sludge
thermal cleaning
solid waste
water

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Increasing WtE Thermal Efficiency: Sharing Energy with Industry

two cases from Sweden and the UK

Dr.ir. Johan DE GREEF

Dr.ir. Kenneth VILLANI

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Waste-to-Energy in 1980s

- stand-alone facilities
- publicaly owned
- processing bulky MSW
  (< 10 MJ/kg)
- ‘simple’ power cycle:
  boiler - turbine - condensor
- plant efficiency < 24%
- main income: ‘gate fee’ + electricity & recovered materials

ISVAG, Antwerp (Belgium)

Keppel Seghers construction:
1980 & 1999

Plant availability 2009: 95%

Technological Developments (EU)

1980

- landfilling dominant
- combustion of bulky household waste
- experiences with corrosion damage
- focus on reducing emissions: dioxines, Cl & S
- efficiency no issue
- local/regional laws

1990

- growing knowledge on corrosion
- focus on optimizing WtE-boiler design
- emissions remain important
- experiences with RDF and sorted waste (LHV ≥ 11 MJ/kg)
- EU waste policy ("Lansink's ladder")

2000

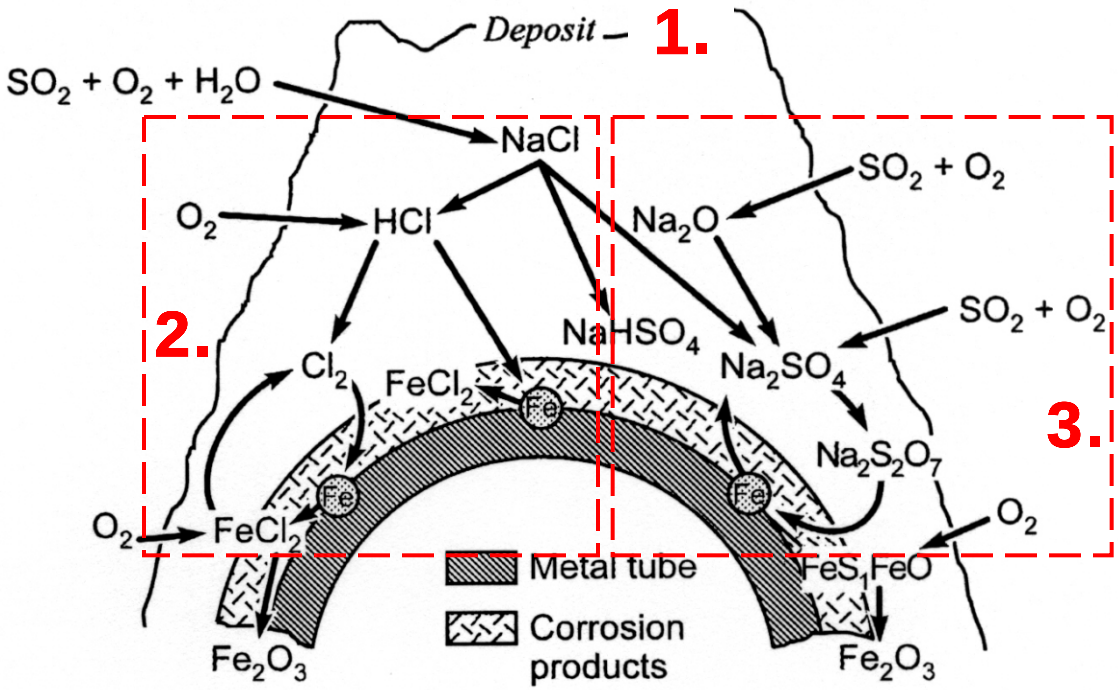
≥ 2010

- corrosion prevention & monitoring
- optimization of combustion (control)
- increasing focus on efficiency & CO_2
- emissions: NOx, PM
- residues
- EU waste policy: WID → WFD

Fuels: Chemical Composition

mass % (dry)	**coal**		**biomass**		**waste**	
	black	**lignite**	**avg**	**straws**	**MSW**	**RDF**
C	70	60 - 75		45	35 - 45	35 - 55
H	4 - 6	6		6	4 - 6	4 - 6
O	3 - 10	15 - 40			25 - 30	20 - 25
N	~ 1.5	0.5 - 1.5		~ 0.5	1.0 - 1.5	0.2 – 1.0
S	~ 1 (0.1 - 2.5)	0.5 - 3	<0.1	0.1 - 0.3	~ 0.2	~ 0.5
Cl	~ 0.1 (0.01 - 0.8)	<0.1	0.01 – 0.2	0.3 - 0.6	0.5 - 1.0	1.5 - 2.5
Na	0.02	<0.5	0.02 - 0.05	0.02	~ 0.5	~ 0.5
K	0.06	<0.15	<0.5	1.0 - 1.5	~ 0.2	~ 0.2
LHV *(MJ/kg)*	***40 – 45***		***10 – 20***	***~18***	***5 – 11***	***11 – 16***

Limiting Corrosion (high Temp)



1. Fouling
2. Cl_2: diffusive reaction
3. SO_2: amplification

- corrosion limit → boiler efficiency limit
- steam *standard* 400°C @ 40 bar = econ. optimum
- higher steam parameters = maintenance cost increase

Limiting LHV

- LHV: Coal > Biomass > Waste (MSW)
- Origin of cost difference (per MW_{EL} installed)

LHV_{coal} / LHV_{waste}	≅ 40/10
plant efficiency correction	x (25% / 40%)
WtE-boiler protection materials	+ 10%
boiler investment WtE / coal	**≅ 3**

- Production of RDF/SRF → LHV_{MSW} x 2 (roughly)
  - mechanical & thermal treatment → <u>energy consuming</u> → $CO_{2,EQ}$ ⇑
  - composting & anaerobic digestion → <u>quality issues</u> residues
- RDF → Cl ⇑ → corrosion risk ⇑ → maintenance cost ⇑

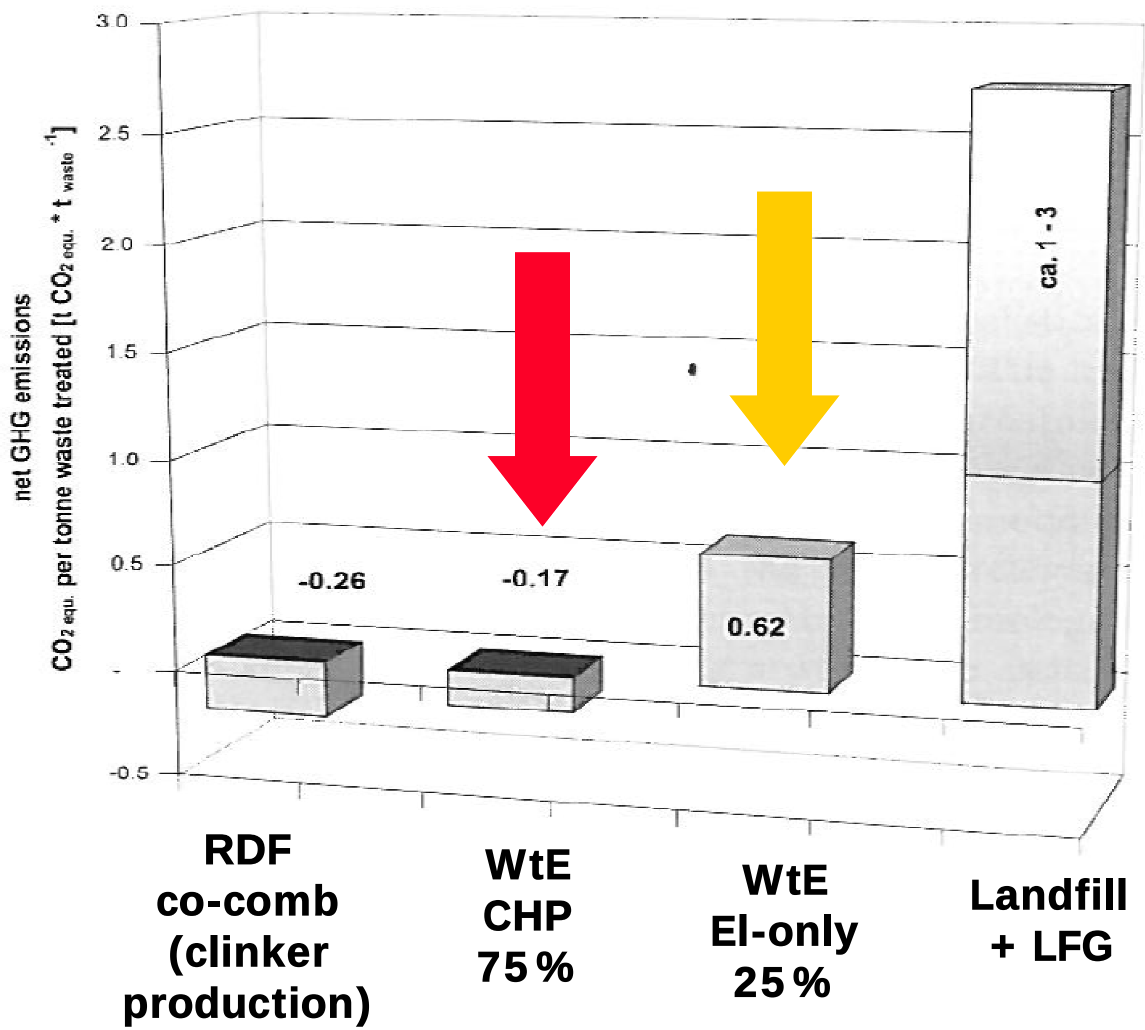
Climate Impact

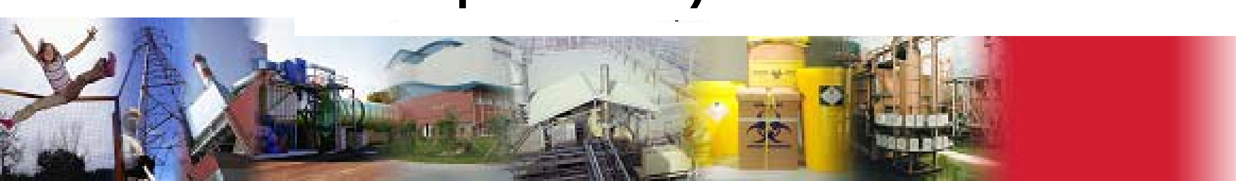
Consonni *et al.* (2008)
Bahor *et al.* (2009)

- RDF-production sensible as part of *integrated waste management* approach
  - regional/national level → coherent policy required
  - match energetic debits & credits of waste processing sites
- Waste-to-Energy = reducing carbon footprint
  - sole major energy contributor in waste treatment ‘chain’
  - plant energetic efficiency = key control parameter
  - combined heat & power → net reduction of $CO_{2,EQ}$!

Climate Impact

Case Study Austria
Ragoßnig et al. (2009)





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Two CHP examples

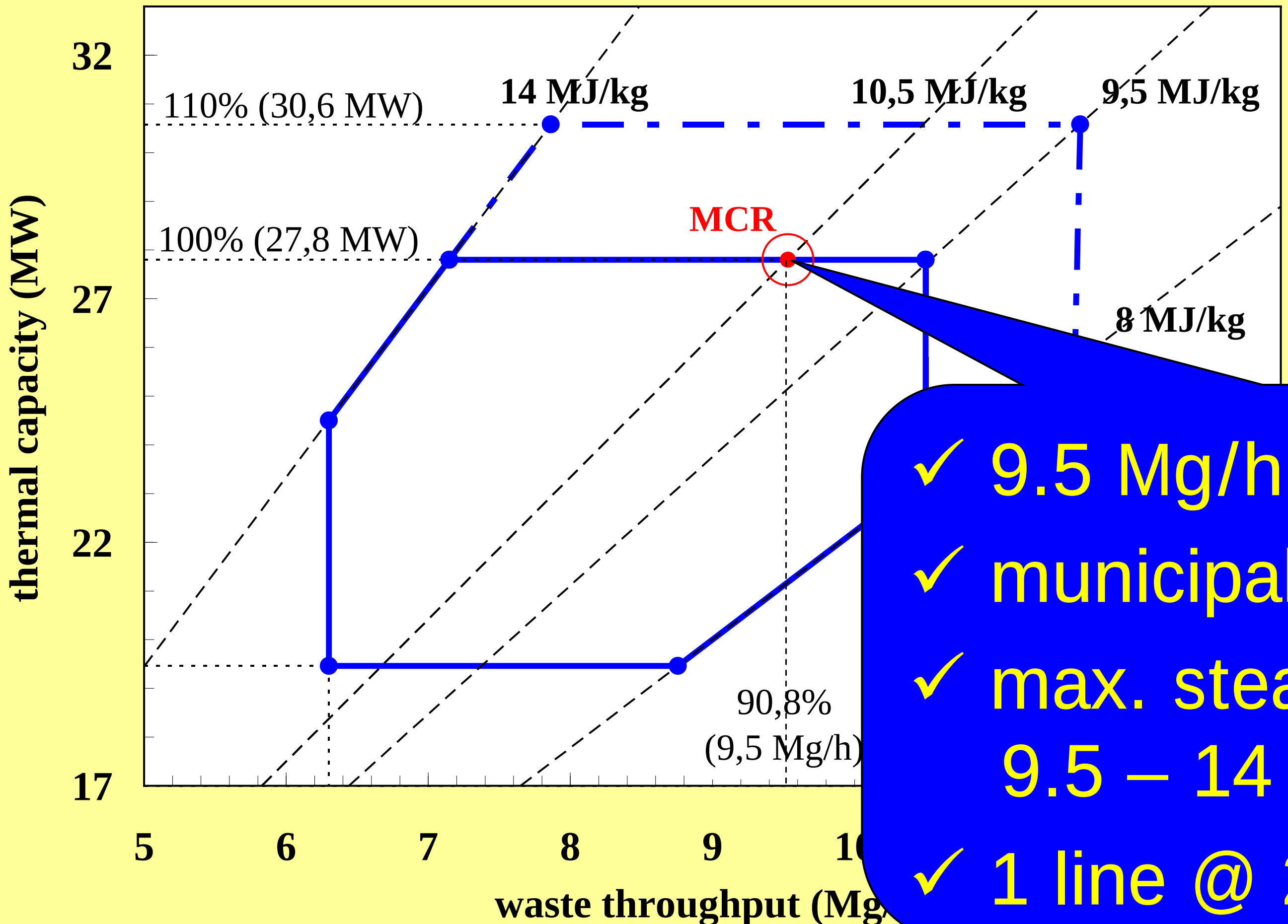
Greater Manchester Waste **(Runcorn, UK)**

Nordic Paper **(Åmotfors, Sweden)**

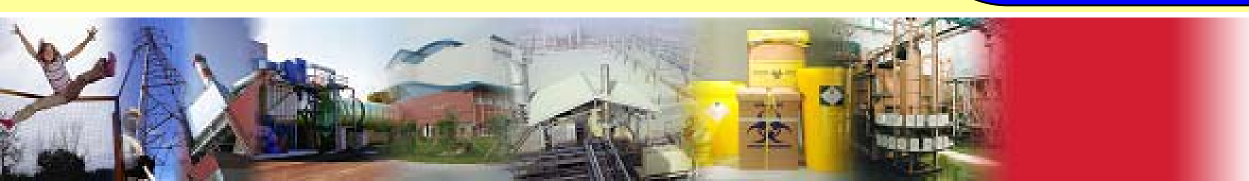
Case 1: Åmotfors (Sweden)

Commissioned: 2010

Combustion Design

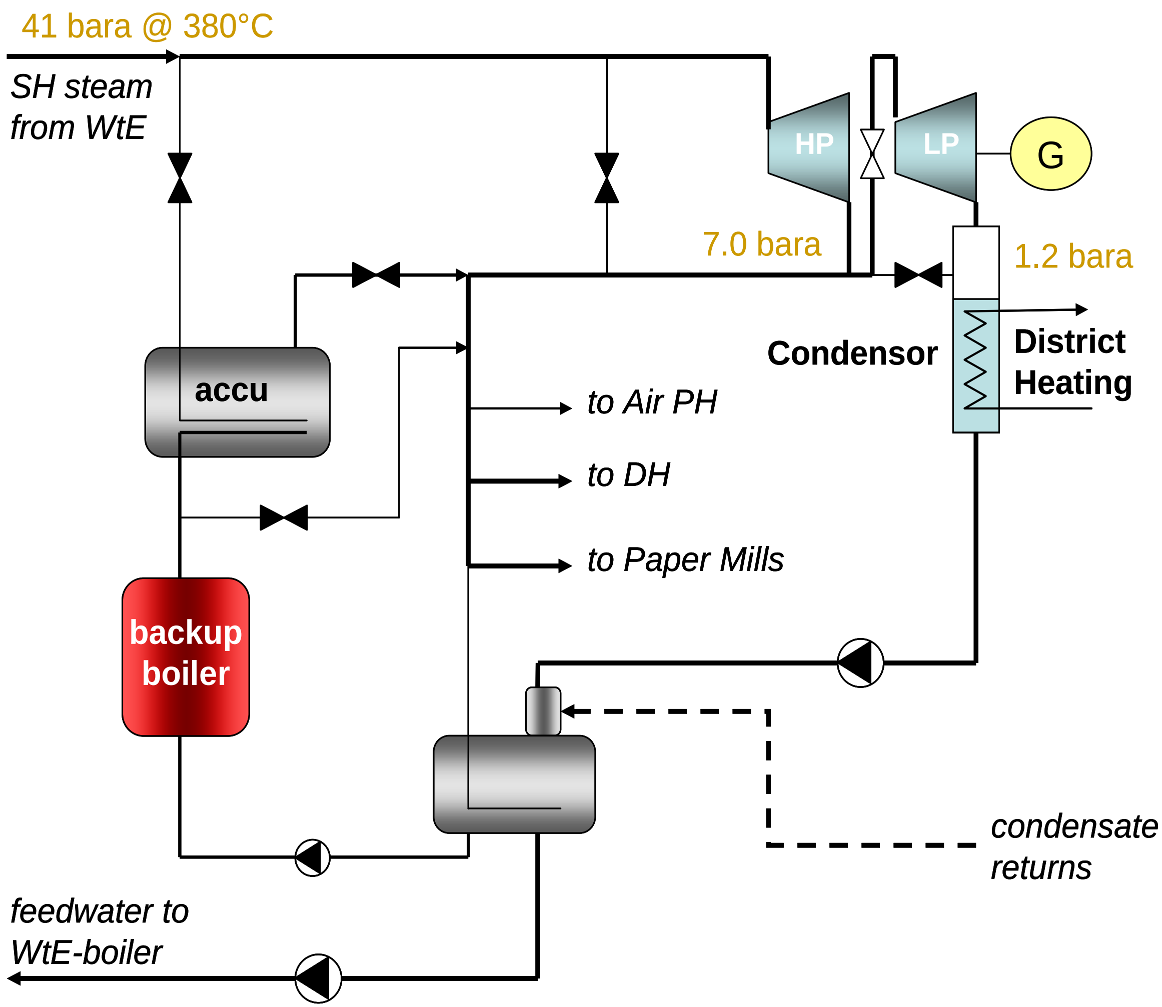


- ✓ 9.5 Mg/h @ 10.5 MJ/kg
- ✓ municipal waste mix
- ✓ max. steaming range: 9.5 – 14 MJ/kg
- ✓ 1 line @ 27.8 MW_{th}



Steam Cycle Design

η = 64%
R1 = 0.85



- 7 bar steam to PM
  - *fluctuating* demand
  - down to 50%
- winter mode
  - 7 bar steam to DH
  - turbine LP stage out
  - electricity: internal load
- summer mode
  - condensor heat to DH
  - turbine full operation
- flexible steam buffer
  - 1st: accu
  - 2nd: backup (gas)

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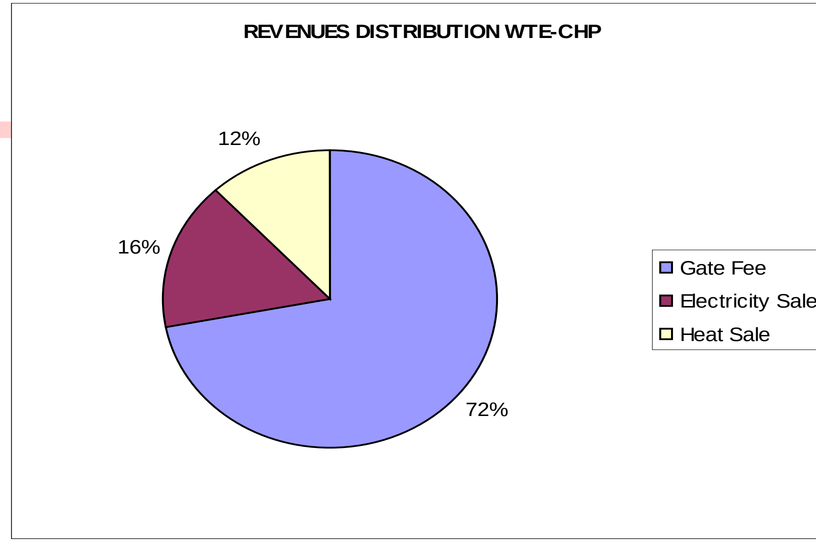
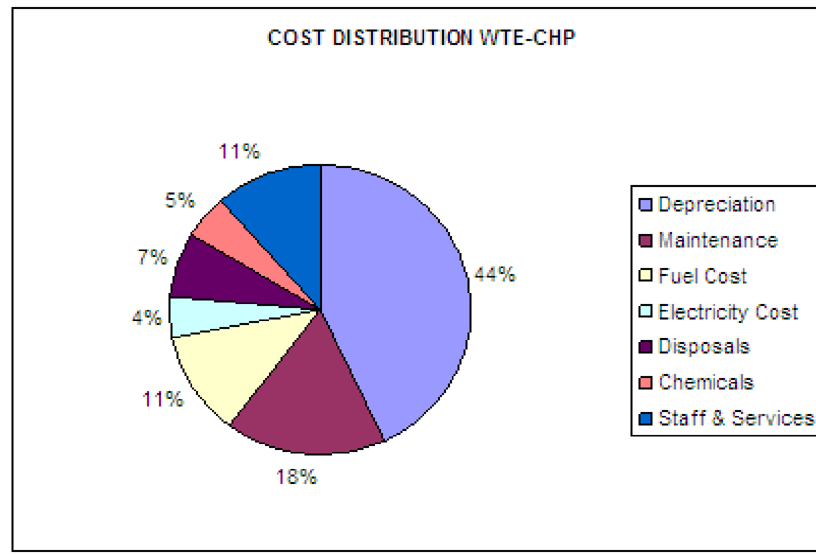
Financials

'000 EUR/year	Past	Future
Revenu	/	**5.200**
Cost (& Depreciation)	**- 6.100**	**-7.000**
NET RESULT	**- 6.100**	**- 1.800**



- Yearly steam generation cost reduced to 30% of original (incl. depreciation of investment)
- Independency from oil prices



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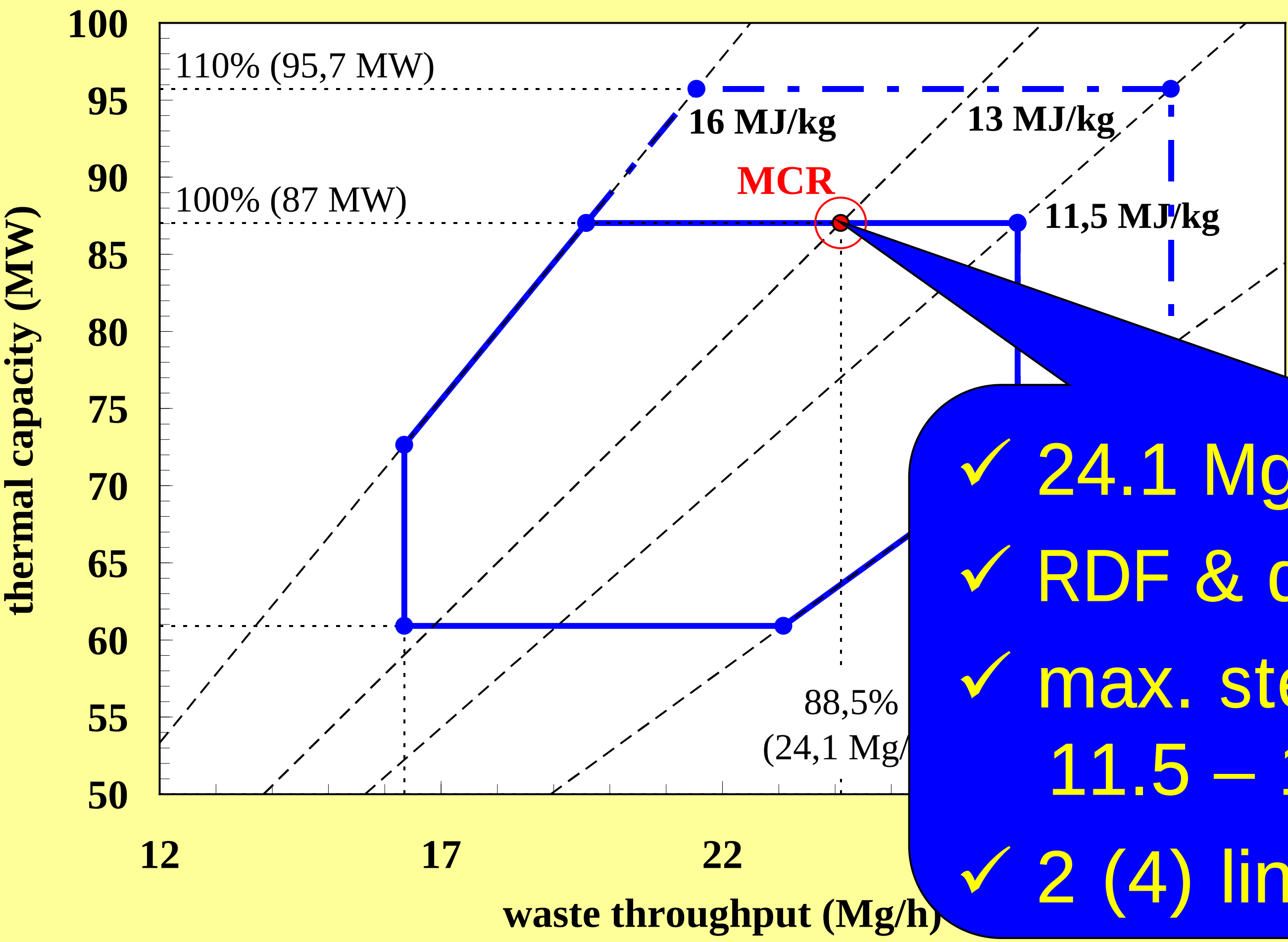
Case 2: Greater Manchester (UK)

commissioning expected: end 2012

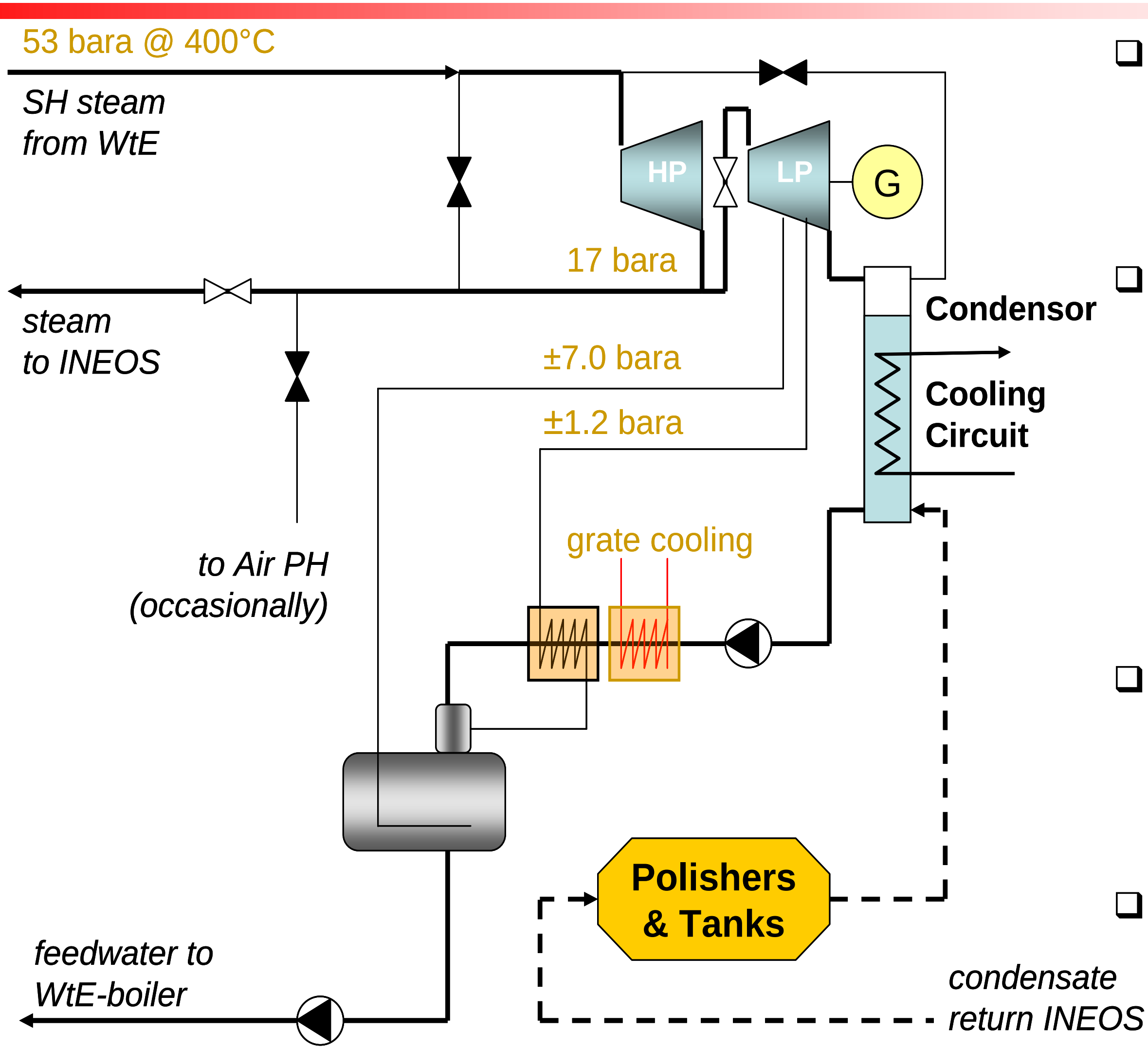
Combustion Design



- ✓ 24.1 Mg/h @ 13 MJ/kg
- ✓ RDF & digestate mix
- ✓ max. steaming range: 11.5 – 16 MJ/kg
- ✓ 2 (4) lines @ 87 MW_{th}

Steam Cycle Design

η = 48%
R1 = 0.86



- 17 bar steam to INEOS
  - large flow: 70-140 ton/h
  - *continuous* demand
- turbine / condensor
  - 2-stage: HP & LP
  - small LP → more efficient
  - limited steam extraction
  - water-condensing → higher electricity prod.
- auxiliary steam saving
  - grate heat in FW PH
  - air PH with 17 bar-steam
- feedwater (return)
  - high salt content
  - storage tanks: autonomy!

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Waste-CHP design principles

- Understanding the client's process
  - average demands/returns
  - variations through time → importance of historical data
- Defining the nominal operation point for the WtE
  - reliable data of waste source, composition & LHV!
  - anticipate to LHV changes
- Boiler design: primarily a financial issue
  - elevated steam parameters technically well possible
  - but ... which budget affordable for maintenance ?
  - reduced boiler outlet temp = 'easy' efficiency gain

Waste-CHP design principles

- Turbine & condensor
  - cope with <u>all</u> load & bypass conditions
  - avoid partial load during majority of time
  - limit number & flows of steam extractions
  - water condensor → limit % moisture @ turbine outlet
- Flue Gas Cleaning system
  - at reduced temperature
  - simple = robust & reliable
- Auxiliary equipment
  - maximise internal heat recovery (grate cooling)
  - buffers between combustion process and extern

Conclusions

- Increasing WtE-boiler steam parameters
  - rather limited gain in efficiency (<10%)
  - maintenance intensive & costly
  - dependent on development of protection materials

- Waste-fired CHP plants (where possible)
  - make large efficiency *jump* possible (>50%)
  - ecologically <u>essential</u> in advanced waste management
  - a matter of *intelligent engineering*

Conclusions

- CHP-plant optimization possible by exploiting
  - advantage of *scale* (~ conventional power plants)
  - advantage of *flexibility*

- Waste-fired CHPs = financially interesting
  - reduction of industrial energy production cost
  - independency of insecure oil market
  - opportunity for private investors

Selected Literature

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