



*Thermal Treatment of Sewage Sludge for CHP
Applications*

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Techno-Economic Evaluation of
Sewage Sludge Gasification

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Thermal Treatment of Sewage Sludge for CHP Applications

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Aim: to assess the commercial viability of CHP plant based on the gasification of sewage sludge sources.

Sewage Sludge Sources

~ European database

Techno-Economic Evaluation

~ simulation of overall plant performance



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Sewage Sludge Sources

A database of sludge characteristics, treatment, quantities, utilisation and costs created.

Information was collected by country and region by each of the partners.

Used to create a decision making database

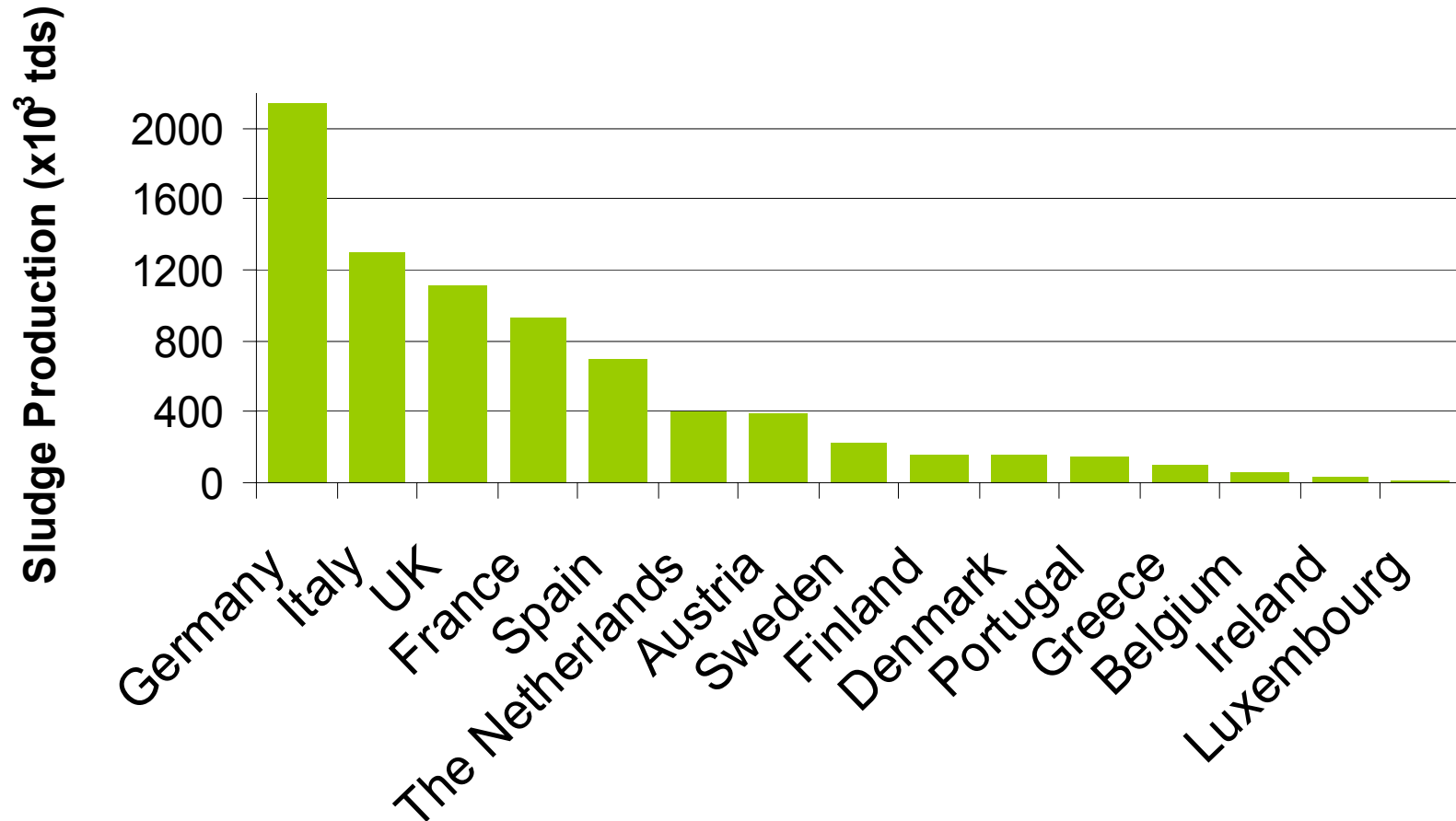


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Sludge Production by Country

(Recent Figures: 1998-2000)

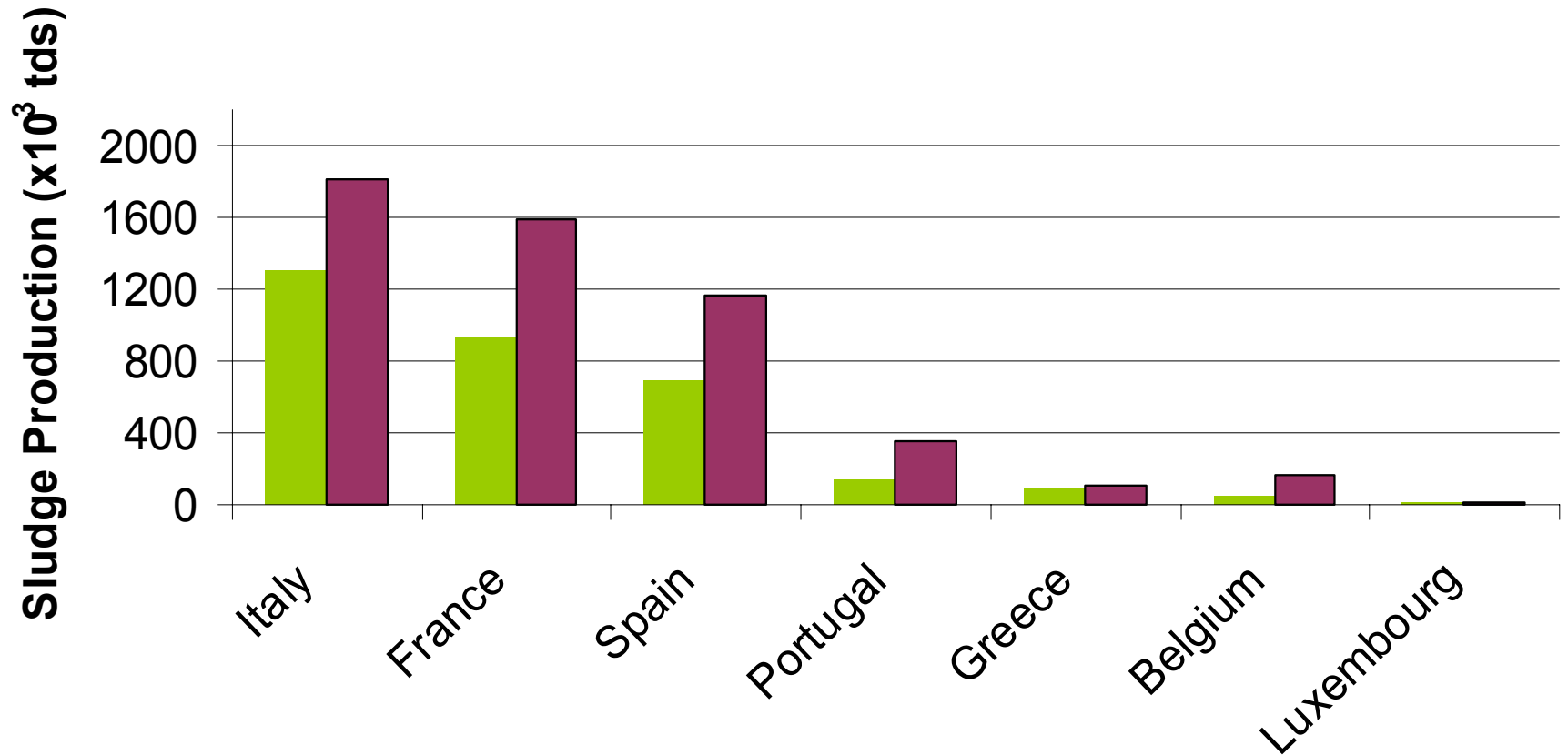




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Estimated Sludge Production by 2010





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Sewage Treatment Works (STW) are classified by size according to Population Equivalent (PE). This is how the information was collected.

However, sludge produced from each size

- Varies by country and region
- Also there is variation within each size

classification: >500,000 PE

500,000 – 200,000 PE

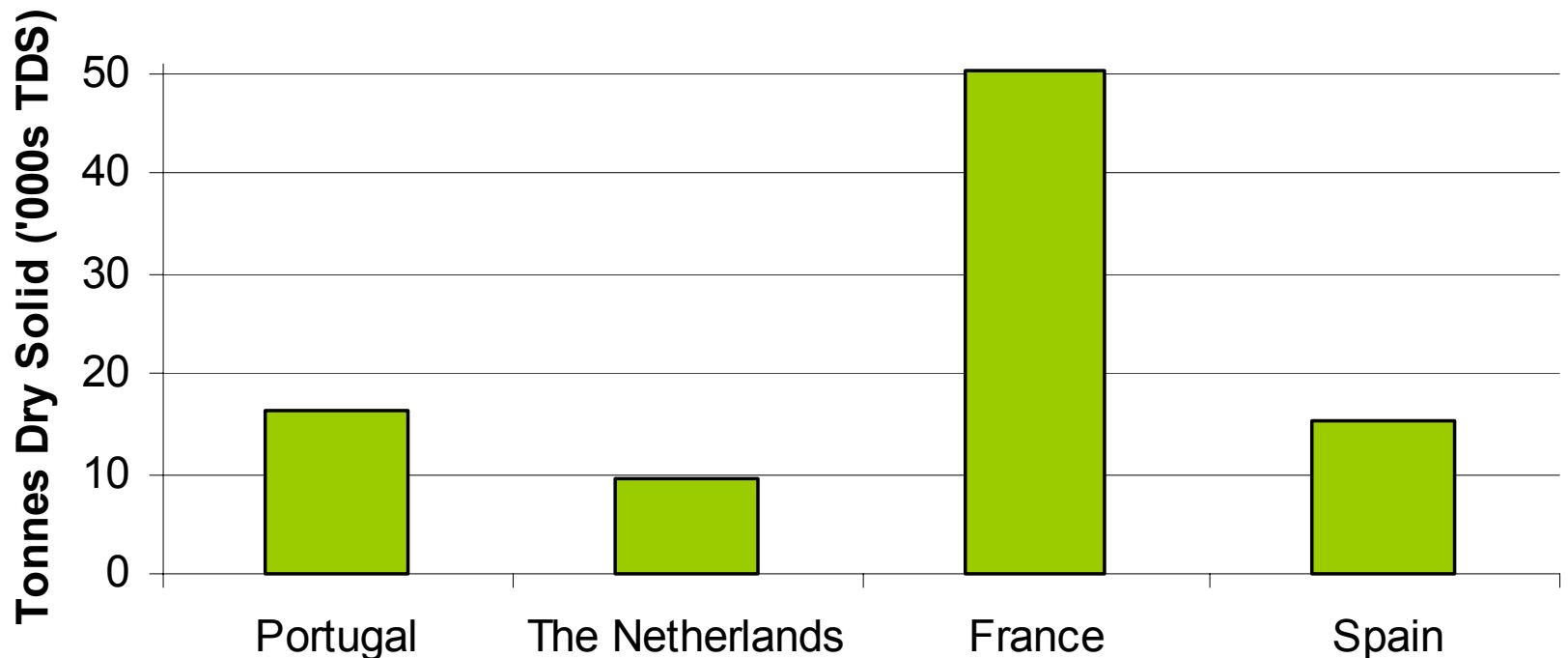


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The largest STW is classified as >500,000 PE. Here are some of the average quantities produced across Europe.

Annual Sludge Production by >500,000 PE STW





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Considering the 500,000 PE STW's within the regions of Germany

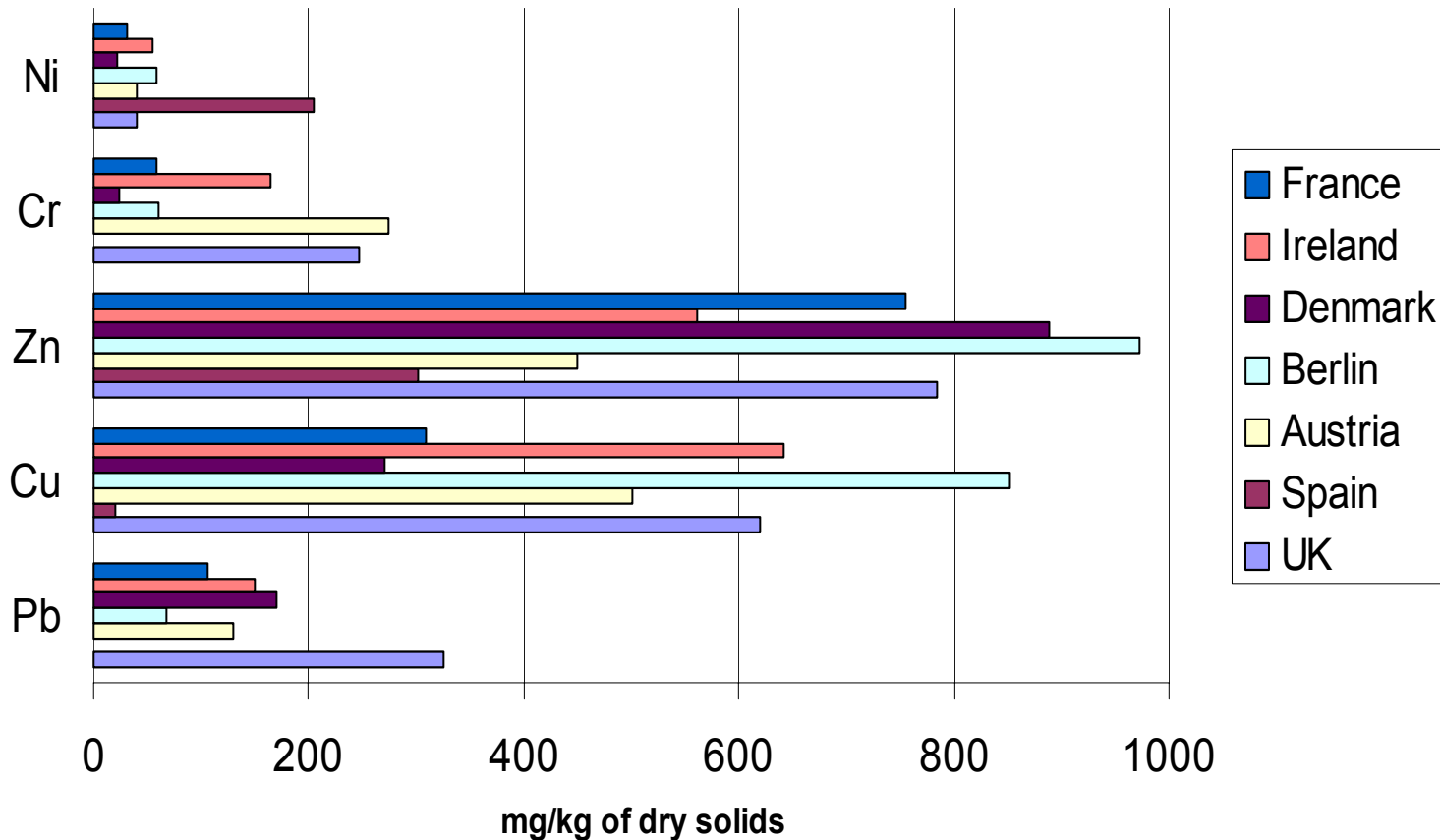
Region	Number	Sludge Produced (TDS)	Approx. Average
Berlin	3	65,400	22,000
Bremen	2	18,500	9,000
Hamburg	1	41,500	42,000
Hesse	1	27,700	28,000
North-Rhine Westphalia	13	1,900,000	146,000



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Sewage Sludge Composition (1)

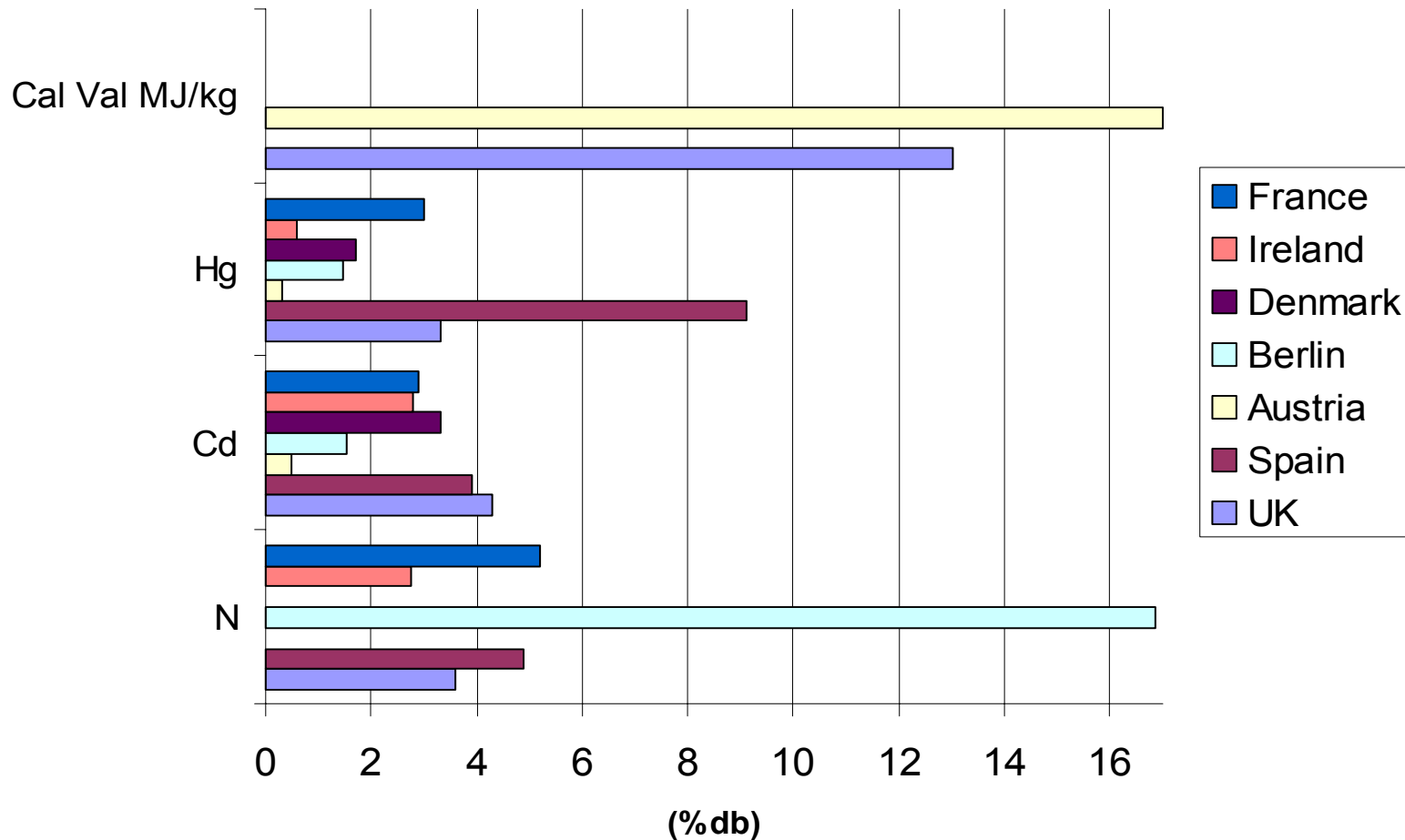




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Sewage Sludge Composition (2)

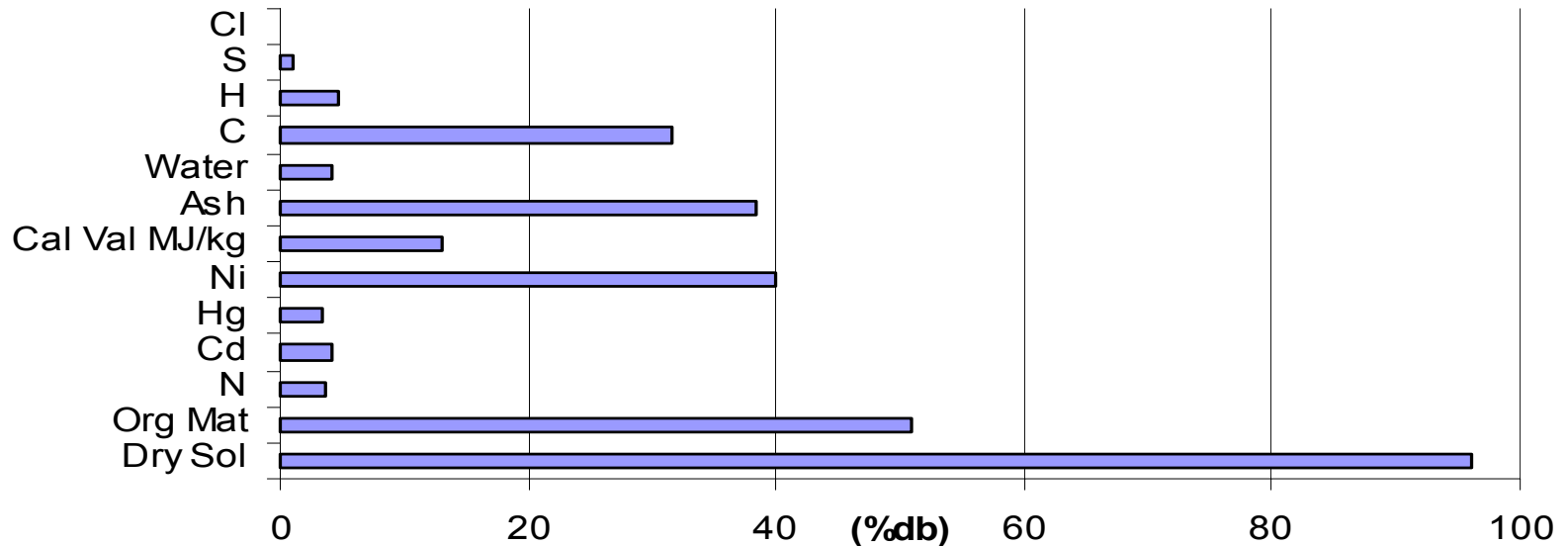
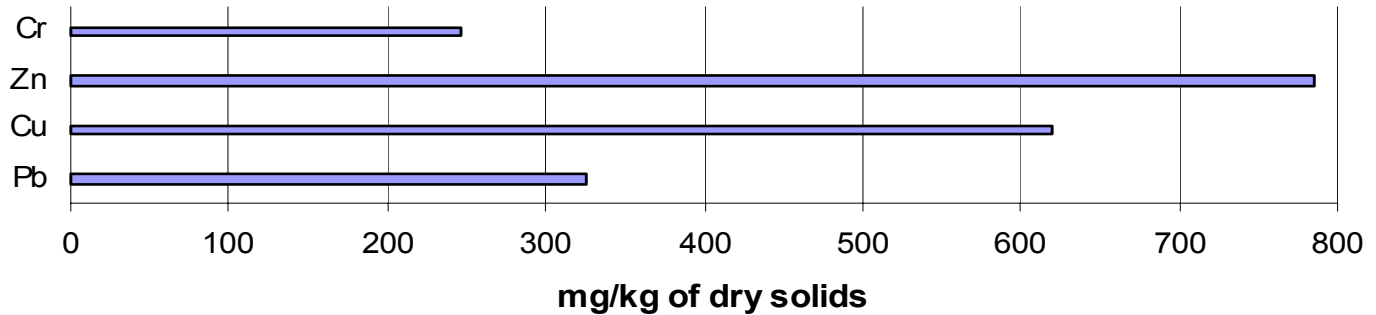




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Sewage Sludge Composition (UK)

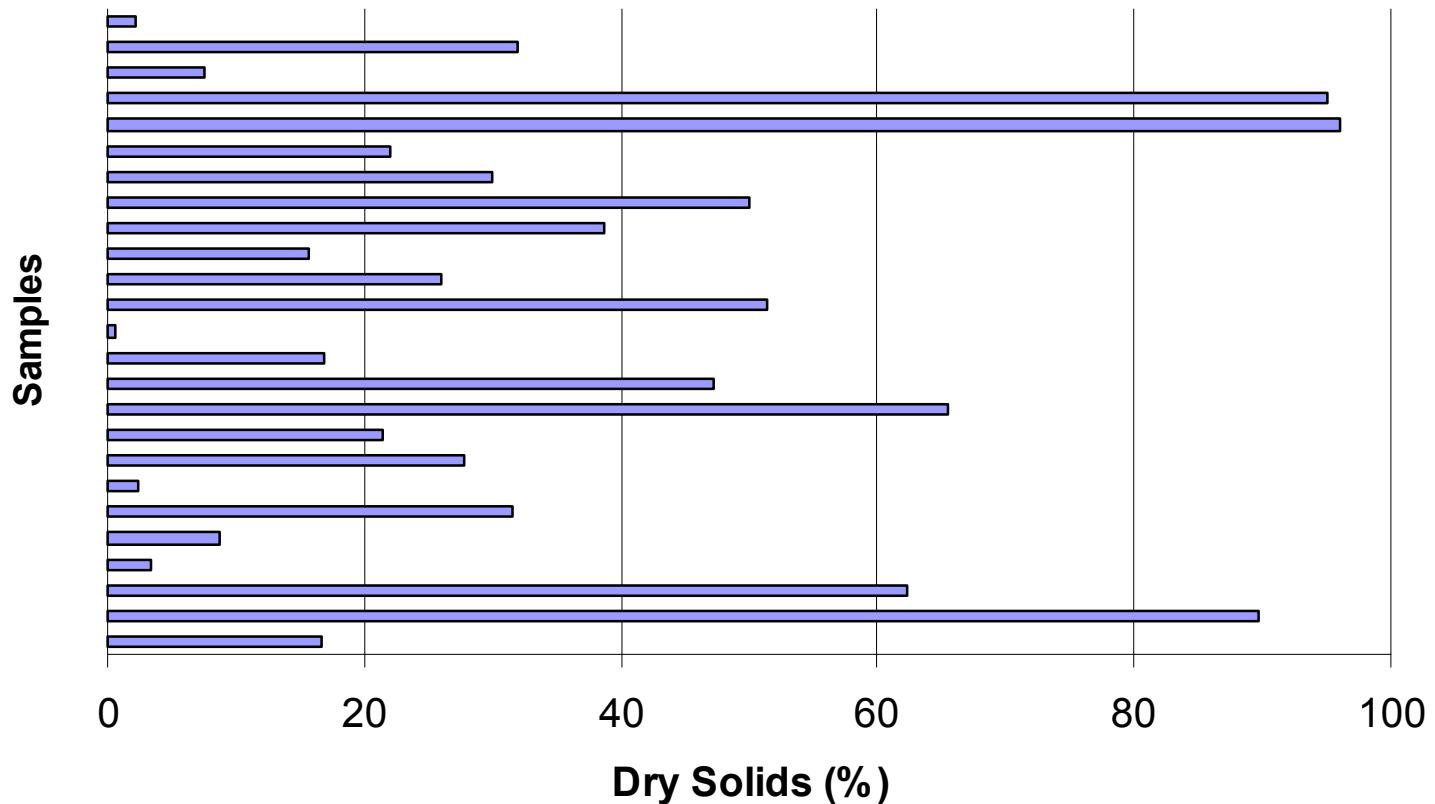




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Sewage Sludge Composition: variability in solids content





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Sewage Sludge Disposal (TDS)	Landfill	Agriculture	Incineration	Other
Spain	18391	460086	46851	5504
Austria	98700	44800	147600	102100
Portugal	90373	44000	0	12627
Luxembourg	5934	1170	1896	0
UK	188853	577668	233289	111090
Denmark	13305	77115	32853	109463
Ireland	14944	3363	0	16177
The Netherlands	68000	110000	200000	23000
Sweden	101047	56294		45937
Italy	1053000	234000	13000	
France	67305	606695	255001	
Finland	14540	23820	0	121150
Greece	90000	6000	0	0



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Techno-Economic Analysis

Aim: to perform a techno-economic assessment of sewage sludge gasification for CHP applications

3 gasification technologies: fixed bed
fluidised bed
spouted bed

CHP unit: engine, generator, heat recovery, control, exhaust

100% sewage sludge, 20% coal, 50% wood



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ECLIPSE process flow simulator

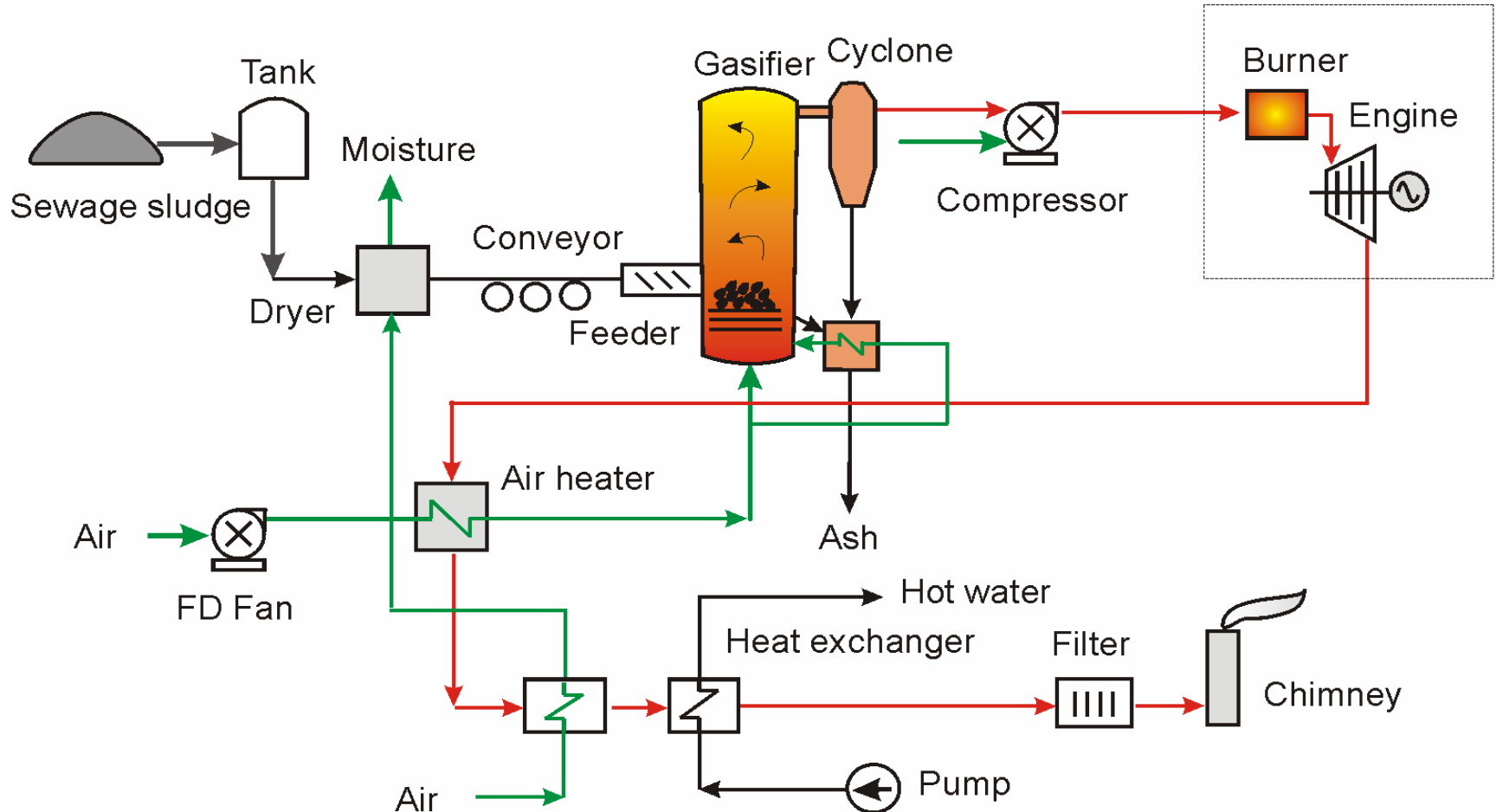
- Process Flow Diagram
- Databases: chemical, cost, utility
- Technical Data
- Mass & Energy Balance
- Economic Evaluation
 - capital costs, fuel costs, electricity selling price
 - sensitivity analyses e.g. scale or conditions



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Fixed Bed Gasifier CHP System

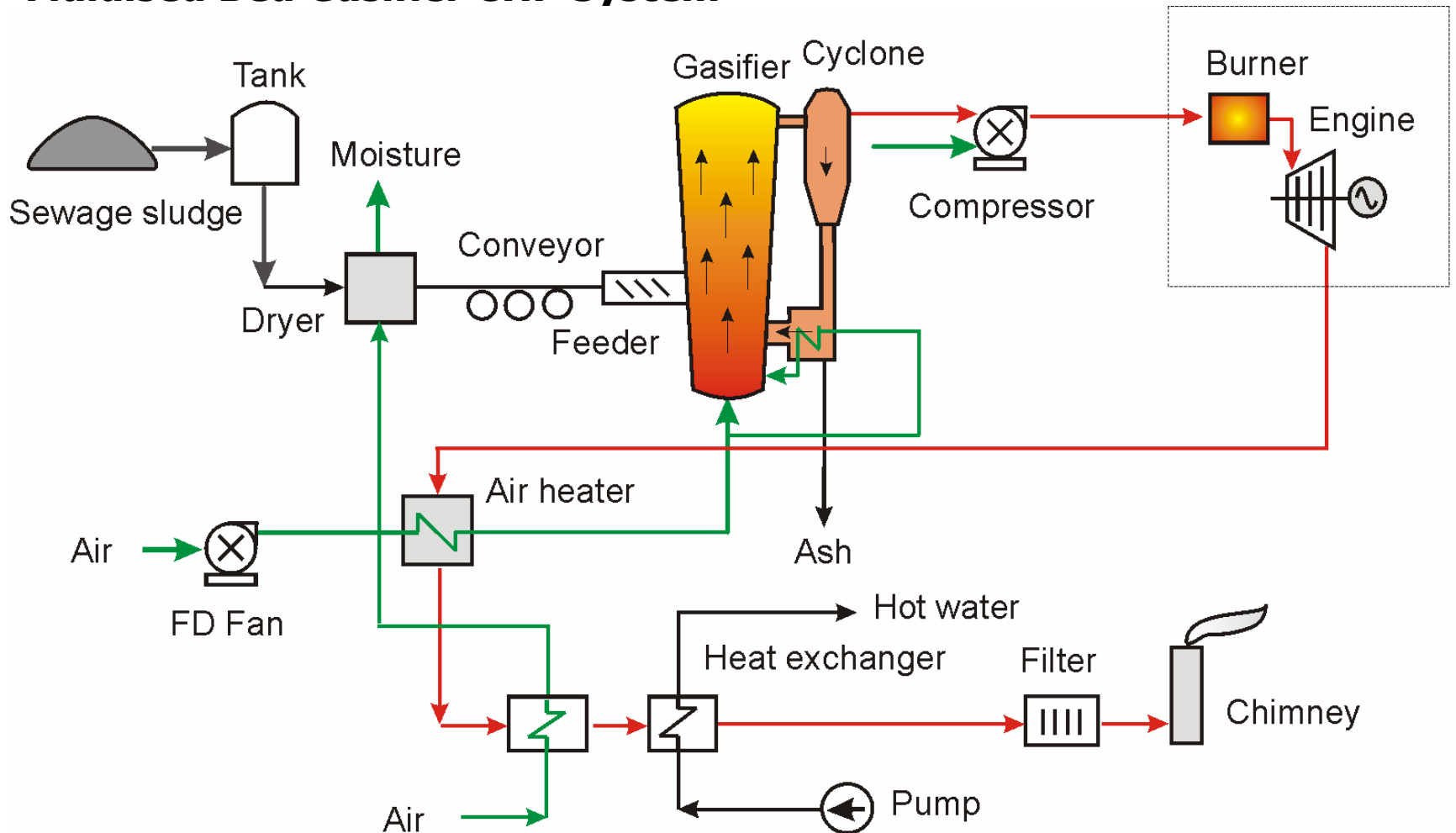




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Fluidised Bed Gasifier CHP System

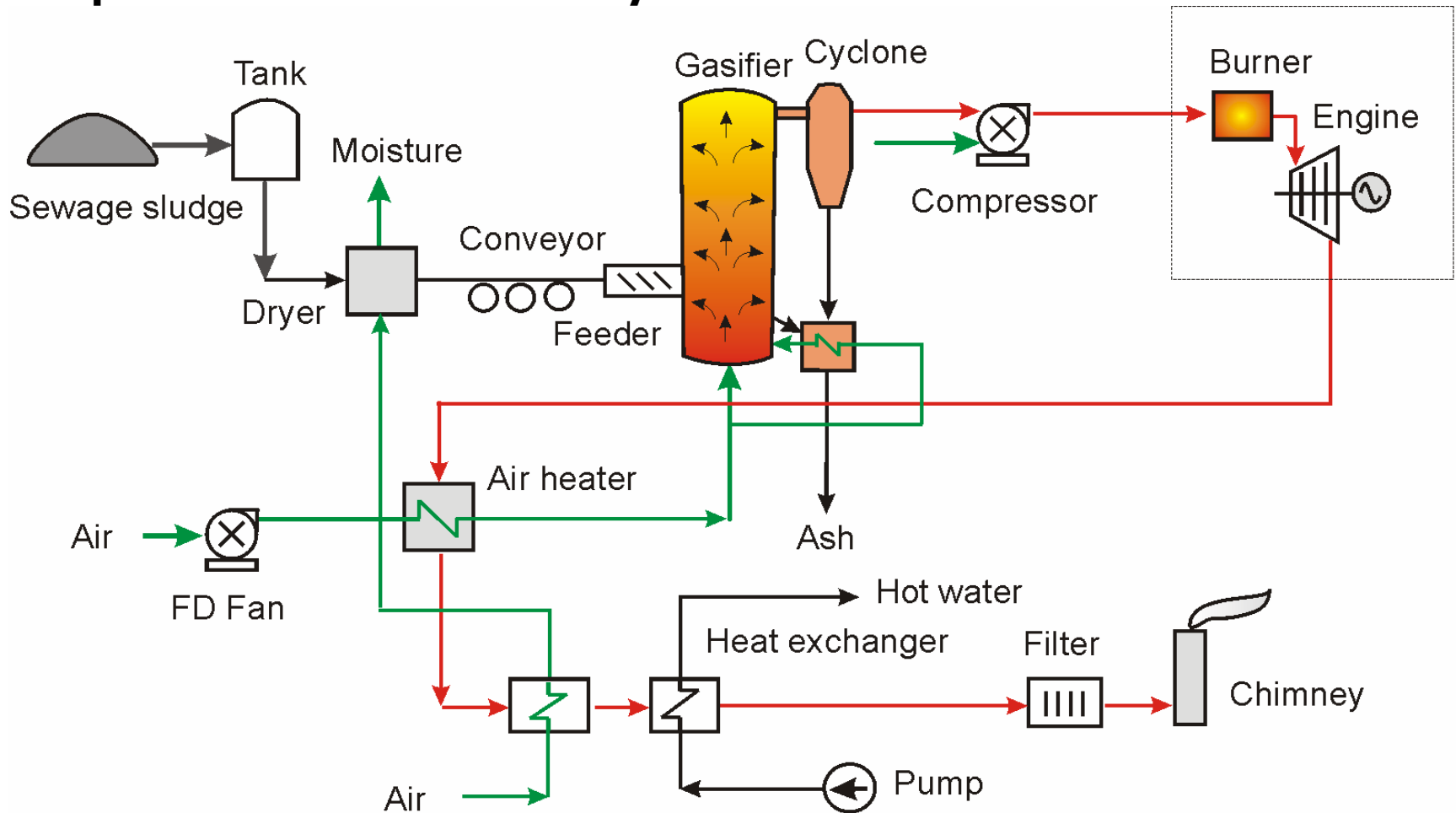




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Spouted Bed Gasifier CHP System





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Feedstock Composition

	Sludge	Coal	Wood
Carbon	54.26	84.00	46.07
Hydrogen	8.67	5.70	6.32
Oxygen	32.43	6.06	47.61
Nitrogen	4.65	1.50	0.01
Sulphur	0.96	2.60	0.00
Chlorine		0.14	
LHV (MJ/kg)	20.42	34.35	18.91
Prox. Anal. (wt %ar)			
Moisture	25	6.30	8.53
Ash	18.78	6.20	1.78



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Technical Performance – 100% sewage sludge

	Spouted Bed	Fluidised Bed	Fixed Bed
Thermal input (kJ/s)	5740	5740	5740
Engine output, (kW)	1050	1130	950
Fan (kW)	42	45	37
Solid separation (kW)	20	20	20
Conveyer (kW)	30	30	30
Total (KW)	92	95	87
Net power output (KWe)	958	1035	863
Thermal output (KWth)	2517	2787	2453
Efficiency (electric), % (LHV)	16.69	18.03	15.04
Efficiency (CHP), % (LHV)	60.53	66.58	57.77
Capital Cost (1000's Euro)	2647	2697	2585



Thermal Treatment of Sewage Sludge for CHP Applications

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Technical Performance – 80% sewage, 20% coal

	Spouted Bed	Fluidised Bed	Fixed Bed
Thermal input (kJ/s)	6464	6464	6464
Engine output, (kW)	1305	1348	1214
Fan (kW)	42	45	37
Solid separation (kW)	20	20	20
Conveyer (kW)	30	30	30
Total (KW)	92	95	87
Net power output (KWe)	1305	1348	1214
Thermal output (KWth)	3013	3150	2947
Efficiency (electric), % (LHV)	20.19	20.85	18.78
Efficiency (CHP), % (LHV)	66.80	69.59	64.37
Capital Cost (1000's Euro)	2858	2914	2792



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Technical Performance – 50% sewage, 50% wood

	Spouted Bed	Fluidised Bed	Fixed Bed
Thermal input (kJ/s)	6026	6026	6026
Engine output, (kW)	1179	1247	1079
Fan (kW)	34	39	34
Solid separation (kW)	20	20	20
Conveyer (kW)	30	30	30
Total (KW)	84	89	84
Net power output (KWe)	1179	1247	1079
Thermal output (KWth)	2532	2744	2550
Efficiency (electric), % (LHV)	19.56	20.69	17.90
Efficiency (CHP), % (LHV)	61.58	66.23	60.22
Capital Cost (1000's Euro)	2726	2778	2663



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Economic Evaluation

- Some factors considered

Sewage: availability, transport, gate fee, ash disposal

Drying: full drying integration, transportation of wet or dry?

Size: >500,000 PE STW

less than 100 in Europe

Sludge produced in each

10,000-50,000 TDS/year

1MWe SSgasf CHP plant

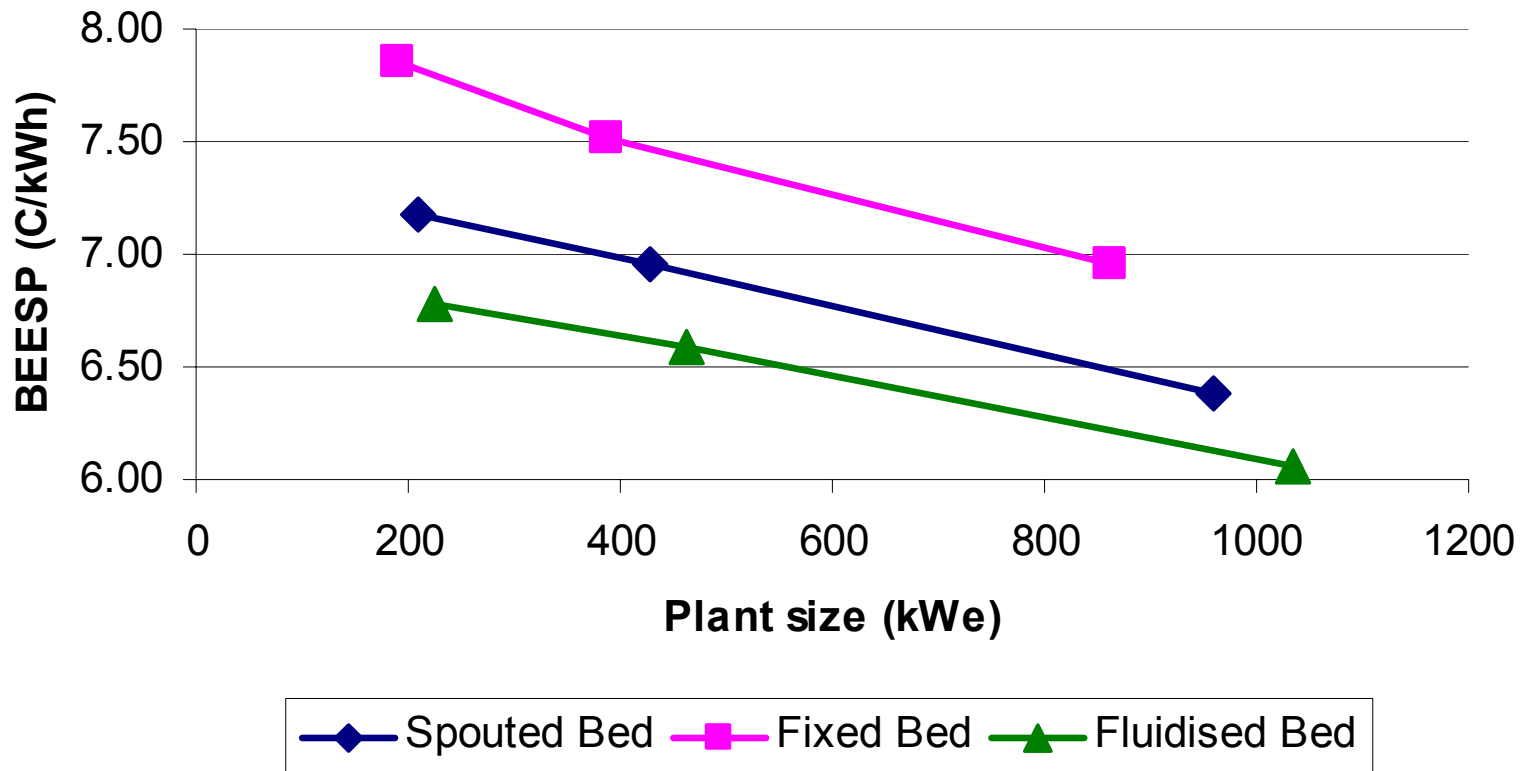
16,000 TDS/year



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Thermal Treatment of Sewage Sludge for CHP Applications

Electricity Selling Price: Plant size – limited cost analysis

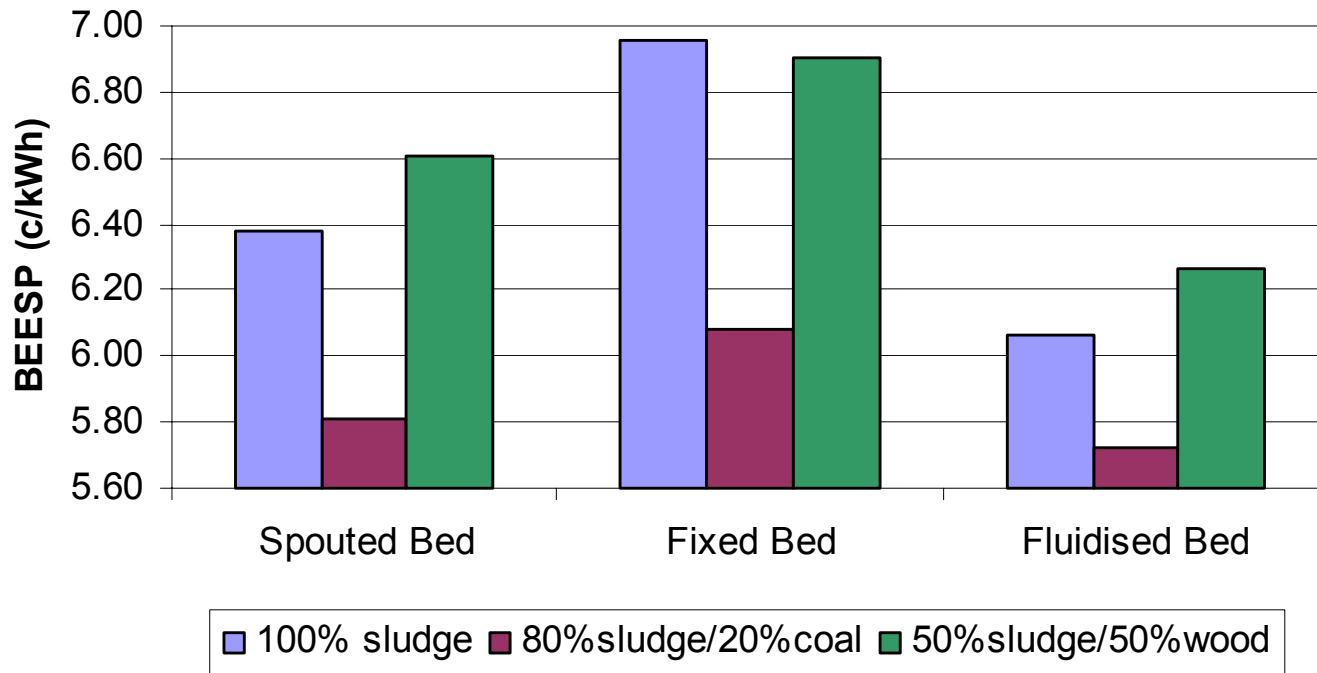




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Electricity Selling Price: Co-utilisation– limited cost analysis





Thermal Treatment of Sewage Sludge for CHP Applications

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Electricity Selling Price: 1MWe Fluidised Bed CHP

STW drying, no transportation		<u>BEESP (c/kWh)</u>
		ash disposal
BEESP	6.06	7.44
Heat "sold" back to STW	3.36	4.74
Integrated drying, no transportation (150E/t)		30+
Required fee/ cost avoidance to reduce BEESP?		
	163 E/t	2.73