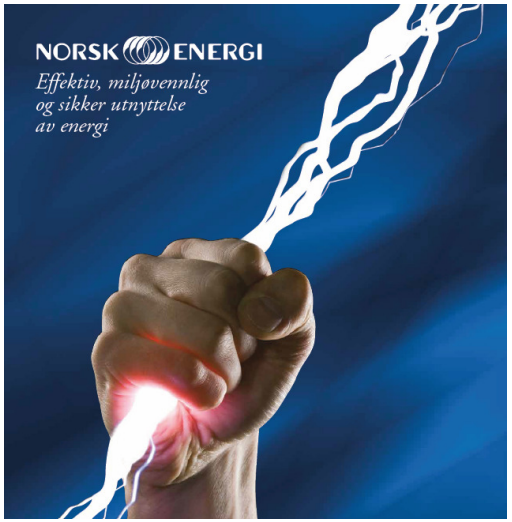

Energy Efficiency in the Ferroalloy Industry

Ferroalloy Europe 2014
23-24 June 2014, Zurich, Switzerland

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Norsk Energi

- **Specialist in thermal energy**

- Norsk Energi is a leading consultancy firm in energy,
- Environment and safety, with special expertise in thermal energy systems.

- Founded in 1916 by the industry in Norway.

- Our company is primarily linked to projects that reduce energy
- consumption and harmful emissions, by other energy efficient
- industrial processes.

- Independent of producers and suppliers of equipment.

- NE has been involved in waste heat recovery project in ferroalloy industry since 1960.

Expert in Energy Recovery:

- Flue gas utilization
- Hot water and steam production
- Feed water system
- Water tube boilers
- Shell boilers
- Steam generators

Norsk Energi participates in all project stages:

- Trouble shooting
- Feasibility study
- Concept study
- Main study and design
- Engineering
- Construction and follow-ups

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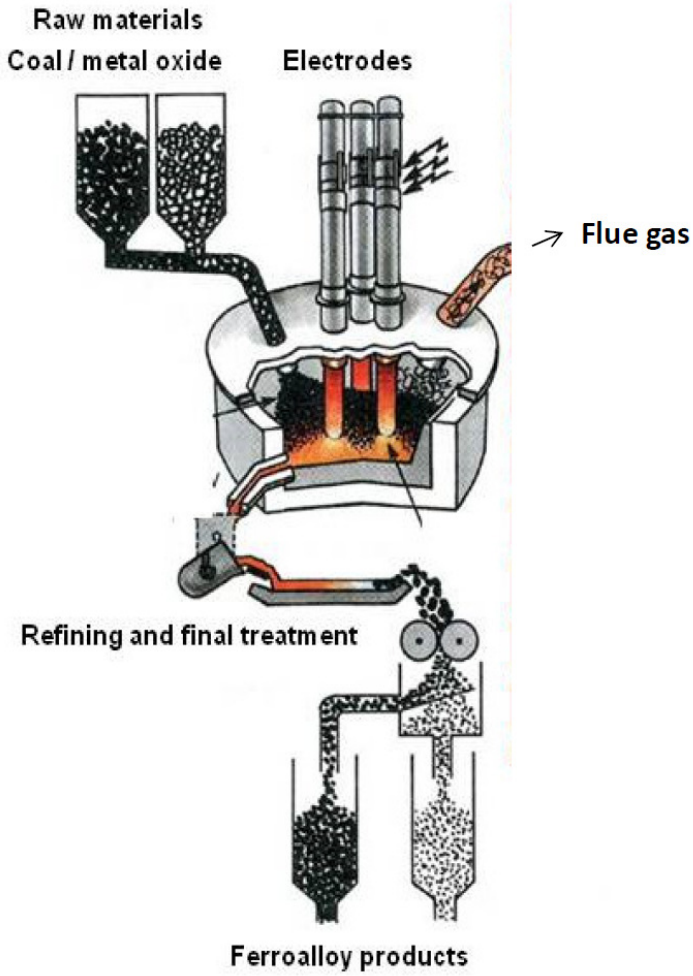
Energy source – Furnace configuration

- **<u>Open or Semi closed furnace</u>**
- Ferro Silicon (FeSi) and Silicon metal (Si-metal)
- Flue gas from the process is leaving as hot gas.
- Energy in the flue gas is typical **80 – 120 %** of furnace electricity consumption.

- **<u>Closed furnace</u>**
- Ferromanganese (FeMn), Silicon magnese (SiMn) and Calsium Carbide (CaC2)
- Flue gas from the process is unburned and rich on combustion compounds as CO and H_2.
- Combustion energy (after cooling and cleaning) in the gas is typical **50 – 60 %** of furnace electricity consumption.



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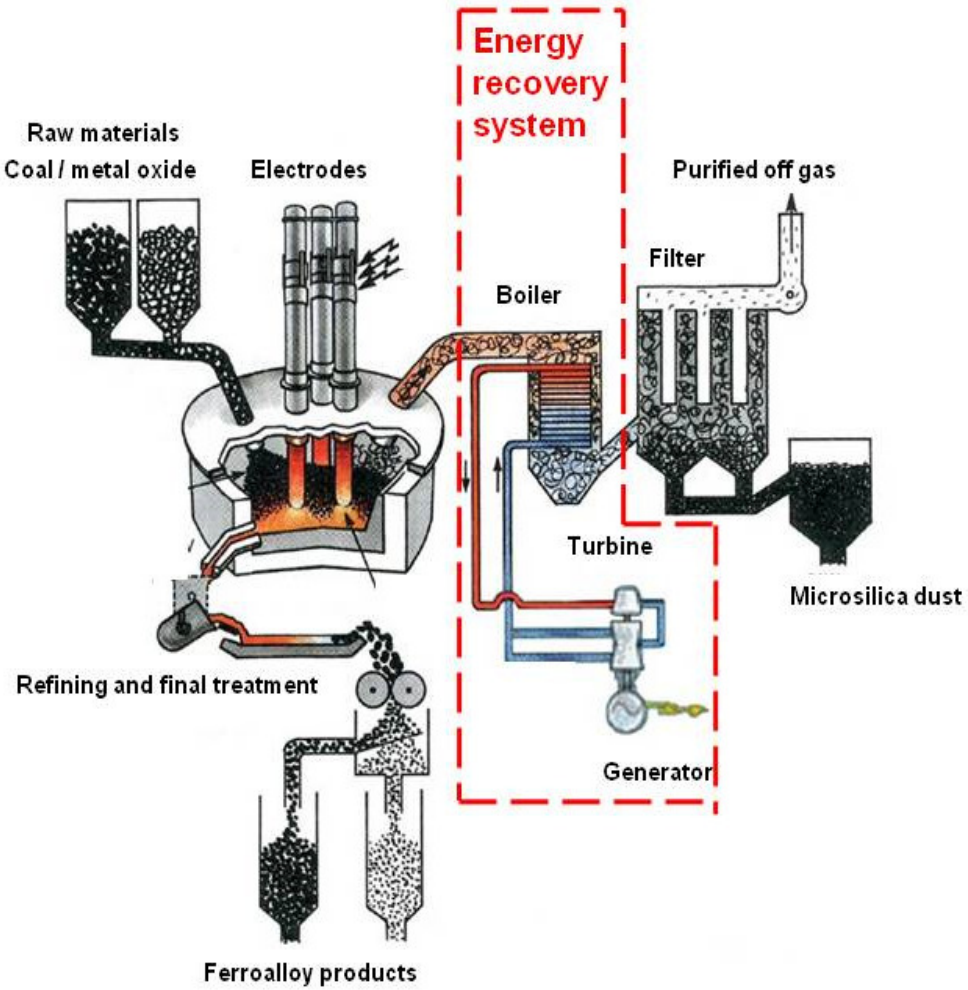
Energy Recovery from open or semi closed furnace

- Ferro Silicon (FeSi) and Silicon metal (Si-metal)



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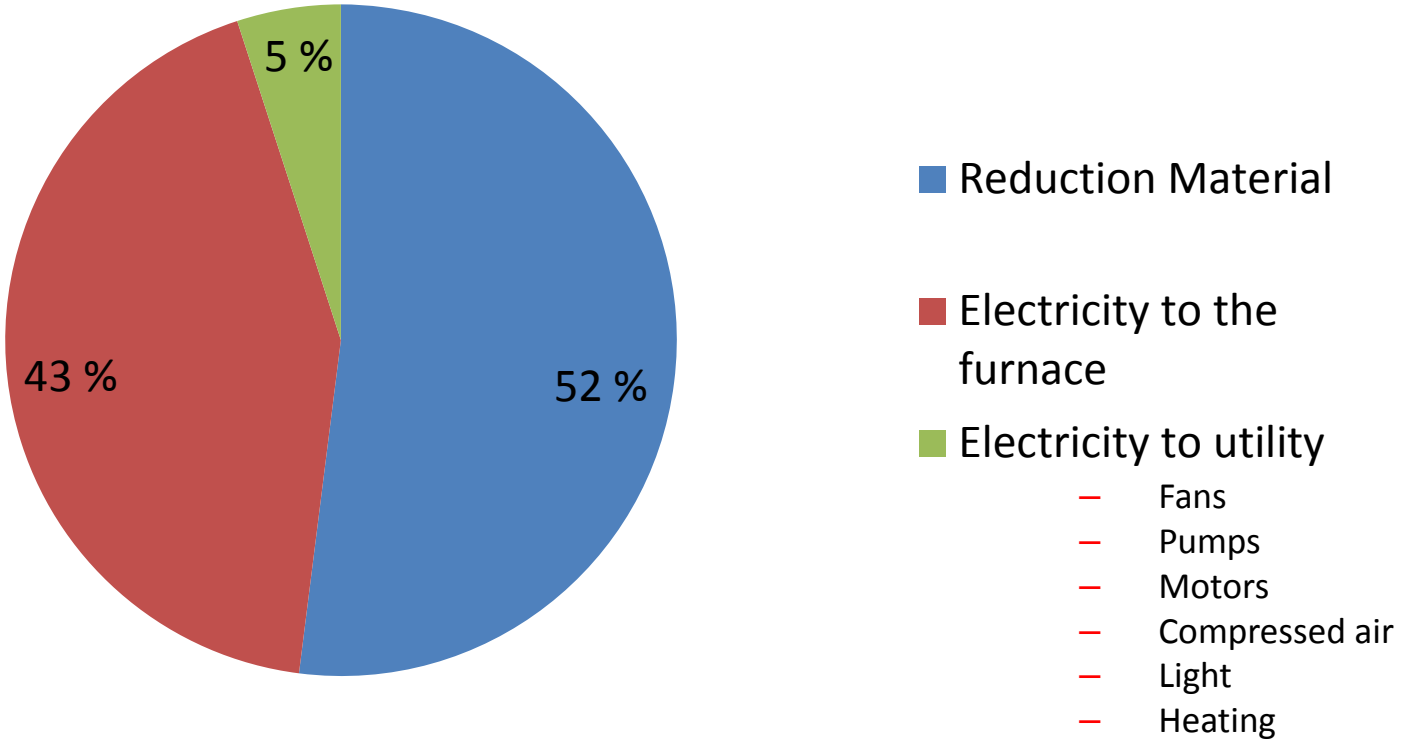
Typical energy consumption for a FeSi-plant



Typical potential reduction on electricity to utility: 10 – 20 %.

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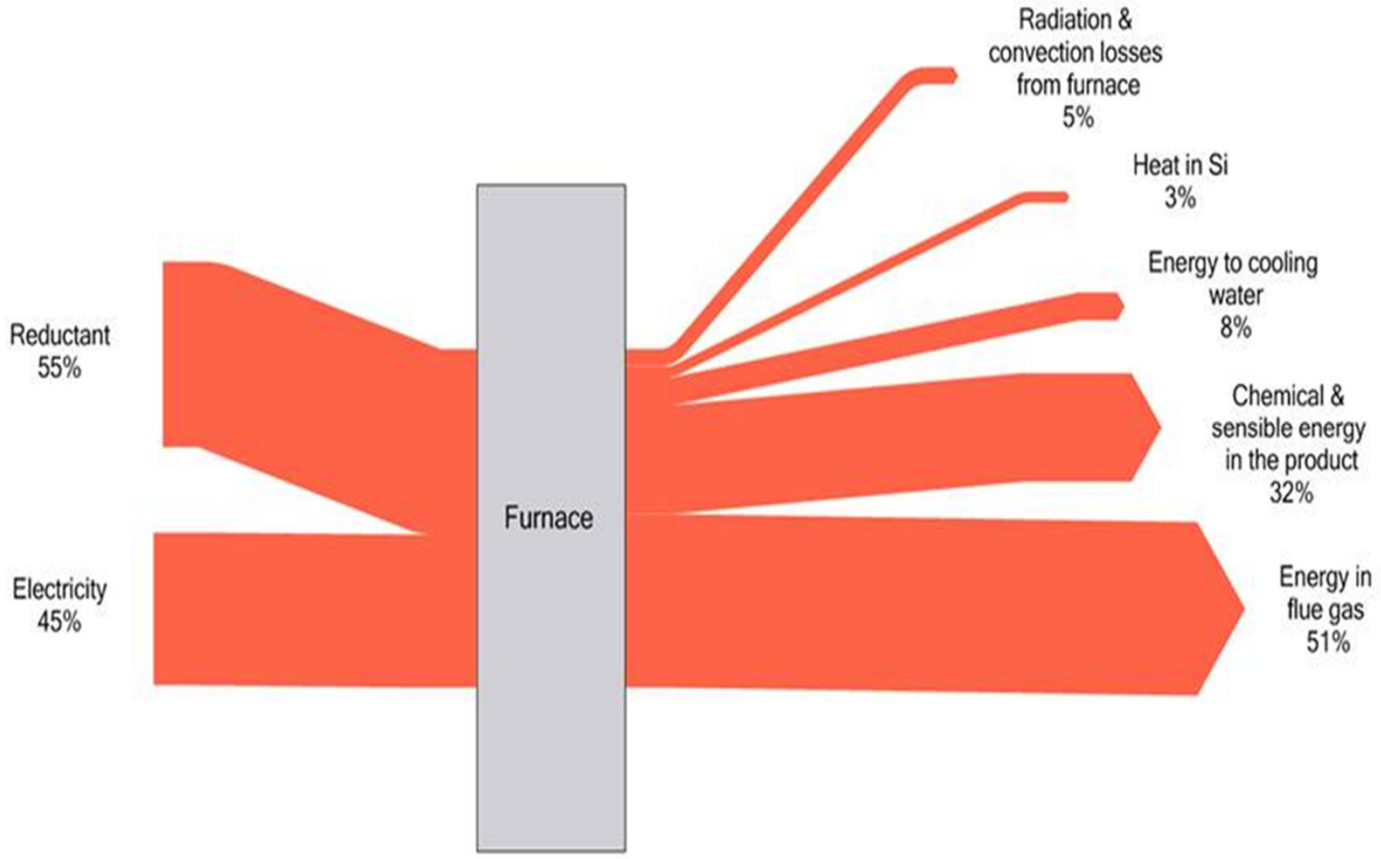
Energy Efficiency in the Ferroalloy Industries

Standard heat balance for a FeSi furnace.



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Energy recovery from cooling water and product.

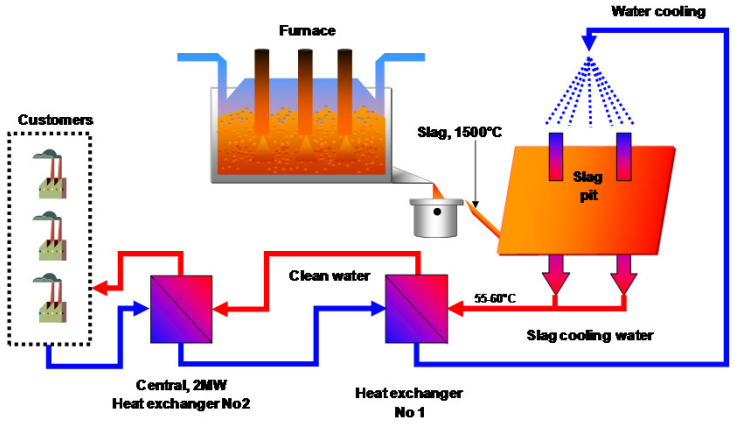
- **Water cooling of furnace hood and outlet**

- Traditionally a water temperature of 30 – 40 ˚C are used.
- Can be used for low temperature heating system, fish farm, etc.

- By increasing the cooling water temperature to 80 – 90 ˚C it can be used for district heating.

- **Heat recovery from slag.**

- Heat recovery system to produce low temperature water 70 – 85 degrees by quenching the slag with water.



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Energy recovery of flue gas

High energy content and temperature

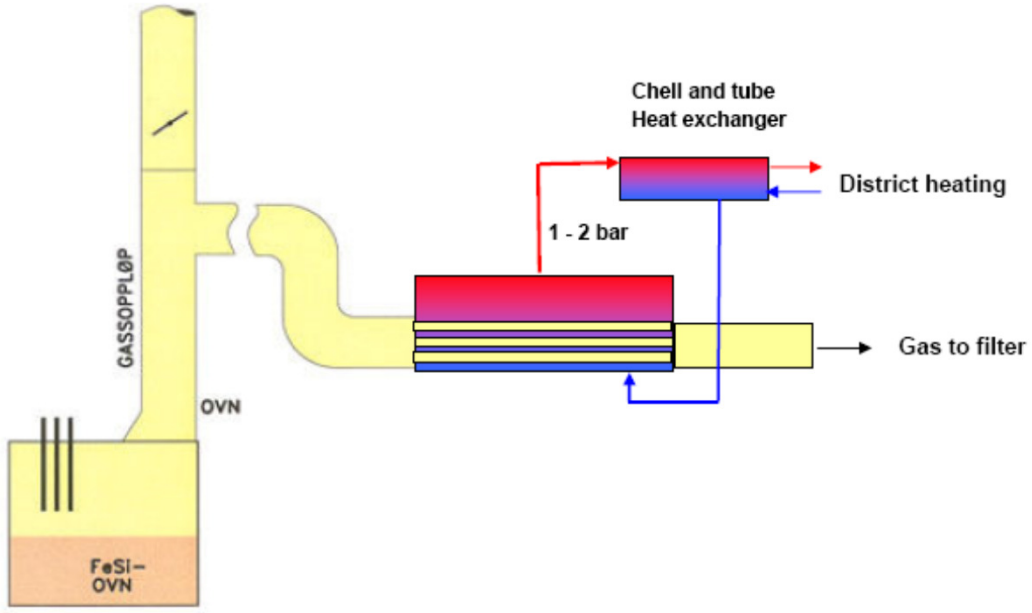
- 80-130 %, ref electricity consumption in the furnace
- Utilizing of steam

- **Heat recovery for steam production**
  - Supply steam to internal or external customer (70 – 90 %, ref electricity consumption in the furnace)
  - Reduce the flue gas volume to the filter

- **Heat recovery for steam production and power production**
  - Reduce the electrical consumption with 20-30 %
  - Reduce the external load on high voltage network

Heat exchangers for steam production to district heat

For heat recovery of steam (1 – 2 bar), only one boiler is needed.
The boiler is a smoke tube boiler and no cleaning equipment is needed.

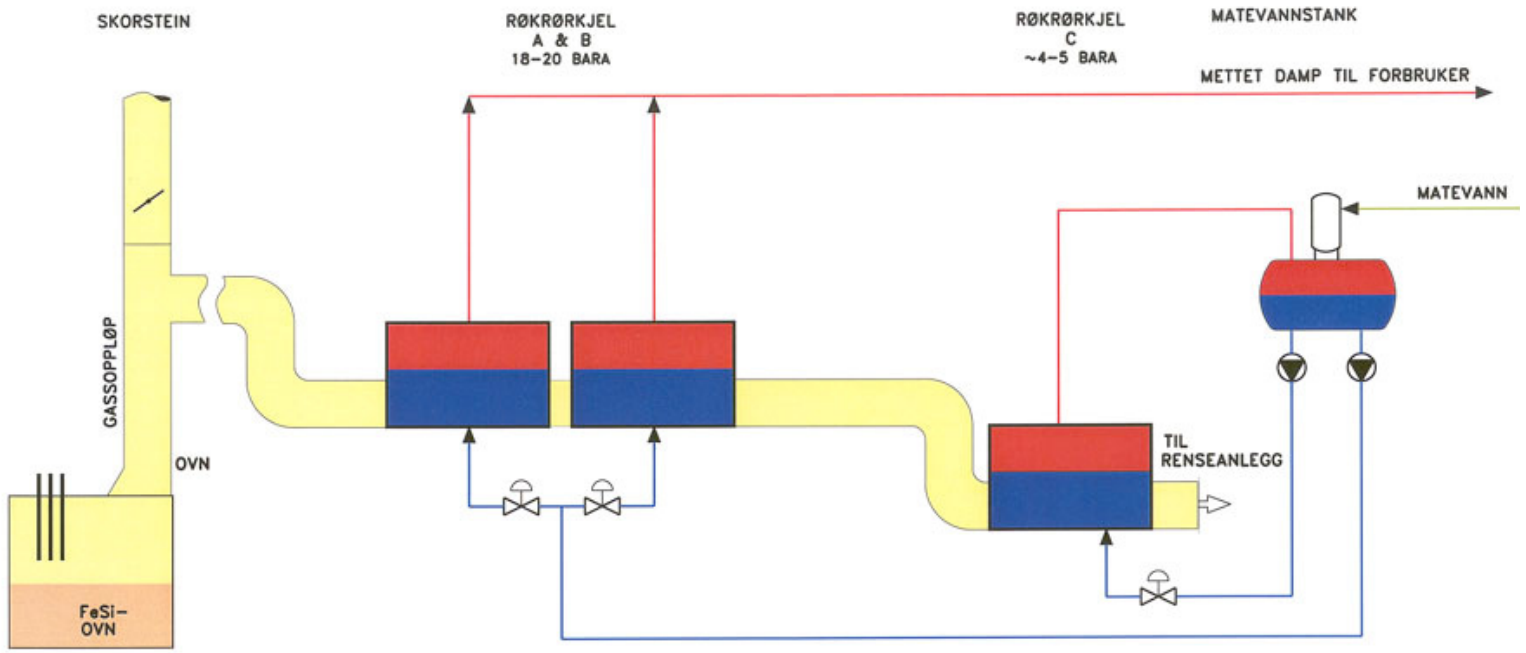


Reference project – Fesil Rana Metall

- 2 Heat recovery boilers from 2 FeSi-furnaces
  - First installed in 1993, the second in 2011
- Shell boilers producing saturated steam
- Total heat recovery approximate: 10 and 12 MW
- Supply heat to the local community

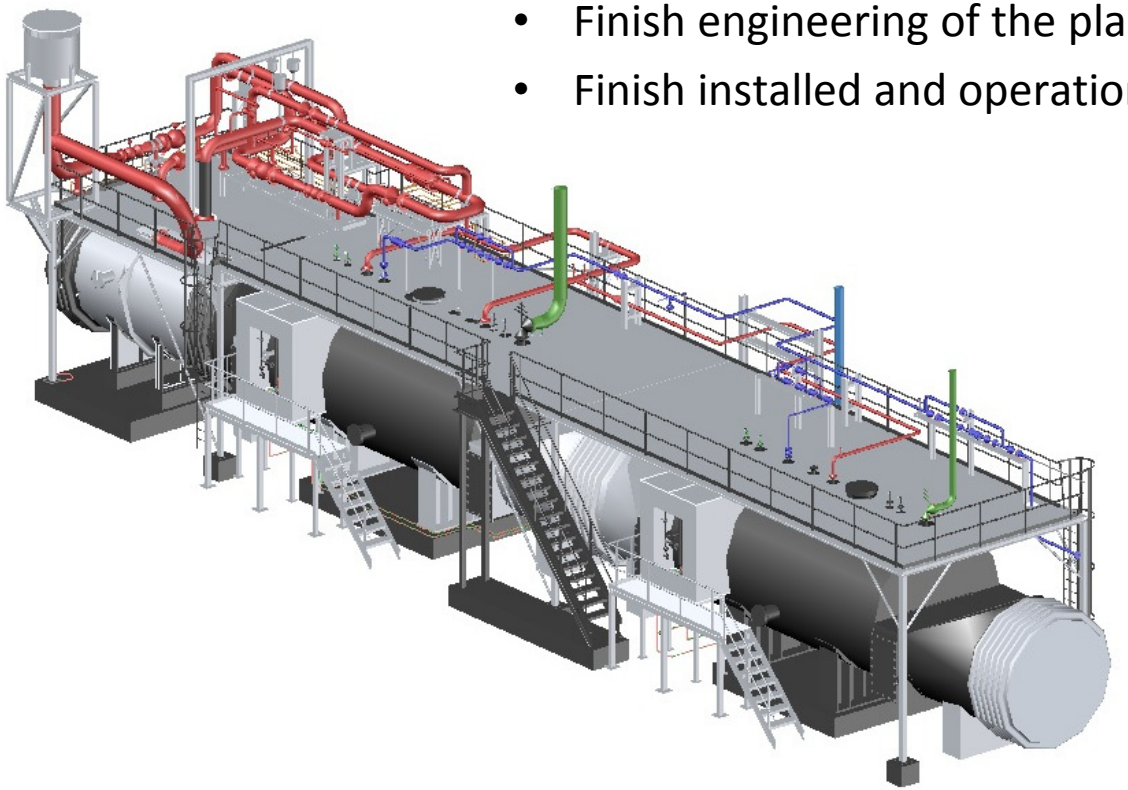
Heat Exchangers for steam production only

For heat recovery of steam (1 – 20 bar), 1, 2 or 3 smoke tube boiler can be used, depending of temperature and pressure.



Reference project – Chemk (Cheljabinsk, Russia)

- Heat recovery from 1 FeSi-furnace
- Smoke tube boiler
- Total heat recovery approximate: 12 MW
- Supply 10 bar and 330 ˚C steam to consumers
- Finish engineering of the plant Q4 2012
- Finish installed and operation in Q3 2014



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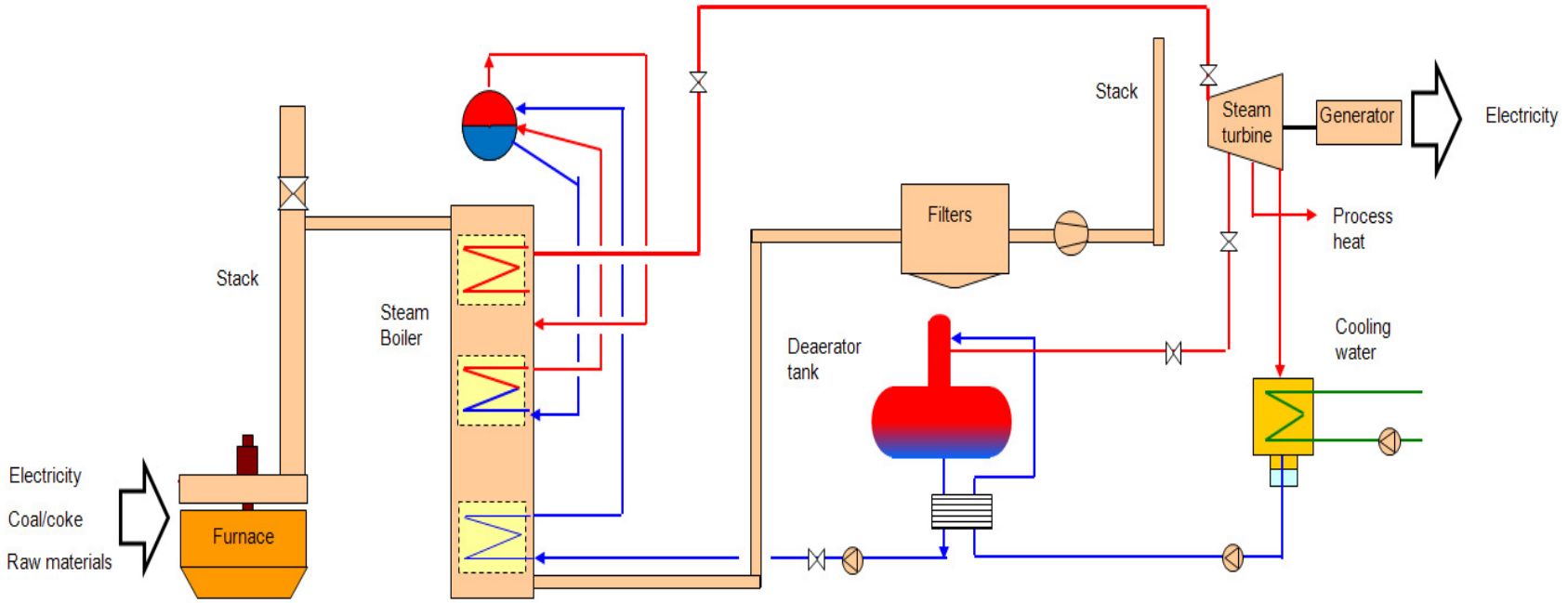
High pressure system



- Characteristic:
- Water tube boiler
- Superheated steam
- Electricity production

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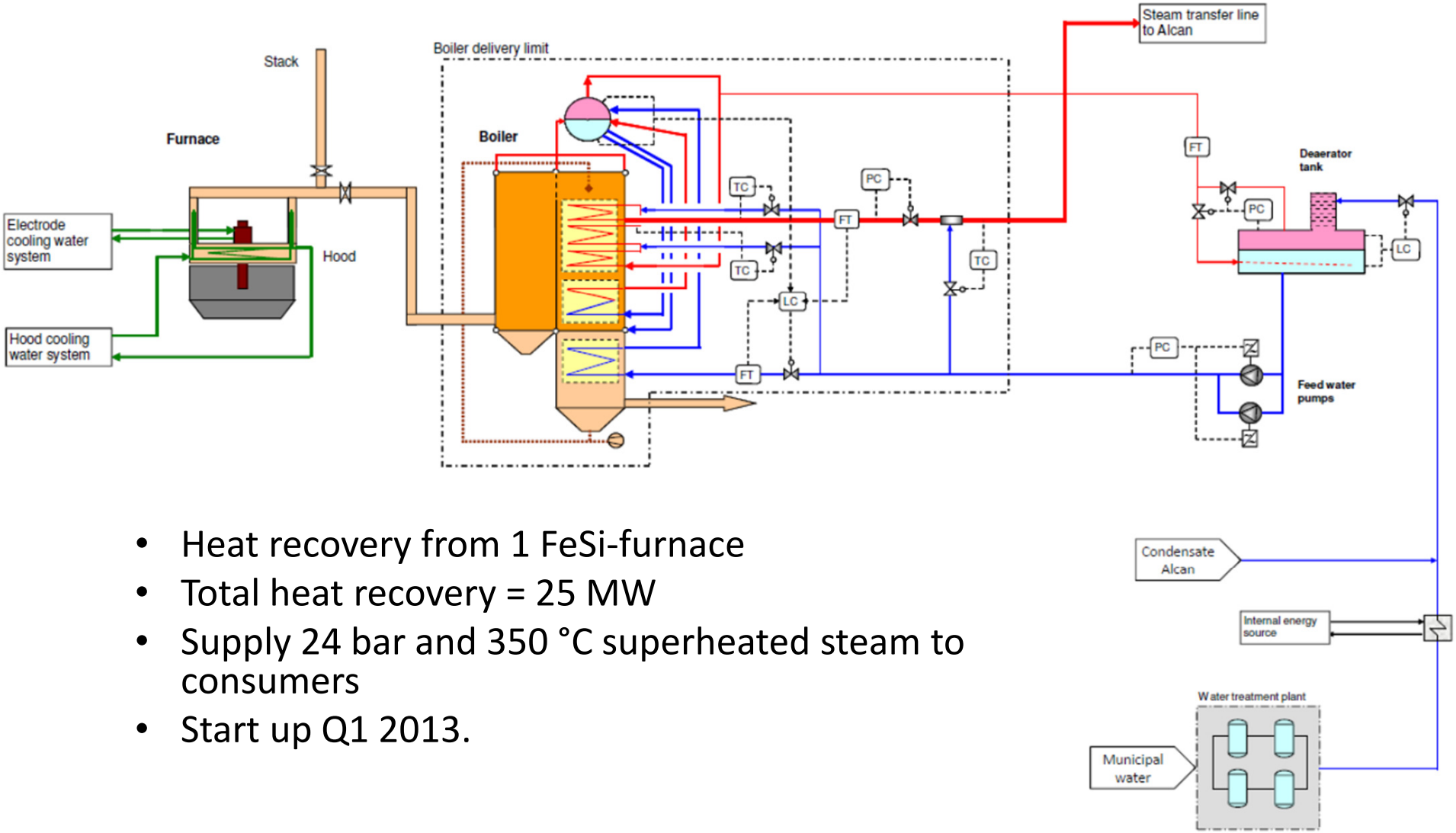
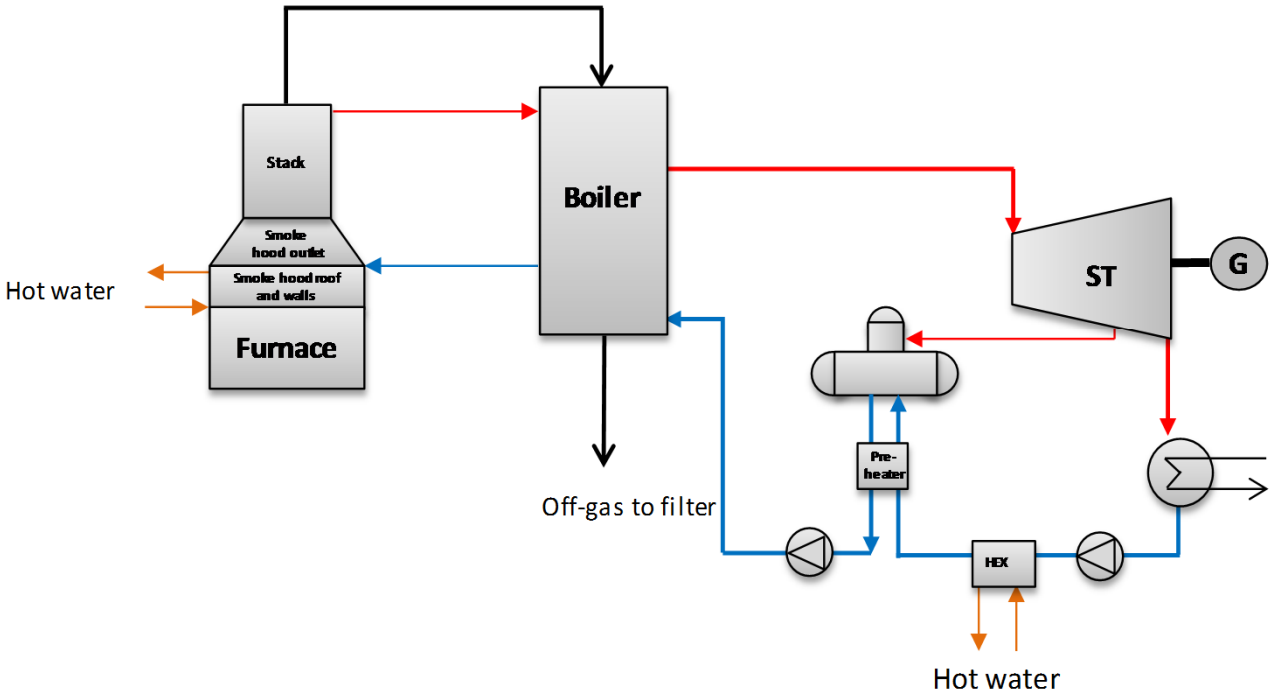
Reference project – Elkem Chicoutimi, Canada



- Heat recovery from 1 FeSi-furnace
- Total heat recovery = 25 MW
- Supply 24 bar and 350 °C superheated steam to consumers
- Start up Q1 2013.

WHR for el. power production – best practice



- Heat recovery of flue gas by use of WHR Boiler
- Replace water cooled element to steam cooled element where possible
- Produce ‘hot’ water in water cooled element for heat recovery (condensate preheating)

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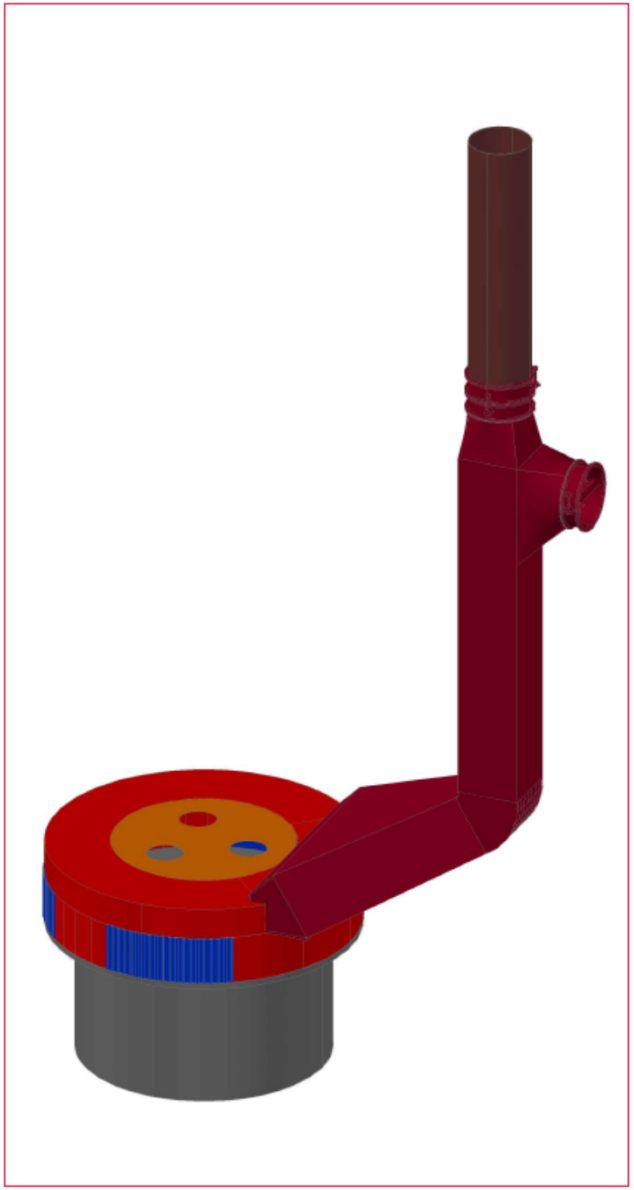
Steam (steam cooling) producing stack

- Steam cooling, instead for water or air cooling
- Designed to handle high flue gas temperature
- Increase the effect of the energy recovery.
- More robust design of the stack.



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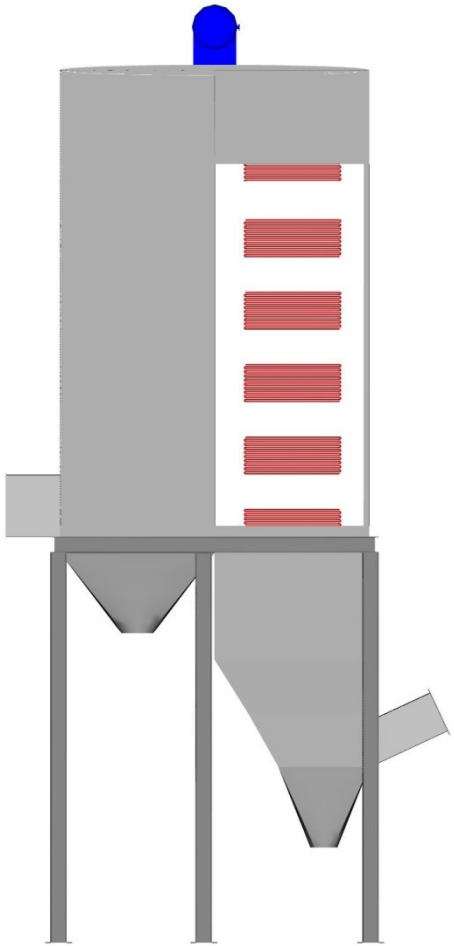
Cooled channel/duct between furnace and boiler

- Smoothes down the large gas temperature variations before entering the tube banks.
- Cooling down the dust before entering the tube banks.



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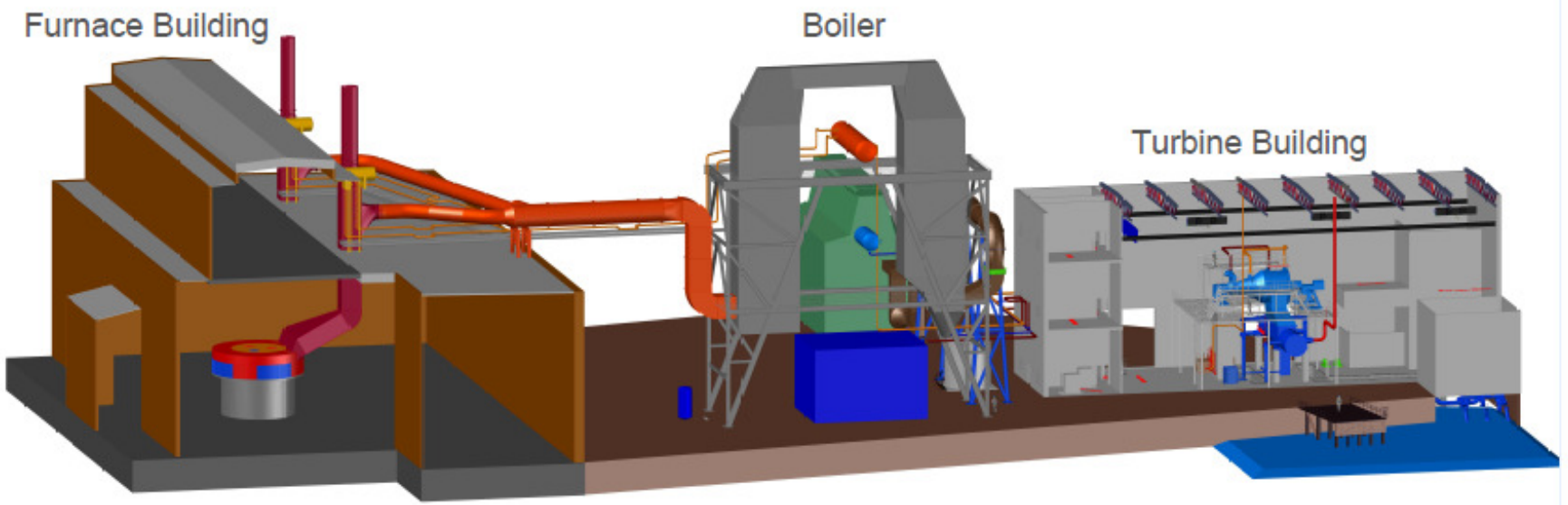
Waste Heat Recovery Plant - Typical

Typical system for Heat Recovery and Power production Plant



Reference project – Finnfjord smelteverk, Norway

- Heat recovery from 3 FeSi-furnaces
- Steam producing cooled ducts close to the furnace
- 2 boilers for heat recovery from the flue gas
- Total heat recovery 115 MW
- Supply 40 bar and 440 ˚C steam.
- Steam turbine size: 40 MW
- Start up October 2012.

Norsk Energi role:

Responsibility of concept study, main study and implementation.

The lead role in the technical concept and design

Responsibility at execution:

- Process and function responsible
- Boiler
- Steam producing element at the furnaces
- Steam turbine
- Feed water system
- Stem and condensate piping between the equipment
- Design and monitoring of water treatment
- Flue gas dampers

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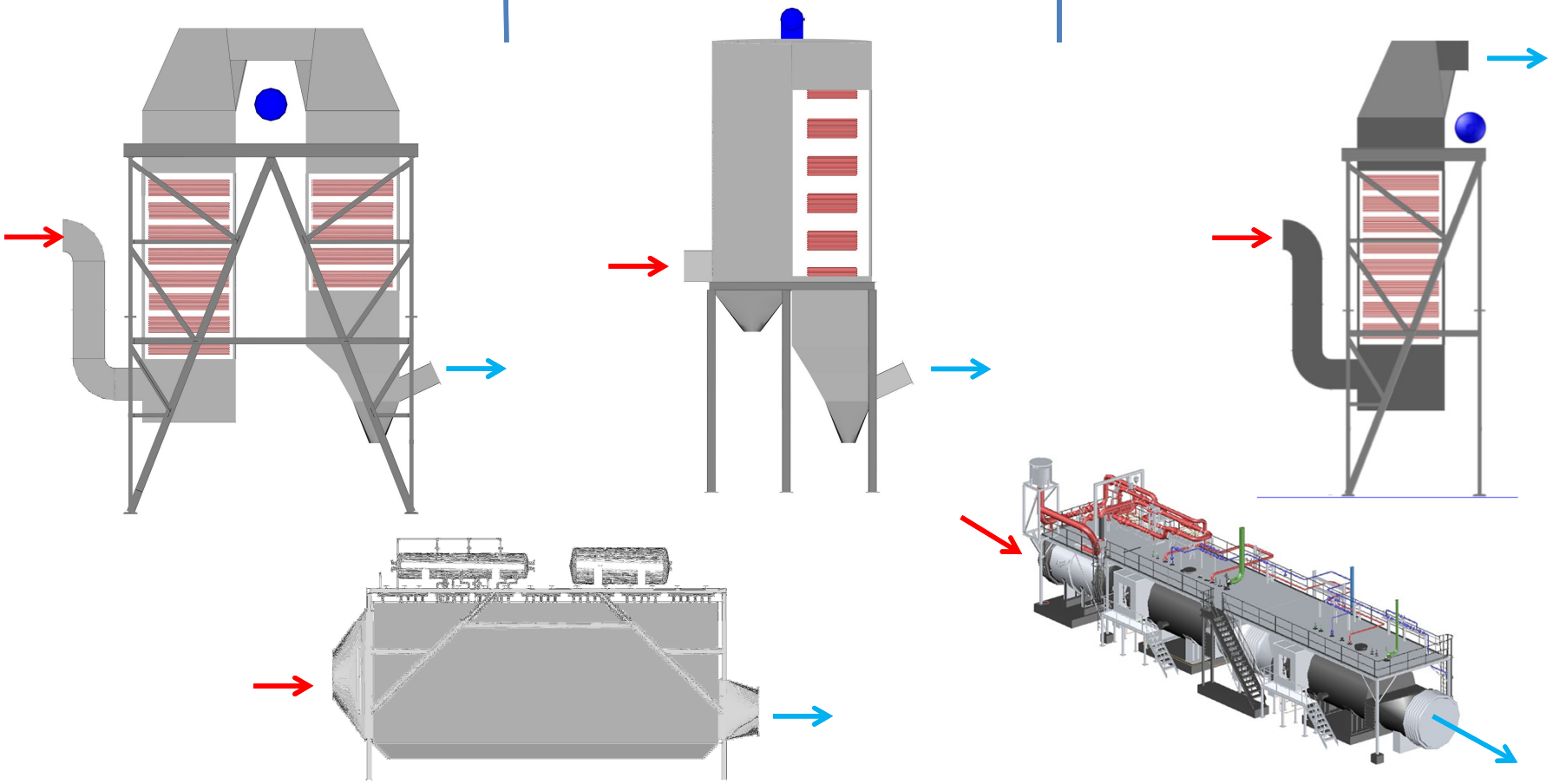
Typical Boiler layout for el power production

– 40 bar, 440 ˚C | 24 bar, 370 ˚C | 13 bar, 330 ˚C



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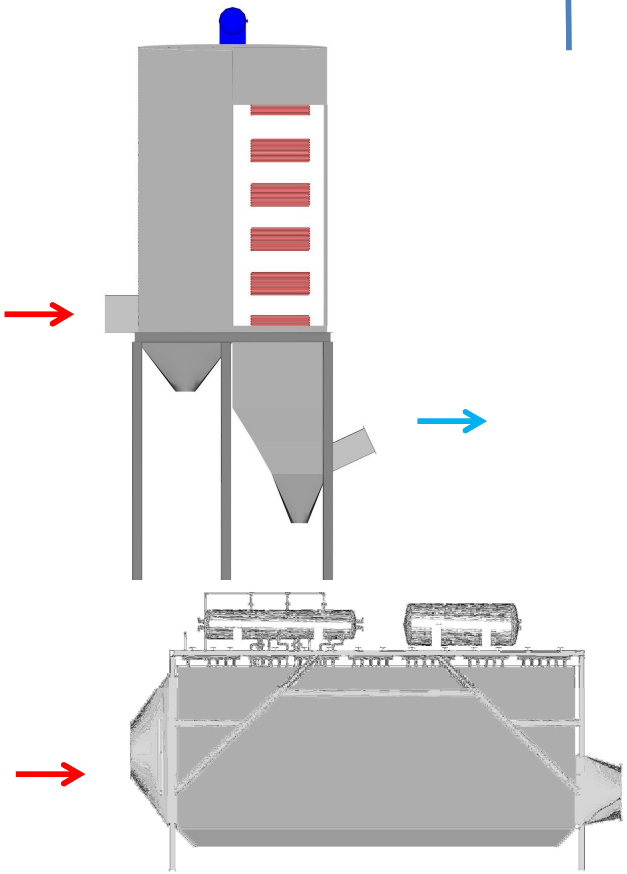
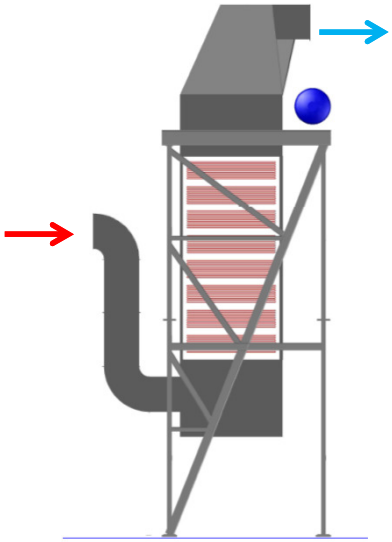
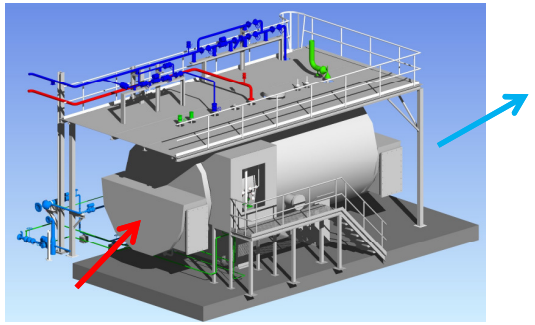
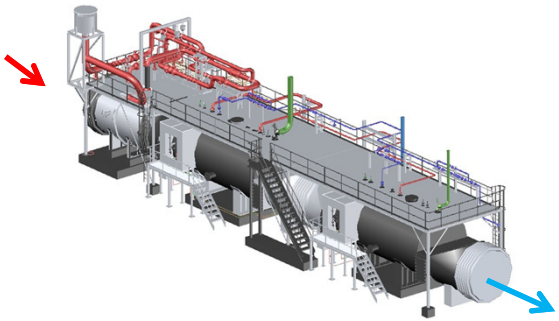
Typical Boiler layout for steam production

20 - 60 bar, Superheated steam	– 1 - 16 bar, – Some superheated	1 - 16 bar, Saturated steam

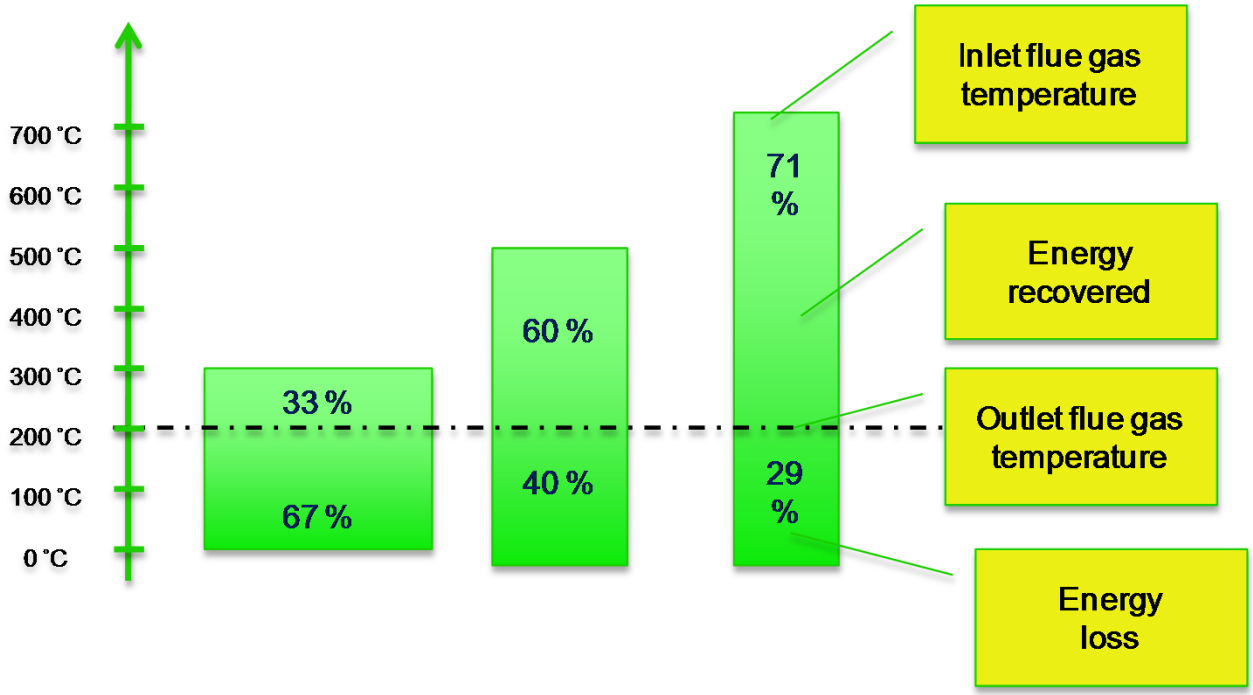








The importance of high flue gas temperature



- If the flue gas is at 300 °C at the inlet, only 33 % of the energy in the gas may be recovered in the boiler and used for steam production
- At 500 °C, approx. 60 % of the energy is recovered
- At 700 °C, approx. 71 % of the energy is recovered

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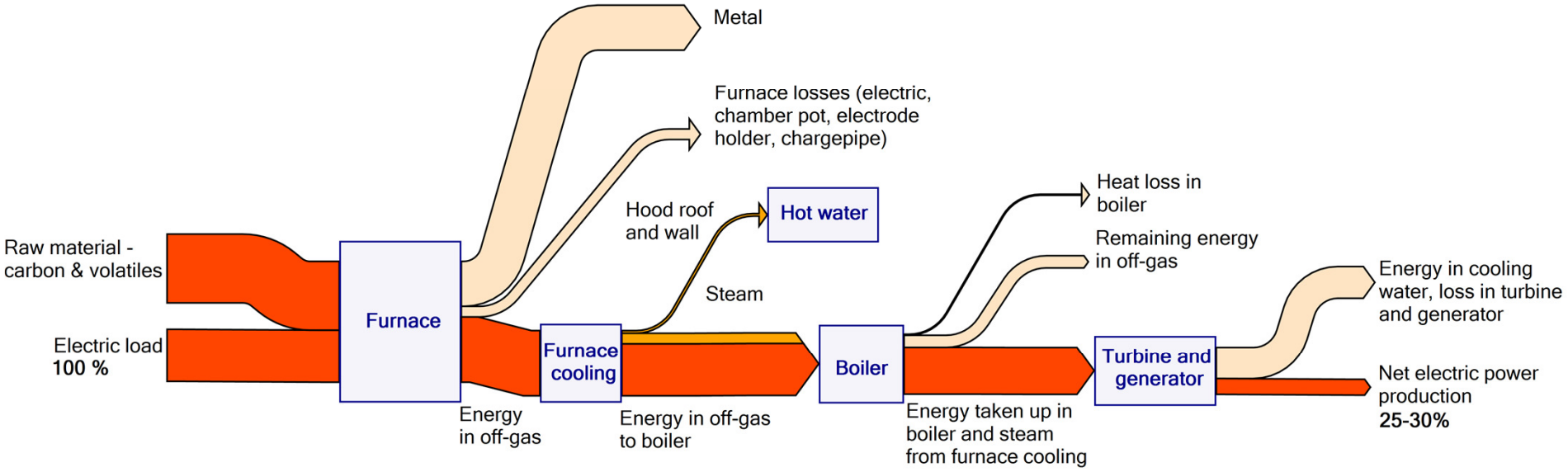
Energy balance through process

Typical Energy Balance of a Waste Heat Recovery Process



Percentages are based on typical numbers

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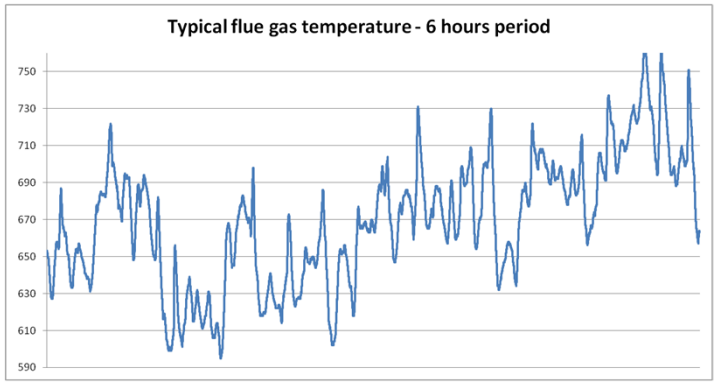
Success factors specially for FeSi and Si-metal processes:

- The WHR system should be designed to handle all flue gas temperature variations from the furnace



- The boiler must be equipped with sufficient dust removing equipment.

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Typical efficiency HRPP Plant

		Low	Typical	High	Factors affecting the efficiency:
Power in flue gas upstream boiler or SCE (ref furnace power)	%	100	115	130	• Type and size of furnace • Raw material (coke, coal, wood) • Water cooling and heat loss
Boiler efficiency (ref power in flue gas)	%	55	70	80	• Flue gas inlet temperature • Heat recovery furnace hood • Heat recovery stack and ducting • Feed water pre-heating • Steam pressure and temperature • Flue gas outlet temperature
Steam turbine efficiency (ref power in boiler)	%	25	30	32	• Steam pressure and temperature • Condensate pressure • Size and type of steam turbine • Water cooling temperature
Net power production (ref steam turbine)	%	88	90	92	• Pump and fan size • Frequency converter • Water cooling • Air cooling
Total electrical power recovery (ref furnace power)	**%**	**12**	**22**	**30**	

Typical example on power production and investment cost

Plant with heat recovery and power production plant from 2 x 30 MW FeSi furnace. Two boilers and one steam turbine					
			Low	**Typical**	**High**
Furnace load (2 x 30 MW)	**MWel**		**60**	**60**	**60**
Power in flue gas (ref furnace power)	MW		63	69	78
Heat recovery boiler	MW		35	48	62
Electrical Power production	MW		8,7	15,0	20,0
Net el production	MW		7,6	13,5	18,4
Typical rated power on steam turbine	MW		9	16	22
Total net electrical power production (94 % plant operation)	GWh		60	115	160
Typical Investment cost	**Mill EUR**		**40 -50**	**65 - 75**	**80 - 90**
Typical investment cost / Typical rated power on steam turbine	Mill/MW		~ 5,0	~4,5	~4
Typical investment cost / Total net el production	Mill/GWh		~0,7	~0,6	~0,6

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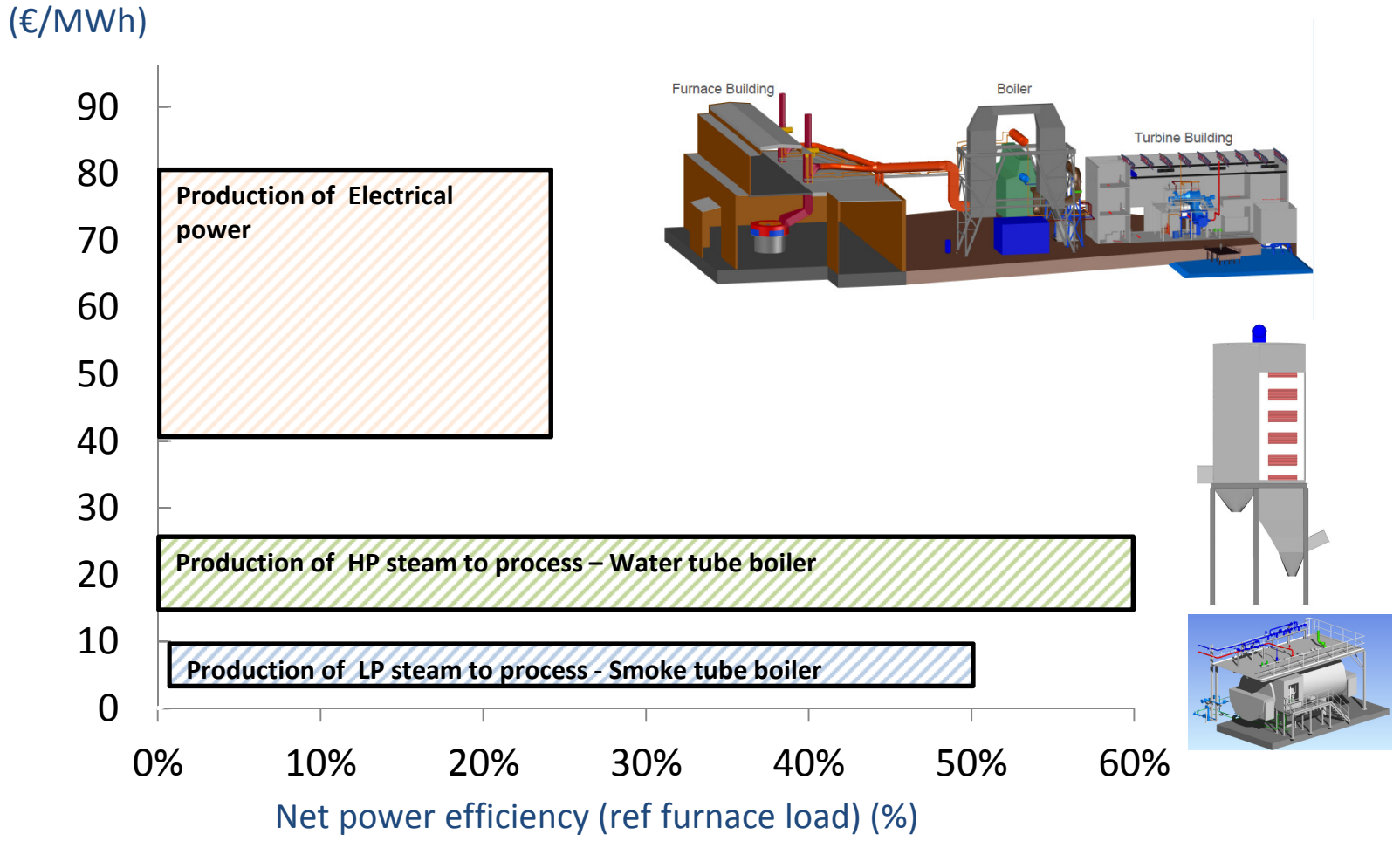
Typical Resulting production cost

Annual capital, operating and maintenance cost



- Water tube boiler: Payment period: 15 year, Interest: 8 %, annuity factor: 0,12.
- Smoke tube boiler: Payment period: 10 year, Interest: 8 %, annuity factor: 0,15.
- Operation and maintenance cost it typical 7-10 % of the resulting production cost.

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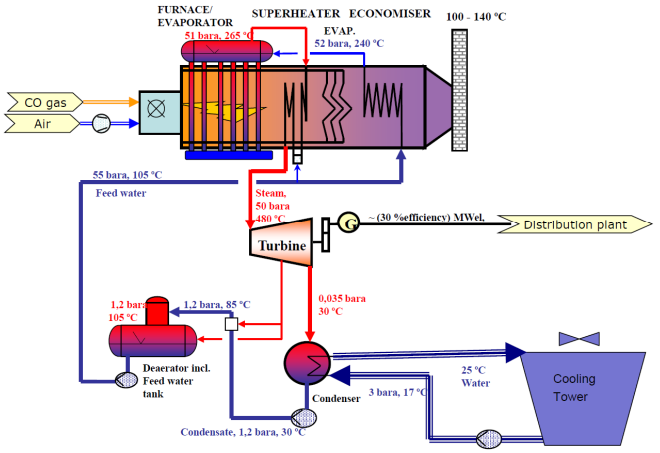
Waste Heat recovery from closed furnace

- **Production in closed furnace**
  - Ferromanganese (FeMn), Silicon magnese (SiMn) and Calsium Carbide (CaC_2)
  - Flue gas from the process is unburned and rich on combustion compounds as CO and H_2.
  - The gas can be cleaned in venture scrubber and used as energy in boilers.
  - Energy is unburned gas is typical 50-60 % of furnace electricity consumption.



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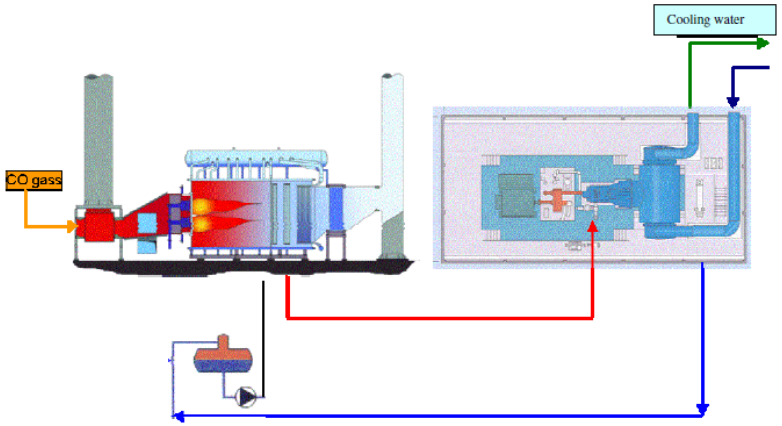
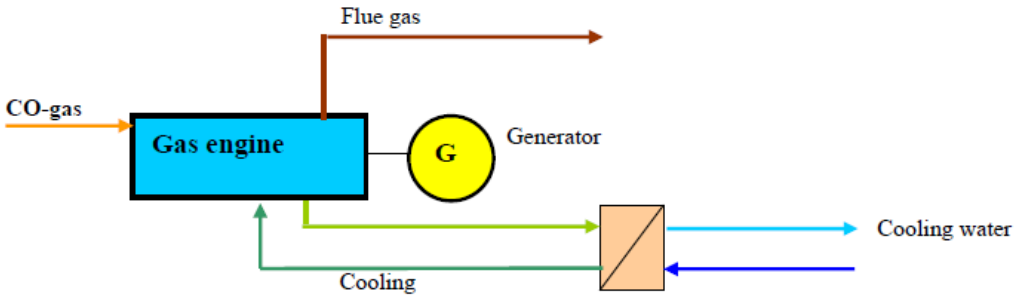
Possible technical solution – CO gas

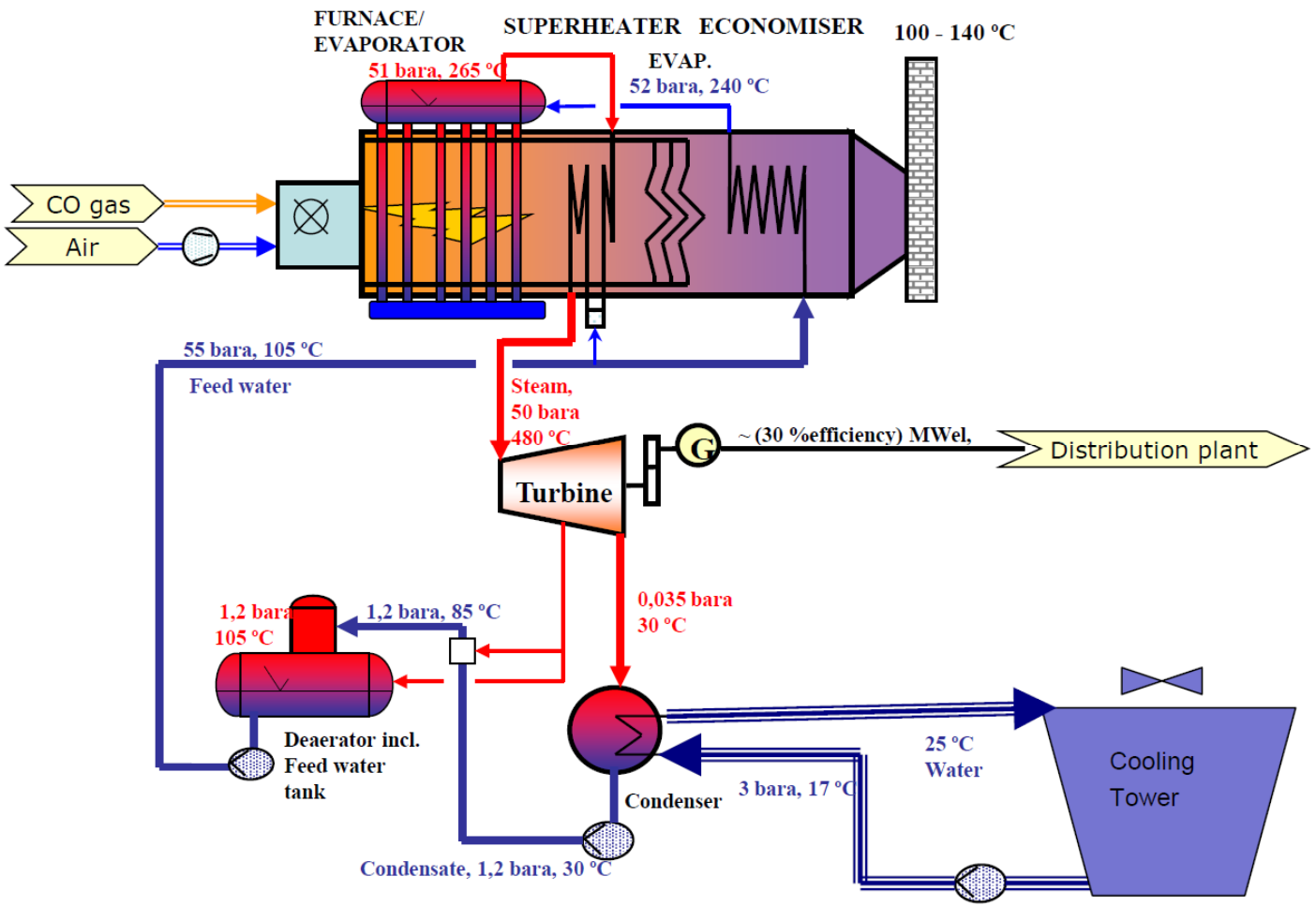
- Steam power plant



- Gas Engine



Steam Power Plant for CO-gas



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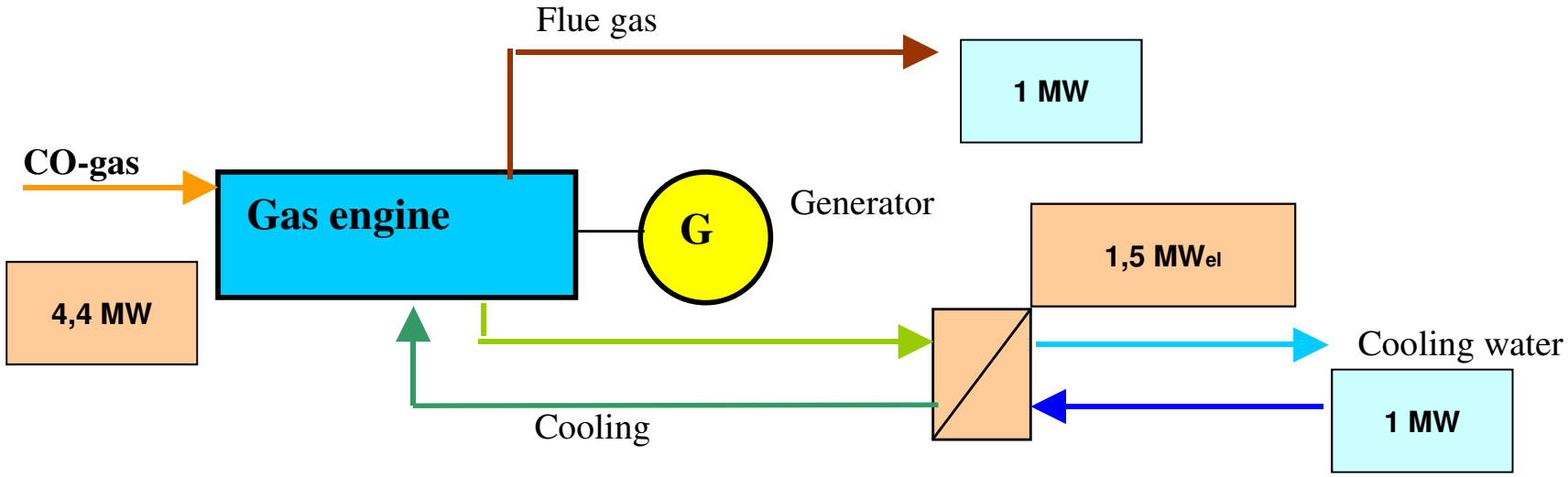
Gas Engine



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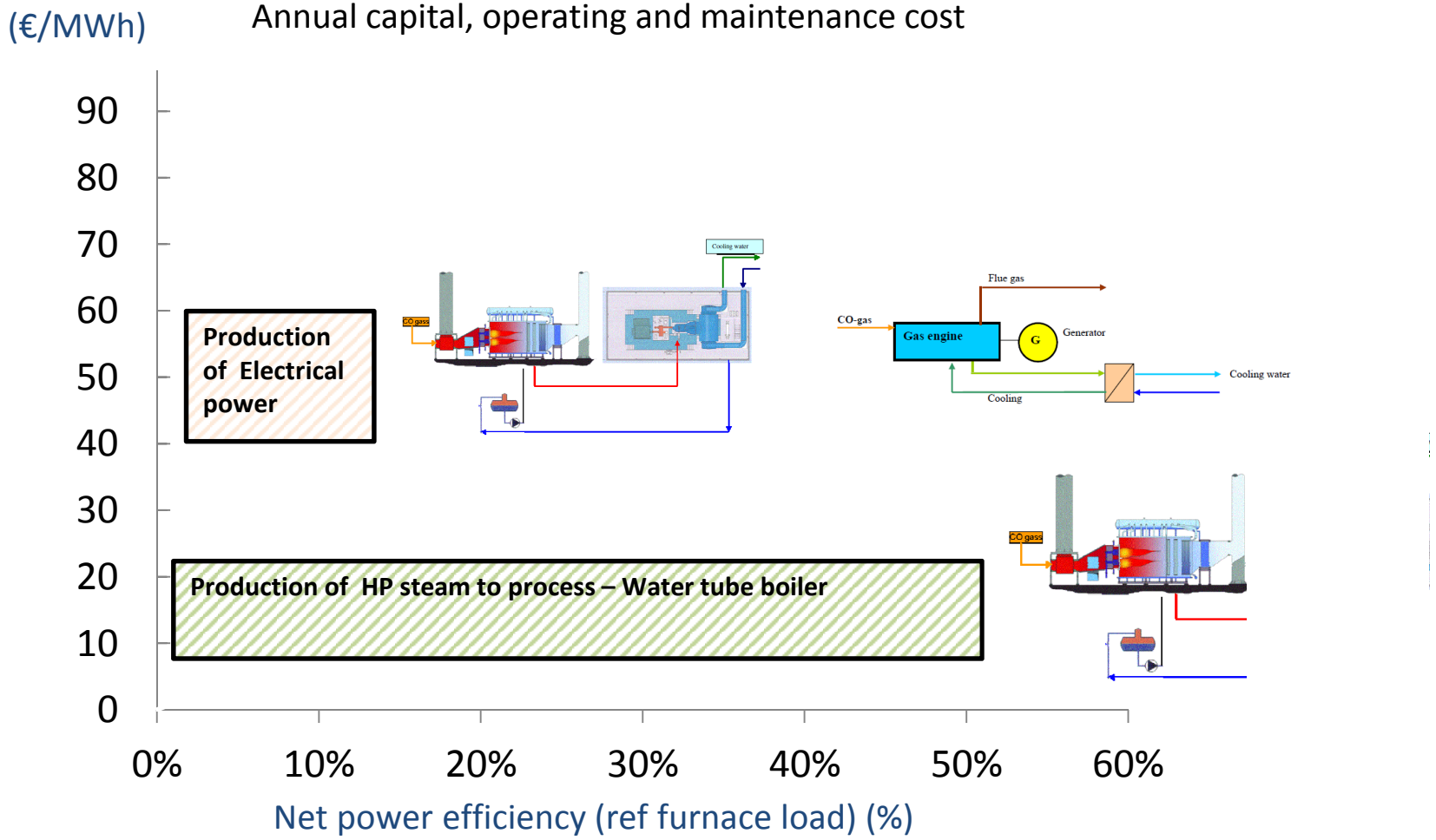
Summary technical – CO gas

- Steam power plant
  - + Well-known technology design
  - - High Capital cost
  - + Low running cost

- Gas Engine
  - - Limited technology design
  - + Low Capital cost
  - - High running cost

Typical Resulting production cost

Annual capital, operating and maintenance cost



- Payment period: 15 year, Interest: 8 %, annuity factor: 0,12.
- **Boiler and turbine**: Operation and maintenance cost it typical 7-10 % of the resulting production cost.
- **Gas Engine:** Operation and maintenance cost it typical 25-35 % of the resulting production cost.

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Other energy efficiency measures

- **Fans – increased efficiency**

- Correct sized fan
  - Oversized fans has poor efficiency.
  - A correct installed fan has an expected efficiency of 80 – 85 %.

- Install frequency converters.
  - With frequency converters the best efficiency is kept at different flow conditions.

- Remove guide vanes in front of fans.
  - Guide vanes may reduce the efficiency by as much as 30 -50%

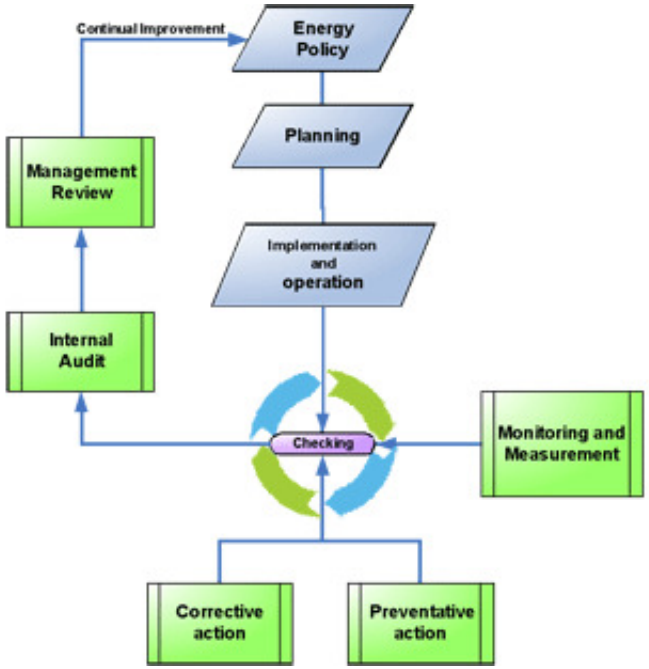
- Remove bends in front of fans.
  - Straighten out the inlet channel or install a large suction box with deflector blades in the bend.

- Example
  - A fan with a volume flow of 90 000 Nm3/h and pressure 5 kPa:
    Efficiency 50 %: 250 kW Power consumption
    Efficiency 83 %: 150 kW Power consumption

  - With 8500 working hours annually, the energy waste is **850 MWh** annually. This is the efficiency potential of one fan. A smelting plant may have several.

Other energy efficiency measures

- **Introduce Energy Management System**.
- - Increases focus on energy efficiency in the plant operation.
- - Routines established and responsibility dedicated to personnel for surveillance of energy efficiency.



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Norsk Energi – possible assistance

Norsk Energi can give assistance for the complete WHR concept.

- Recommendation for the WHR concept
  - Flue gas temperature
  - Number of boilers
  - Type and layout of boiler
  - Steam pressure and temperature
  - Size of steam turbine, auxiliary, etc
- Design basis for boiler and steam turbine and auxiliary equipment:
- Technical specifications for boiler and steam turbine and auxiliary equipment:
- Technical evaluation and consultancy during the execution

Expert in Energy Recovery:

- Flue gas utilization
- Hot water and steam production
- Feed water system
- Water tube boilers
- Shell boilers
- Steam generators

Norsk Energi participates in all project stages:

- Trouble shooting
- Feasibility study
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- Main study and design
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Thank you for your attention!

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