• Introduction – parameters, sources
• Supply situation 2010
• Production and potential in EU33 and immediate neighbours
• Challenges
INTRODUCTION

AREA CONSIDERED: EU 33 and immediate neighbours.

SOURCES:
- Databases – ProMine, FODD
- USGS, BGS web sites
- Industry sources – web sites, industry presentations
- Professional/scientific journals
  (selected references on last slide in file)

- FOCUS on the 14 critical resource types
Aitik: copper
Kittilä: gold
Kiruna: iron
Bjørnevåtn: iron

Metallic Mineral Deposit Map of the Fennoscandian Shield
1:2 000 000
Leading primary producer countries for minerals/metals defined as critical (data for 2010) (BGS, 2011)

<table>
<thead>
<tr>
<th></th>
<th>First</th>
<th>%</th>
<th>Second</th>
<th>%</th>
<th>Third</th>
<th>%</th>
<th>∑ %</th>
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<td>88</td>
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<td>6</td>
<td>Australia</td>
<td>5</td>
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<td>56</td>
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<td>18</td>
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<td>Graphite</td>
<td>China</td>
<td>86</td>
<td>India</td>
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<td>Brazil</td>
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<td>S. Africa</td>
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<td>Niobium*</td>
<td>Brazil</td>
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<td>Canada</td>
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<td>PGM</td>
<td>S. Africa</td>
<td>60</td>
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<td>Tantalum*</td>
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<td>5</td>
<td>Bolivia</td>
<td>2</td>
<td>91</td>
<td>3.3</td>
</tr>
</tbody>
</table>

*: Statistics from USGS, for metal production (Ga and Ge) and metal in concentrate (Nb and Ta)
Antimony

- **World production** was 147,000 t in 2010 (BGS, 2011), 88% from China.
- **Main uses**: Flame retardant in plastic

**Production, Europe**

- Göynük mine SW of Ankara is the sole producer in the EU33, now being developed for large-scale mining after >100 years of artisanal production.

**Potential**

- >40 deposits documented in France + 12 Au-Sb. Les Brouzils (Vendée) was assessed in the 1990s.
- Sb was mined in Austria, Serbia and Slovakia up until 1990-91.

Beryllium

- **World production** was 3,550 t in 2010 (BGS, 2011), 84% from Spor Mountain ("cut-off" 1000 ppm)
- **Main uses**: Numerous “high-tech”, especially military applications.

**Potential, Europe**
- Be is a significant constituent in the Beauvoir kaolin deposits in a rare-metal-bearing granite in the Massif Central
- 10 deposits in FODD database, 6 in NW Russia, 3 in Finland and 1 in Norway
- 2 of the deposits in Russia are large (29 Bt and 74 Mt) but low grade (270 and 190 ppm), but also contain lithium.
- Høgtuva (Norway) is small (0.35 Mt) but higher grade (1800 ppm)
- Perha/Perga in NW Ukraine is probably the world’s richest deposit (mean BeO quoted as 0.55%)
Cobalt

- **World production** was 105,000 t in 2010 (BGS, 2011), 67% from DR Congo
- **Main uses**: alloys, magnets, batteries

**Production, Europe**

- Cobalt is a significant component in the Ni-Cu deposits in the Pechenga area (NW Russia) (> 160 Mt @ 0.67% Ni, 0.31% Cu, 0.023% Co)
- Talvivaara (Finland) contains a resource of 1,550 Mt @ 0.22% Ni, 0.49% Zn, 0.13% Cu, 0.02% Co
- Co is present in various Ni-Cu sulphide ores in the Nordic countries, several of which are being explored: recovery depends on Ni-Cu grade.

**Potential**

- Ni laterites are being exploited in Greece, Macedonia and Kosovo. Several deposits contain Co (0.02 – 0.16%), which is not currently extracted
- Bidding in progress for rights to two large Ni-Cu-Co ore bodies in the Voronezh Crystalline Massif (1400 km SSE of Moscow)
- The area of the Skutterud Mine (Norway) is currently being re-assessed
Fluorspar

• **World mine production** was 5.9 Mt in 2010 (BGS, 2011), 56% from China. Spain, UK and Germany produced Σ 3.7% in 2010.

• **Main uses**: HF, metallurgical industry

**Production, Europe**

• Minersa mines fluorspar (+ other industrial minerals) in NW Spain: the company also produces fluorine compounds

• Fluorspar (and barytes) are mined at the Clara Mine in Oberwolfach in the Schwarzwald (Germany)

• Production from a re-opened mine in Bulgaria (Chiprovtsi) is scheduled to reach 50,000 t/a in 2012.

**Potential**

• Potential in Spain, UK and Germany, partly restricted by planning issues.

• Storuman (Sweden): Indicated and inferred (JORC) resource of 27.8 Mt @ 10.21% fluorspar

• Lassedalen (Norway): Min. 1km long network of veins, 0-13m wide and 200 — 250m long, with 40-80% fluorspar. Best drilled part of deposit contains 4 Mt @ 29% fluorspar
**Gallium**

- **World production** was 106 t in 2010 (USGS, 2011), 54% from China and 13% from Germany – mostly from trace levels in bauxite. Roskill estimate > 200t in 2010.
- **Main uses**: Integrated circuits (GaAs), laser diodes

**Production, Europe**
- France, Hungary, Slovakia and Russia (+ Germany) have production capacity (and several countries outside Europe)

**Potential**
- Bauxite contains $30 - 100 \text{ g/t Ga}$ which also occurs in Zn ore and in certain coals. Not all the Ga in bauxite is accessible.
- Ga ($97 - 622 \text{ g/t}$) is known from a Li-Au-Ag ore found in Kingman, Arizona and from several types of hydrothermal ore body (e.g. Apex, Utah which contained 0.64% Ge and 0.32% Ga)

How systematic is our knowledge of Ga in coals or possible ore bodies in Europe?
Germanium

- **World production**, mainly from trace levels in zinc ore, was 120 t in 2010 (BGS, 2011), 83% from China.
- **Main uses**: optical applications, catalysts

Production, Europe

- OMG Kokkola Chemicals (Finland) produces Ge oxide from Co concentrate (and is a major producer of Co compounds and nanoscale products)
- Xstrata Zinc produces Ge oxide from Zn concentrate at its plants in N Spain
- Umicore produces Ge metal and a range of Ge compounds at its recycling plant in Belgium

Potential

- Coal seams may contain significant contents of Ge (up to 0.4%). Ge is enriched in coal ash and grades of several % have been registered.
- Ge has been extracted (1975-93) from Zn ore in now-exhausted vein deposits in the Massif Central (Saint-Salvy)

[Ge metal (Photo: Wikipedia)]
Graphite

- **World production**: 2.1 Mt in 2010 (BGS, 2011), 86% from China. Producers in Europe are Austria, Norway, Romania and Turkey. Imports were c. 12 x production in Europe
- **Main uses**: Metallurgical industry, batteries and many others

**Production, Europe**
- Skaland Graphite (Norway) is currently the only stable supplier of flake graphite in Europe (IM, 2012).
- Oysu Graphite produces amorphous graphite in Turkey.
- The Kaisersberg mine near Leoben (Austria) was opened in 2009, in an area where graphite has been mined since 1755.

**Potential**
- The Kringel project in C Sweden is being developed on the basis of a resource of **8.9 Mt @ 6.9 – 11.3% C**. Planned production 13,000 t/a with 40% as large flakes.
- Several companies are investigating potential in Norway.
- There is probably potential in several other areas.
Indium

• **World refinery production** was 574 t in 2010 (BGS, 2011), 52% from China. Producers in Europe are Belgium, Germany, Italy, Netherlands, Russia and UK (Σ 49 t)

• **Main uses**: Flat screens, special glass, low melting-point alloys

**Production, Europe**

• Primary production comes mainly from trace levels of In in zinc ores (and is governed by demand for Zn). In is also found in certain lead, copper and tin ores. There are no indications of deposits which are mineable, primarily for In.

• There are trace levels of In in certain ores in the Kupferschiefer and in the Iberian Pyrite Belt

• The Mt Pleasant Sn-In-Zn deposit in New Brunswick contains **12.4 Mt @ 0.38% Sn, 0.86% Zn and 64 g/t In** (planned mining from 2015).

• Data on secondary production are not clear. USGS (2012) indicates that secondary production may be almost 2 x primary production.
Magnesite/magnesium

- **World production of magnesite** was 21.8 Mt in 2010 (BGS, 2011), 64% from China. Major producers in Europe are Austria, Greece, Netherlands, Russia, Slovakia, Spain and Turkey. Σ EU 33 production was **16.3%** of world production: reserves are significant.

- **World production of magnesium** was 885,000 t in 2010 (BGS, 2011), 82% from China. There was no production of Mg metal in the EU33.

- **Main uses**: refractory materials (magnesite), alloys (Mg)

- The problem is not access to Mg resources but market forces which have led to concentration of production of Mg metal in China

- Norway was a significant producer of Mg metal up to 2001 (9% of world production). A new company plans to start production of Mg metal (and silica) using Mg-rich olivine \((\text{Mg},\text{Fe})_2\text{SiO}_4\) as a raw material, from 2014.

- Other new technologies are being developed in S Africa and Australia
Niobium

• World production was 62,900 t in 2010 (USGS, 2011), 92% from Brazil.

• Main uses: ferroniobium and other alloys

Potential

• The Sokli carbonatite in NE Finland contains a resource of 250 Mt @ 0.21% Nb in phosphate-rich rock. Production planned at earliest in 2015.

• Alkaline intrusives in the central part of the Kola Peninsula contain >200 Mt @ >0.33% Nb, >0.02% Ta and >1.2% REE

• The Sæteråsen deposit SW of Oslo contains 8 Mt @ 0.245% Nb, 0.35% REE and 2.25% Zr.

• Nb was mined in the Fen carbonatite (Norway) from 1953-65 from an impure carbonatite with ~0.25% Nb.
Platinum metals (PGM)
(platinum, palladium, osmium, iridium, ruthenium, rhodium)

- **World production:** 482,000 kg (99% Pt + Pd) in 2010 (BGS, 2011), 60% (31% Pt) from South Africa and 30% (24% Pd) from Russia.
- The South African ores are PGM ores (11.1 Bt @ >4 g/t PGM), those in Russia are Ni-Cu ores, also very rich in PGM (2.2 Bt @ 5 g/t PGM + 1.45% Cu, 0.77% Ni).
- **Main uses:** autocatalysts (> 50%), jewelry, electronic applications

**Production, Europe**
- 50 kg Pt+Pd were produced from copper mines in Poland and 17 kg in Serbia.
- PGM are produced from Ni-Cu matte from Canada at Kristiansand (Norway)
- The Harjavalta refinery (Finland) produces Cu “cake” enriched in PGM

**Potential**
- The Keivitsa open-pit mine in N Finland has a total resource of 240 Mt @ 0.28% Ni, 0.41% Cu and 0.29 g/t Pt+Pd
- The Sakatti deposit, near Keivitsa is described as a world-class Cu-Ni-PGM deposit
- The Sompujärvi deposit NE of Kemi contains ~35Mt @ 8.4 g/t (Pt+Pd): >10 deposits in the same province have PGM potential and varying grades of Au, Ni and Cu
- The Imandra-Varzuga zone in the central Kola Peninsula contains 4 deposits, the richest containing 12.8 Mt @ 13.2 g/t PGM, 0.17% Cu and 0.23% Ni
- PGM occur in other ore types, e.g. in chromitite, but tonnages and grades are lower than in the above settings.
Yttrium, erbium, terbium and ytterbium all have their names from Ytterby: alsoholmium, thulium and gadolinium were first discovered in minerals from Ytterby.

**Rare Earth Elements**

- **World production** was 123 000 t in 2010 (BGS, 2011)
- REE are not so rare (0.3 – 64 g/t in the crust), except Pm
- The ores contain several REE (usually also U and Th): processing is challenging
- **554** projects outside China, few in Europe outside Norden, NW Russia
- **Main uses**: Catalysts, magnets, metallurgical applications, phosphors ++

Several REE have properties which are uniquely important in a wide range of high-tech applications.

**Potential in Europe** includes:

- REE in alkaline intrusions, carbonatites, skarn, + related pegmatites, e.g. Norra Kärr (Sweden) – 60 Mt @ 0.54% TREO + 1.72% ZrO₂
- REE in apatite (e.g. Kiruna (Sweden) – study in progress)
- Beach sands (e.g. Peramos (Greece) – 5.7 Mt @ 1.17 % REE)
- New deposit types, e.g. palaeoplacers
- Lovozero (Kola Peninsula) (reserves >200 Mt @ >1.2% REE) is in ?sporadic production
Tantalum

• **World production** of tantalum was 682 t in 2010 (USGS, 2011), 26% from S Brazil, 21% from DR Congo, 18% from Mozambique. There is no production in Europe.

• **Main uses**: Capacitors, alloys, medical applications

**Potential, Europe**

• Alkaline intrusives in the central part of the Kola Peninsula contain >200 Mt @ >0.33% Nb, >0.02% Ta and >1.2% REE

• Nortec Minerals is exploring the Tammela lithium-tin-tantalum deposit in SW Finland: other Ta-bearing pegmatites are known in S Finland.

• The Beauvoir granite in the Massif Central (see Be) is a potential resource for Ta and Nb.
World production of tungsten was 61,700 t in 2010 (BGS, 2011), 84% from China.

Producers in Europe are Austria, Portugal, Russia and Spain (Σ 5,077 t)

Main uses: W carbide, alloys

Production, Europe

- The Mittersill scheelite deposit (CaWO$_4$) (Austria) yielded 975 t W metal in 2010.
- The Panasqueira W-Sn mine in Portugal yields 1,100 t concentrate/a.
- The Los Santos open-pit W mine near Salamanca was opened in 2010 (output in 2011: 442,000 t @ 0.27% WO$_3$)
- Russia’s most important W deposit is the Tyrnyauz W-Mo deposit: production has been sporadic.

Potential

- The Hemerdon deposit in SW England has a measured and indicated resource of 71 Mt @ 0.02% Sn and 0.15% W + inferred resources of 147 Mt.
- Several W deposits in Sweden are being investigated. The Yxsjöberg deposit was mined for W in three periods between 1918 and 1989 (from its discovery in 1728 it had been mined for Cu).
## Potential in Europe for production of metals/minerals defined as critical

<table>
<thead>
<tr>
<th>Metal</th>
<th>Producing countries</th>
<th>Potential, EU33</th>
<th>Potential, rest of Europe</th>
<th>Comments</th>
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<tr>
<td>Antimony</td>
<td>Turkey</td>
<td>Austria, France, Serbia, Slovakia</td>
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<tr>
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<td>Ukraine, ?Norway, ?Russia</td>
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<tr>
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<td>Russia</td>
<td>Finland, Greece</td>
<td>Norway, Russia</td>
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<td>Germanium</td>
<td>Belgium, Finland, Spain</td>
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<td>Graphite</td>
<td>Austria, Norway, Romania, Turkey</td>
<td>Finland, Sweden</td>
<td>Russia</td>
<td>Quality (flake) is important</td>
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<tr>
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<td>Belgium, Germany, Italy, Netherlands, Russia, UK</td>
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<td>*Production from trace levels in Zn ore</td>
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<td>Magnesium/</td>
<td>* Austria, Greece, Netherlands, Russia,</td>
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<td>There is currently no Mg production in the EU34</td>
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<td>Niobium</td>
<td>Finland</td>
<td>Russia, Norway</td>
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<tr>
<td>PGM</td>
<td>Poland, Serbia (minor amounts)</td>
<td>Finland</td>
<td>Russia</td>
<td>Refinery production from Norway, Russia</td>
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<td>REE</td>
<td>Russia</td>
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<td>Russia</td>
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<tr>
<td>Tungsten</td>
<td>Austria, Portugal, Russia, Spain</td>
<td>Sweden, UK</td>
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Critical raw materials in Europe

The list of commodities is based on the report published by the EC, DG Enterprise and Industry:

Deposit classifications according to the tonnage expressed in metric tons (1,000 kg)

Commodity
- Antimony
- Beryllium
- Cobalt
- Fluorspar
- Gallium
- Germanium
- Graphite
- Indium
- Magnesium
- Niobium
- PGM (Platinum Group Metals)
- Rare Earth
- Tantalum
- Tungsten

Pattern
- Old deposits and prospects
- Deposits under exploitation

Deposit size
- Very large deposit
- Large deposit
- Medium deposit
- Small deposit
Challenges:
There is a potential for many of the critical mineral resources in Europe, BUT:

• We need better data on deposits, especially in relation to trace metals, and of course, we need to investigate historically known ore fields to greater depth

• Why not include all the critical mineral resources – e.g. phosphate, especially as several phosphate deposits are important also as hosts for special metals?

• Statistics are very poor for certain industrial minerals, especially those with a large spectrum of quality levels. Certain qualities are both rare and important (therefore critical) but commercial interests restrict access to information.

• Market dominance works against strategic interests when one country or company dominates world supply (and can easily “break” competitors)

• Technology and markets change rapidly relative to the normal time-scale for finding and opening a mineable deposit.

• Strategists in the technological, metallurgical and mining industries must act (together) 5-10 years before the prices rise (as China did with REE)

• We have major challenges related to image and capacity
Thank you for your attention!

Høgtuva Be-Y-Nb-U-Zr deposit, N Norway
Selected references

General:
Fennoscandian Ore Deposit Database (FODD): http://en.gtk.fi/research2/program/mineralpotential/fodd.html
ProMine: http://promine.gtk.fi/

Antimony: http://www.tri-starresources.com//projects/page/turkey
Cobalt: Global Cobalt Corporation: http://www.slideshare.net/globalcobaltcorp
Fluorspar: http://www.tertiaryminerals.com/
Fluorspar: http://www.minersa.net/minersa_group.htm
Fluorspar: http://www.mineralienhalde.de/html/the_grube_clara.html
Gallium: http://arswebsite.wordpress.com/
Graphite: http://flindersresources.com/i/pdf/Presentation/Presentation.pdf
Indium: http://www.adexmining.com/overview.php