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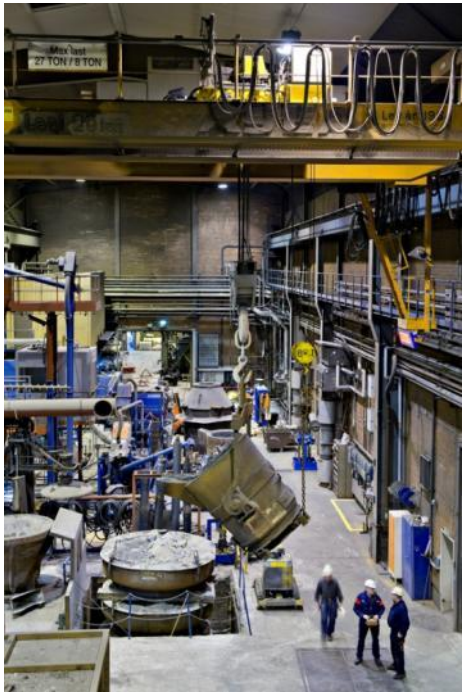
Swedish Experience of Practical application of Process Integration



Chuan Wang
Jan-Olov Wikström

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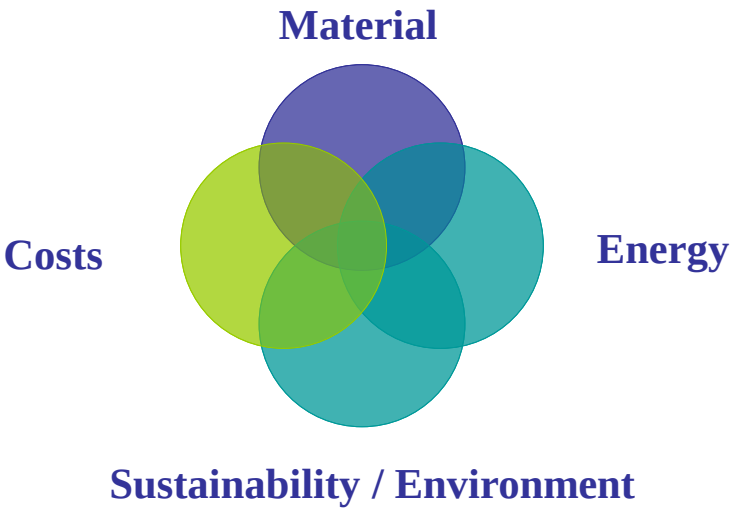
What is Process Integration?

IEA:

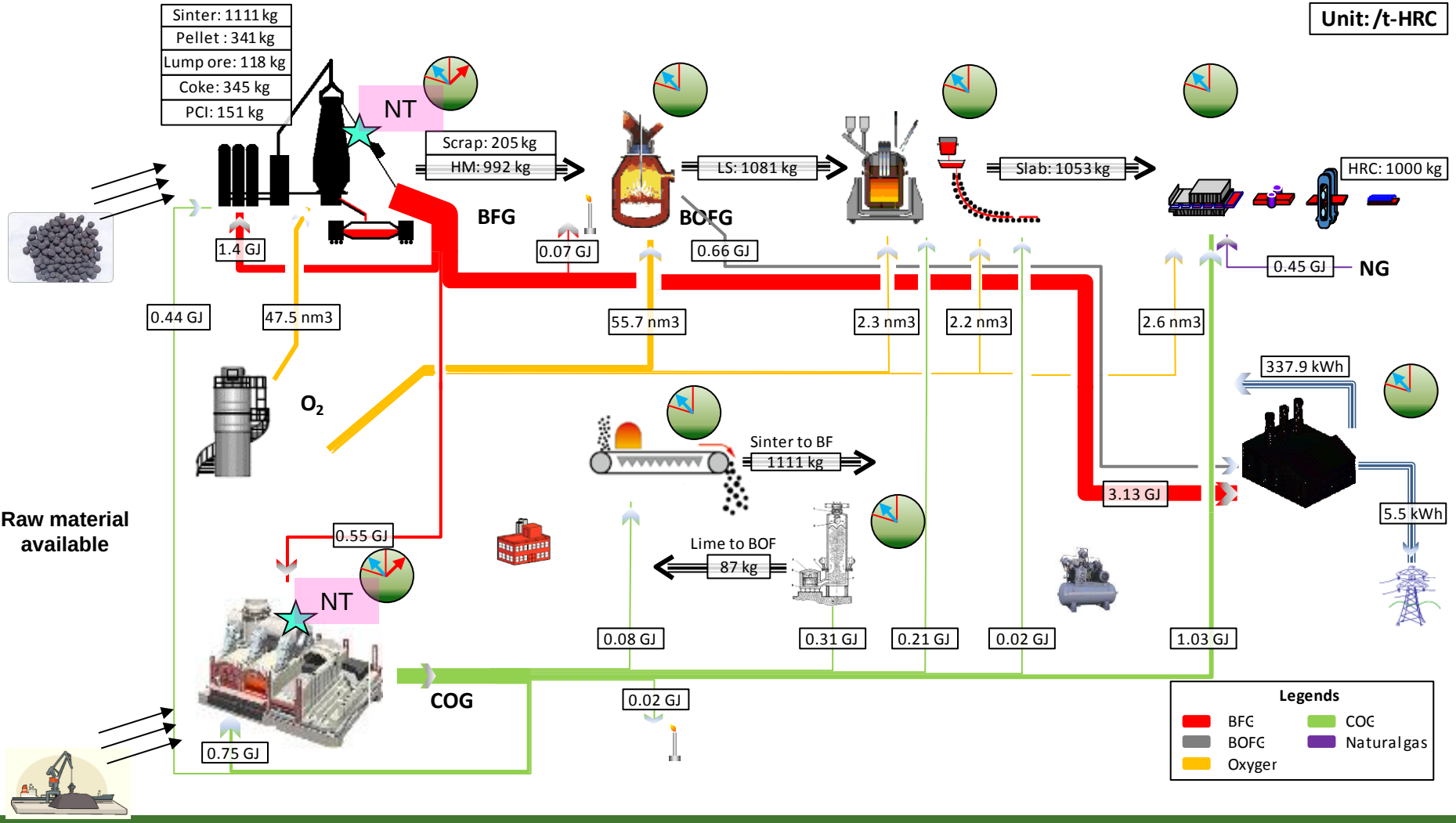
> *"Systematic and General Methods for Designing Integrated Production Systems, ranging from Individual Processes to Total Sites, with special emphasis on the Efficient Use of Energy and reducing Environmental Effects."*



Optimisation: given a system or process, find the best solution to this process within given constraints.
Objective function: indicator of performance, e.g. emissions, energy, costs.
Decision variables: variables that influence process behaviour and can be adjusted for optimisation.

Holistic perspective for changes

- A standard European steel plant



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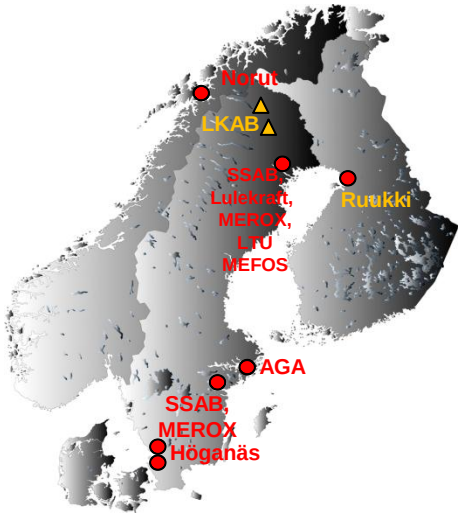
PRISMA – Centre for Process Integration in Steelmaking

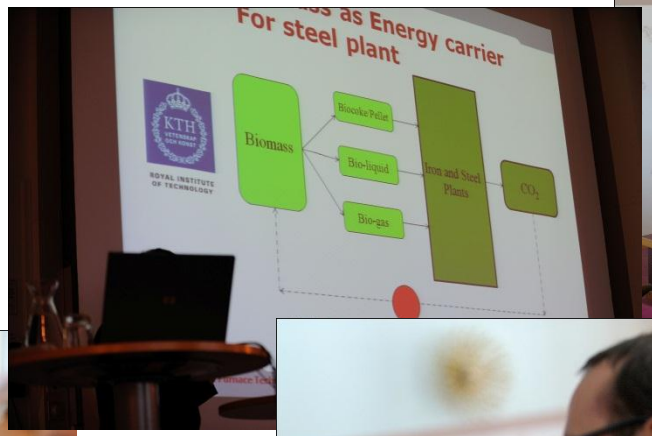


- System analysis & optimisation: *Energy, materials, GHG*
- 7 Industrial members
- Joint research program
- Company specific program
- 10 full-time researchers
- External projects
- International networking

Communication and learning processes

Process Integration Forum

Annual Information and Project communication forum, open to everyone.



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Production system models PRISMA

Scrap based steel production

CHP

Mining and benefication

Integrated steel production

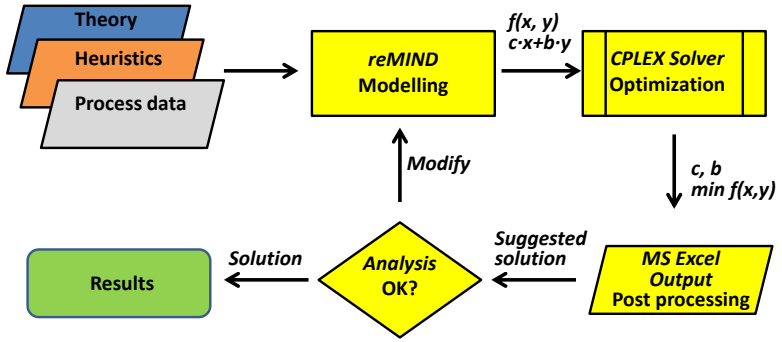
Modelling tools used in the center

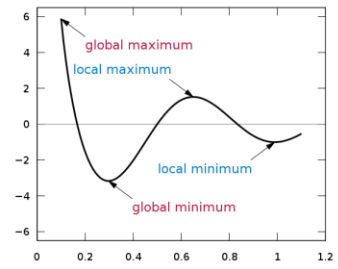
Optimization tools:

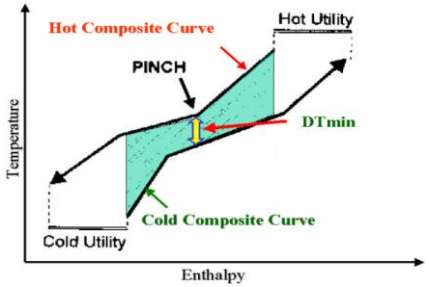
Mathematical programmering; Pinch analysis; Exergy analysis; GAMS, etc.

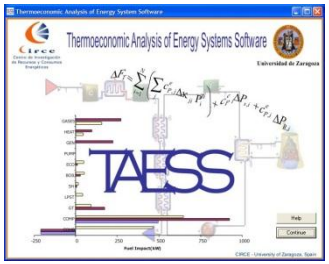
Assisting tools:

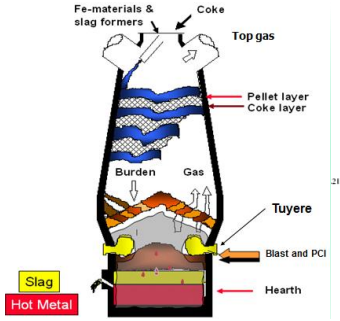
Aspen, FactSage, HSC, Matlab, Masmod, CFD, RIST, HEATSEP, etc.

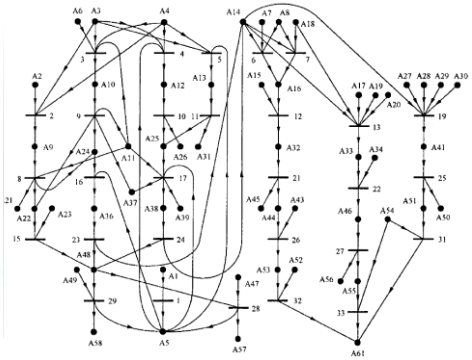


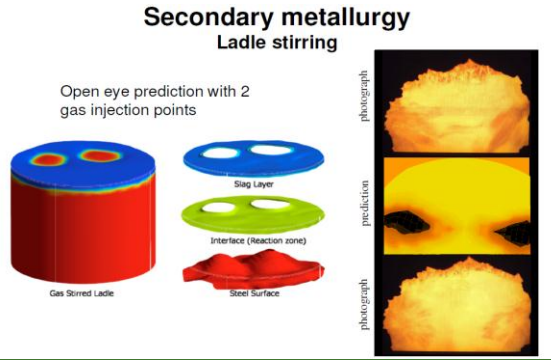


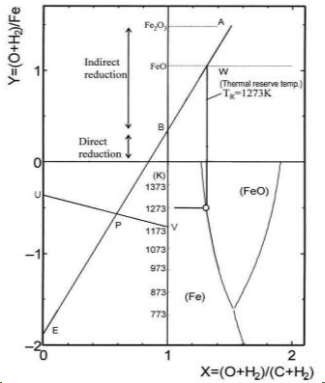


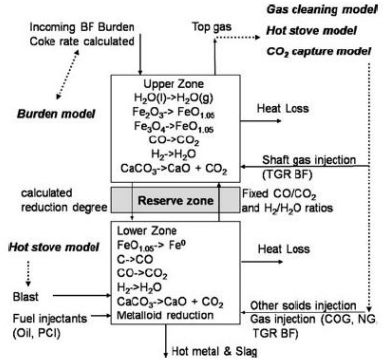


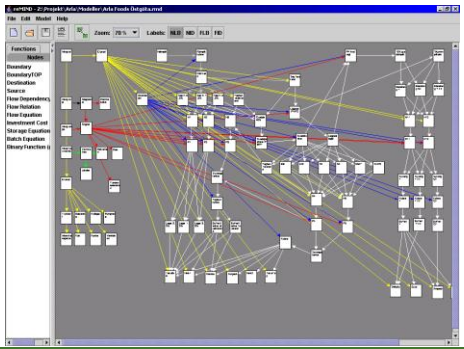












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Application examples of Process Integration

PRISMA projects in the area of

- Energy efficiency, and
- Material efficiency

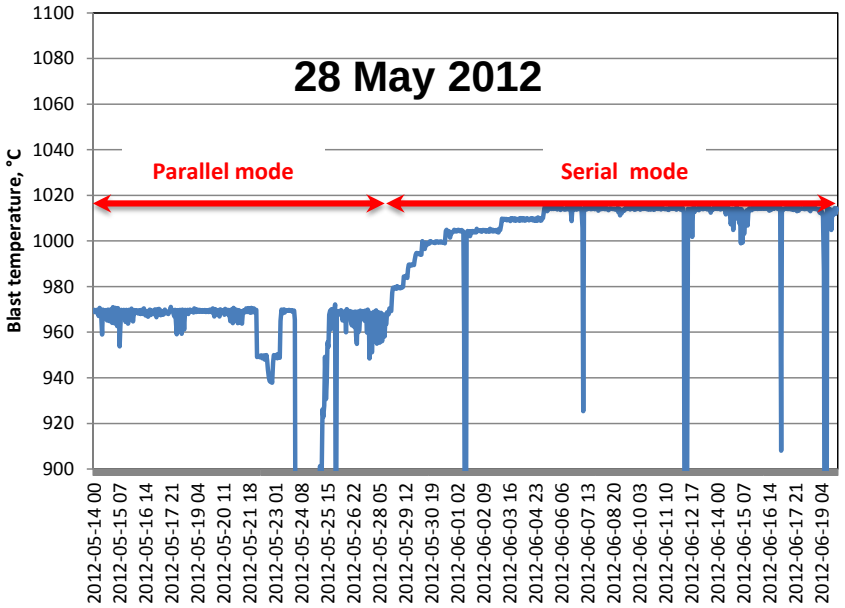
Case studies at SSAB EMEA in Oxelösund, Sweden

Oxelösund's integrated plant

- Coking plant
- Two blast furnaces
- Steel plant
- Rolling mill
- Power plant
- Own harbour

Change of hot stoves' operation mode

- SSAB EMEA, Oxelösund



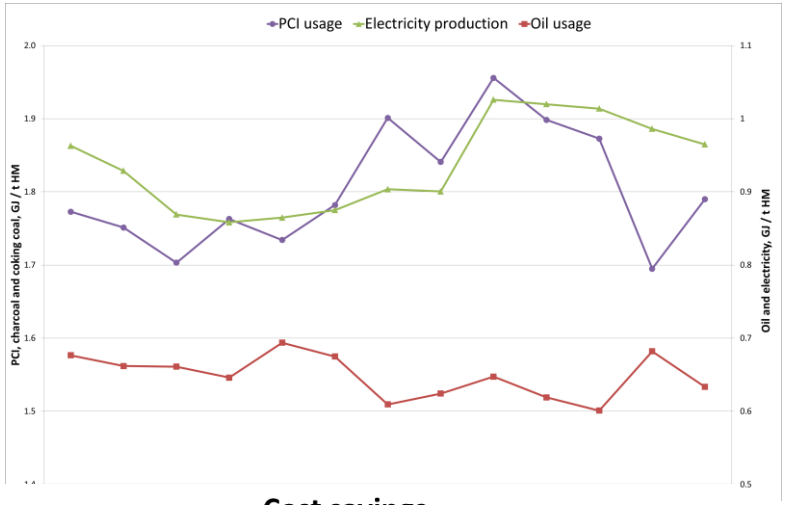
- More energy to the hot stoves
- Less BFG to PP
- Possibility for increased hot blast temperature
- Reduced coke rate
- Improved process gas utilization

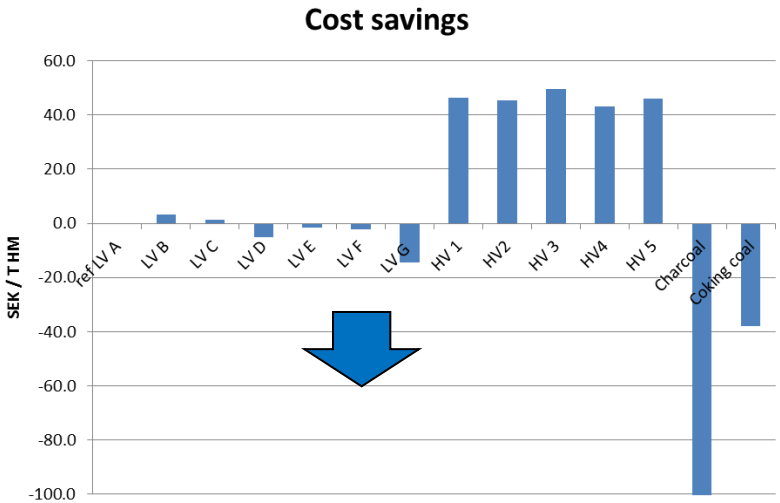
- Blast temperature
  - calculated + 100 °C
  - achieved + 60 °C
- Coke
  - achieved – 9 kg/tHM·100 °C
- Cost saving of 6.5 MSEK per year
- **Non-investment cost!**

Optimal coal injection at varying production rates

Question: How does different coal influence the operation costs?

- Energy saving
  - Less primary energy required and increased power generation
    - High heating value in the BFG when injecting the high volatile coal makes more COG gas available to the RF at RM, thus reducing the oil consumption.
    - The high volatile coal may lead to the highest electricity production in PP due to an increased energy in the BFG.
    - Fuel rate is slightly increased.
- Cost saving
  - High volatile coal most cost efficient at low production rate





Cost saving:
- 60-80 MSEK at a production rate of 1.5-2 Mton hot metal per annum

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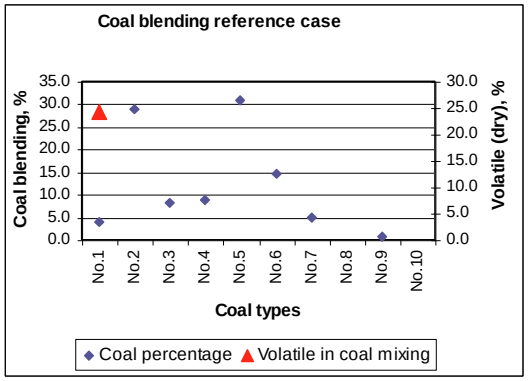
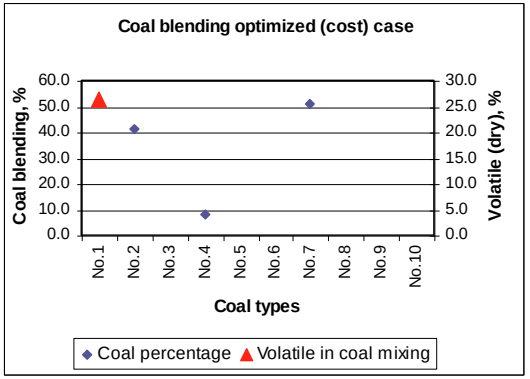
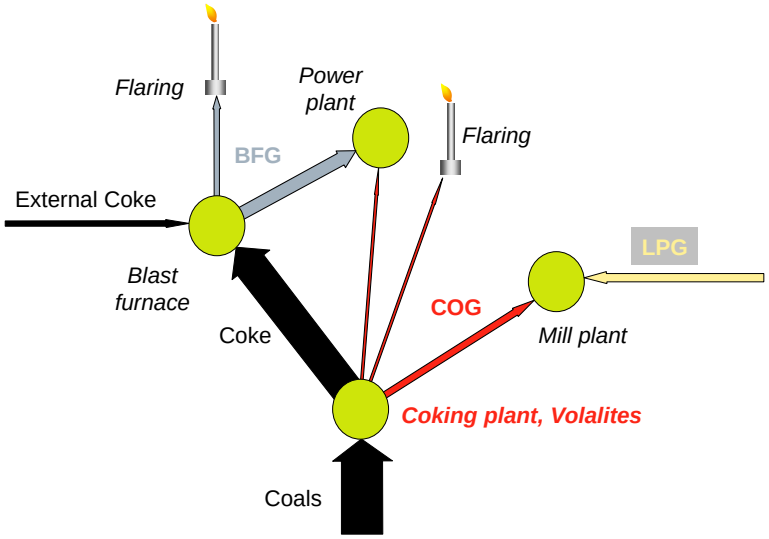
Case of Ruukki metals, Raahe Steelworks, Finland
- Optimised coal blending at the coking plant

Potential cost saving by optimised coal blending at the coking plant.







Items	Opti. coal blending scenario, %
COG production	9.2
COG used at the rolling mill	19.9
Own Coke to BF	-1.0
Total purchased coke	8.0
LPG consumption at the strip mill	-28.7
Coal blending material cost	-5.7
Purchased electricity	-5.4
Coke production cost	-4.8
Total production cost	-2.6

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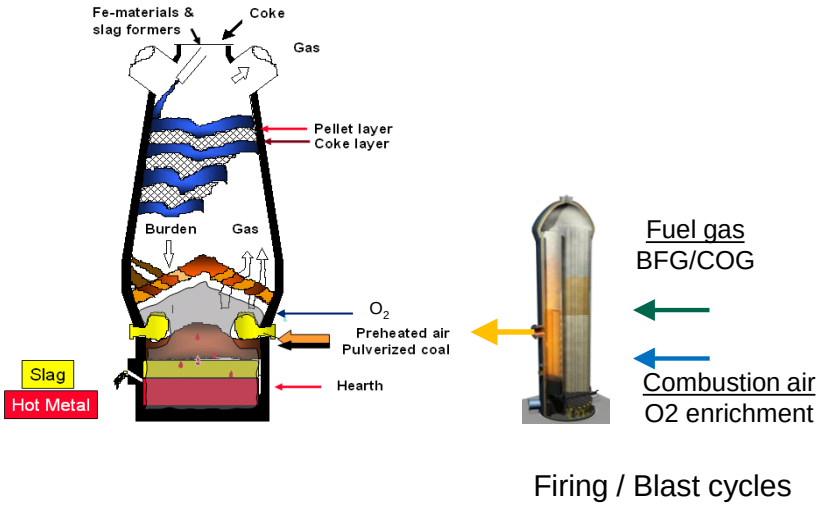
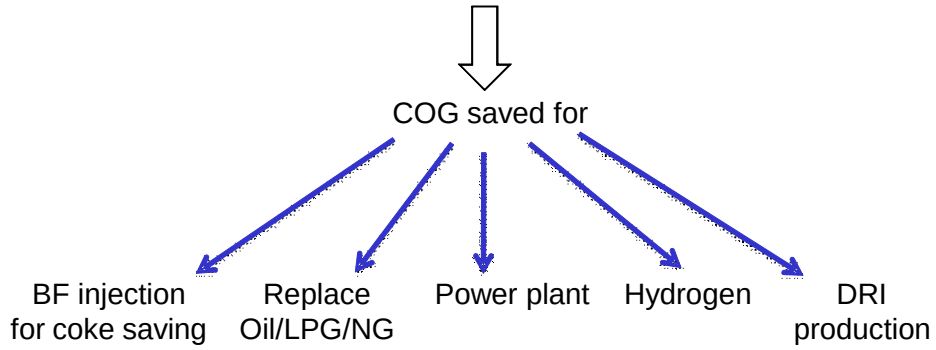
Case of Stove oxygen enrichment (SOE) at different sites

Potential economical benefits and effects of SOE application at different steelworks under different conditions!



Evaluation 1: Fixed COG rate ⟹ highBl.temp ⟹ Coke/PCI saved

Evaluation 2: Fixed Bl.temp. ⟹ COG saving



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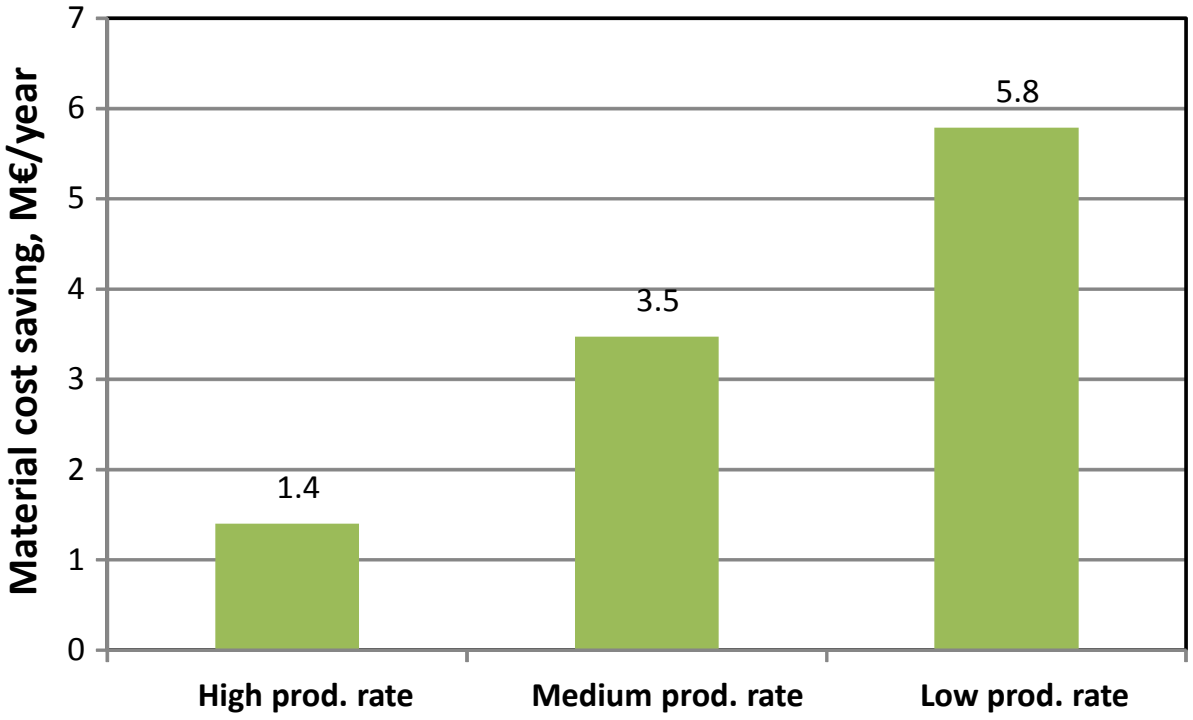
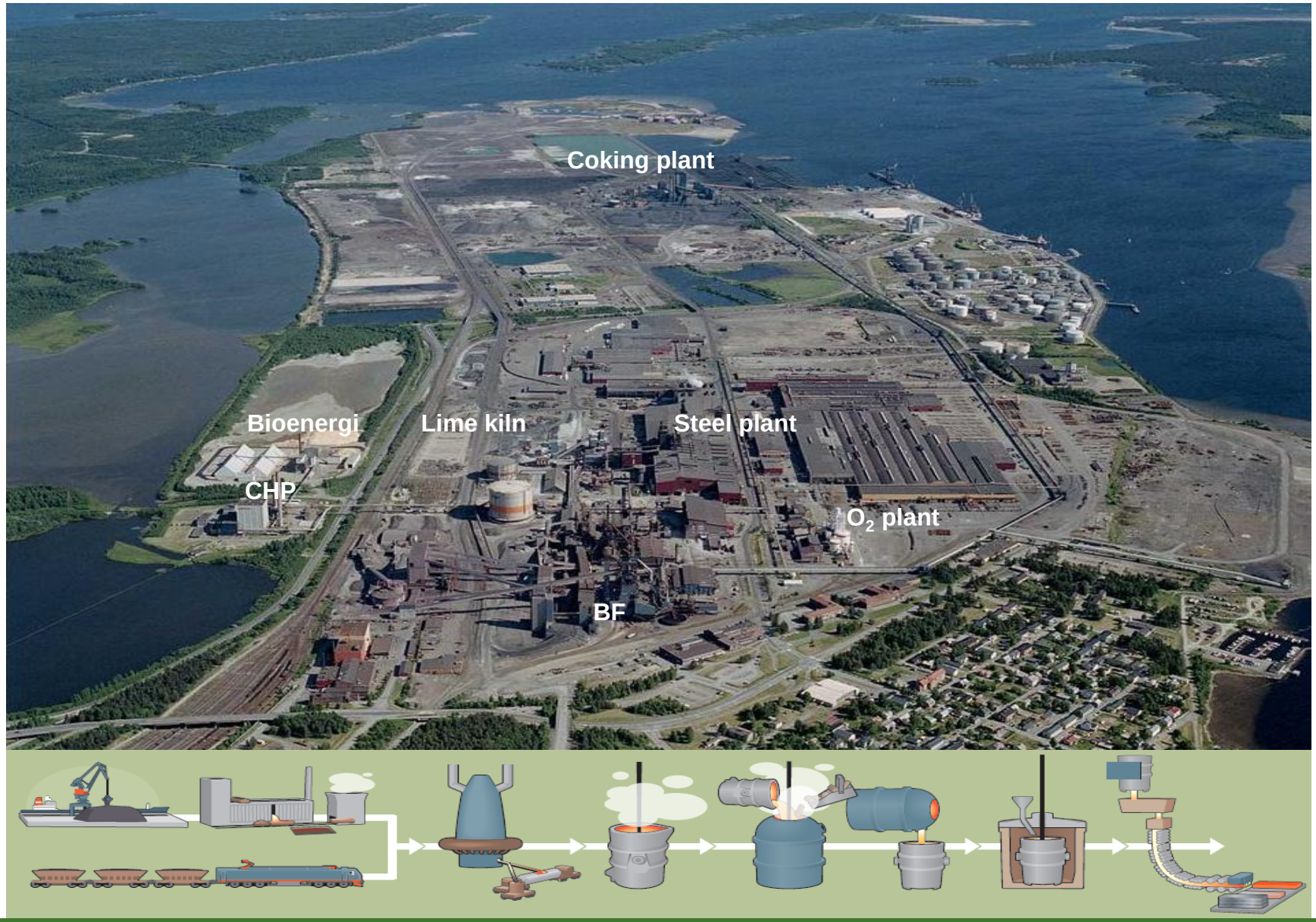
Economical evaluation of SOE at Ruukki



Preferably use COG saved from hot stoves at the reheating furnaces to substitute LPG!

The cost saving are varying at different production rates!

Bird's-Eye photo of SSAB EMEA Luleå



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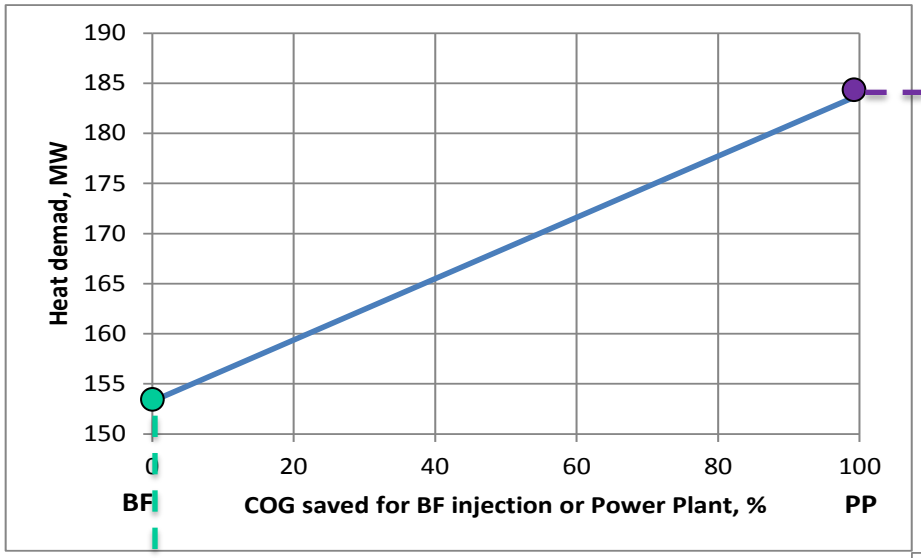
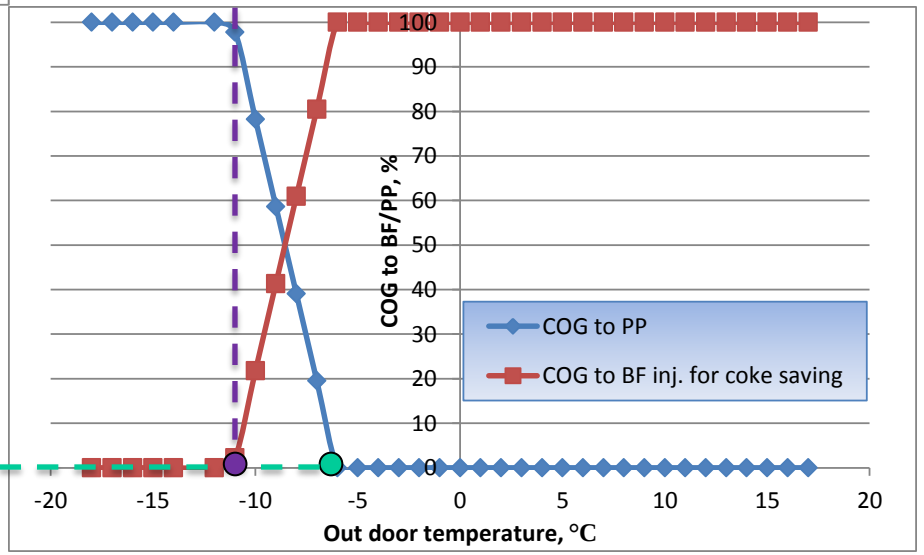
Distribution of COG saved in hot stoves at SSAB Luleå



(-11 °C; 183.8 MW)

(-6 °C; 153.3MW)



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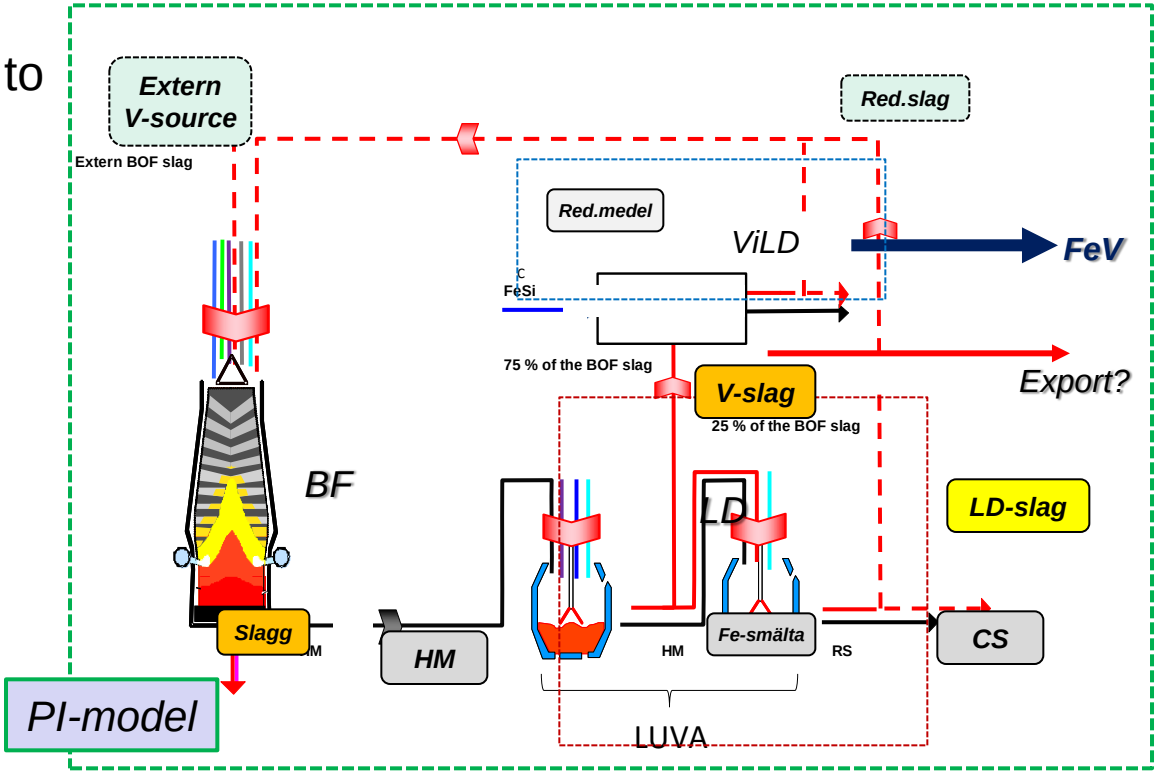
Examples of material efficiency

- Ferrovanadium recovery from LD slag for the case of SSAB EMEA in Luleå

- Common Nordic solution
  - Regional efforts for untreatable wastes

LuVA/ViLD at SSAB EMEA, Luleå

- Background
  - High *V* in LD slag
  - Limits the LD slag external use
  - Meanwhile, valuable *V* product.
- Aim
  - Determine the best method to recover Vanadium
- Method
  - Modeling of different scenarios based on:
    a) Metallurgical knowledge
    b) Industrial trials with two-slag practice in LD



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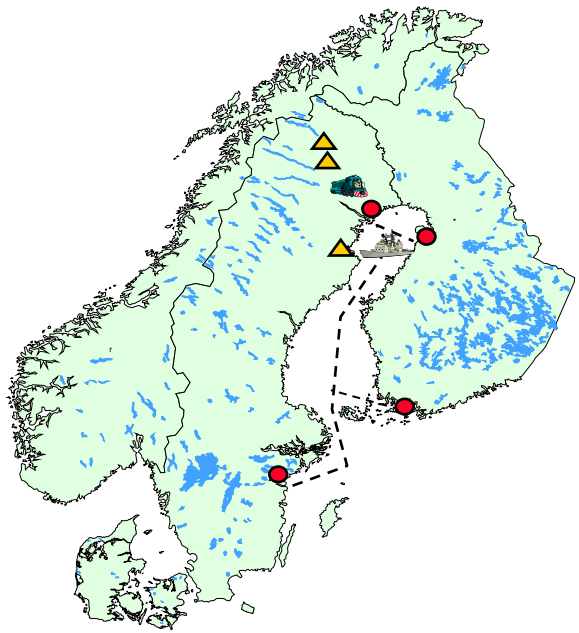
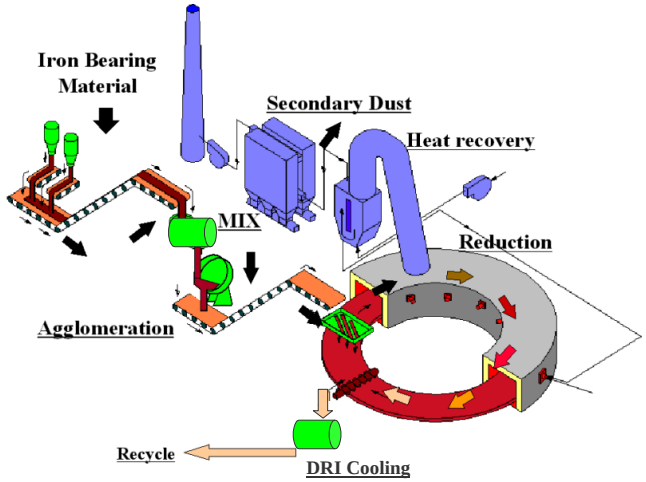
Results – LuVA/ViLD

- Optimal practice (based on LD trials and modeling)
  - Min *V*-content in HM (~0.36%) can be achieved by recycling of secondary, stored LD slag and secondary slag fines fraction.
  - Requires higher tolerance for *P* in the hot metal → lower tapping temp and no dolomitic lime in the LD.
- Consequences
  - Decrease of the LD slag storage,
  - Requires 100% MPBO pellet in the BF burden.

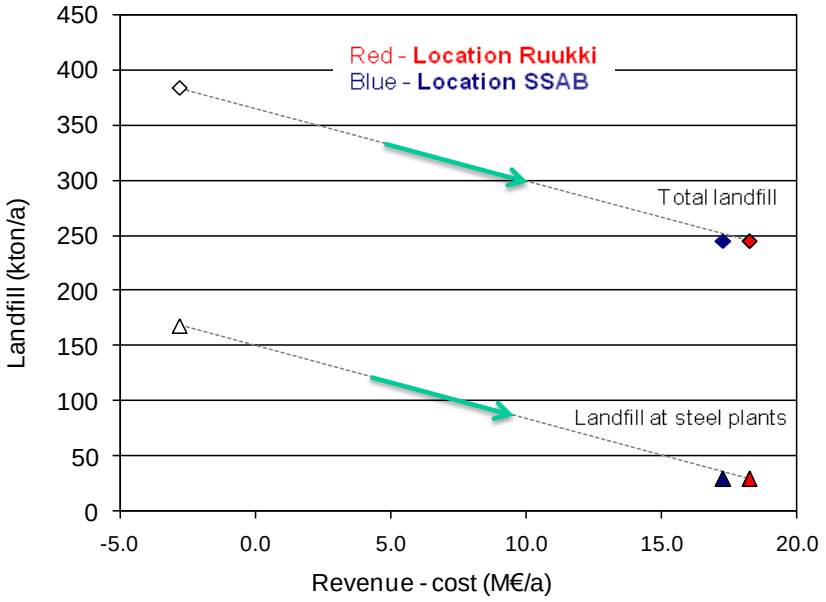
RHF – a common Nordic solution for untreatable wastes





Unit: kton/year

Steelworks	Waste amount
SSAB EMEA, Luleå	60
SSAB EMEA, Oxel.	70
Ruukki	80
FN Steel	20



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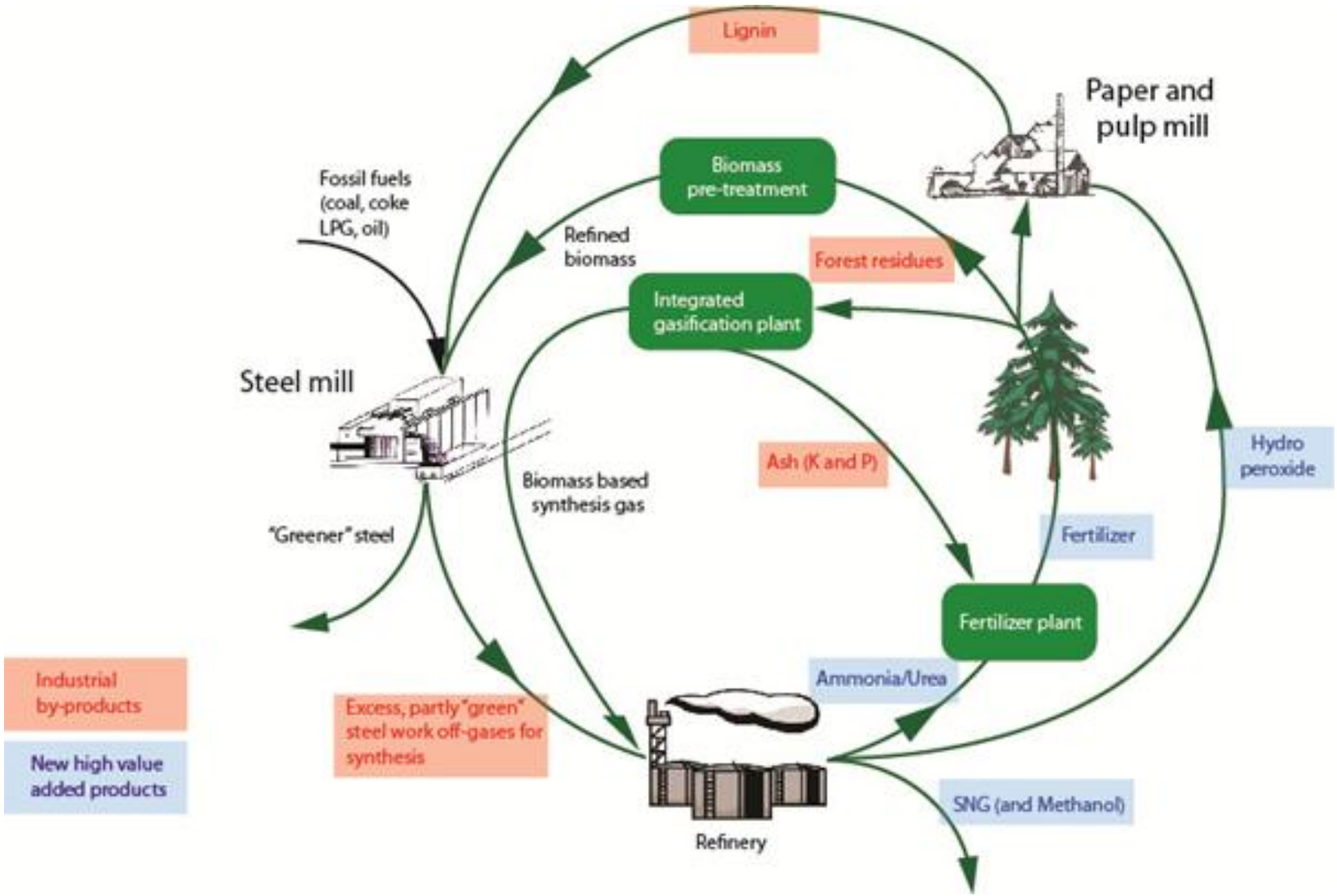
Towards the industry symbiosis …



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On-going projects in the area of energy and CO_2 mitigation

- Biomass utilization in the BF
- Optimisation of BF hot stove operation
- Dry slag granulation and heat recovery
- Preheating and surface cleaning of scrap
- Reuse of low temperature heat (T< 350 °C)
- Process integration for resource management
- Flue gas recirculation with SOE - a new concept
- High efficiency low NO_x BFG based combustion systems in steel reheating furnaces

Concluding remarks

- PI is a useful tool for the steel industry to improve its energy and material efficiency by finding optimal solutions in a most economic and sustainable manner.
- PI can be used for searching answers on strategic issues, e.g. how new processes will fit into the site, retrofit questions, investments, production planning, etc.
- The more complex the system, the higher probability to find new and improved solutions with a system oriented approach.
- Global integrated efforts are needed to further reduce CO_2 emission from the steel industry.

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Thanks for your attention!

More information about Swerea MEFOS
Please visit www.swerea.se/mefos

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