Eco-efficient Solutions in the Finnish Metallurgical Industry

Juho Mäkinen,
VTT Business Solutions
Structure of the presentation

1. Metallurgical industry in Finland
2. Eco-efficient features in the Finnish metallurgical industry
3. Harjavalta industrial park
4. Outokumpu flash smelting technology
5. Ferro-alloys technologies of Outokumpu
6. Extraction of iron with low carbon dioxide emissions
2. Eco-efficient features in the Finnish metallurgical industry

- Conservation of energy and intelligent use of non-fossil energy sources
- Minimizing the impact on the environment; air, water, soil
- 6 BAT’s = Best Available Technologies
- ASM Historical Landmark Award for the Outokumpu Flash Smelting Process in 2002
- About 50% of the world copper and 30% of nickel is produced by Flash Smelting
3. Harjavalta industrial park
The history of Harjavalta industrial area

1944 Copper smelter is moved from Imatra to Harjavalta
1945 The start up of the Outokumpu copper smelter

The Harjavalta copper smelter before Flash Smelting

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The history of Harjavalta industrial area continued...

1944 Copper smelter is moved from Imatra to Harjavalta

1945 The start up of the Outokumpu copper smelter

1947 The start up of the Kemira sulfuric acid plant
The history of Harjavalta industrial area continued...

1944 Copper smelter is moved from Imatra to Harjavalta.
1945 The start up of the Outokumpu copper smelter
1947 The start up of the Kemira sulfuric acid plant
1949 The start up of Outokumpu copper flash smelter
FLOW SHEET OF COPPER SMELTER

1. **Concentrate, silica sand**
2. **Feed mixture**
3. **Oxygen** and air
4. **Flue dust**
5. **Slag**

**SCREENING AND GRINDING**

- Silica sand, coke, reverts
- Air and oxygen

**PRESSURE DRYING**

- Steam

**CONCENTRATOR**

- Slag concentrate

**SLAG COOLING**

- Silica sand, coke, reverts
- Air and oxygen

**FLASH SMELTING FURNACE**

- Matte
- Scrap, anode scrap
- HEAT EXCHANGER

**CONVERTER**

- Blister
- Propane, air

**ANODE FURNACE**

- Cu-ANODE

**ANODE CASTING**

- Ni drying
- Ni Electric furnace bins

**Acid plant**
1944 Copper smelter is moved from Imatra to Harjavalta
1945 The start up of the Outokumpu copper smelter
1947 The start up of the Kemira sulfuric acid plant
1949 The start up of Outokumpu copper flash smelter
1959 The start up of Outokumpu nickel flash smelter
1971 The start up of the oxygen plant
1995 The start up of AGA hydrogen plant
1995 The start up of Direct Outokumpu Nickel process (DON)
2000 OMG Harjavalta Nickel Ltd is founded
2000 Porin Lämpövoima Ltd starts the energy production
2002 OMG starts the nickel chemical production
2004 Boliden Harjavalta Oy is founded
The utilisation chain of sulphur starting from a copper mine to sulphur dioxide, sulphuric acid and ending at consumer’s dinner-table

Raw material acquisition
Raw materials refining
Transporting
Products making
Sulphur chemicals using / Raw material acquisition
Raw materials refining
Transporting
Products making
Products using
Transporting
Products using

Copper deposit
Copper flash smelting off gases
Surphuric acid plant

Ilmenite deposit
Ilmenite
Ilmenite deposit
Ilmenite

Bauxite deposit
Bauxite
Bauxite deposit
Bauxite

TiO₂ plant
TiO₂

FeSO₄

Al₂(SO₄)₃

Wastewater treatment

Phosphorous acid

Nitric acid

Potassium chloride

Nitric acid

Ammonia

Fertilizer industry

Barley growing

Cattle feed

Food production

Sugar- and starch industry

Paper industry

Chemical pulp (bleaching)

ClO₂ making

Sulphur dioxide

Natural gas

Potassium mine

Apatite mine

Potassium chloride

Nitric acid

Ammonia

Sulphuric acid

Fertilizer industry

Phosphorous acid

Nitric acid

Ammonia

Sulphur dioxide

Sulphuric acid

Domestic market / Consumer

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## Product and company diversity progress 1945 - 2005

<table>
<thead>
<tr>
<th>Year</th>
<th>Company</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>1945</td>
<td>Outokumpu</td>
<td>Anode copper</td>
</tr>
<tr>
<td>2005</td>
<td>Boliden</td>
<td>Anode copper, nickel matte, sulphuric acid, sulphuric dioxide, oleum, granulated nickel slag, diluted sulphuric acid, mercury precipitate.</td>
</tr>
<tr>
<td></td>
<td>OMG</td>
<td>Nickel cathodes, nickel briquettes, nickel powders, nickel fine powder, nickel solutions, nickel chemicals, ammonium sulphate and cobalt sulphate solution</td>
</tr>
<tr>
<td></td>
<td>Kemira Oyj</td>
<td>Aluminium sulphate</td>
</tr>
<tr>
<td></td>
<td>Kemira GrowHow</td>
<td>Urea phosphate, different kinds of fertilizers, urea</td>
</tr>
<tr>
<td></td>
<td>AGA</td>
<td>Gaseous oxygen, hydrogen and nitrogen, liquid oxygen, nitrogen and argon.</td>
</tr>
<tr>
<td></td>
<td>Porin Lämpövoima</td>
<td>Process steam, high temperature steam, process energy, district heating energy, raw water, salt-free and precipitated water, electric energy and compressed air</td>
</tr>
</tbody>
</table>
Material and energy exchange of Harjavalta Industrial Park

ADVANTAGES:

- Environmental and recycling benefits
- Better energy efficiency
- Better product diversity when different companies can concentrate to their own core know-how areas
- Marketing and logistic benefits
- Improved safety activity
- Image factors
- Cultural differences is a positive factor in co-operation
How to govern the eco-efficiency of the activities in an industrial park?

- There is no umbrella organization to govern the activities of individual companies in the park.
- The overall supervision is carried out by the environmental authorities.
- They have the final decision making power in environmental permissions and they also monitor the emissions from various sources in the park.
4. Outokumpu Flash Smelting Technology
Theory of Flash Smelting - reactions

- Dissociation reactions – endothermic (require energy)

- Oxidation reactions – exothermic (produce energy)

- Oxidation reaction are not completed, the degree of oxidation depends on the amount of available oxygen.

- Iron sulphides are oxidized easier than copper sulphides.
Flash smelting furnace

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Cu production by process
Sulfur Capture in Copper Smelters (Forecast)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>SULFUR CAPTURE (%)</th>
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<tbody>
<tr>
<td>1996</td>
<td>90</td>
</tr>
<tr>
<td>1998</td>
<td>91</td>
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<tr>
<td>2000</td>
<td>92</td>
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<td>2002</td>
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<td>2004</td>
<td>94</td>
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<tr>
<td>2006</td>
<td>95</td>
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<td>2008</td>
<td>96</td>
</tr>
<tr>
<td>2010</td>
<td>97</td>
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</tbody>
</table>

- **South America**
- **Australia**
- **Africa**
- **Asia excl. Japan**
- **North America**
- **Europe**
- **Japan**
- **ISA + PS + Acid Plant**
- **MITSUBISHI + Acid Plant**
- **FSF + FCF + Acid Plant**
- **FSF + PS + Acid Plant**
Flash Smelters around the world
<table>
<thead>
<tr>
<th>Reference</th>
<th>Location/Country</th>
<th>Smelting Type</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Outokumpu Oy, Harjavalta, Finland</td>
<td>Cu smelting</td>
<td>1949</td>
</tr>
<tr>
<td>2.</td>
<td>Outokumpu Oy, Harjavalta, Finland</td>
<td>Ni smelting</td>
<td>1959</td>
</tr>
<tr>
<td>3.</td>
<td>Furukawa Co Ltd., Ashio, Japan</td>
<td>Cu smelting</td>
<td>1956</td>
</tr>
<tr>
<td>4.</td>
<td>Outokumpu Oy, Kokkola, Finland</td>
<td>Pyrite smelting</td>
<td>1962</td>
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<tr>
<td>5.</td>
<td>Combinatul Chimico Metalurgic, Baia Mare, Romania</td>
<td>Cu smelting</td>
<td>1966</td>
</tr>
<tr>
<td>6.</td>
<td>The Dowa Mining Co Ltd., Kosaka, Japan</td>
<td>Cu smelting</td>
<td>1967</td>
</tr>
<tr>
<td>7.</td>
<td>Nippon Mining Co Ltd., Saganoseki, Japan</td>
<td>Cu smelting</td>
<td>1970</td>
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<tr>
<td>8.</td>
<td>Sumitomo Metal Mining Co Ltd., Toyo, Japan</td>
<td>Cu smelting</td>
<td>1971</td>
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<td>9.</td>
<td>Hindustan Copper Ltd., Ghatsila, India</td>
<td>Cu smelting</td>
<td>1971</td>
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<td>11.</td>
<td>Hibi Kyodo Smelting Co Ltd., Tamano, Japan</td>
<td>Cu smelting</td>
<td>1972</td>
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<td>12.</td>
<td>Norddeutsche Affinerie AG, Hamburg, Germany</td>
<td>Cu smelting</td>
<td>1972</td>
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<tr>
<td>13.</td>
<td>Nippon Mining Co Ltd., Hitachi, Japan</td>
<td>Cu smelting</td>
<td>1972</td>
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<tr>
<td>14.</td>
<td>Western Mining Corporation, Kalgoorlie, Australia</td>
<td>Ni smelting</td>
<td>1972</td>
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<tr>
<td>15.</td>
<td>Karadeniz Bakir Isletmeleri AS, Samsun, Turkey</td>
<td>Cu smelting</td>
<td>1973</td>
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<tr>
<td>16.</td>
<td>Peko Wallsend Metals Ltd., Tennant Creek, Australia</td>
<td>Cu smelting</td>
<td>1973</td>
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<td>17.</td>
<td>Nippon Mining Co Ltd., Saganoseki, Japan</td>
<td>Cu smelting</td>
<td>1972</td>
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<tr>
<td>18.</td>
<td>BCL Limited, Selebi-Phikwe, Botswana</td>
<td>Ni smelting</td>
<td>1973</td>
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<tr>
<td>No.</td>
<td>Company/Location</td>
<td>Smelting Type</td>
<td>Year</td>
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<td>19</td>
<td>Hindustan Copper Ltd, Khetri, India</td>
<td>Cu smelting</td>
<td>1974</td>
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<td>20</td>
<td>Rio Tinto Minera SA, Huelva, Spain</td>
<td>Cu smelting</td>
<td>1975</td>
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<td>21</td>
<td>Phelps Dodge Corporation, Playas, USA</td>
<td>Cu smelting</td>
<td>1976</td>
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<td>22</td>
<td>Gécamines, Luilu, Zaire</td>
<td>Direct to blister</td>
<td>1978</td>
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<td>23</td>
<td>Kombinat Górniczo-Hutniczy Miedz, Glogow, Poland</td>
<td>Direct to blister</td>
<td>1978</td>
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<td>24</td>
<td>Korea Mining &amp; Smelting Co Ltd., Onsan, South Korea</td>
<td>Cu smelting</td>
<td>1979</td>
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<td>25</td>
<td>Norilsk Mining &amp; Metallurgical Co, Norilsk, Russia</td>
<td>Ni smelting</td>
<td>1981</td>
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<td>26</td>
<td>Norilsk Mining &amp; Metallurgical Co, Norilsk, Russia</td>
<td>Cu smelting</td>
<td>1981</td>
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<td>27</td>
<td>Caraiba Metais SA, Camacari, Brazil</td>
<td>Cu smelting</td>
<td>1982</td>
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<td>28</td>
<td>Philippine Associated Smelting &amp; Refining Co., Isabel, the Philippines</td>
<td>Cu smelting</td>
<td>1983</td>
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<td>29</td>
<td>Jiangxi Copper Corporation, Guixi, China</td>
<td>Cu smelting</td>
<td>1985</td>
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<td>30</td>
<td>Mexicana de Cobre SA, El Tajo, Mexico</td>
<td>Cu smelting</td>
<td>1986</td>
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<td>31</td>
<td>MDK G Damianov, Srednogorie, Bulgaria</td>
<td>Cu smelting</td>
<td>1987</td>
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<td>32</td>
<td>Codelco, Chuquicamata, Chile</td>
<td>Cu smelting</td>
<td>1988</td>
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<td>33</td>
<td>Jinchuan Non-ferrous Metals Co, Jinchang, China</td>
<td>Ni smelting</td>
<td>1992</td>
</tr>
<tr>
<td>34</td>
<td>Magma Copper Co., San Manuel, USA</td>
<td>Cu smelting</td>
<td>1988</td>
</tr>
</tbody>
</table>
35. Roxby Management Services Pty Ltd, Olympic Dam, Australia
   Direct to blister 1988

36. Compania Minera Disputada de las Condes SA, Chagres, Chile
   Cu smelting 1995

37. Kennecott Utah Copper Corp., Salt Lake City, USA
   Cu smelting 1995

38. Kennecott Utah Copper Corp., Salt Lake City, USA
   Cu converting 1995

39. Jinlong Copper Co Ltd., Tongling, China
   Cu smelting 1997

40. Indo-Gulf Fertilisers & Chemical Ltd, Gujarat, India
   Cu smelting 1998

41. Mineração Serra da Fortaleza Ltda, Fortaleza, Brazil
   Ni smelting 1998

42. WMC Resources Ltd, Olympic Dam, Australia
   Direct to blister 1999

43. Boliden Mineral AB, Rönnskär, Sweden
   Cu smelting 2000

44. Southern Peru Copper Corporation, Ilo, Peru
   Cu smelting

45. Southern Peru Copper Corporation, Ilo, Peru
   Cu converting

46. National Iranian Copper Industries Co., Khatoon Abad, Iran
   Cu smelting 2004

47. Yanggu Xiangguang Copper Co., China
   Cu-smelting

48. Yanggu Xiangguang Copper Co., China
   Cu-converting

49. KGHM Polska Miedz S.A., Glogów, Poland
   Direct to blister

50. Jiangxi Copper Corporation, Guixi, China
   Cu smelting

51. Konkola Copper Mines Plc., Zambia
   Direct to blister
Relative amount of copper produced in smelters ("pure FSF" vs. others)
5. Ferro-alloys Technology of Outokumpu
Outokumpu FeCr smelting process

Based on pellets.

- Furnace charge is preheated in stationary shaft kiln.

- Smelting furnace is closed and sealed.

- CO-gas is cleaned and utilized in the plant and outside.
Outokumpu Tornio Works

- Full capacity after last expansion:
  - FeCr: 270,000 tons
  - Slabs: 1,600,000 tons
  - Coil products: 1,200,000 tons
    - Hot rolled: 300,000 tons
    - Semi-cold rolled: 150,000 tons
    - Cold rolled: 750,000 tons

- Specialized in:
  - Custom-made volume production in selected product areas
  - Supplying cost efficiently high quality volume products
  - Using best available technology
  - New products from RAP line

- About 2,300 employees
The most integrated stainless steel works in the world (Outokumpu Tornio works)

- Own chrome – safe supply
- Stable FeCr quality
- Liquid FeCr and use of own CO saves primary energies
- FeCr-converter increase melting capacity and saves energy
- Hot slab charging in Hot Rolling Mill
- Short processing time and lower logistical costs
- Savings in product handling
- Integrated southbound and northbound logistics
- Terneuzen Mill close to main markets
Main principles of environmental management

- Improvement of material efficiency and utilization of byproducts
- Improvement of energy efficiency
- Continuous improvement: ISO 14001 and R&D as tools
- Utilization of best available technology (BAT) to keep the emissions at low levels
- Active co-operation with authorities

⇒ Aim is to be the best in eco-efficiency
The ecological balance of Tornio FeCr -plant

FeCr - PLANT
ECOLOGICAL BALANCE 2002

IN
ELECTRICITY 3469 kWh
(12.18 GJ)
COKE 507 kg
LIQUID NATURAL GAS 0.06 "
OIL 0 "
LUMPY ORE 768 "
FINE CONCENTRATE 1532 "
QUARTZ 308 "
ELECTRODE PASTE 7 "
OTHER 15 "

EMISSIONS TO AIR
DUST 0.20 kg
CO₂ 593 "
NO₂ 0.87 "
SO₂ 0.38 "

OUT
FeCr 1000 kg
SLAG 1181 "
CO 708 Nm³
(CO EQUALS 196 kg OIL)

EMISSIONS TO WATER
SOLIDS 13.8 g
Cr 0.4 "
Zn 1.0 "
CN 0.7 "
OIL 0 "

DUMPING PLACE
WASTE 35 kg

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Specific CO$_2$ emissions at Outokumpu Tornio FeCr Plant, kg CO$_2$/t FeCr
Effect of Technology development on CO$_2$ emission and power consumption in FeCr production

![Graph showing CO$_2$ Emission per ton FeCr and Power consumption kWh/t HC FeCr for different processes: Base Case, Pelletizing/ Sintering, Pelletizing Sintering+Preheating+Closed Furnace, and Full utilization of Furnace CO in addition.]
Without technology development the CO\textsubscript{2} emission level at Outokumpu Tornio FeCr plant would be more than 3-fold compared to the present actual figures.

**CO\textsubscript{2} emissions at Outokumpu Tornio FeCr plant with and without technology development**

**CO\textsubscript{2} EMISSIONS, REAL**

**CO\textsubscript{2} EMISSIONS WITHOUT IMPROVEMENTS**

*Challenges of Eco-efficiency, 5.12.2006, VTT Espoo*
Effect of technology development on cumulative CO$_2$ emission reduction at Outokumpu Tornio FeCr plant

CO$_2$ EMISSION REDUCTION IN FeCr PRODUCTION IN TORNIO

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Outokumpu Technology’s latests FeCr technology transfer project references

<table>
<thead>
<tr>
<th>Project</th>
<th>Year</th>
<th>Location</th>
</tr>
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<tbody>
<tr>
<td>Ferrometals</td>
<td>1998</td>
<td>South Africa</td>
</tr>
<tr>
<td>Hernic</td>
<td>1999</td>
<td>South Africa</td>
</tr>
<tr>
<td>Assmang</td>
<td>2001</td>
<td>South Africa</td>
</tr>
<tr>
<td>Tubatse</td>
<td>2002</td>
<td>South Africa</td>
</tr>
<tr>
<td>SA Chrome</td>
<td>2002</td>
<td>South Africa</td>
</tr>
<tr>
<td>Hernic 2</td>
<td>2005</td>
<td>South Africa</td>
</tr>
<tr>
<td>Donskoy GOK</td>
<td>2005</td>
<td>Kazakhstan</td>
</tr>
<tr>
<td>IFM</td>
<td>2007</td>
<td>South Africa</td>
</tr>
<tr>
<td>Xstrata Wonderkop</td>
<td>2007</td>
<td>South Africa</td>
</tr>
</tbody>
</table>

- Already now about 5-7 million tons less CO₂ emissions
Estimate of cumulative CO$_2$ emission reduction in FeCr production in South Africa achieved by utilization of Outokumpu technology

FeCr PRODUCTION
Outokumpu Technology Technology Deliveries
Effect on CO$_2$ emissions

Forecast
6. Extraction of Iron With Low Carbon Dioxide Emissions
Reduction of iron ores

Conventional blast furnace reduction of iron oxides
- Pelletizing
- Sintering
- Coking
- Oxygen removed as CO$_2$
- 95 % of primary iron production

Direct reduction by natural gas
- Oxygen removed as H$_2$O+CO$_2$
- 3-4 % of primary iron production

Direct reduction by hydrogen
- Oxygen removed as H$_2$O
- 1-2 % of primary iron production
View of Circored plant in Point Lisas, Trinidad
Circored®: Gas Based Direct Reduction of Iron Ore Fines

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Basic reactions in the bath