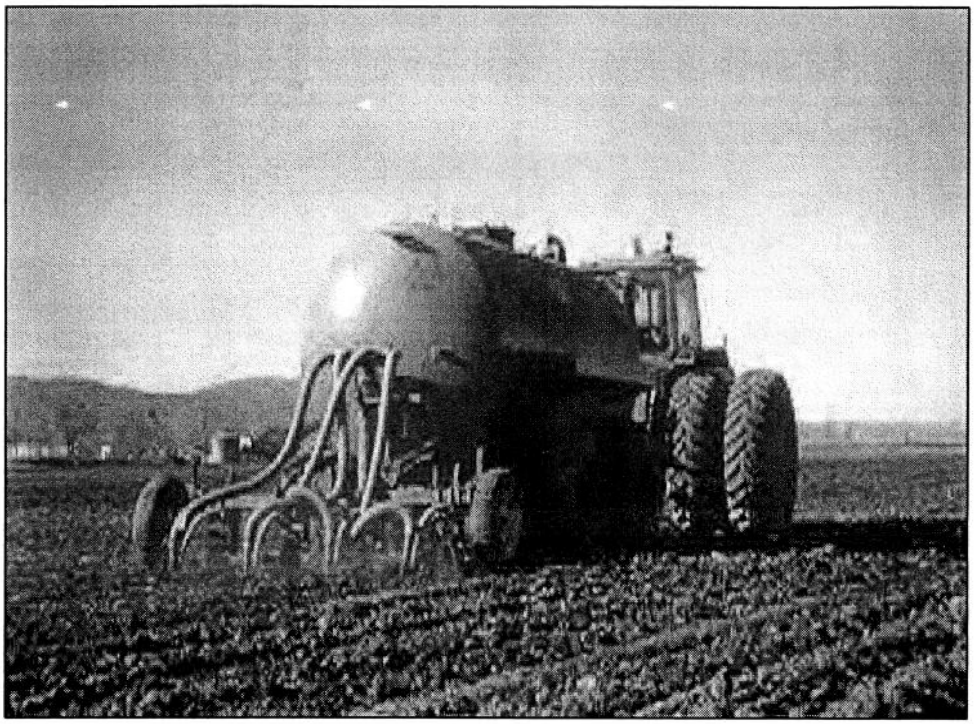

Odour control

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Sludge application

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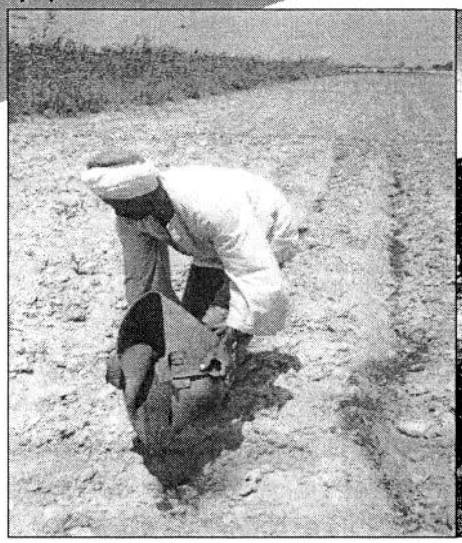

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Sludge Use on Trees

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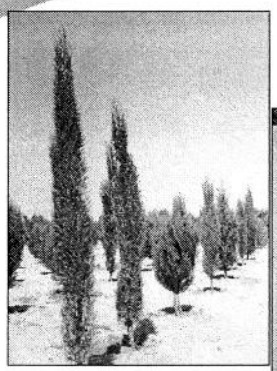
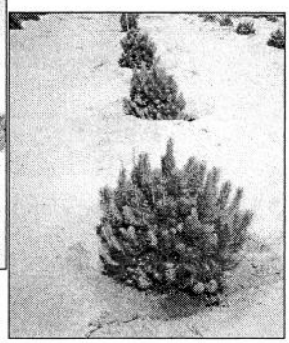
- Urgent need for reforestation and timber products
- Maximises resources
- Coppice plantations renewable energy resource





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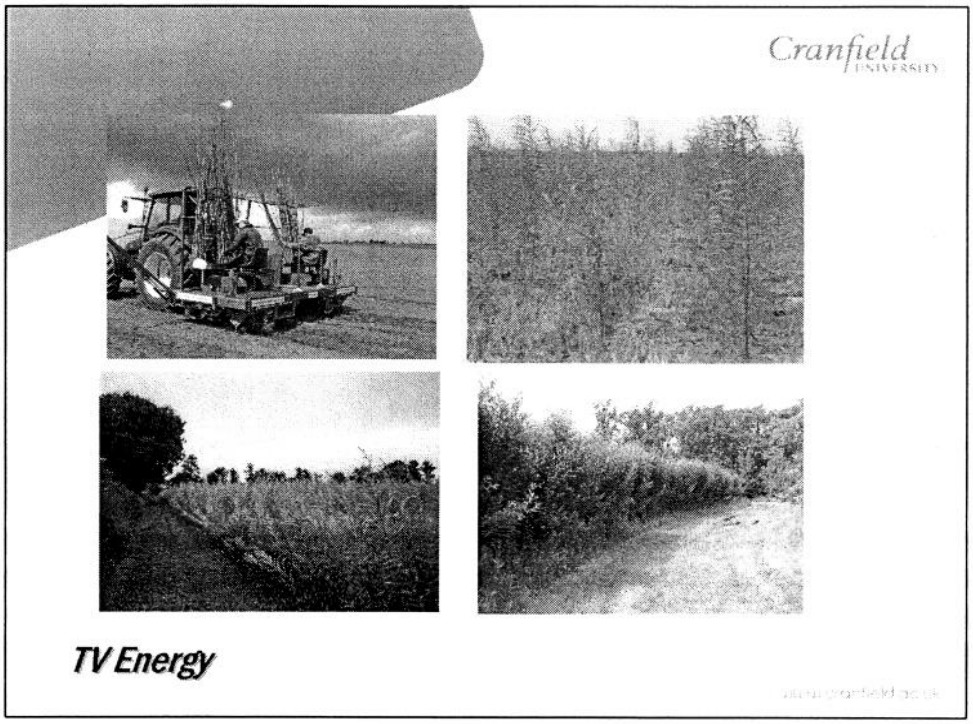
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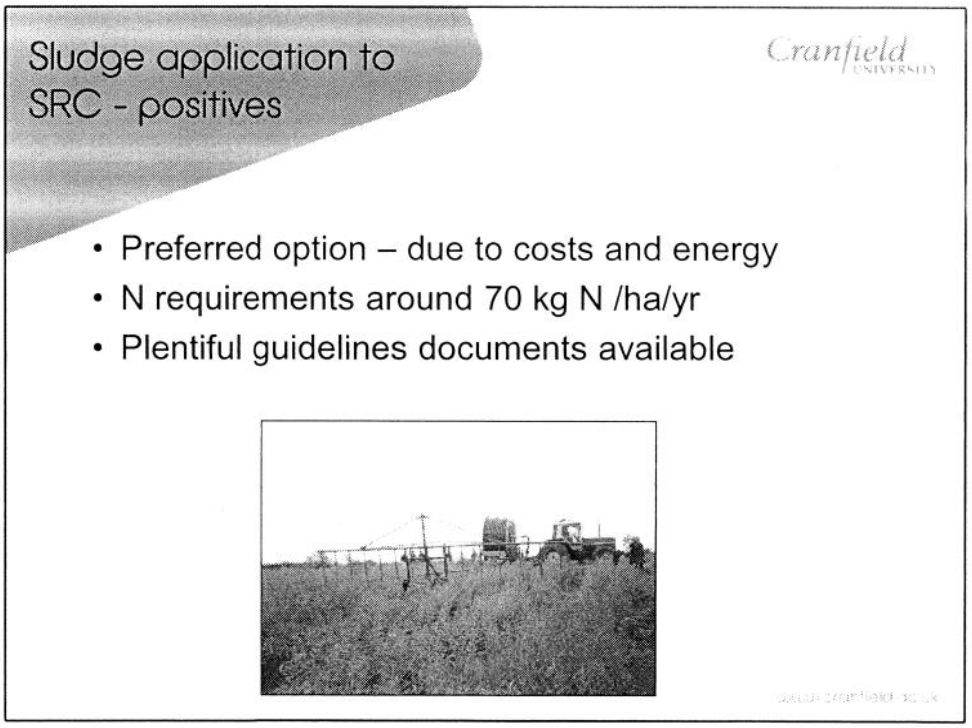
TV Energy


Sludge application to
SRC - positives
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• Preferred option – due to costs and energy
• N requirements around 70 kg N /ha/yr
• Plentiful guidelines documents available

Sludge application to SRC - negatives

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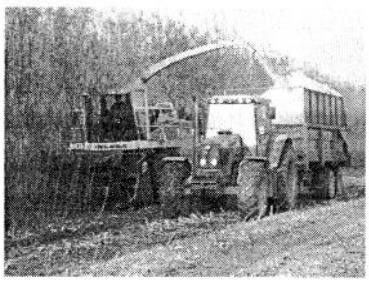
- Not possible to inject or incorporate sludge
- Cannot apply at all, 1 year in 3
- Can only apply solid sludge 1 year in 3
- Small field sizes currently not economical



Forestry

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- Conventional
- Enhances growth
- Improves soil quality and fertility
- Sludge can be applied at different times from agriculture
- Accessibility

Land Reclamation

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- Benefits
  - nutrients
  - improves speed and quality of restoration
  - cost effective
  - high application rates (50-100 tds/ha)
- Restrictions
  - operational logistics
- Small outlet 6 % possible increase

Utilisation Routes

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Energy Recovery

Thermal Technologies

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- Combustion
- Pyrolysis
- Gasification

Combustion

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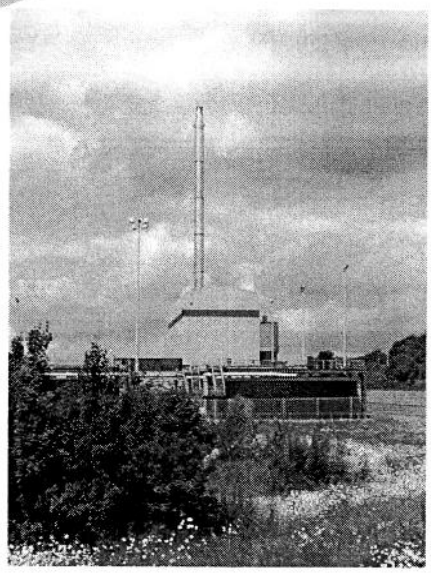

What is combustion

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- Combustion of fuel

  FUEL+AIR $\longrightarrow$ HEAT+WATER+CO_2+N_2

- LHV = HHV – latent heat of water (including water from hydrogen)

- *HHV = gross calorific value* or *gross energy*
  - defined as heat released by a specified quantity (initially at 25°C) once it is combusted and the products have returned to a temperature of 25°C.

Water is important

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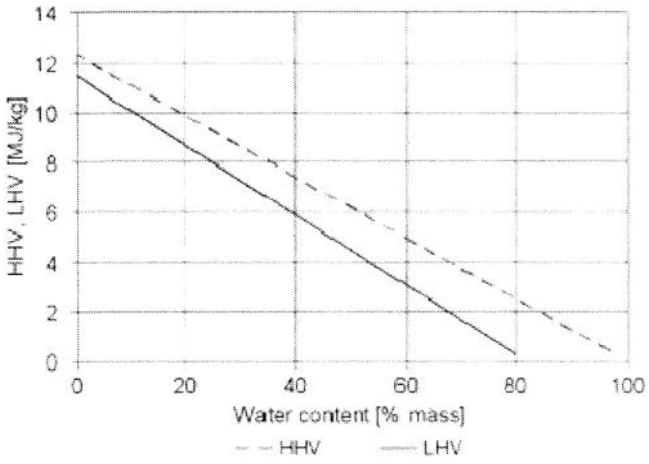

HHV – higher heating value, LHV – lower heating value

Fuel and technology comparison

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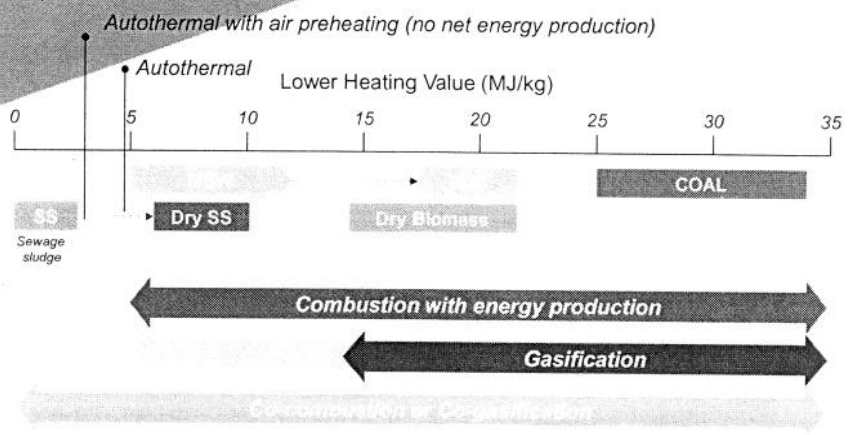

- LHV is the key criterion for fuel quality
- No standard fuel specification with regard to its quality for raw forms of waste or biomass materials
- Standards being developed for pellets/briquettes (wood pellets, RDF)

Incineration

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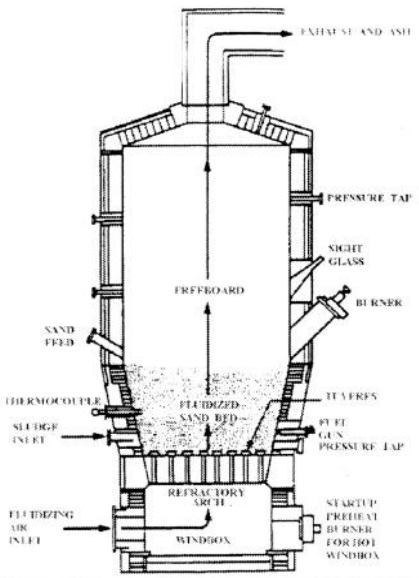
- Yorkshire Water
  - 940,000 PE
  - 3.3 tds/h of sludge cake
  - 15t bed of sand fluidised by hot air
  - Combusts sludge to ash at 850°C
  - Heat recovered from flue gases to pre-dry the feed sludge

Incineration

- Thames Water - 34.7 GWh of renewable energy to the London area
- Waste heat boiler recovers energy by cooling the flue gas
- Cooling water boils and steam produced sent through a steam turbine producing electricity

Sludge incinerator



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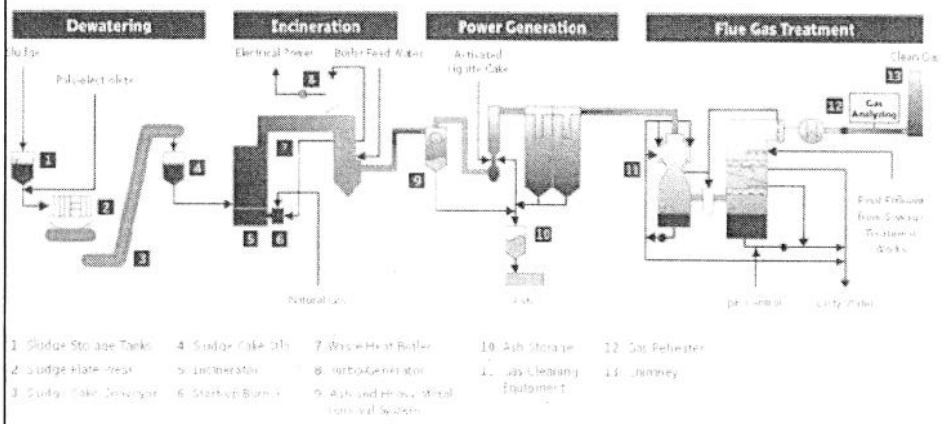
Sludge incineration process



http://www.thameswater.co.uk/en_gb/Downloads/PDFs/Wastewater_Crossness_260606.pdf

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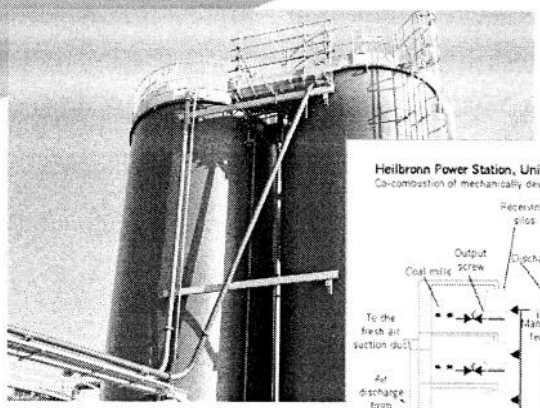
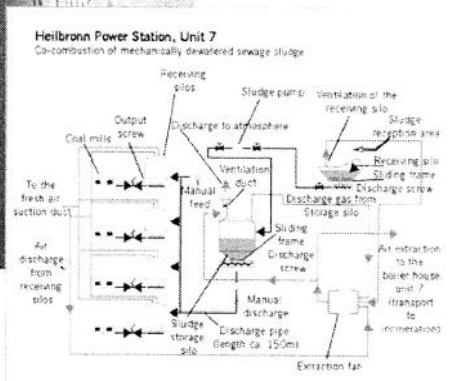
Combustion

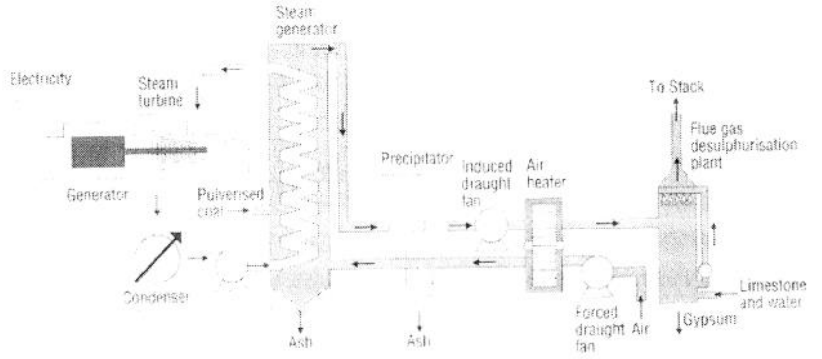




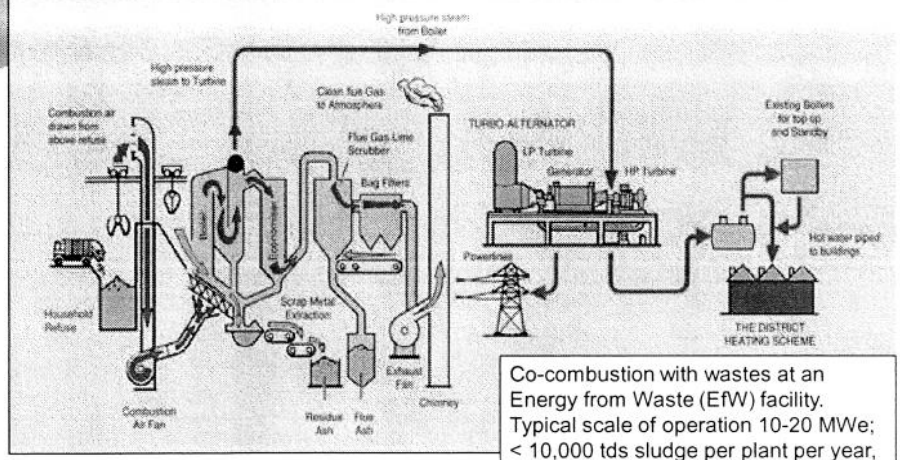
Longannet and Heilbronn

co-combustion, with fuel

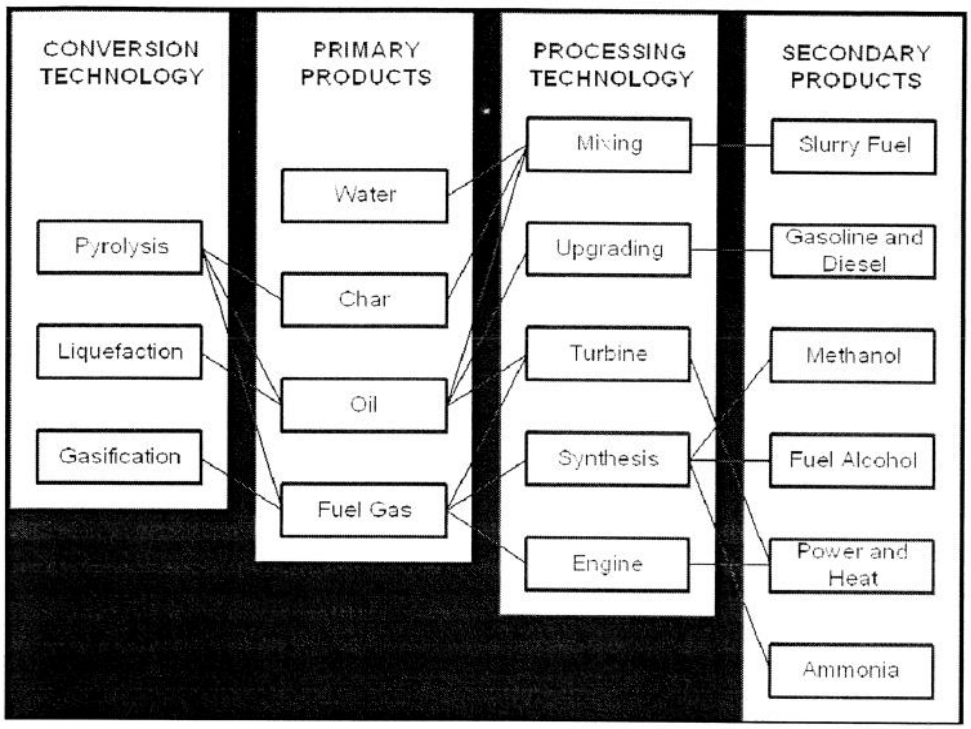
Typical scale of operation >100MWe;
> 50,000 tds sludge per plant per year.

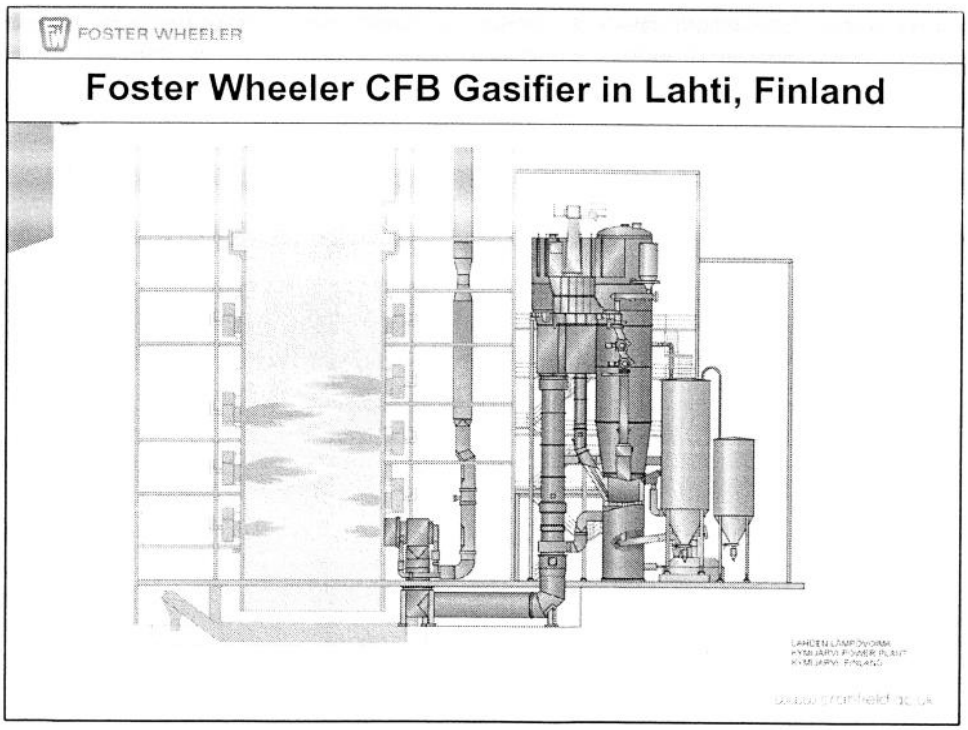


Co-combustion with waste



Co-combustion with wastes at an Energy from Waste (EfW) facility.
Typical scale of operation 10-20 MWe;
< 10,000 tds sludge per plant per year, also up to 50,000 tds sludge per plant per year.


CONVERSION TECHNOLOGY
PRIMARY PRODUCTS
PROCESSING TECHNOLOGY
SECONDARY PRODUCTS
Pyrolysis
Liquefaction
Gasification
Water
Char
Oil
Fuel Gas
Mixing
Upgrading
Turbine
Synthesis
Engine
Slurry Fuel
Gasoline and Diesel
Methanol
Fuel Alcohol
Power and Heat
Ammonia


FOSTER WHEELER
Foster Wheeler CFB Gasifier in Lahti, Finland

LAHTI

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Supplier: Foster-Wheeler

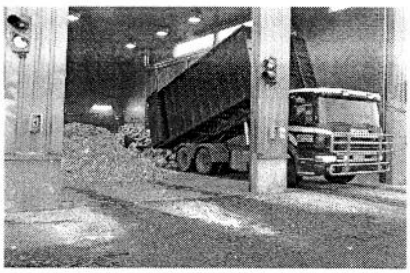
- Start-up: 1998
- TIC: 12 MEURO (30% EC support)
- Fuel cap: 80 MW max wood wastes and other wastes
- Operating data 1998 - 2002
  - --Availability: ~ 80 % 1998
  - –Operating time 27 000 h
  - –Fuel used 0.5 million ton

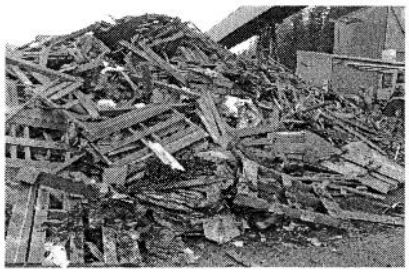
tps

Sister Plant at Electrobel, Ruien, Belgium in operation this year

FOSTER WHEELER

Lahti Fuels





Lecture aims

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- To be appreciate the regulatory framework for sludge re-use
- To be aware of the main sludge re-use options

Water Industry aid in the improvement of sludge quality and re-use options

Ensure that sludge utilisation recognised as posing 'no risk' to food safety or human health

RESOURCE RECOVERY