Techno-economic study of an integrated steelworks equipped with oxygen blast furnace and CO_2 capture

Presentation by Lawrence Hooey

Co-authors: Andrew Tobiesen

Jeremy Johns

Stanley Santos

Financial support

- Swedish Energy Agency
- IEA GHG R&D Programme
- SSAB
- LKAB
- Swerea MEFOS member companies

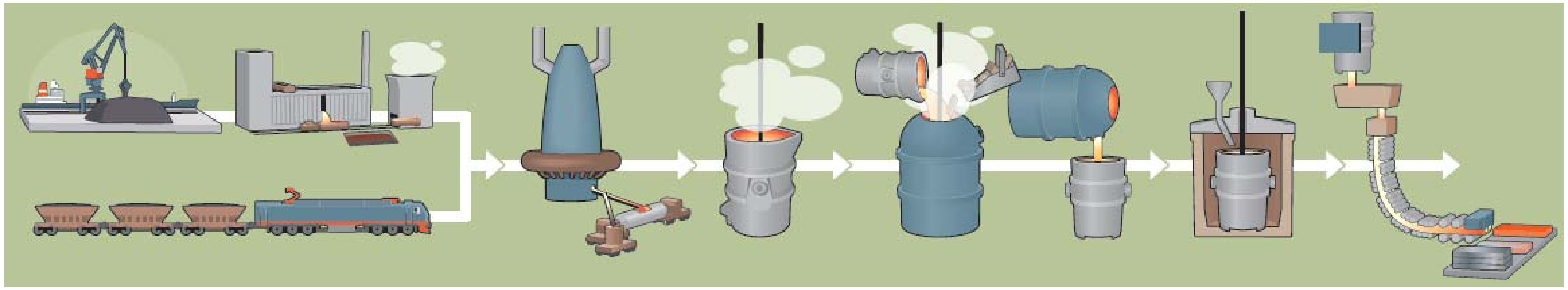
Contents

- Purpose
- Assumptions, Methodology
- Integrated steelmaking, BF & OBF system
- CO_2 Capture & systems effects
- Results
- Conclusions

Purpose

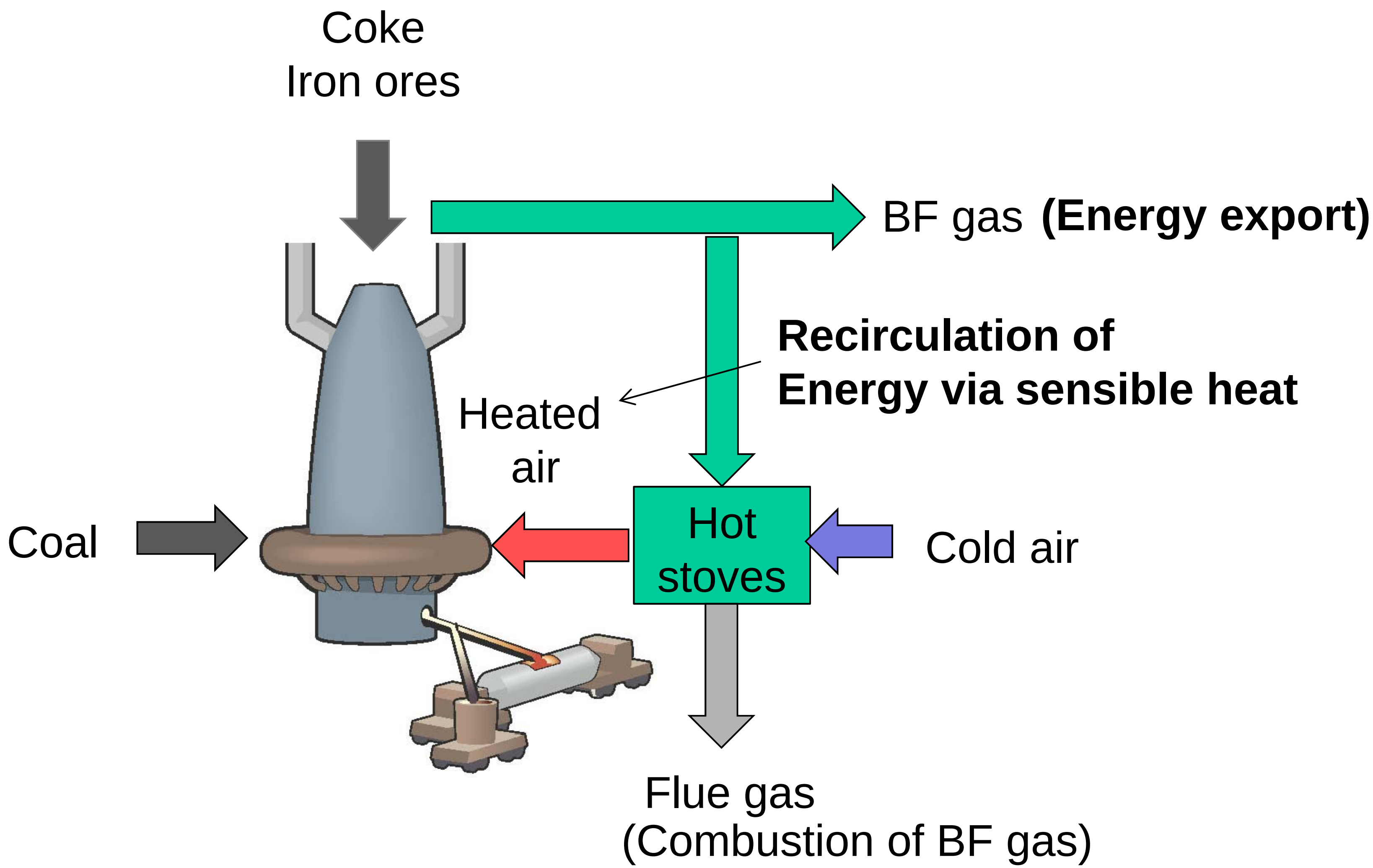
- Determine the cost of avoiding CO_2 emissions from integrated steelmaking using an Oxygen Blast Furnace (and end of pipe – to be published)

$$CO_2 \text{ Avoidance Cost} = \frac{Cost_{HRC\_capture} - Cost_{HRC\_ref}}{CO_{2\ emission\_ref} - CO_{2\ emissions\_capture}}$$



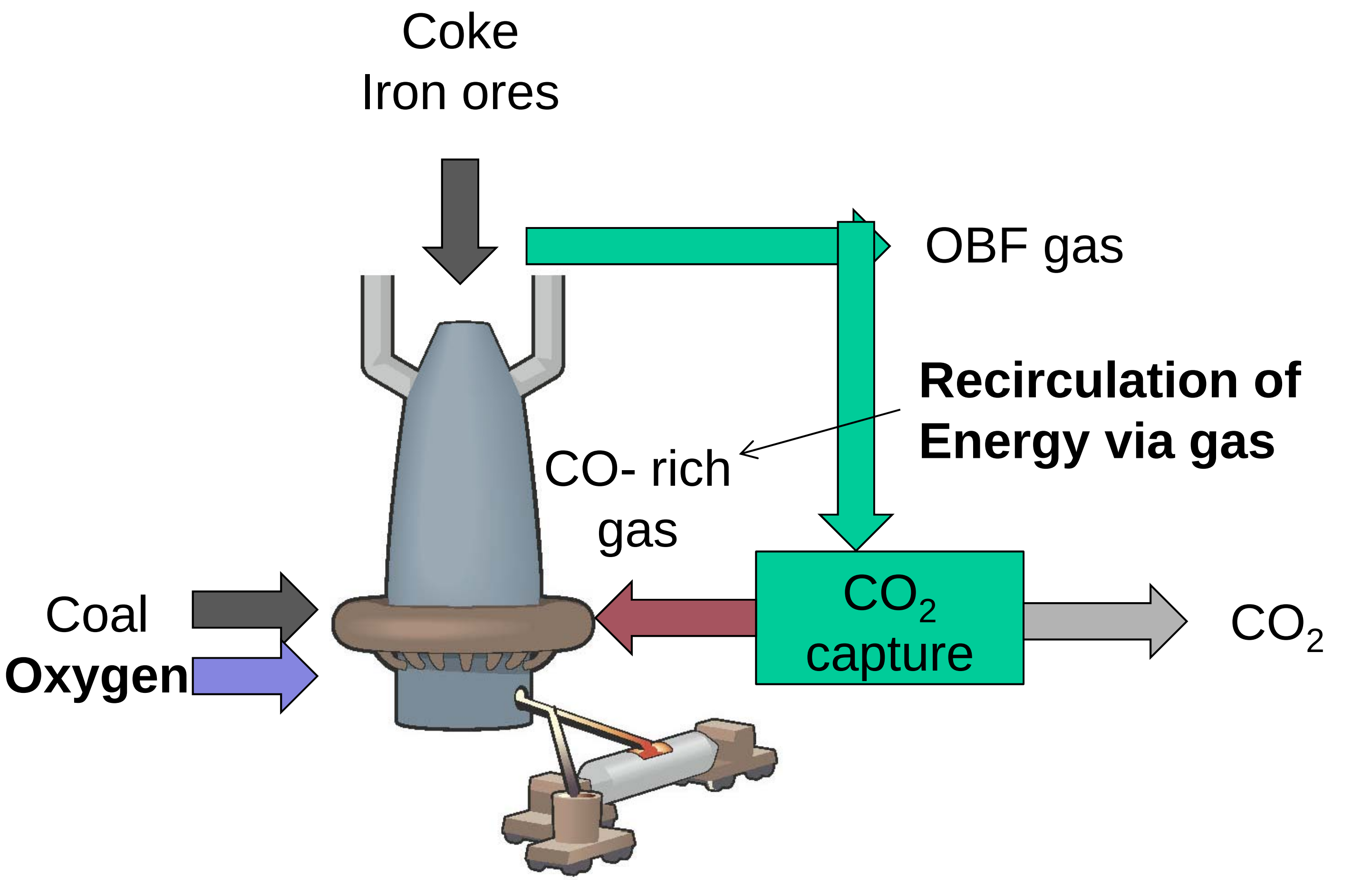
swerea | MEFOS

BF



Coke
Iron ores
BF gas (Energy export)
Recirculation of
Energy via sensible heat
Heated
air
Coal
Hot
stoves
Cold air
Flue gas
(Combustion of BF gas)

OBF


Coke
Iron ores
OBF gas
Recirculation of
Energy via gas
CO- rich
gas
Coal
Oxygen
CO_2
capture
CO_2

Assumptions

- Western European Atlantic Coastal Site
- Access to natural gas and a CO_2 pipeline 110 bar
- Reference plant has typical European performance figures and operation with sinter, pellets, lump ore, PCI, some scrap in converter
- Production of 4 MT standard grade hot-rolled coil
- Cost of land not included
- Greenfield projects

Assumptions- Boundary Limits

Incoming streams:

Iron ores
Scrap
Fluxes & alloys
Coking Coal
PCI Coal
Natural gas

Lime production	Steelmaking
Coke production	Rolling mill
Sinter Production	Oxygen production
Ironmaking	Power & steam production
Ancillary operations	CO_2 capture

Outgoing streams:

Hot rolled coil
By-products
Solid wastes
Flue gases
Diffuse emission

No import or export of electricity

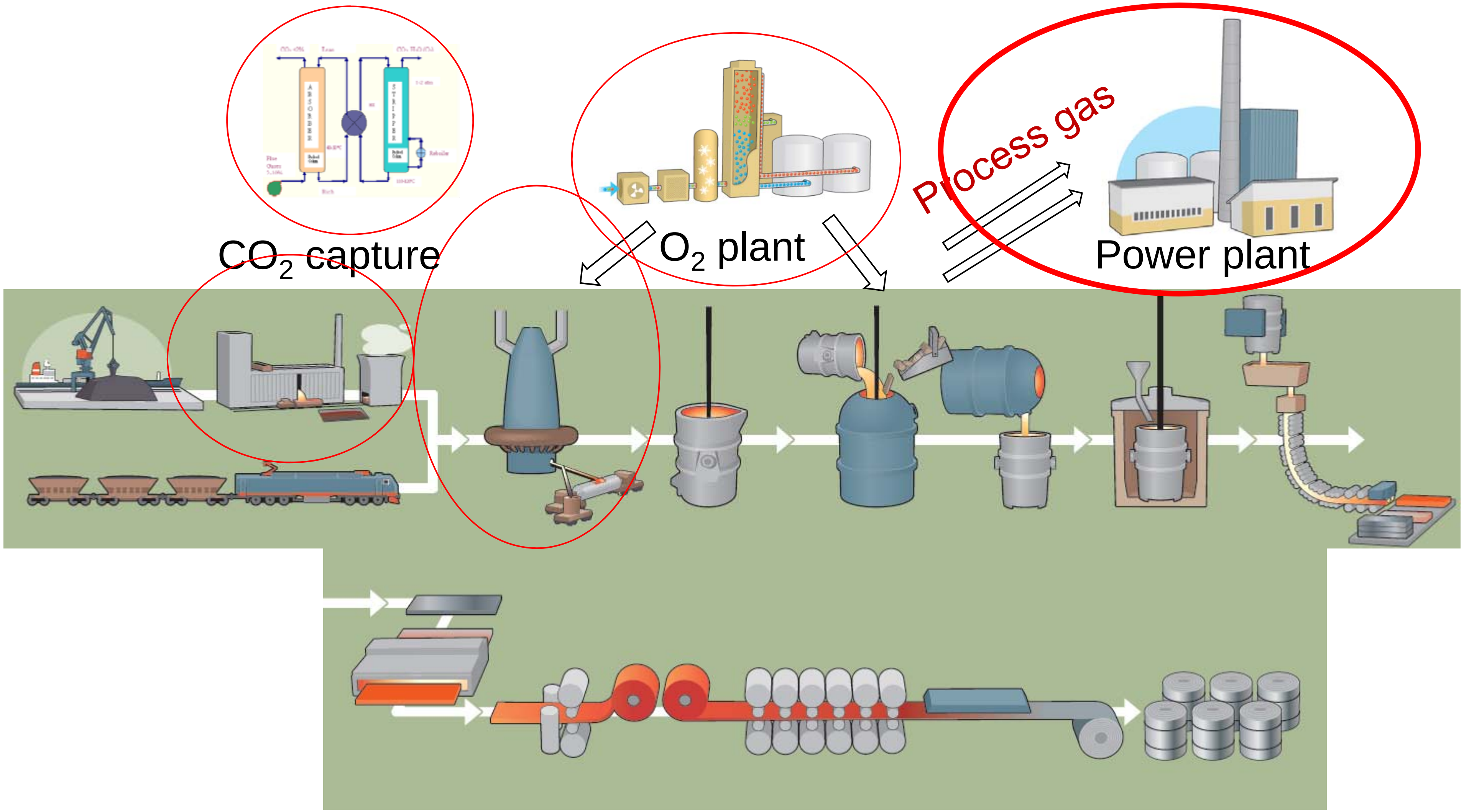
Technical model

- Masmod integrated steelplant model (Excel)
  - All major units modeled
  - Calibrated to typical European operation
  - Static heat and mass balances, solved iteratively
  - Level of detail varies for different units
- Oxygen blast furnace
  - BF model modified to calculate OBF performance
- CO_2 capture
  - Protreat®, optimized with MDEA/Pz chemical absorption
  - Operating parameters input to Masmod model

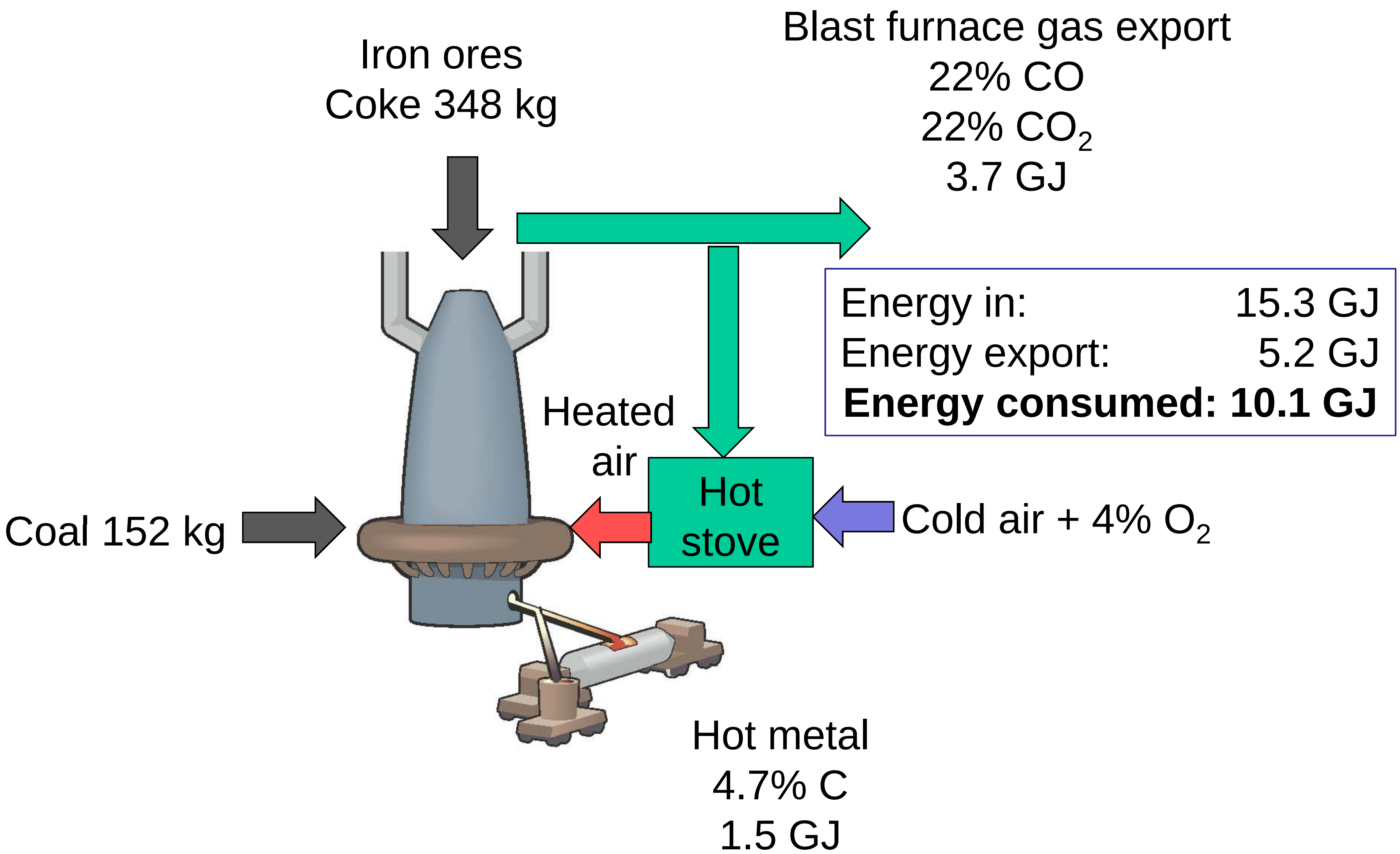
Financial Modeling

- Discounted cash flow through-cost model
- Cost of HRC adjusted to Net Present Value = 0
- Discount rate 10%
- Project Lifetime 25 years
- Long term trend prices for materials
- Capital costs from database & vendor supplied information
- Base year 2010

Integrated steelmaking

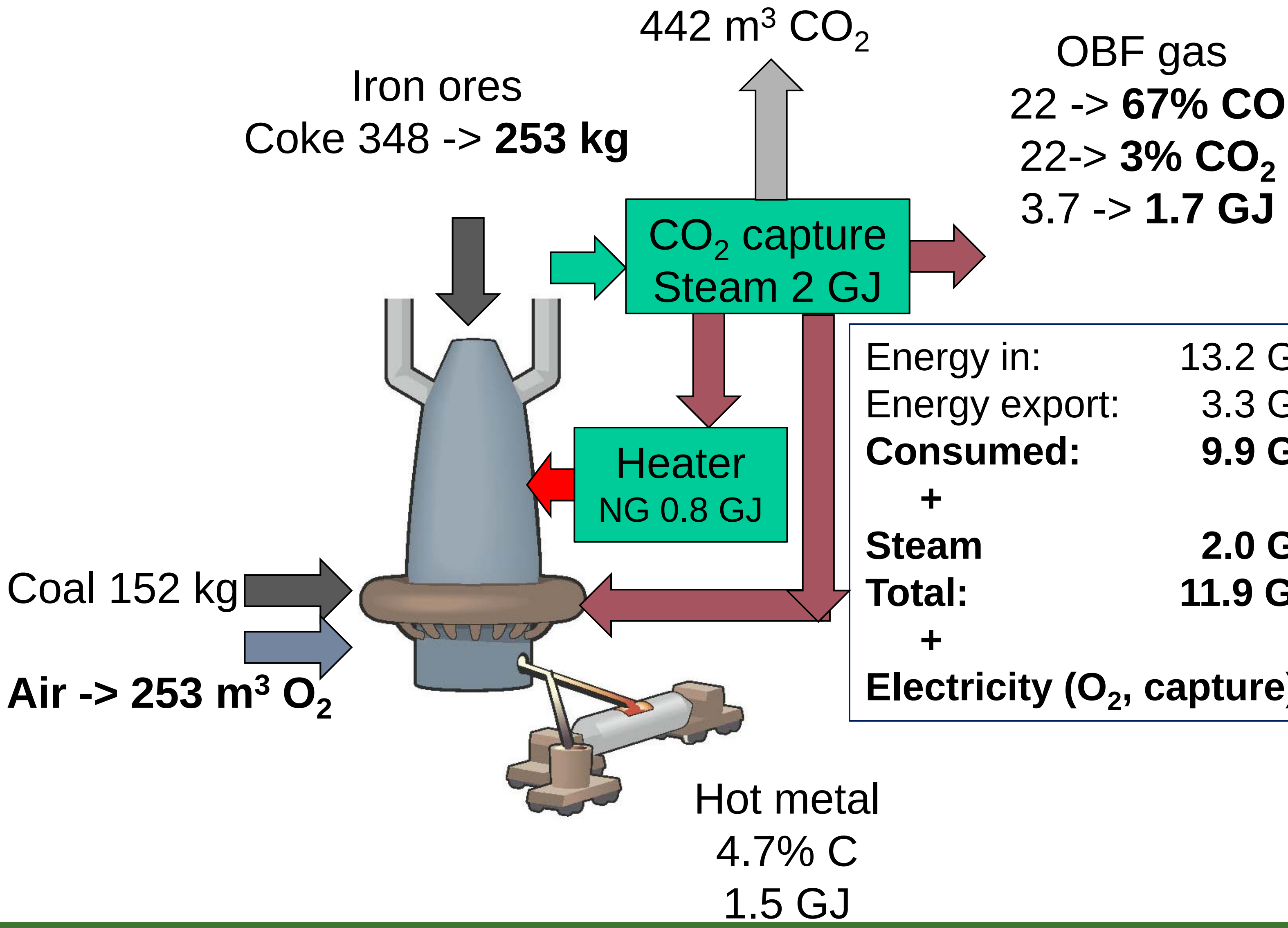


Reference Blast furnace



swerea | MEFOS

Oxygen Blast furnace

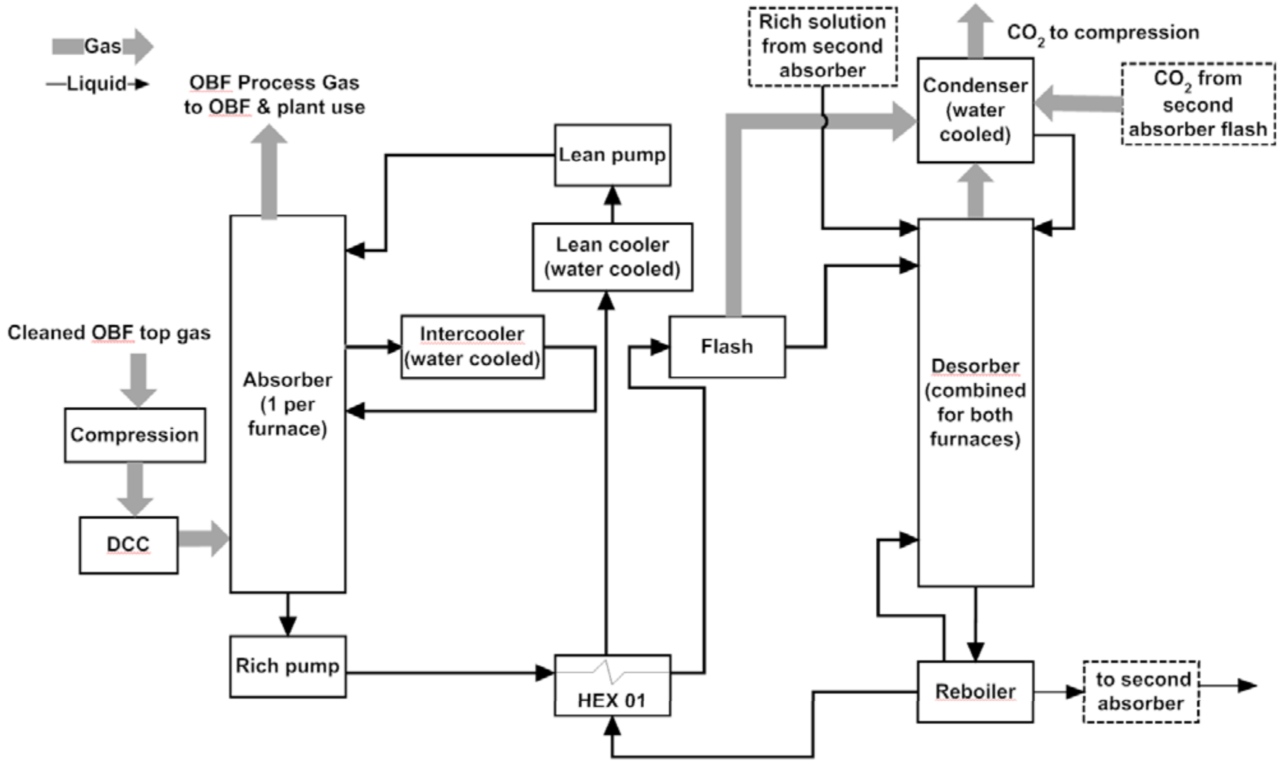


Energy in:	13.2 GJ (15.3)
Energy export:	3.3 GJ (5.2)
Consumed:	**9.9 GJ (10.1)**
+	
Steam	**2.0 GJ**
Total:	**11.9 GJ**
+	
Electricity (O_2, capture)	

swerea | MEFOS

CO_2 Capture

- MDEA with piperazine modeled and optimised
  - Established system, reliable performance & cost estimates
  - More suitable for high CO_2 concentration streams than MEA
  - Produces pipeline grade CO_2
  - 2.35 GJ/t CO_2 captured



swerea MEFOS

System-changes with OBF

- CO_2 capture and compression added
- Steam boilers added
- Low purity O_2 plant added
- Smaller coke plant
- *Higher electricity production required*
- Less process gas available

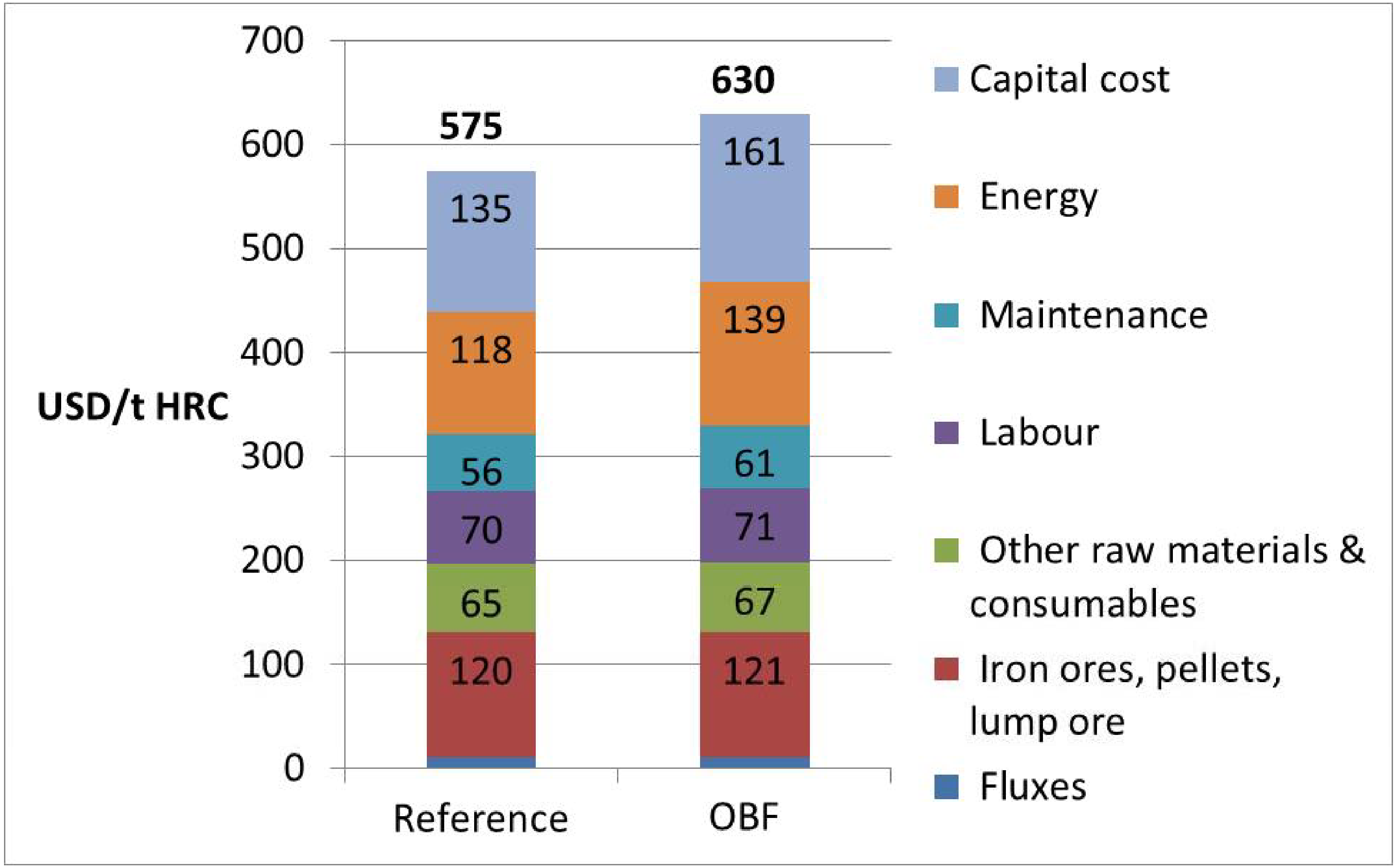
Steam & Electricity

	Power plant	Demand kwh/t HRC	Steam	Demand GJ/t HRC
Reference Plant	Steam cycle 32% eff BF, BOF, NG	400	Steam recovery only from BOF	--
OBF Plant	NGCC 57% eff. NG	573	Steam boilers BF, BOF, NG	2

Overall Energy Consumption

Fuel GJ/t HRC	Reference	OBF
Coking coal	16.3	12.4
PCI coal	5.0	5.0
Natural gas	0.8	5.0
SUM	22.2	22.5

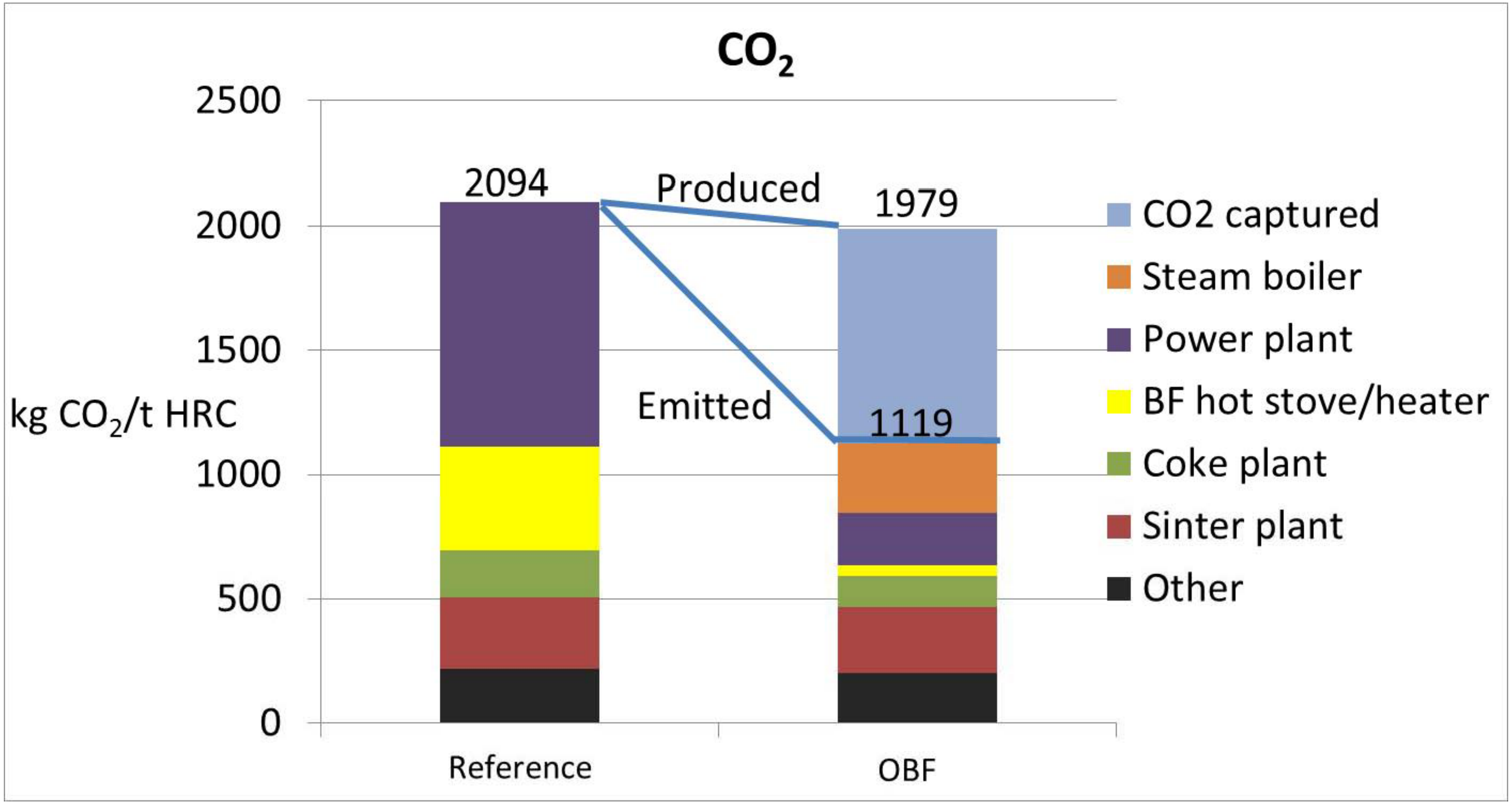
Break-even cost of HRC



swerea MEFOS

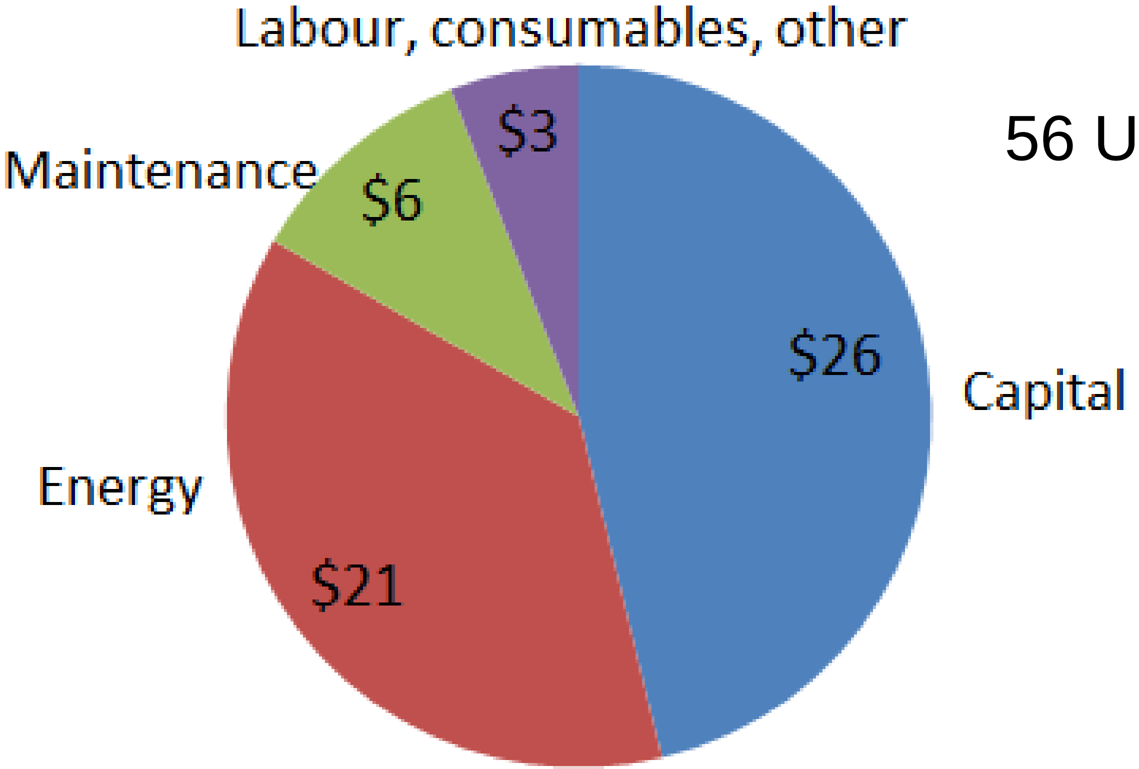
Emissions

Avoidance 975 kg (47%)



swerea MEFOS

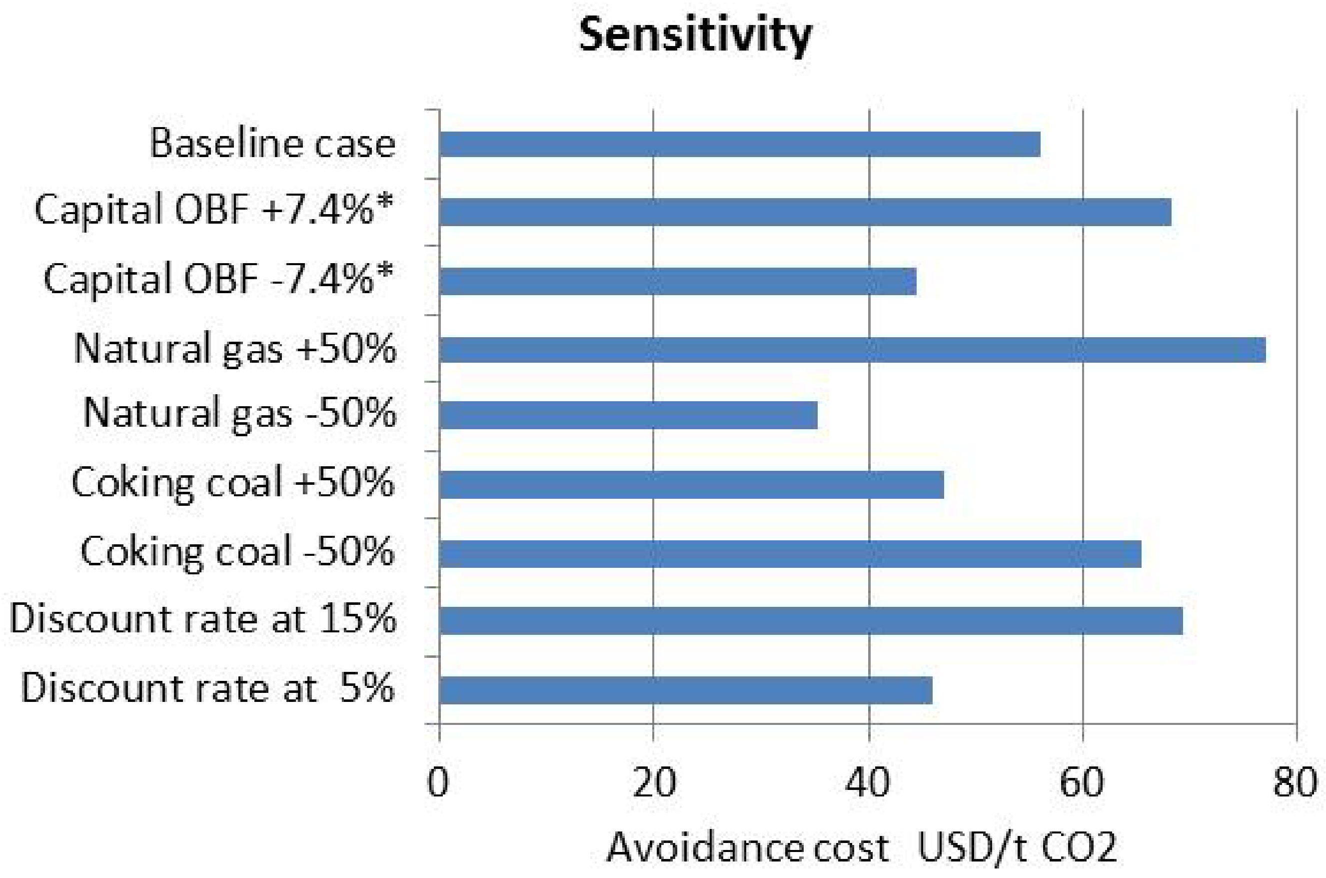
Cost of avoidance



56 USD/t CO_2 avoided

Sensitivity

- Energy, Capital



* represents a 50% change in the difference in investment cost

Conclusions

- OBF system allows for fuel shift and increased CO_2 concentration in gas stream for improved capture
- Under the given assumptions the avoidance cost is 56 USD/t at nearly 50% CO_2 avoidance; highly sensitive to energy and capital costs
- Numerous complex system effects
- Further optimization is possible (e.g. CHP plant, waste heat integration)
- Pilot & demonstration scale developments will be very important
  - e.g. ULCOS (Europe); COURSE50 (Japan)

Thank you for your attention!

swerea MEFOS