Imperial College London

The suitability of different types of industry for inter-site heat integration

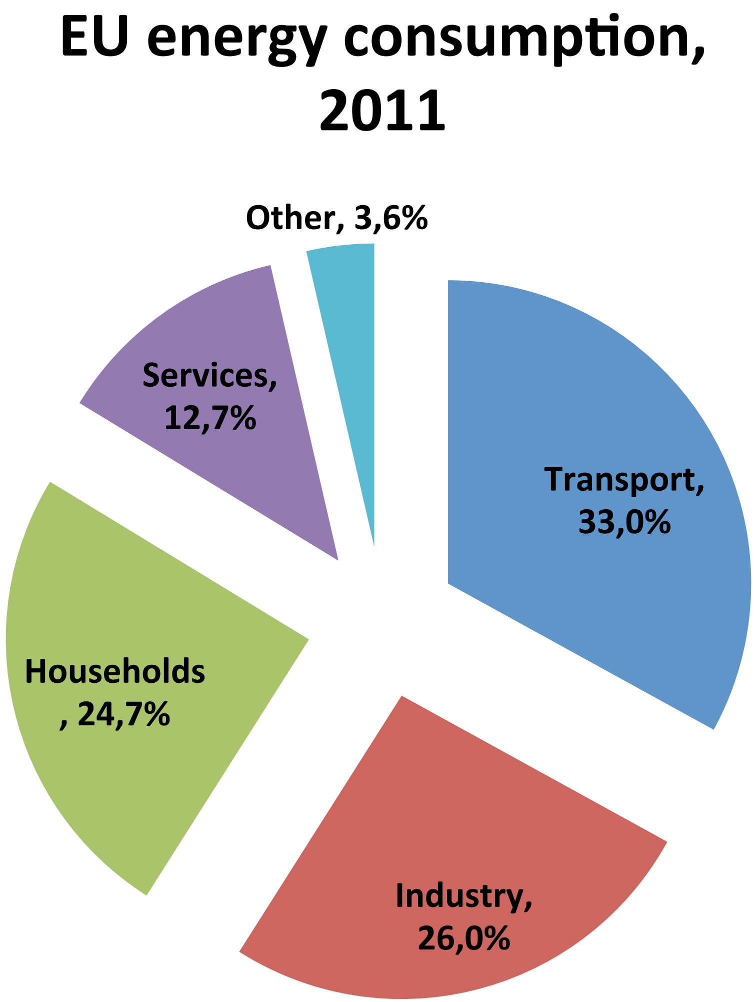
Thomas Hills, Ajay Gambhir, Paul S. Fennell

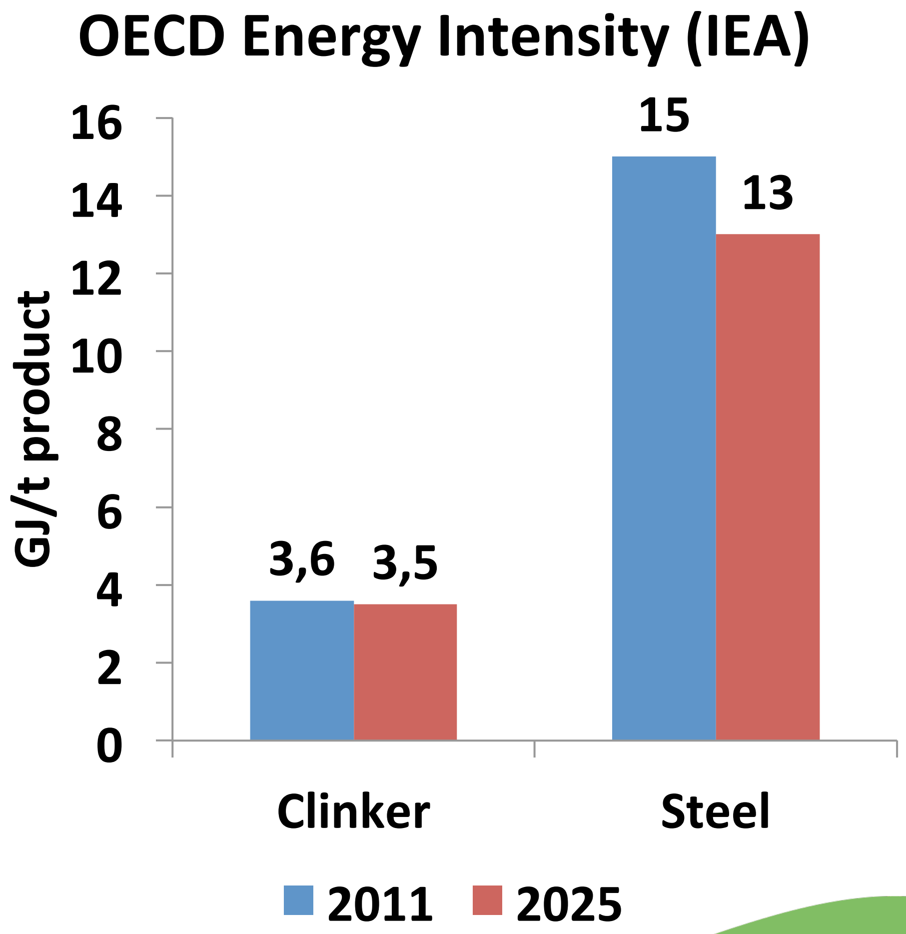
thomas.hills07@imperial.ac.uk

Grantham Institute for Climate Change

Imperial College London

Industry uses 26% of EU energy



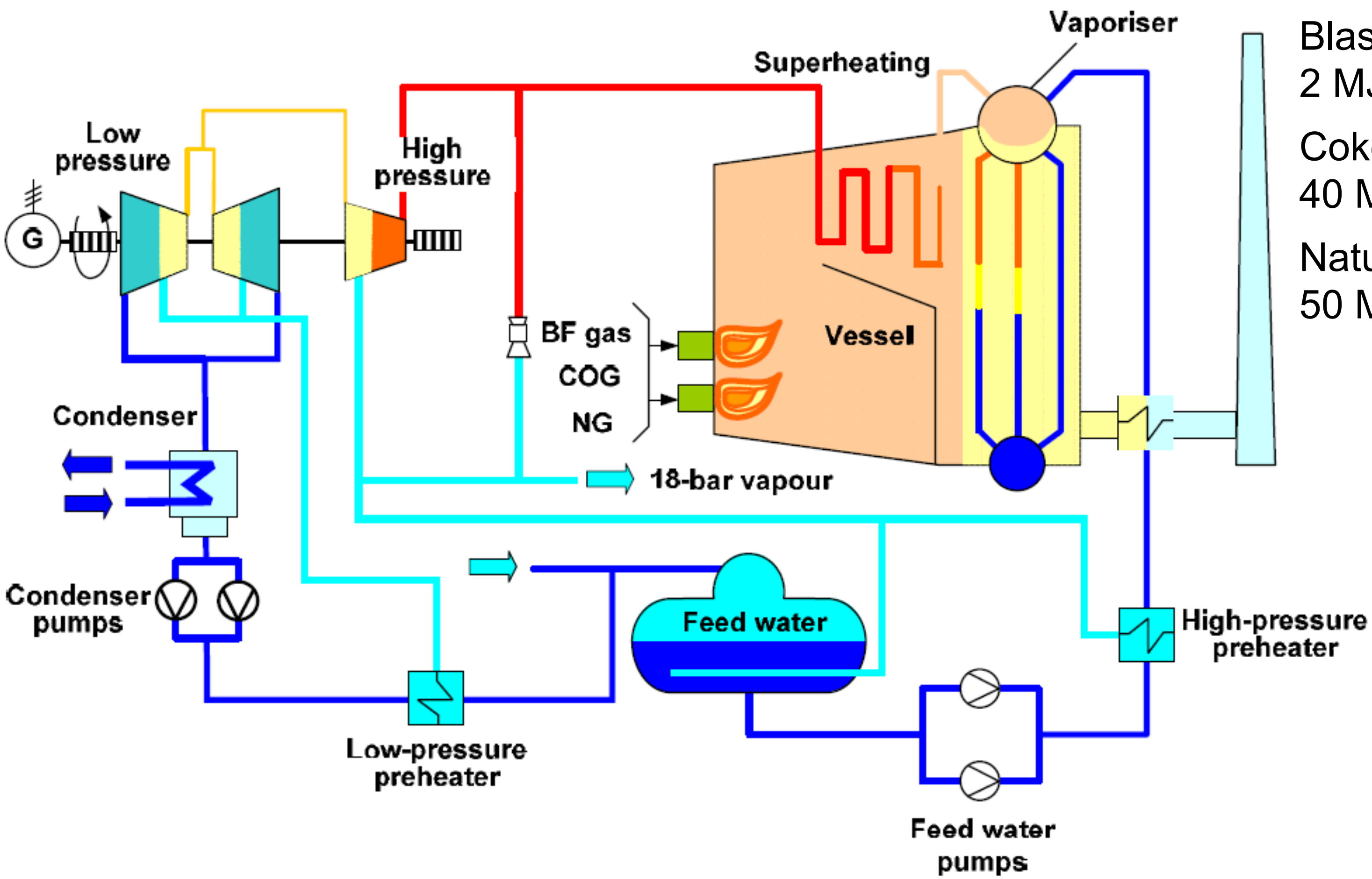


http://ec.europa.eu/energy/publications/doc/2013_pocketbook.pdf

Grantham Institute for Climate Change

Imperial College London

Where is exergy wasted?



Blast Furnace Gas (BFG): 2 MJ/kg

Coke Oven Gas (COG): 40 MJ/kg

Natural Gas: 50 MJ/kg

"The energy efficiency of such a combination is about 15 – 20 % lower compared with a commercial power station."
(EC BAT Reference Document on Iron & Steel, 2013)

Grantham Institute for Climate Change

Imperial College London

Method

1. Design and measure the four plants

- Energy and exergy analysis

2. Develop a heat exchanger network (Total Site Analysis)

- Pinch analysis
- Energy and exergy analysis

3. Design a comparative 'solution'

- Heat-to-power and CHP

4. Compare the two scenarios

- Payback period
- Investment costs
- Energy savings

Grantham Institute for Climate Change

Imperial College London

Choice of plants

- Many studies have looked at plants which are easier to integrate
  - Kalundborg (based around a refinery and power station)
  - Matsuda et al 09 – 30% saving in a site containing power plants, refineries, (petro)chemical plants…
  - Kim et al 10 – “180 chemical or petrochemical plants”
  - Hackl et al 11 – 120 MW potential savings at a “chemical cluster”
- What about the more difficult processes?

Grantham Institute for Climate Change

Imperial College London

1. Design and measure the four plants

Cement plant

3 Mtpa (105 kg/s)

364 MW inputs

Heat lost in flue gas

Coal → Flue gas

Steel plant

3.8 Mt/y (121 kg/s)

2.7 GW

Lots of fuel gases

Coal → Fuel gases

Fertiliser plant

500 ktpa (17.4 kg/s)

365 MW inputs

Already well-integrated

Natural Gas → H_2SO_4

Recycled paper plant

400 ktpa (12.7 kg/s)

327 MW inputs

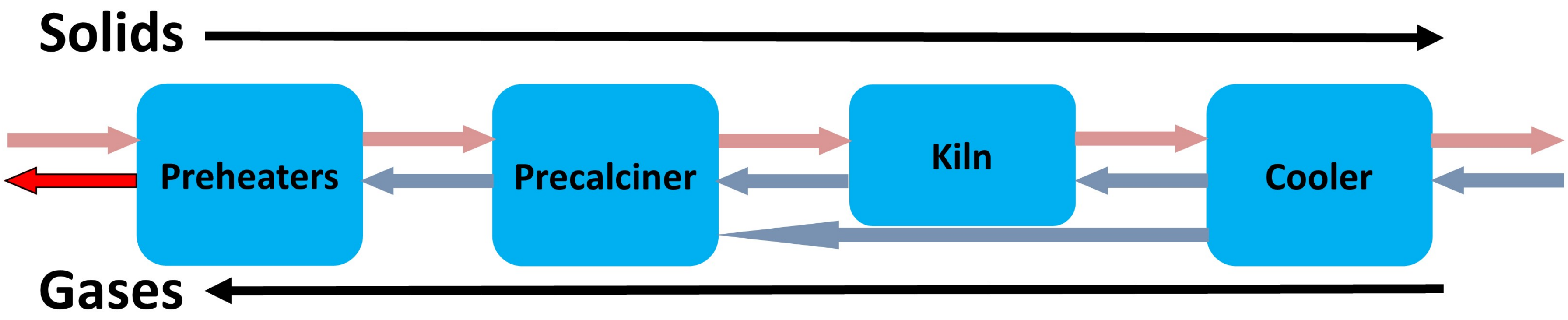
Mostly electric – few integration opportunities

Electricity → Warm Water

- Plant data mainly from EC's BAT Reference documents

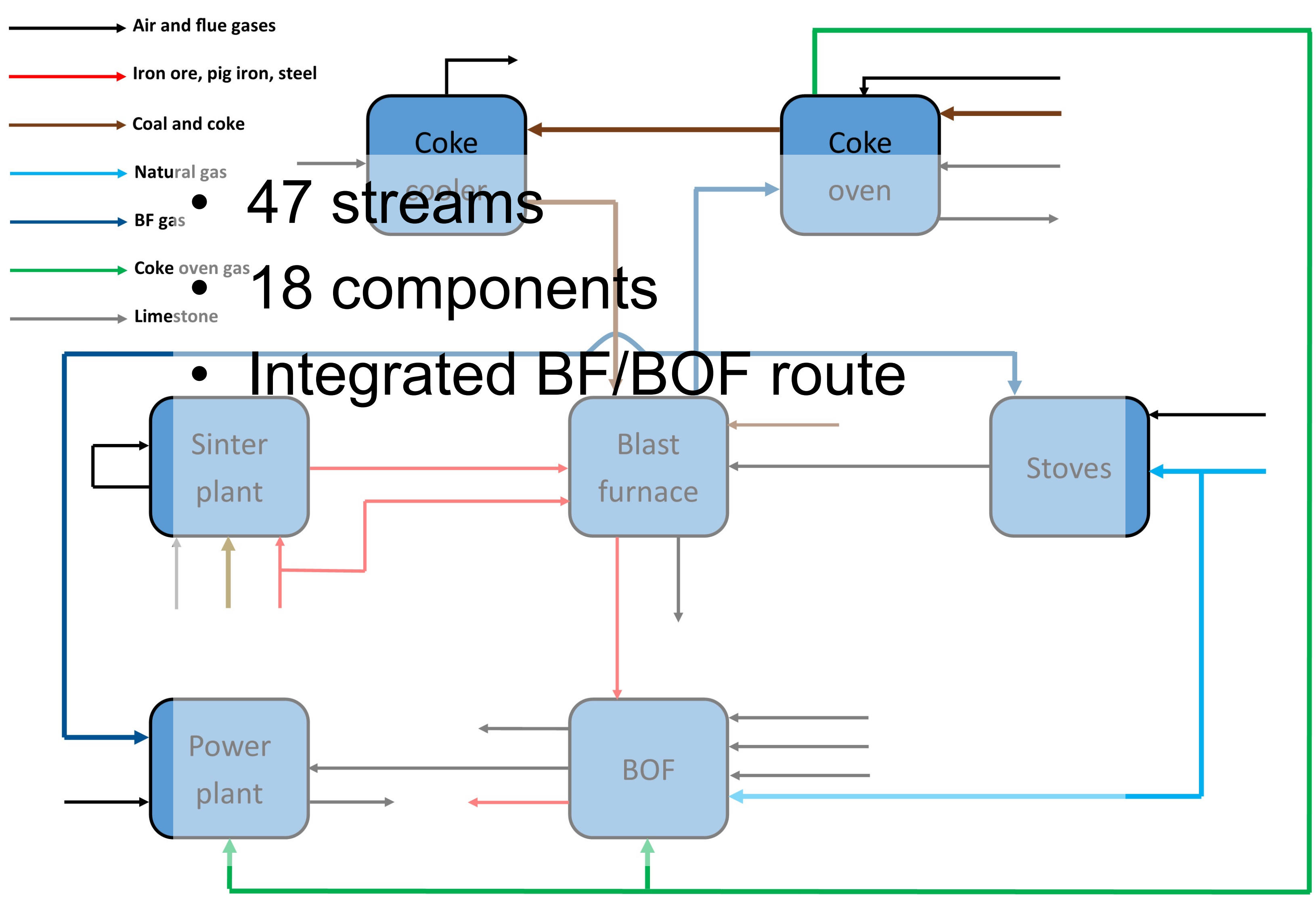
Grantham Institute for Climate Change

Cement plant



- 16 streams
- 6 components
- Counter-current flows of gases and solids
- Grinding steps omitted

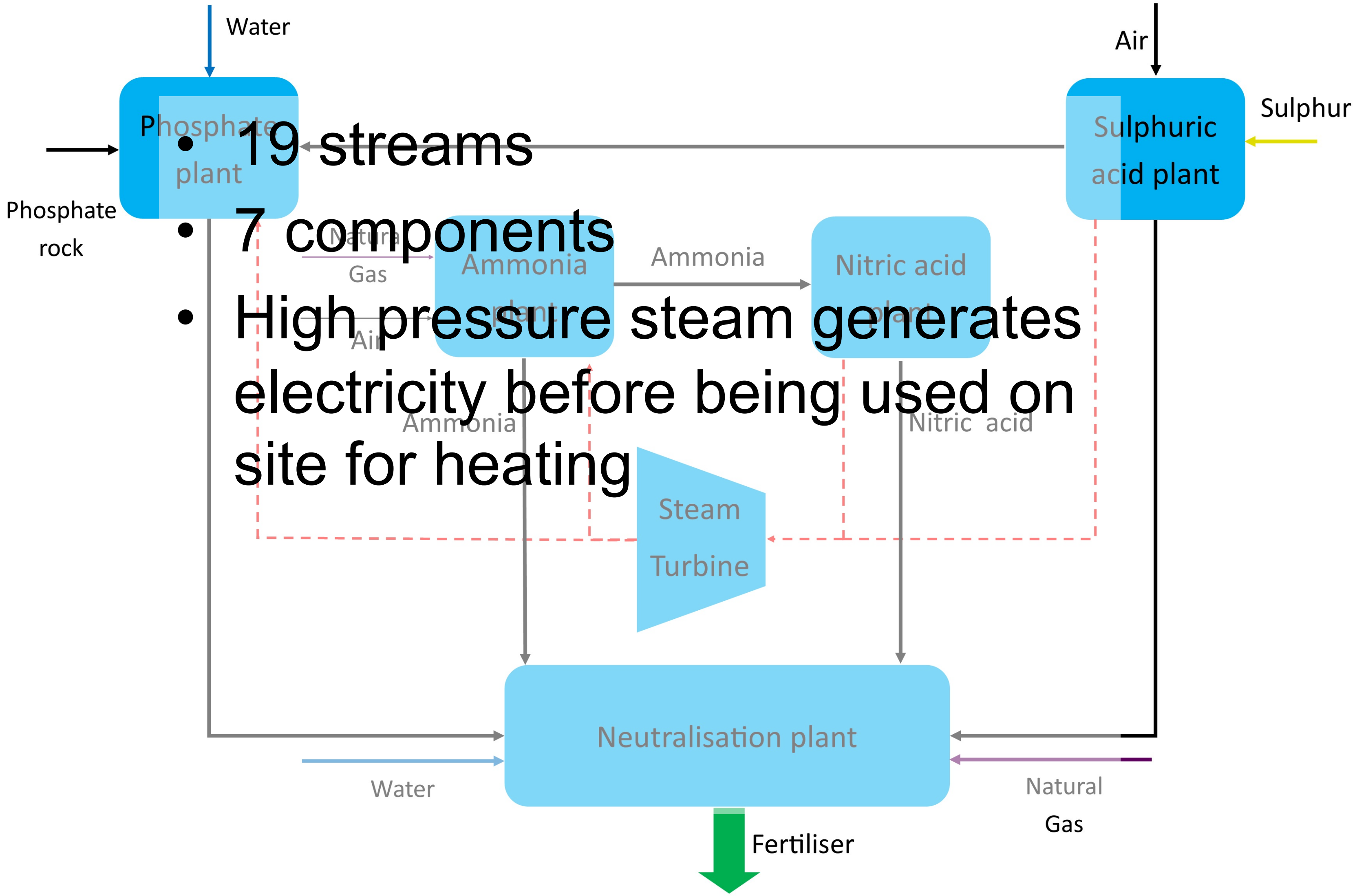
BF/BOF Steel plant



- 47 streams
- 18 components
- Integrated BF/BOF route

Fertiliser plant

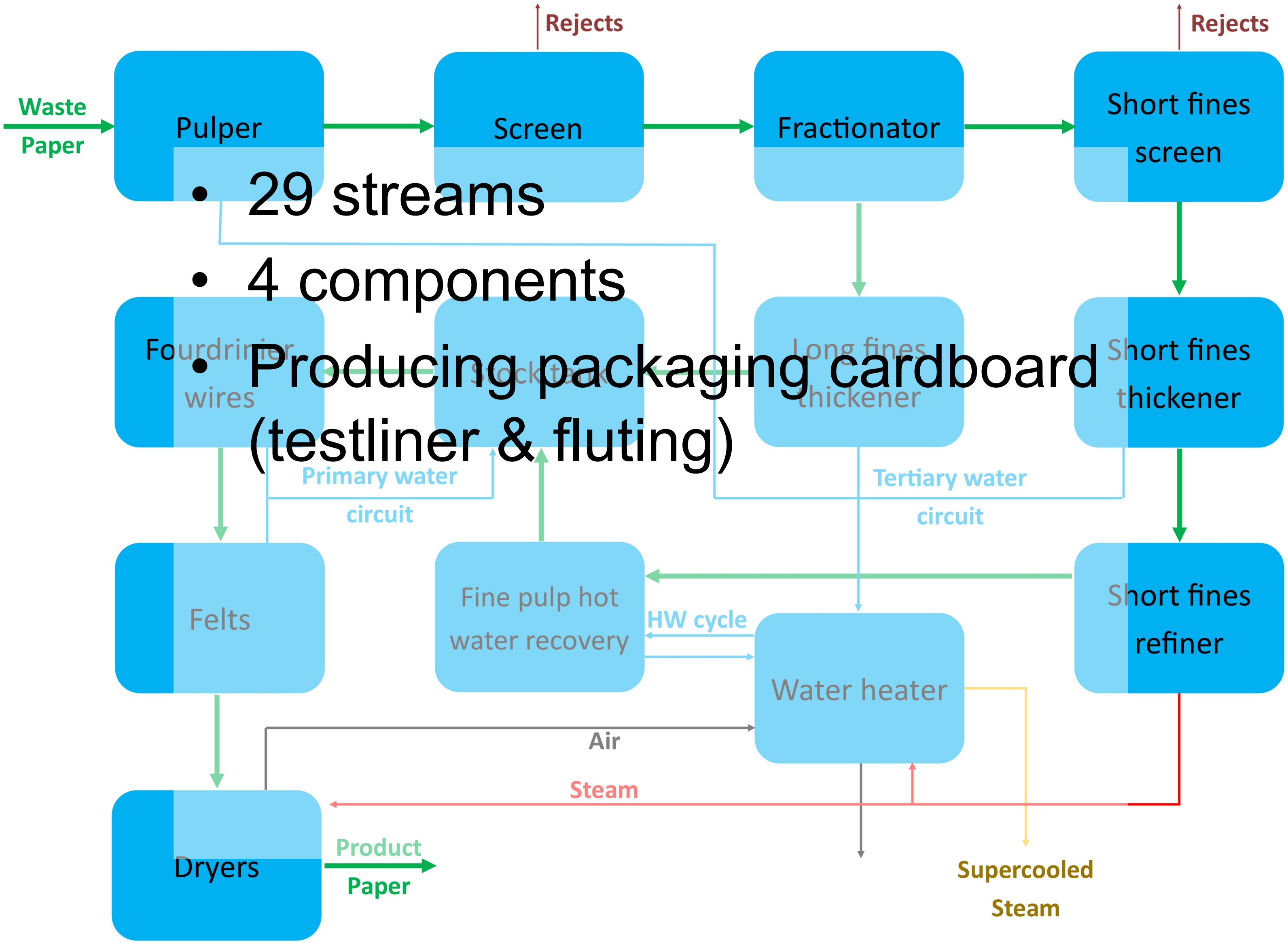
- 19 streams
- 7 components
- High pressure steam generates electricity before being used on site for heating



Imperial College London

Recycled paper plant

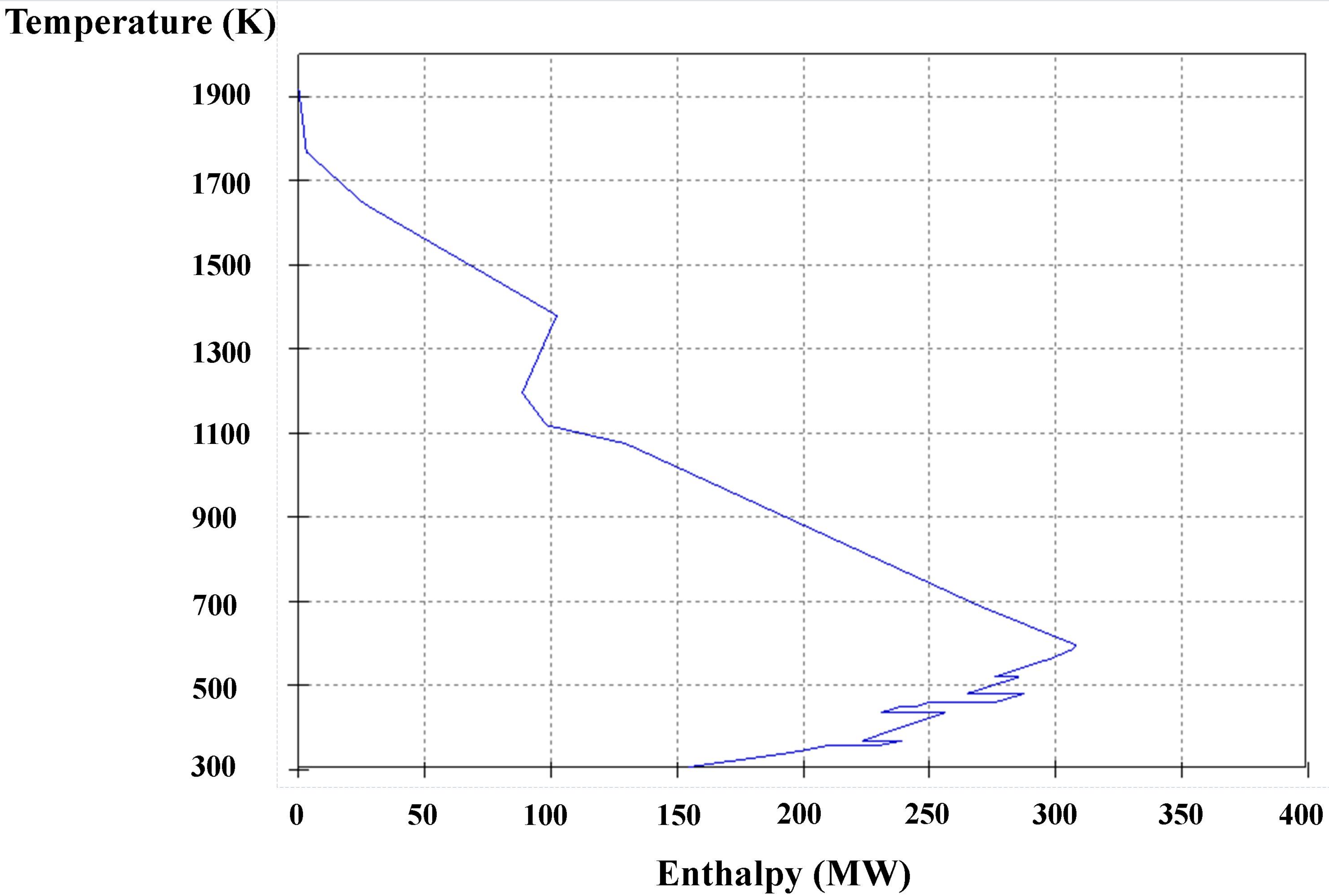
- 29 streams
- 4 components
- Producing packaging cardboard (testliner & fluting)



2. Develop a Heat Exchanger Network

- Minor flows ignored
- ΔT_{min} = 10K (this is a *theoretical* exercise)
- Heat exchanger costs from various correlations
- No costs of extra plant except heat exchangers and ancillaries included
- Mid-2013 Euros

Grand Composite Curve (GCC)

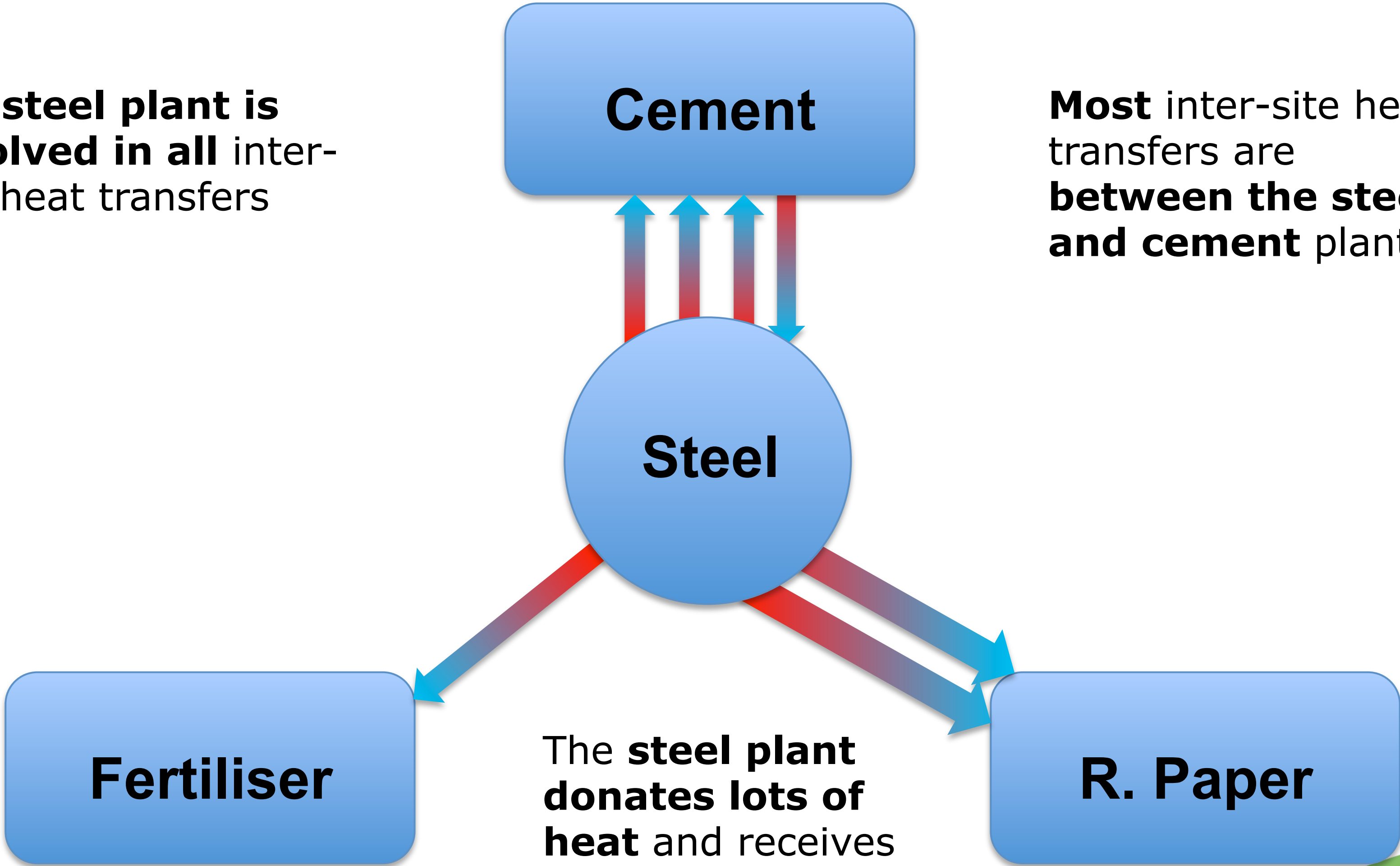


Imperial College London

Results – Heat Exchanger Network

The **steel plant is involved in all** inter-site heat transfers

Most inter-site heat transfers are **between the steel and cement** plants

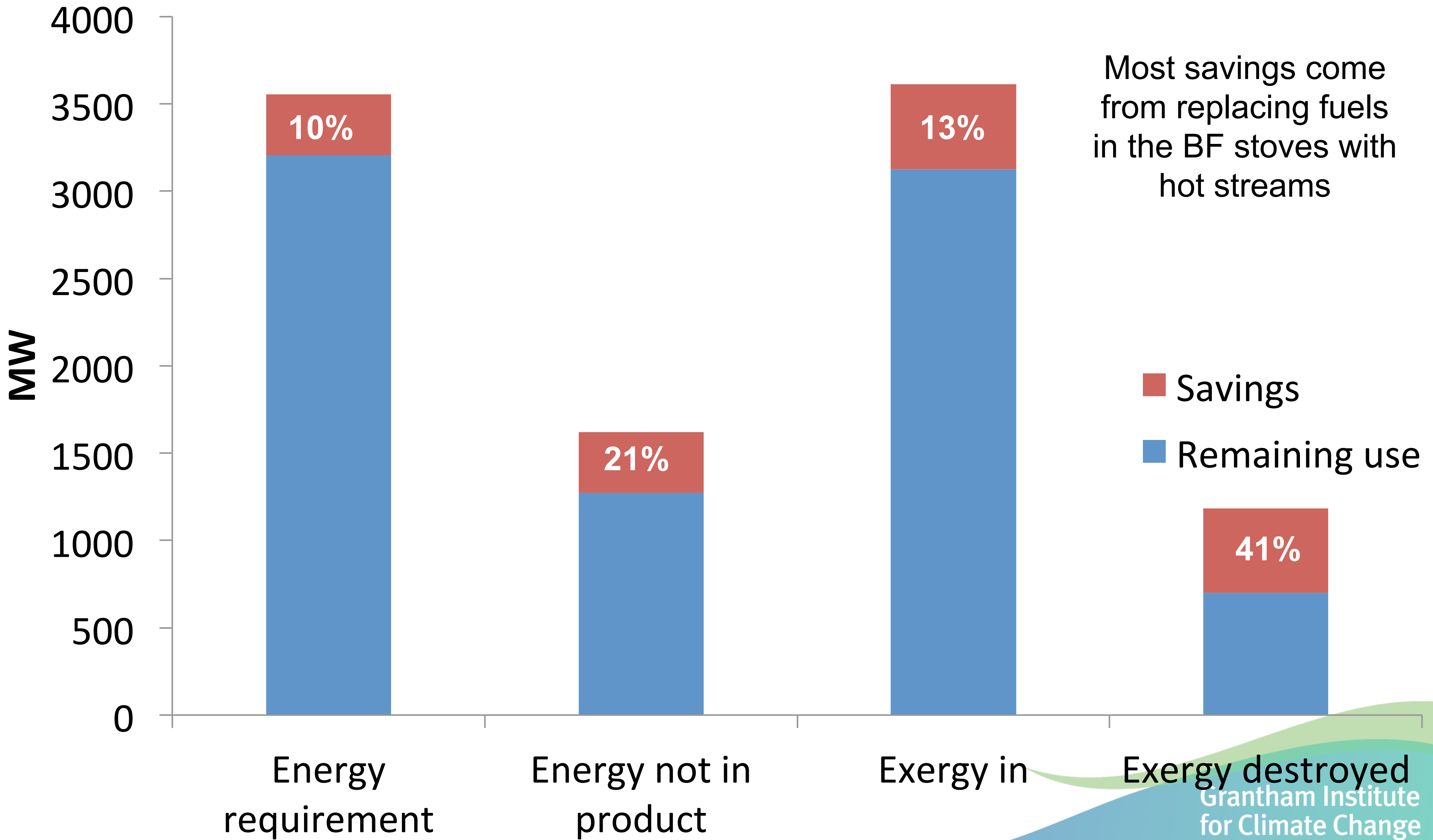


The **steel plant donates lots of heat** and receives only a little

Grantham Institute for Climate Change

Imperial College London

Results – energy & exergy savings



Grantham Institute for Climate Change

Results – Heat exchanger network

Characteristic		Value	Unit
Fuel savings (power)		485.5	MW
Number of heat exchangers		16	
Total heat transfer area of HEN	Heat integration	20 205	m^2
	Steam generation	5 263	
Cost of HEN	Heat integration	13.5	M€
	Steam generation	1.3	
Specific cost of HEN		17	€/kW
Payback period		**43**	**Days**

What doesn't this include?

Exclusions

Results don't include:

- Alterations to existing plant *(e.g. more BF stoves?)*
- Use of metals other than carbon steel in HEXs
- Cost of back-up units
- Cost of rebuilding plant in a new location
- Financing & Legal

3. Design a comparative solution

	CHP	ORC	Total
Heat load (MW)	790.9		790.9
Overall efficiency	0.79	0.14	
Power output (MW)	208.8	34.52	243.32
Capital cost (k€)	152 217	69 762	221 979
Fuel cost (k€/y)	151 550		151 550
Operating cost (k€/y)	7 989	560	8 549
Electricity value (k€/y)	149 324	24 660	173 984
Heat value (k€/y)	100 889		100 889
Annual profit (k€/y)	90 674	24 100	114 774
Payback period (y)	**1.68**	**2.83**	**1.93**

Imperial College London

4. Compare the two scenarios

Heat exchanger network	Electricity generation
43 day payback period	1.9 year payback period
€ 14.8 M investment	€ 220 M investment
Old correlations	Newer cost correlations
Requires adjacent plants	Plants can be isolated
Requires trust between managers & investors	Independent operations
Relatively obscure units (High-temp HEXs)	Relatively new processes (e.g. ORC)

Who would invest in a HEN or electricity generation system?

Grantham Institute for Climate Change

Conclusions

- There is **significant theoretical scope for** energy exergy & financial **savings** through inter-site heat integration
  - even after considering an alternative investment

- Savings are predicated on the **intimate locating of plants** and their sharing of heat
  - Are the rewards worth the risks? Is it practical?

- Such networks are **more suitable in new industrial centres** than already-established ones

Conclusions & future opportunities

- However, **inter-site integration is worth looking at** – but its suitability is dependent on the plants

- Limited set of plants – **what plants are more suitable?**
  - What ***sizes*** of plants are more suitable?

- **Intelligent climate policy** may spur on development of such systems

Imperial College London

Thanks!

Thomas Hills

Department of Chemical Engineering &

Grantham Institute – Climate Change and the Environment

Imperial College London

thomas.hills07@imperial.ac.uk

+44 (0)7501060451

uk.linkedin.com/in/thomashills/

Grantham Institute for Climate Change