SEWAGE

Thermal Treatment of Sewage Sludge for CHP Applications

15/16 September 2003, Brussels

SEWAGE SLUDGE GASIFICATION FOR CHP APPLICATIONS

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FP5 Contract No. ENK5-CT2000-00050

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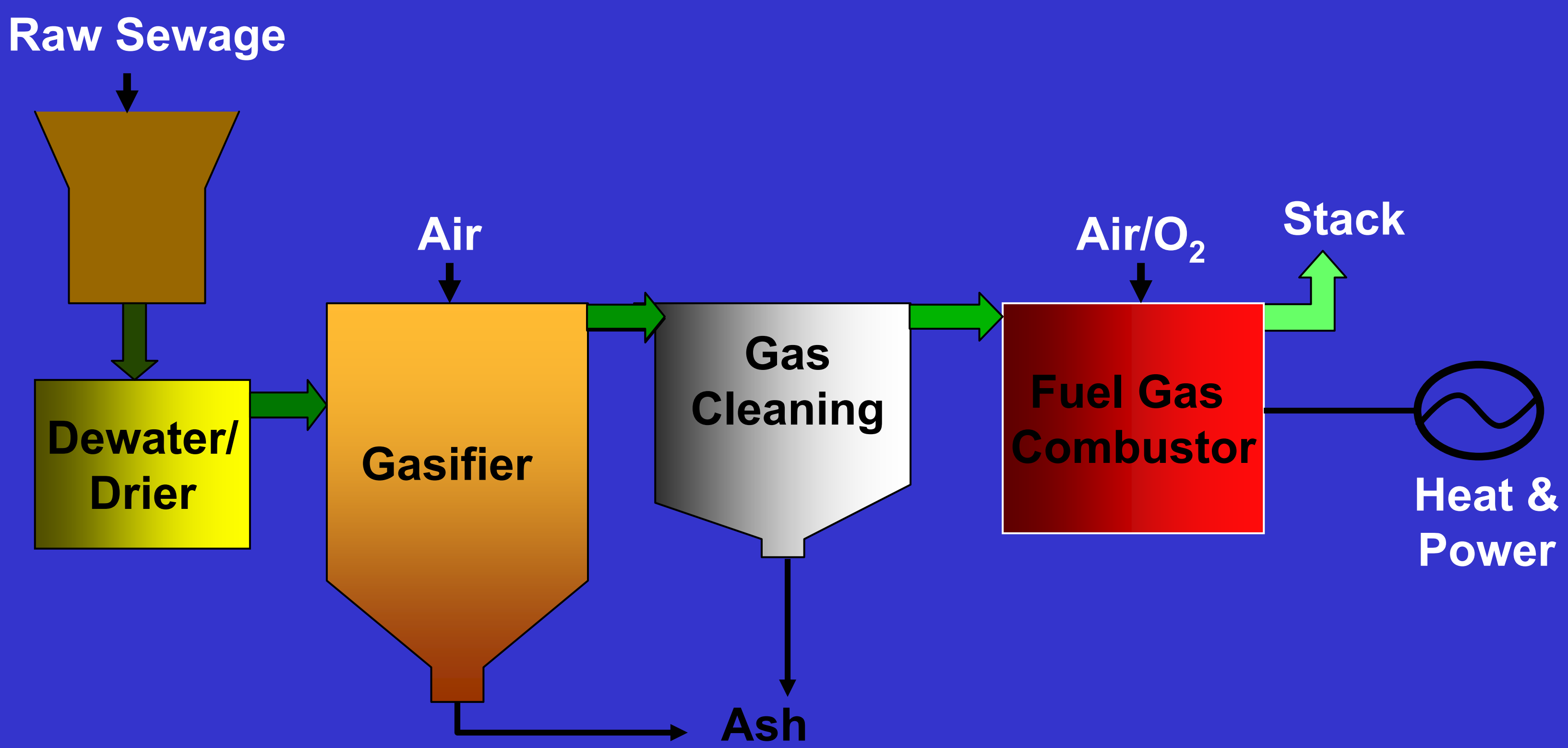
Project Partners

- EMC Environment Engineering Ltd, UK *(Co-ordinator)*
- University of Ulster, NI
- VTT Energy, Finland
- University of Zaragoza, Spain
- Imperial College of Science and Technology, UK
- Sistemas de Transferencia de Calor, Spain
- Institute for Chemical Processing of Coal, Poland

Project Duration

1 October 2000 – 30 September 2003

SEWAGE SLUDGE GASIFICATION



$-H_2O$

$C + \frac{1}{2}O_2 \leftrightarrow CO$
$C + O_2 \leftrightarrow CO_2$
$C + CO_2 \leftrightarrow 2CO$
$C + H_2O \leftrightarrow CO + H_2$
$C + 2H_2 \leftrightarrow CH_4$

- H_2S
- Particulates
- NH_3

$2H_2 + O_2 \leftrightarrow 2H_2O$
$2CO + O_2 \leftrightarrow 2CO_2$
$CH_4 + 2O_2 \leftrightarrow CO_2 + 2H_2O$

SLUDGE GASIFICATION ISSUES

- **Feedstock preparation and handling**
- **Gasification technology and performance**
- **Fuel gas combustion performance**
- **Environmental emissions and ash residue management**
- ***Quality, quantity and source of sewage sludge***
- ***Economic viability***

Preparation, Handling and Feeding Systems

Important Issues:

- **Transporting liquid sludge**
- **Dewatering**
- **Drying/pelletising**
- **Transporting dried sludge**
- **Storage**

Liquid Sludge Transportation Options

	Screw	*Chain*	*Belt*	*Bucket Elevator*	*Pump**
Area required	1/2	3	4	1	1
Capital costs	3	4	2	4	3
Maintenance costs	3	3	1	3	4
Operation costs	4	4	1	4	2
Energy consumption	4	3	2	3	1
Slope	$0\text{-}90^{o}$	$0\text{-}75^{o}$	$0\text{-}30^{o}$	$60\text{-}90^{o}$	$0\text{-}90^{o}$
Hermetically sealed	Yes	No	No	No	Yes
Type of sludge	Most	>50% ds	Most	Dried	2-35% ds
Overall Evaluation	3.1	3.4	2	3	2.2

** Peristaltic and piston*

Best 1 ↔ 5 Worst

STC

Mechanical Dewatering Options

	Belt Presses	*Centrifuges*	*Filter Presses*
Area required	**3**	**1**	**5**
Capital cost	**1**	**3**	**5**
Maintenance costs	**4**	**4**	**3**
Operational costs	**4**	**1**	**5**
Energy consumption	**2**	**3**	**3**
Technical viability	**4**	**1**	**3**
Overall Evaluation	**3.1**	**2.4**	**3.9**

Best 1 ↔ 5 Worst

Broad comparison – as for each technology different commercial systems are available all having different characteristics

STC

Thermal Drying Options

	Drum Drier	*Disk Drier*	*Fluid Bed*	*Thin Layer*	*Belt Drier*
Area required	2	3	4	2	4
Capital costs	3	3	4	4	2
Maintenance costs	3	3	2	2	2
Efficiency	32	3	4	3	4
Emissions	5	45	5	5	2
Flexibility	1	3	2	3	2
Final Product Quality	5	2	4	2	2
Overall Evaluation	2.8	3.3	3.5	3.1	2.2
% ds in cake	>90	65-94	>90	<65	>90
Final product	granulated /no dust	fine particles	granulated /no dust	fine particles	pellets/no dust
Density (kg/m^3)	700-800	700-800	700-800	700-800	350

Best 1 ↔ 5 Worst

STC

Dried Sludge Transportation

Screw Conveyer

Pneumatic Conveyer

- Degradation behaviour compared with a reference coal
- Results showed that sludge pellets can be handled and conveyed to the gasifier without significant problems.

STORAGE

Johanson Indicizer Test Rigs

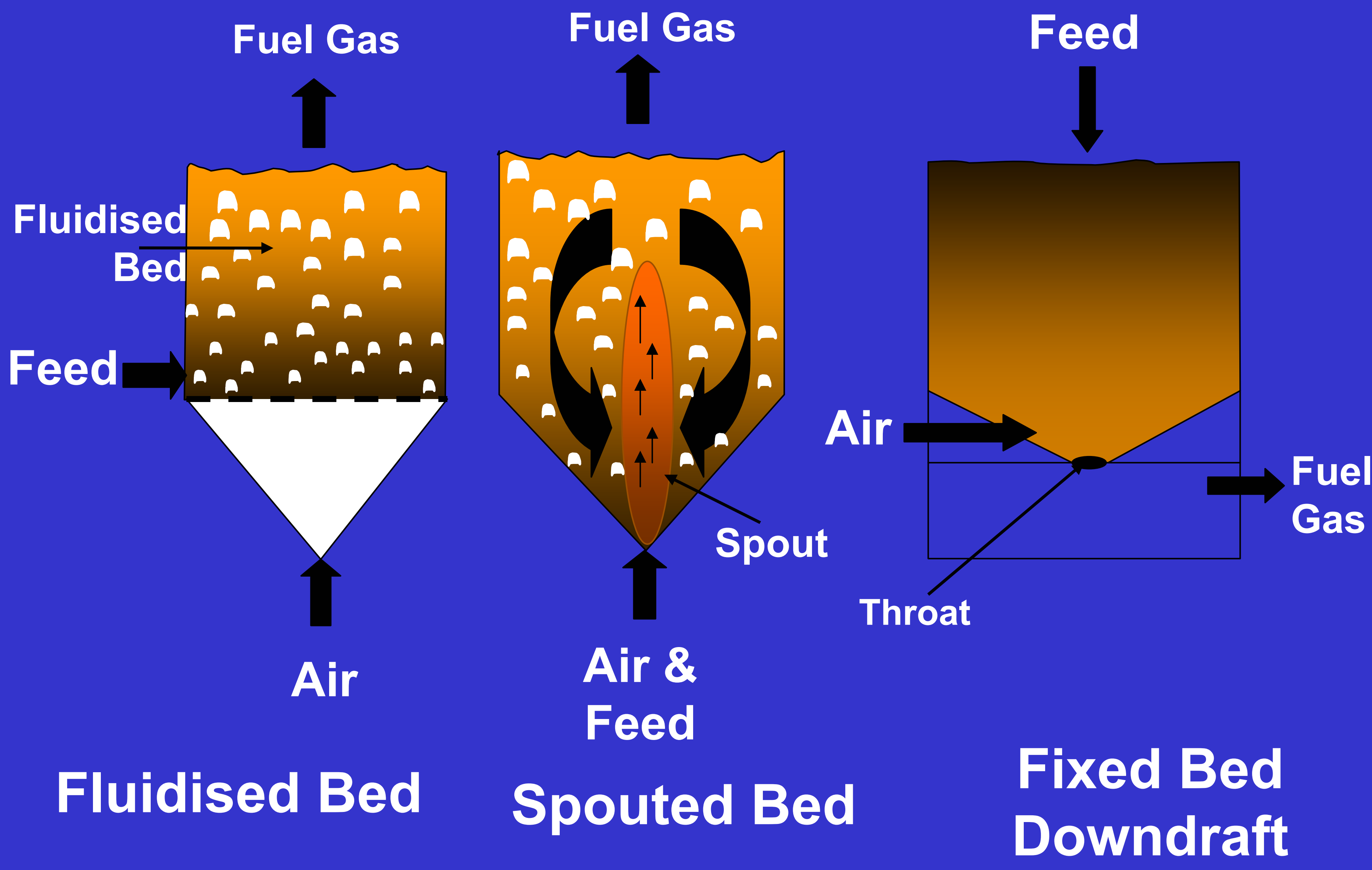
- Flow characteristics from storage hoppers
- To identify potential problems and provide hopper design parameter data
- As long as pellets are kept dry and stored in hopper with adequate outlet dimensions and wall angles, few problems should be encountered

Gasification Technology and Performance

- **Establish the suitability of circulating fluidised bed, spouted bed and fixed bed gasification technology for sewage sludge.**

- **Impact of various parameters on process operability, performance and fuel gas characteristics.**
  - **Sludge type**
  - **Co-firing**
  - **Operating conditions**

Gasifier Types



Typical Characteristics of Thermally Dried Sewage Sludge

Moisture	8%
Volatile Matter	55%
Ash	35%
Calorific Value	16 MJ/kg
C	30%
H	3.5%
N	3%
S	1%
Cl	0.04%

Si	10%
Al	5%
Fe	3%
Ca	5%
Na	0.2%
K	0.3%
P	4%
Ba	0.06%
Hg	0.0001%
Pb	0.02%
Zn	0.09%

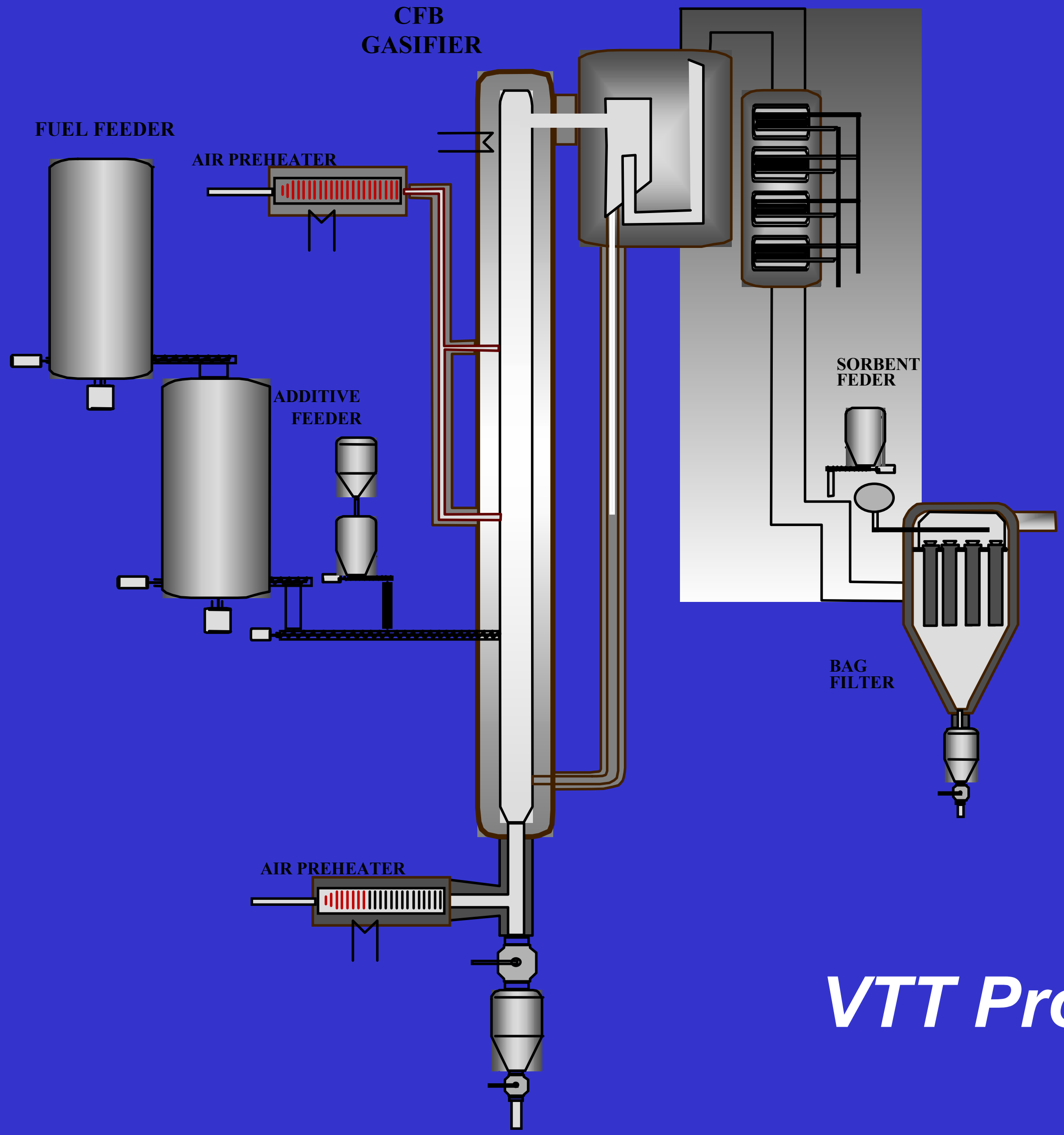
Overall

- Characteristics variable
- High ash – low CV
- High trace metals
- High N
- Very reactive

POTENTIAL ISSUES FOR S/S GASIFICATION

- **Operational problems**
  - **Bed sintering**
  - **Ash fouling**
  - **Tar formation**
- **Fuel gas calorific value and consistency**
- **Gaseous emissions**
  - **High N**
  - **High trace metals**
- **Ash residues**
  - **Utilisation/disposal**
  - **Trace metals, C & S^{2-}**

Circulating Fluidised Bed Gasifier



VTT Processes

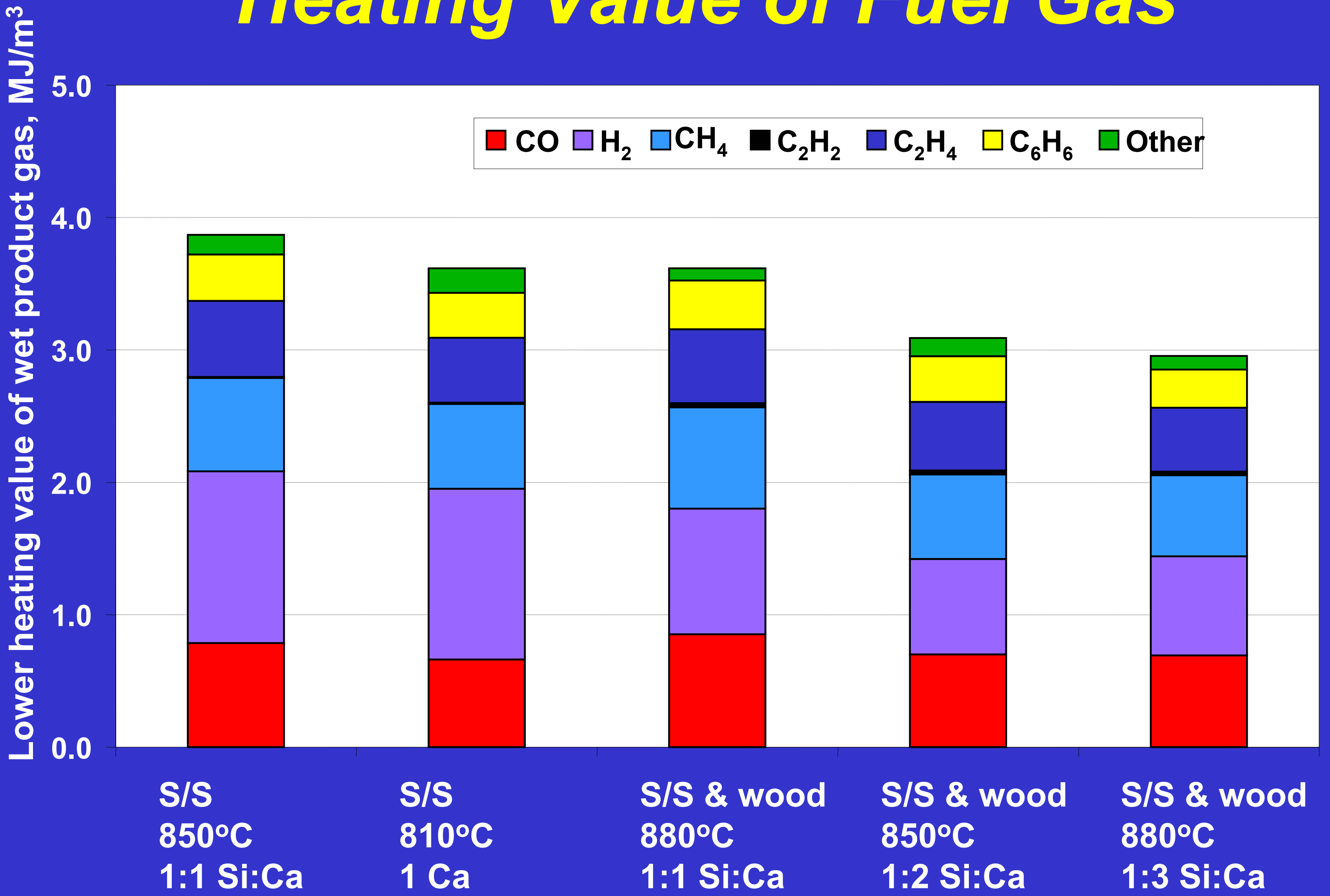
CFB Gasification Test Programme

- Initial trials successfully completed at bench scale on sludge and co-fired with wood. Data gained was used as a basis for the PDU scale CFBG tests.

- Feedstocks
  - Digested, thermally dried sewage sludge
  - Composted sewage sludge containing wood additive

VTT

Heating Value of Fuel Gas



High C conversions: around 90%

VTT

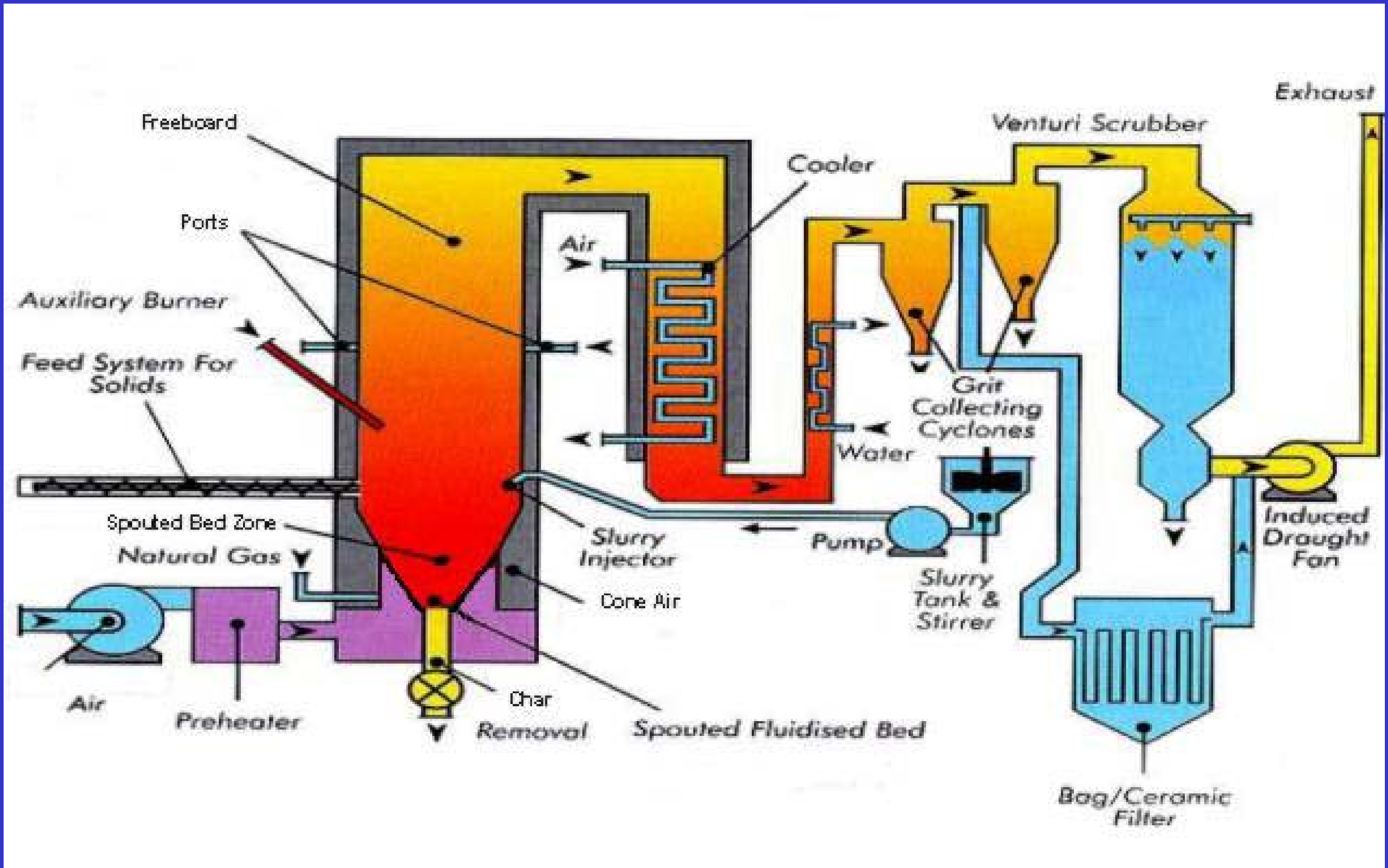
CFB Gasification: Summary

- Circulating fluidised bed gasification of sewage sludge is a technically feasible option

- All tests successful
  - No notable sintering or deposit formation
  - Low levels of tar
  - However, NH_3 and HCN levels were high (NH_3 1.1%; HCN 300 ppm)…….200-360 NOx mg/m^3
  - H_2S levels ranged from 600 to 900 ppm (350-490 SO_2 mg/m^3)

- Optimised composting results in a reasonable CV and the quality of the feedstock can be improved significantly by co-firing with better quality fuel (e.g. wood chips).

Spouted Bed Gasifier



EMC Environment Engineering Ltd

Spouted Bed Gasification Test Programme

- **Programme**
  - **4 samples of thermally dried, digested and undigested sewage sludge**
  - **Conditioner**
  - **Co-firing with coal**
  - **Bed temperature**
- **Spouted bed environment too vigorous for dried S/S**
- **Pre-treating with conditioner, co-firing and increasing bed temperature improved operability and fuel gas CV**

Fixed Bed Downdraft Gasifier

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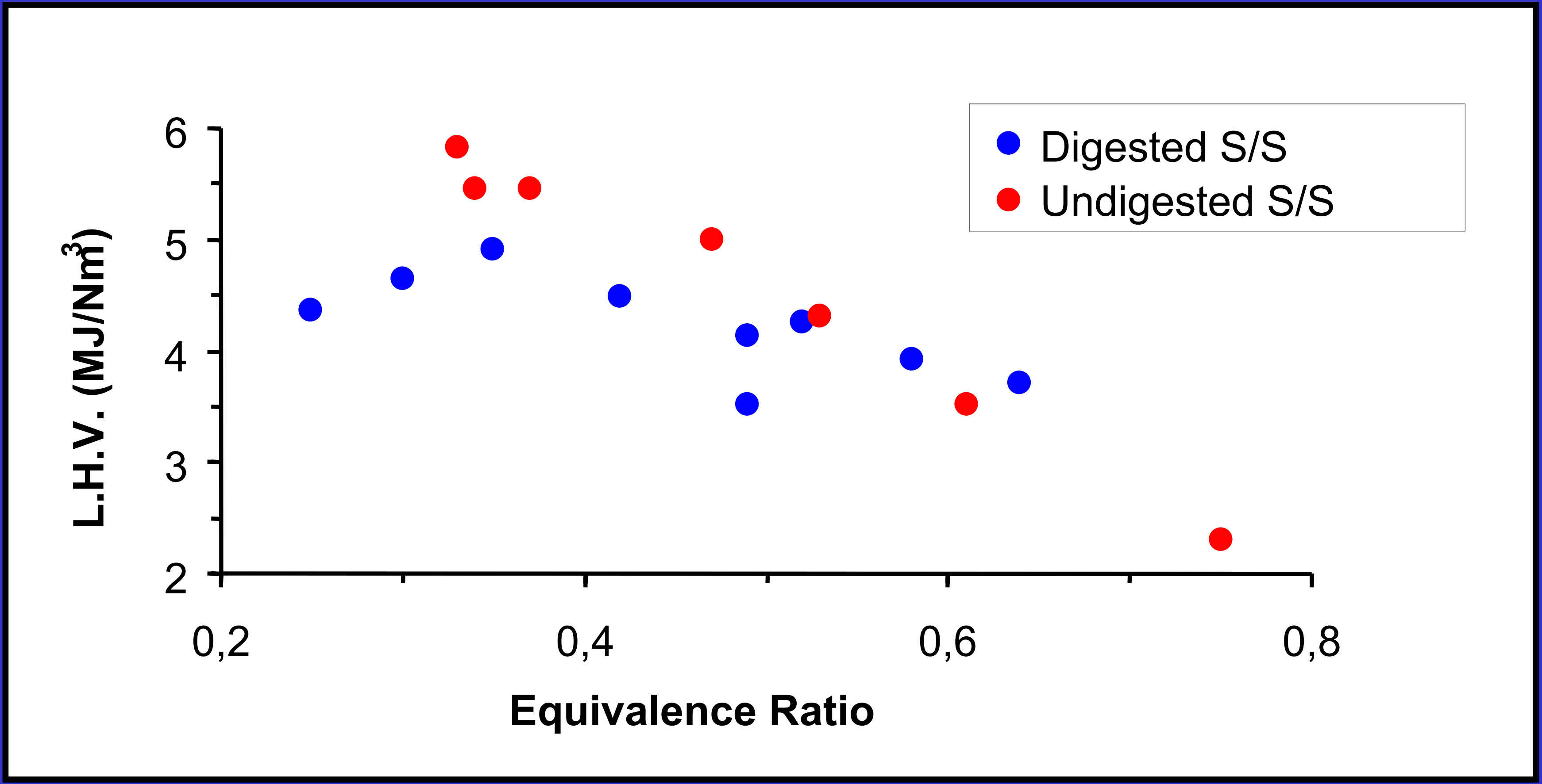
Fixed Bed Gasification Test Programme

- **Extensive programme of trials**
  - **Digested & undigested sewage sludge**
  - **Air to fuel ratio**
  - **Co-firing ratio**

- **Optimum gasification conditions for:**
  - **Minimising slag formation on the grate**
  - **Achieving good fuel gas quality & C to gas conversions**

Fixed Bed Gasification: Fuel Gas Quality



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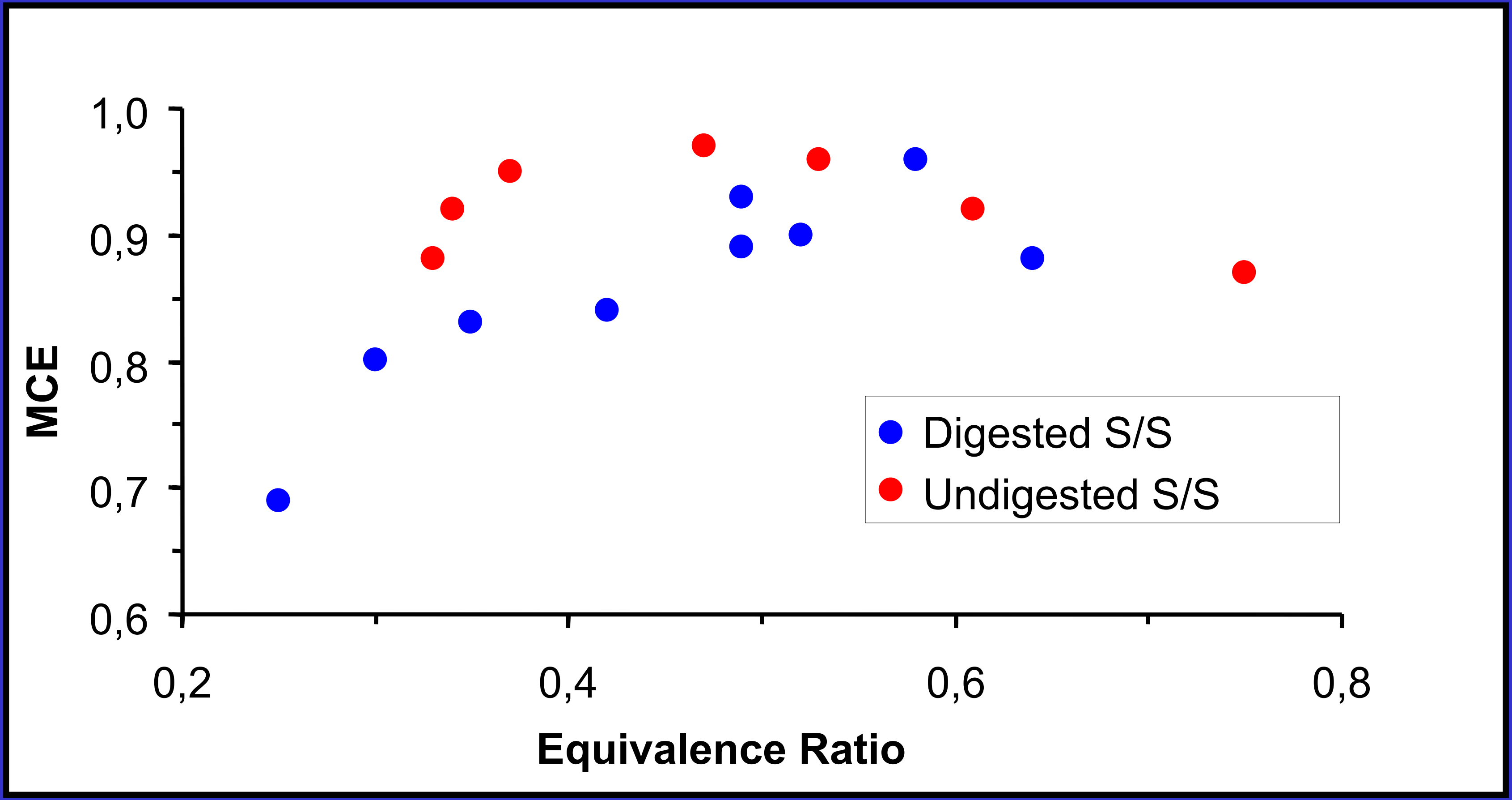
Fixed Bed Gasification: Mass Conversion Efficiency



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Fixed Bed Gasification: Summary

- **Overall results demonstrated that fixed bed downdraft gasifier technology is a technically feasible option for small scale applications**
- **Optimum conditions identified for:**
  - **minimal slag and tar formation**
  - **good conversion of solid to gas**
  - **gas quality**
- **To minimise potential operational problems, co-firing sewage sludge in blends with other fuels such as wood wastes, was recommended**

Comparison of Gasification Technologies

Fluidised Bed

Technically feasible option

Good scale-up potential

Good operability

In-situ S control

Low levels of tar

Low quality fuel gas

Co-firing composted S/S

Spouted Bed

Limited to co-firing

Good scale-up potential

Poor operability on S/S alone

In-situ S control

Low quality fuel gas

Co-firing Recom[d]

Fixed Bed

Technically feasible option

Limited scale-up potential

Optimum T°C to minimise slag and tar formation

Fairly clean fuel gas (wet scrubbing)

Low quality fuel gas

Co-firing Recom[d].

Fuel Gas Combustion Performance

Performance tests were carried out using a small diesel engine operated on gas generated from the fixed bed gasifier

Diesel Engine

University of Zaragoza

Fuel Gas Combustion Summary

- **34kW generation system adapted to operate on sewage sludge derived fuel gas**
- **Optimum operating conditions were established**
- **Reduction up to 94% in diesel fuel consumption**
- **Efficiency up to 26% (fuel gas energy to electrical power)**
- **Emissions, mg/m^3**

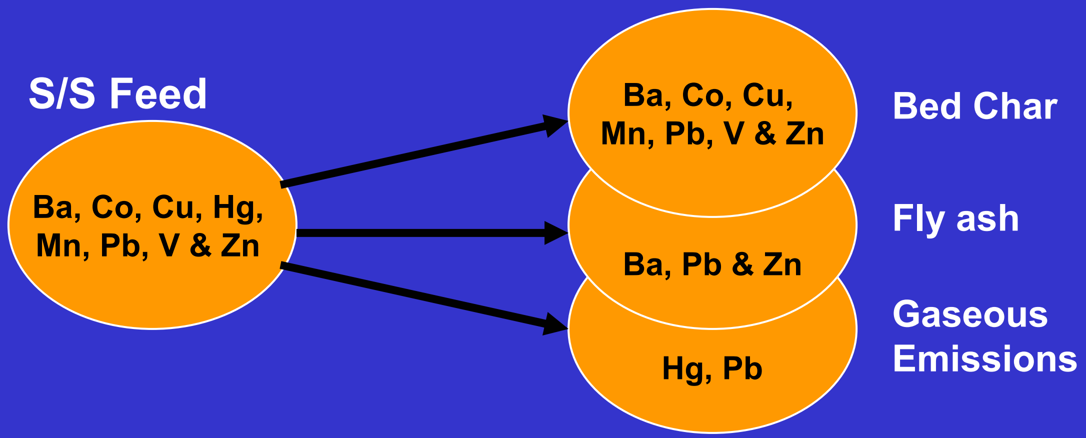
NOx	120
SO_2	2
HC	< 2

Environmental Performance

- **Fate of heavy metals and gas cleaning requirements**
- **Ash residue management**

Fate of Heavy Metals

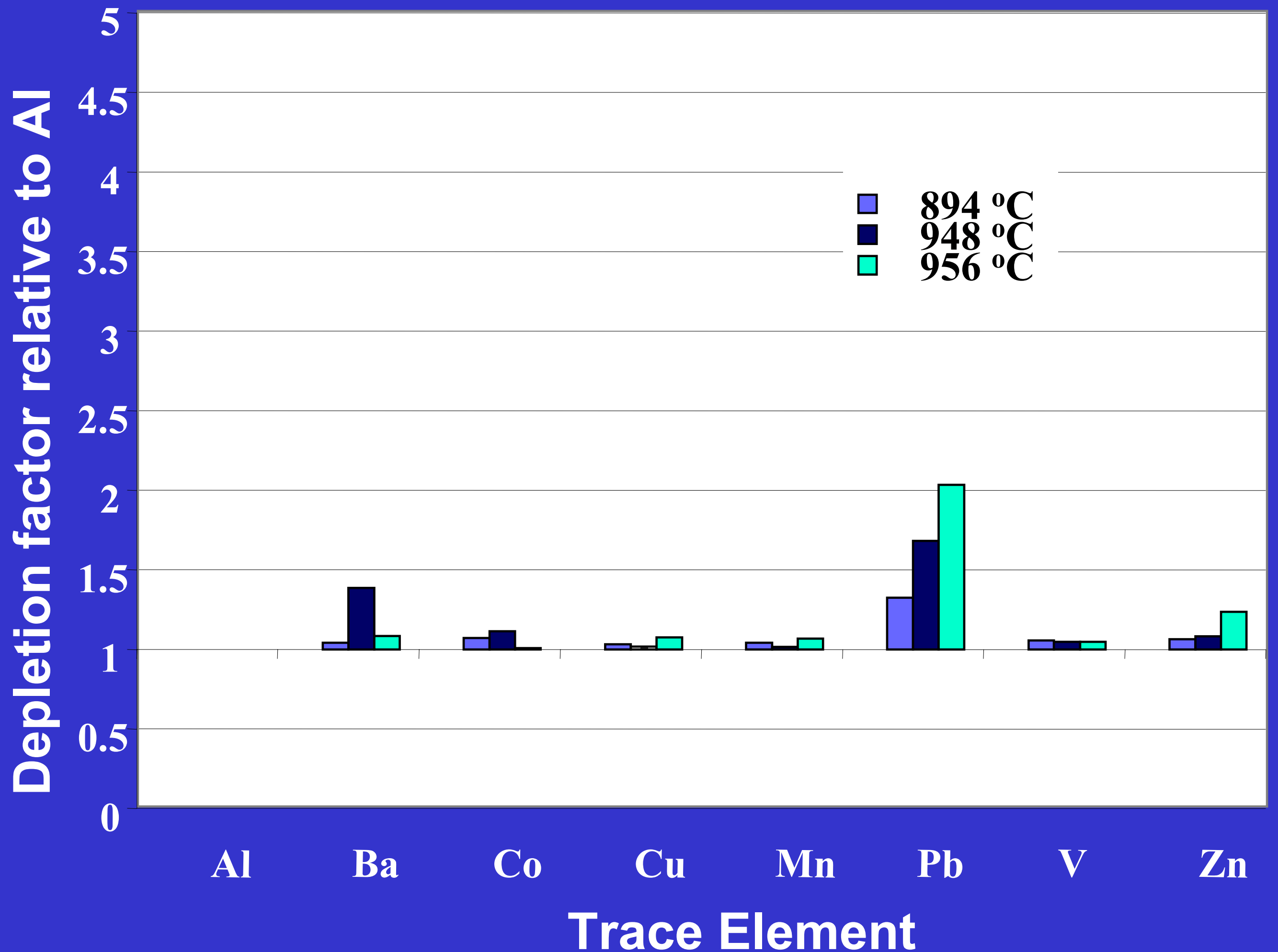
- Elements such as Ba, Cu, Hg, Pb and Zn can be present in S/S at levels which may cause concern for disposal of the ash residues and environmental emissions
- The fate of these elements was investigated and the impact of bed temperature and S/S type determined



- Thermodynamic equilibrium modelling was used to explain observed behaviour

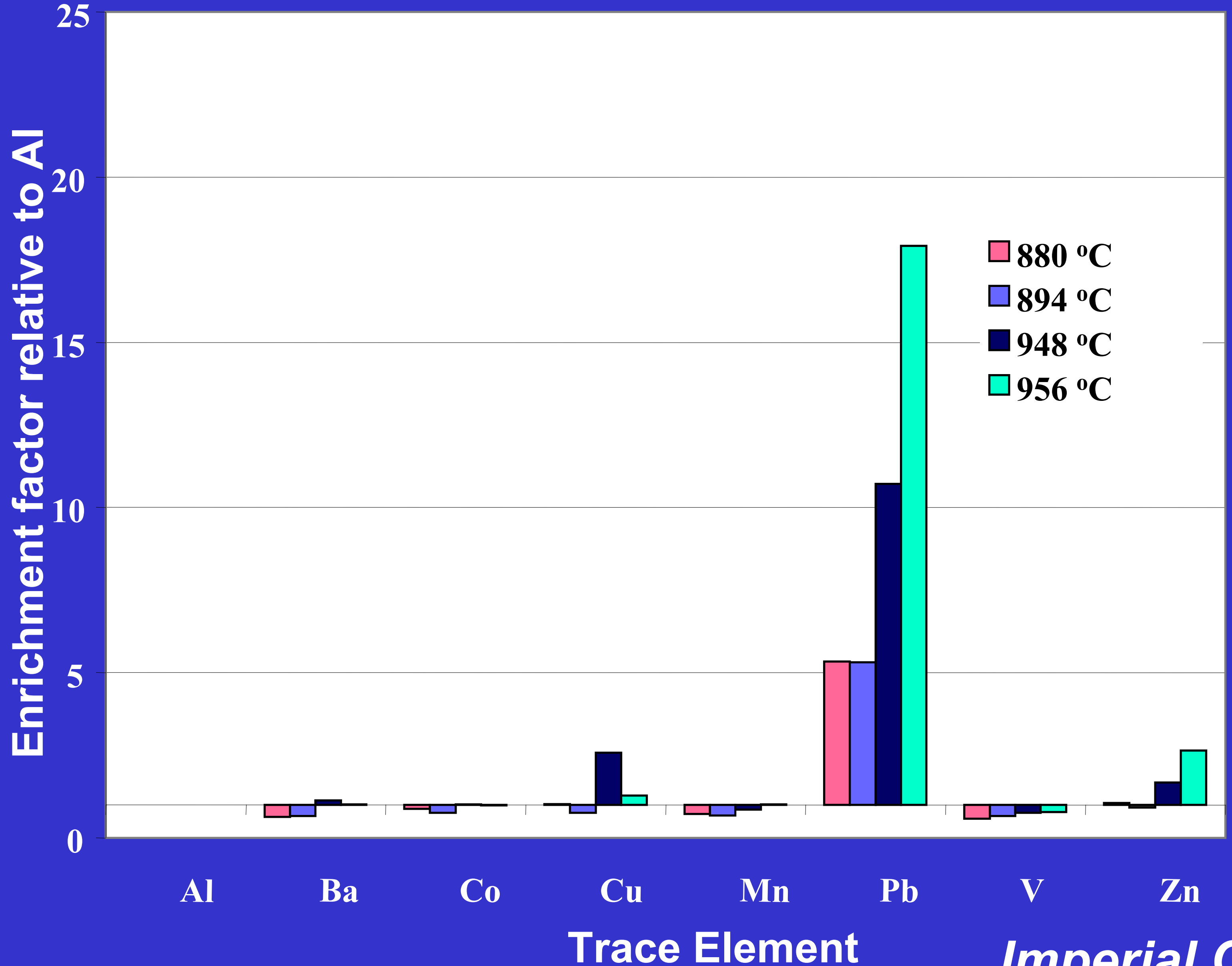
Imperial College

Bed Depletion for Elements of Concern



Note: Level of Hg in ash residues very low

Fly Ash Enrichment for Elements of Concern



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Implications

- At gasifier temperatures of around 900°C:
  - Most of the Hg will be released as gaseous emissions
  - A significant proportion of Pb and rather less Zn (& Ba) will be released….enriched on fly ash
- Wet scrubbing should be effective for removing all these elements from the gas, with the possible exception of Hg.
- An Activated Carbon system for Hg removal may be required.

Environmental Performance: Ash Utilisation

- Characteristics of Ash Residues
  - Variable
  - Relatively high levels of C, S^{2-}, and heavy metals
- Disposal in near term
- General characteristics to identify potential utilisation options
- Further testing essential to ensure compliance with technical and environmental requirements and to identify the economic viability.

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Potential Ash Utilisation Options

Direct Use

Applications where residual C can be used beneficially

- Manufacture of cement products
- Ornamental bricks
- Lightweight aggregate
- Alternative aggregate in asphalt

Pre-Treated Residues

Pre-treatment techniques incur high processing costs

- Mineral filler substitute in asphalt
- Aggregate in concrete products & flowable fill
- Brick manufacture

EMC

Overview I

- Technically feasible options for transporting, dewatering and drying sewage sludge have been identified
- Thermal drying improves sludge quality in terms of CV and pelletising improves handleability
- Sludge characteristics are very variable but generally contain high levels of ash, N and heavy metals
- Fixed and fluidised bed gasification technologies are technically feasible options for producing low quality combustible gas from S/S for small scale applications
- Quality of fuel gas can be improved by co-firing with higher CV waste/biomass fuels

Overview II

- **Sewage sludge derived fuel gas can be used to replace up to 94% diesel fuel in an IC engine**
- **Emissions of NOx and SO_2 were relatively low using conventional gas cleaning technologies, however, there may be a requirement for an additional Hg removal system**
- **Potential ash utilisation options have been identified but in the near term disposal to landfill is the most likely option**