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Sustainable steel production
CO2 emission from integrated steel production

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COMPREHENSIVE STUDY REGARDING GREENHOUSE GAS EMISSION FROM IRON ORE BASED PRODUCTION AT THE INTEGRATED STEEL PLANT SSAB TUNNPLÅT AB

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COMPREHENSIVE STUDY REGARDING GREENHOUSE GAS EMISSION FROM IRON ORE BASED PRODUCTION AT THE INTEGRATED STEEL PLANT SSAB TUNNPLÅT AB

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Abstract

During the years 2001 – 2002, a comprehensive study regarding of the CO\textsubscript{2} emission related to the steel production for the integrated steel making production route was carried out. The study was financed by SSAB and carried out by a research group with members from SSAB, MEFOS and LTU. The aim was to study the emissions from the existing system and how these could be influenced by process changes and by process modifications. The calculations were made using a global spreadsheet model for calculating the CO\textsubscript{2} emissions, developed from an existing Energy- and Process Integration model of the same system. The calculated cases included the existing BF/BOF route as well as integration of other processes e.g. an electric arc furnace, COREX, DR processes and new future smelting reduction process (Sidcomet). All new existing alternative ore based process technologies would increase the specific CO\textsubscript{2} emission from the system. A technology transfer to scrap based metallurgy would significantly decrease the emission level, but is not feasible for SSAB due to the future product mix and the structure of scrap availability. In a 5-20 year perspective the existing steel making process route with the use of magnetite ore for pellet production has the lowest specific CO\textsubscript{2} emission. In a long-term perspective (20 –50 years) alternative process routes, e.g., based on H\textsubscript{2} and DRI could be of interest. Studies on such changes are, however, big projects and should be carried out as joint European and/or international efforts.
Introduction

The global warming caused by greenhouse gas emission e.g. carbon dioxide, is one of the major environmental challenges of the 21st century. In the Kyoto agreement, a global reduction in 2010 by 6-8% of the greenhouse gases from the 1990 level is enforced [1]. For Sweden, the commitment to the Kyoto protocol allows for a 4% increase, however the governmental goal is a 4% reduction as average for the period 2008-2010 from the 1990 level [2]. The steel industry accounts for 7% of the global CO$_2$ emission, and of this nearly 70% originates from the BF/BOF route. During the period from 1950 to 1980 the world’s steel production increased considerably. This is mainly due to larger production units, improved metallurgical processes and process yield, as well as improved process control. The energy crisis in mid-70s and early 80s affected the energy use in the industry. The specific use of oil, which is a measure of the energy conservation, has decreased continuously from 1970. Energy recovery, i.e. recovery of energy rich process gases, has also increased and is in many cases used as internal fuel for various processes. According to IISI, the world’s crude steel production in 2002 was 902Mt [3]. The raw materials used for steel production today are still dominated by hot metal from the blast furnaces (i.e. ore based production) and steel scrap. The oxygen based processes, e.g. the BF/BOF route accounts for 60% of the production. The EAF steel-making ratio was 33.9% and the rest, 6.1% was produced in other processes. The annual increase in the steel production is predicted to be about 2%, where the main production increase is in China. For Sweden, the total steel production in 2002 was 5.8 Mt and the BF/BOF share of this was 66.3%.

In a study of the greenhouse gas emission from the steel industry, de Beer et al. [4] reported emissions of 1.6 – 2.2 tCO$_2$/t product from the BF/BOF route. For EAF-based production the emission varies from 0.6 to 0.9 tCO$_2$/t product. In a study by Birat et al. [5], the specific CO$_2$ emission from several traditional and new production routes was analysed. From a CO$_2$ perspective, it was found that it is important to increase the share of recirculated scrap globally. It was shown that routes containing ore have a higher energy use and thus higher CO$_2$ emissions. The BF/BOF route showed the lowest CO$_2$ emissions for the ore based production with 2.2 tCO$_2$/t steel. Future research is predicted to decrease the emissions even further. In a study by Aichinger et al. [6], further analyses have been made of the calculation and accounting principle. In this study the CO$_2$ emissions for ore based production was calculated to be 1.5 tCO$_2$/t steel. Credit was introduced for by-products recovered from the steel plant, e.g. process gases and BF slag for cement production, hence the lower emissions.

In this paper a comprehensive study of the CO$_2$ emission related to the steel production for the integrated steel making production route is reported. The specific CO$_2$ emissions were calculated both for the existing BF/BOF route and for integration of technologically possible alternatives e.g. EAF, COREX, DR process and a new future smelting reduction process (Sidcomet), into the existing steel making route. The analysis included processes up to casting of slabs (this is the end-product as the rolling mills of SSAB Tunnplåt AB are situated elsewhere). The scope of this paper is to describe the computer-based analysis and the results as well as to give an in-depth analysis of the possibility of decreasing the CO$_2$ emissions from an existing steel plant system by process changes and modifications or by integration of alternative process equipment.
The iron and steel making routes

Reference case: the existing steel plant system

The SSAB Tunnplåt AB steel plant is a BF/BOF route based system. The blast furnace (BF) is operated with 100% pellets, and is equipped with pulverised coal injection (PCI), normally 140 kg/tHM (tonne hot metal). The coke plant produces the majority of the coke used in the BF. There are two basic oxygen furnaces (BOF converters) in the system, operated with hot metal from the BF and a small amount of scrap. The crude steel is further treated in the alloying processes, CASOB and RH-vacuum oven. The steel making is followed by two continuous casters. The slabs are transported 1000 km by train to the rolling mill located in Borlänge. The process gases produced from the coke oven, BF and BOF are recovered as coke oven gas, BF gas and BOF gas. The gases are used internally as primary fuel; the coke oven plant is under-fired with pure coke oven gas, and the hot stoves for the BF are fired with a mixture of BF gas and coke oven gas. The coke oven gas is also used in various heating burners at the steel plant as well as for primary fuel in a steam boiler and in a lime furnace. Since the rolling mill for the steel plant is located at another geographical location of the company, a surplus of process gases arises. The surplus is therefore used as primary fuel in a combined heat and power plant (CHP), producing steam, heat and electricity. The produced power is used within the steel plant system and the heat covers the main demand from the district community heat network. Drying gas from the power plant is also delivered to a nearby wood-pellet plant.

Alternative steel making processes

An alternative steel production route to the BF/BOF route is the scrap-based production in the electric arc furnace (EAF route). The main iron source is scrap, but the EAF can also be operated by use of direct reduced iron (DRI/HBI) or with a mix of DRI and scrap. The main energy source for the route is electric power.

The DRI/HBI is produced by reducing iron ore in solid state. The direct reduction processes are normally natural gas or coal based. There are three types of reactors, the shaft oven processes, the fluidised bed processes and the rotary hearth processes. The shaft oven processes (e.g. Midrex, Hyl) are the most developed processes for direct reduction and account for almost 85% of all DRI produced. The fluidised bed reactors can be operated with both natural gas (e.g. Finmet, Circored) and coal (e.g. Circofer). For the rotary hearth processes (e.g. Fastmet, Itmk3, Fastmelt, Redsmelt, and Sidcomet) are other developed processes. In the study, a rotary hearth process combined with a separate melting furnace (Sidcomet) has been chosen as an integrated alternative to the BF to produce liquid hot metal.

The smelting reduction processes have been developed to produce hot metal from iron ore without use of coke. Several processes have been proposed using ore or agglomerated ore (e.g. COREX, AISI, and Technored) and processes using fines (e.g. Finex, Dios, Hismelt). In the analysis the COREX process in some different system designs has been chosen as an integration alternative to the BF.

Method

The analysis was conducted in a mathematical simulation model derived for the steel plant system. A number of cases were chosen to describe the process enhancements or the process alternatives of interest for the investigation. The comparison between the different cases was
made with respect to the specific CO$_2$ emission for each process chain. The specific CO$_2$ emission was defined as the normalised emission per ton of slab out from the system.

**Process simulation model**

The calculations were made in a spreadsheet simulation model for the total energy system. It was developed from an earlier SSAB model for energy optimisation (Grip et al. [7]), and consists of one process module calculating the mass- and energy flows in the system and one CO$_2$ module using the mass- and heat balance data to calculate the CO$_2$ emissions, Figure 1.

The process module includes simulation models for the main processes in the existing system; coke oven plant; blast furnace; BOF furnaces as well as for the CHP plant. For the ladle metallurgy, simplified models describing the yield and material consumption are used. New process alternatives are included by a mass balance sheet, based on process data. All models are governed by an interface controlling the different sub models. As far as possible, simulations for the BF process have been validated against real process data. For new process technologies, e.g. Corex, Midrex, Sidcomet and EAF, process data from various sources have been used for the modelling [8, 9 and 10]. Process data have been adapted to fit into the existing steel plant system.

**Calculation principle**

In an industrial energy and production system, such as the integrated steel plant system, the different processes are connected together by primary and secondary products. Because of this, the individual processes often affect each other. Several things might make the analysis more difficult. Some materials used in iron and steel making have generated CO$_2$ emissions in their preparation. There are processes generating CO$_2$ emission inside the steel plant border that is emitted in by-products (e.g. process gases) outside the steel plant border. The use of by-products might also result in a global decrease of the CO$_2$ emissions due to replacement of fossil fuels. There are principally three ways of making the analysis:

- as an inventory analysis, including only direct emissions (i.e. actual emissions) from the system
- as an effect-oriented analysis, also including indirect upstream emissions (i.e. earlier emissions) from raw material preparation or products used in the production and downstream emissions related to by-product use.
- as an LCA analysis, taking into consideration the total emission during the total life cycle of the product.

In order to take the specific aspects of the current system into consideration, an effect-oriented calculation philosophy has been chosen. The LCA analysis is not applicable since the life cycle emission of the product is of no relevance to this study. The analysis methodology
chosen is based on the method proposed by Aichinger et al. [6], and is based upon five principles:

- **Relevance**: the system boundary chosen should appropriately reflect the greenhouse gas emission from the system.
- **Completeness**: the calculation should include all emission sources and activities within the system.
- **Consistency**: the result should allow for meaningful comparisons of emission performance over time.
- **Transparency**: the analysis should be conducted in a factual and coherent manner, based on a clear audit trail.
- **Accuracy**: The emission calculations should have the precision needed for the intended use, and provide reasonable assurance on the integrity of the calculated emission.

Besides the direct emissions within the system, the indirect emissions from the preparation of the raw materials and the use of the process gases in the combined heat and power plant are included. The specific CO₂ emission, defined as the total emission from the process step divided by the production volume of the primary product, from each primary process product, i.e. coke, hot metal, liquid steel and steel slab, is calculated stepwise on the basis of calculated or measured process variables. The CO₂ emission is calculated as the carbon entering the system (as CO₂) subtracted by the carbon leaving the system in products and compounds other than the primary and carbon dioxide. The indirect emissions are then added by multiplying the actual material use by its specific emission, Table 1. This implies that the first process in the production chain is calculated first (i.e. the coke oven) and gradually the other processes are calculated on the basis of the earlier calculated emissions.

For carbon, leaving the system in other forms than CO₂, a credit is introduced in the analysis. The carbon is therefore only debited the process where it is used. For re-circulated materials, credits are given if they replace materials with a related CO₂ emission. The electricity produced in the CHP is credited the system steel plant/CHP. Since the BF slag is not granulated, this has not been included as a credit in the analysis. In order to take into account the CHP in the analysis, a final (fictive) process step is production of primary steel slabs including the electricity generated (per ton of steel slab, calculated from the CHP balance). The stepwise calculation gives the total accumulated emission for all processes in the Luleå system, per tonne of slab.
Description of the cases

The steel making system has been analysed with respect to changed production practice or integration of new process equipment. The existing BF/BOF route (process configuration 1-3-6-8, Figure 2) was thoroughly analysed in 8 different cases. Replacement of the BF by integration of Corex (4-6-8 and 2-4-7-8) and integration of Corex with the BF (1-3;4-6-8) was analysed. Integration of smelting reduction processes (5-6-8) was exemplified by integration of the Sidcomet process into the system. The BF/BOF route was compared to the EAF route by integration of an EAF (7-8 and 2-7-8) into the system. For the last scenario the DR plant is assumed to be operated using a gas with a low CO₂ emission factor (i.e. natural gas). Totally 7 different process routes were analysed in 15 calculated cases. A reference case was created according to the SSAB production in 2001. The reference case is used as a basis for the comparison. The different cases with a brief description are shown in Table 2.

Table 2. Cases and production routes that have been analysed

<table>
<thead>
<tr>
<th>Case</th>
<th>Description</th>
<th>Process route</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Normal production practice during 2001; Coke plant; BF (130kg PCI, 331kg coke, O₂ enrichment, 100% pellet, BOF slag); BOF (scrap, pellet); CHP (Coke oven-, BF- and BOF gas)</td>
<td>1-3-6-8</td>
</tr>
<tr>
<td>2</td>
<td>BF (no PCI)</td>
<td>1-3-6-8</td>
</tr>
<tr>
<td>3</td>
<td>BF (180 kg PCI)</td>
<td>1-3-6-8</td>
</tr>
<tr>
<td>4</td>
<td>BF (no BOF slag recycling)</td>
<td>1-3-6-8</td>
</tr>
<tr>
<td>5</td>
<td>BF (pellet/DRI 70/30)</td>
<td>1-3-6-8</td>
</tr>
<tr>
<td>6</td>
<td>BOF (no scrap, DRI)</td>
<td>1-3-6-8</td>
</tr>
<tr>
<td>7</td>
<td>BOF (scrap preheating)</td>
<td>1-3-6-8</td>
</tr>
<tr>
<td>8</td>
<td>BF (coke oven gas injection in BF)</td>
<td>1-3-6-8</td>
</tr>
<tr>
<td>9</td>
<td>BF replaced by COREX[9] (pellet, coal)</td>
<td>4-6-8</td>
</tr>
<tr>
<td>10</td>
<td>BF replaced by COREX[9] (ore, coke, coal)</td>
<td>4-6-8</td>
</tr>
<tr>
<td>11</td>
<td>BF replaced by Sidcomet</td>
<td>5-6-7</td>
</tr>
<tr>
<td>12</td>
<td>BF, BOF replaced by EAF (scrap)</td>
<td>7-8</td>
</tr>
<tr>
<td>13</td>
<td>BF, BOF replaced by DR plant (ore, pellet); COREX[9], EAF</td>
<td>2-4-7-8</td>
</tr>
<tr>
<td>14</td>
<td>COREX integrated with BF</td>
<td>1-3,4-6-8</td>
</tr>
<tr>
<td>15</td>
<td>BF, BOF replaced by EAF (DRI/scrap)</td>
<td>2-7-8</td>
</tr>
</tbody>
</table>

Each case was analysed according to the specific CO₂ emission for the system steel plant/power plant. The results are summarized in Table 3. For comparison, the corresponding CO₂ emission for HM and LS production has also been calculated.
Results

The CO₂ emissions, calculated for the total system, including slab production at the steel plant and generation of power at the CHP, are summarized in Table 3. The specific CO₂ emission is affected by the distribution of the ferrous burden and reductants. The use of process by-products is also an important factor affecting the emission, e.g. how the process off-gases are utilised. Credits are only given for carbon or by the substitution factor for process by-products that are utilised externally. No credits are given for BF slag, which could have been utilised for producing slag cement.

The specific CO₂ emissions from ore based production are calculated to 1690 – 3510 kg CO₂/tS (ton slab). For alternatives based on the EAF, the emissions are 420 – 1370 kg CO₂/tS. The different process routes show a large scattering, depending on the choice of equipment and operation practise, Figure 4. The lowest emission for iron ore based production is achieved within the existing route where also the scattering between the different alternatives is the smallest. For the COREX alternatives (alternatives 9-10, 13-14) large differences between the lowest and highest emission value are shown. The main reason for this is the use and recovery possibilities for the COREX gas. For integration of EAF the system there are large differences due to the choice of raw material, the higher value corresponds to use of DRI.

<table>
<thead>
<tr>
<th>Case</th>
<th>HM</th>
<th>LS</th>
<th>Steel (steel plant/ CHP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BF</td>
<td>1</td>
<td>1386</td>
<td>1389</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1435</td>
<td>1453</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1404</td>
<td>1428</td>
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<tr>
<td></td>
<td>4</td>
<td>1400</td>
<td>1429</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>1311</td>
<td>1339</td>
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<tr>
<td></td>
<td>6</td>
<td>1400</td>
<td>1588</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>1385</td>
<td>1338</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>1480</td>
<td>1472</td>
</tr>
<tr>
<td>COREX</td>
<td>9</td>
<td>2177</td>
<td>2172</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>3211</td>
<td>3011</td>
</tr>
<tr>
<td>Sidcomet</td>
<td>11</td>
<td>1438</td>
<td>1622</td>
</tr>
<tr>
<td>EAF</td>
<td>12</td>
<td>319</td>
<td>319</td>
</tr>
<tr>
<td>COREX/MIDREX</td>
<td>13</td>
<td>2413</td>
<td>2480</td>
</tr>
<tr>
<td>COREX/BF</td>
<td>14</td>
<td>1476</td>
<td>1492</td>
</tr>
<tr>
<td>MIDREX/EAF</td>
<td>15</td>
<td>-</td>
<td>1209</td>
</tr>
</tbody>
</table>

Specific results for the existing BF route

For the BF cases 1-8, the specific CO₂ emission for the total system is 1800 – 2000 kg CO₂/tS. The corresponding emission for HM was 1300 – 1480 kg CO₂/trj, or 1340 – 1590 kg CO₂/tLS (liquid steel).

By increasing the PCI rate from 0 (case 2) to 130 kg PCI /tHM (case 1), the CO₂ emission decreases with approximately 50 kg CO₂/tRJ. Only a marginal change of the emission is achieved by additional increase of the PCI rate to 180 kg PCI /tHM (the upper PCI rate
analysed). When increasing the injection from 0, external moisture is removed as the PCI rate is increased to keep the raceway flame temperature (RAFT) constant. Injection rates over the point where the RAFT is balanced without external moisture will not result in a significant CO₂ emission decrease. By recycling BOF slag through the BF (compare cases 1 and 4) a decrease of the emission can be achieved. The BOF slag replaces a slag forming additive that otherwise needs to be calcinated, CaCO₃ → CaO + CO₂, which requires energy and it replaces a material that contains CO₂. The recycling therefore gives a credit in the BOF system, lowering the CO₂ emission from the steel plant system. By charging DRI into the BF (case 5), the slag volume will decrease significantly, resulting in a considerable decrease in coke demand and thus CO₂ emission. But DRI used as cooling agent in the BOF converter (case 6) increases the emission significantly. Injection of coke oven gas in the BF (case 8) shows a decreased consumption of coke. The total emission is comparable with PCI cases 3 and 4. The distribution of scrap/HM, is the single largest factor affecting the specific CO₂ emission for LS. An increased scrap rate from ~17% to 21% (case 7) decreases the emission with nearly 50 kg. The differences between cases 1-5 and 8 are due to different emissions from the BF.

Specific results for integration of new processes into existing system

By replacing the BF by a COREX (cases 9-10), the corresponding CO₂ emission is 2580 – 3500 kg CO₂/tS. The big difference is due to the use of completely different raw materials; the lower value corresponds to a theoretical COREX operated with similar raw material quality as the reference BF. Credit has not been given to the full amount of the produced off-gas from the system, due to limitations in external users (thermal limit at the CHP of 320 MW). Integrating a COREX and Midrex (case 13) results in an emission level for the system of 2720 kg CO₂/tS. Combinalional operation with BF and COREX, recycling the COREX off-gas into the BF (case 14) presents the lowest emission figure for the COREX alternatives, 1869 kg CO₂/tS. The COREX alternatives 10, 13 and 14 are made with similar configurations and can be compared, while case 9 is evaluated for similar raw materials as the reference system.

By replacing the BF with a smelting reduction process, Sidcomet (case 11), the corresponding CO₂ emission was calculated to 1833 kg CO₂/tS.

By integration of a scrap based EAF (cases 12), the lowest emission 419 kg CO₂/tS is achieved. If the EAF is operated with 100% DRI (case 15), the corresponding emission is 1370 kg CO₂/tS. Note that the CO₂ factor for electricity is based on a European average, 0.6 kg CO₂/kWh.

Discussion

Effect of different process routes

The analysis shows that the CO₂ emission from the existing production system in Luleå is estimated to be 1800 kg CO₂/tS. This includes the effect of the process off-gases used in the CHP plant and emission from raw material preparation outside the system boundary, e.g. transports and pelletising, this is the lowest known emissions published. Integration of new process alternatives for ore based production instead of the BF did not give any decrease in the global emission from the system, c.f. 3. This could partly be expected as these processes were designed for other purposes than lowering the CO₂ emission. Use of DRI in the BF could decrease the global emission significantly. The possibility of utilising the BF slag in cement production has not been included in the analysis. Granulated BF slag is an important
A DRI-based EAF would also be an alternative that would lower the emissions significantly. However, in order to produce DRI a cheap, low emission-based fuel is needed, normally natural gas where no other use has been identified. In Sweden no such resource exists, so the closest solution could be to produce DRI based on Swedish ore and Norwegian natural gas. Integration of EAF into the system, i.e. melting scrap, would significantly give less emission than production from ore. A crucial issue when doing this is the availability of scrap, which is low in sparsely populated areas like northern Sweden. The recovered scrap corresponds to the steel produced some 10-50 years earlier multiplied by the recycling rate. Due to the global increase of the demand for steel, and the fact that the recycling rate is less than 100%, there will always be a demand for steel produced from iron ore. It is obvious that the emission from ore based production is higher than from production based on scrap. A large part of this is due to how the upstream CO₂ emission for scrap is taken into account. In the calculations made, and in other studies, scrap is treated as a CO₂ free material. In a global perspective all scrap recovered should be used for steel production, in order to decrease the emissions. The main question remaining is where and how this should be done. Transporting scrap from abroad and sending the finished products back would be a bad practice from both an economic and from an environmental perspective. In principle scrap, based production should be situated close to the scrap source and end user.

**Effect of the electricity grid**

Depending on the way the power is generated, the CO₂ intensity from the power generation varies. In the analysis a European average, 0.6 kg CO₂/kWh has been used. The corresponding figure for Sweden is 0.3 kg CO₂/kWh, due to the large share of hydro- and nuclear power [11]. A sensitivity analysis of the power dependency on the analysis is shown in Figure 4, where the emissions related to the power generation have been varied between 0 and 1.2 kg CO₂/kWh. Two tendencies are shown in the figure; for process alternatives where the internal use of power is lower than the internal power produced, e.g. the EAF alternative, the specific emissions are increased with an increased CO₂ emission for the power. For alternatives where the internally produced power is higher than that which is used, an increased emission for the power generation will decrease the specific CO₂ emission for the steel. In these cases, the surplus of power will act as a credit for the steel production. The variations for these alternatives are low (c.f. 4, cases 1-10). The variation for cases 11-13, and 15 are higher. However, the variations does not influence the order between the processes.
Comparison of effect-oriented analysis and inventory analysis

The calculations made in this study were made with an effect-oriented calculation method. Alternatively the analysis could have been made with an inventory analysis. A comparison between the two calculation methods based on the same cases as described earlier, Table 2, is shown in Figure 5. For the inventory analysis, the system boundary corresponds to the existing steel plant system and includes only direct emissions at the site. Hence, the effect of the pellet production or electricity generation is not included, since it is emitted outside the system boundary. The emissions calculated with the different methods differ in absolute values but the conclusions drawn from the analysis are still the same.

**Effect of the pellet production**

The specific CO$_2$ emission for hot metal production in the Luleå system is 1386 kg CO$_2$/tHM. The use of the magnetite ore in the LKAB pellets is one of the explanations of this low figure. The specific CO$_2$ emission for pellets from hematite ore is 154 kg CO$_2$/t, corresponding figure from magnetite ore is 51 kg. For sinter, the emission factor is 270 kg CO2/t. The chemical energy in the magnetite ore results in lower energy demand for the pelletising process. The specific energy decrease results in a CO$_2$ emission reduction of 100 kg CO$_2$/t. This is the main reason for the difference between the two pellet types. A comparison of the specific CO$_2$ emission calculated for the reference BF and three modern steel plants from an international study [6] is shown in Figure 6.
Conclusion

- A method and a tool for evaluating the CO₂ emissions from for an integrated steel plant have been developed. The tool can be used to analyse the effect of process changes within the existing processes as well as integration of new process technologies. The method is effect-oriented. It takes into account how the surroundings are affected by the steel plant.
- New process technologies such as COREX, Midrex – COREX or Sidcomet will not result in lower CO₂ emissions for the system studied. The traditional COREX plants are today working well and are a proven technology. However in the local gas-energy balance of SSAB it results in higher CO₂ emissions, alone or in combination.
- Increased recycling of scrap for steel production results in significantly reduced emissions, both for EAF based production and if increased into BOF. All scrap recovered should be utilised for steel production.
- SSAB Tunnplåt AB should continue with its ore based production. Among ore based steel plants it shows the lowest specific CO₂ emissions in the world. The use of 100% pellet produced from magnetite ore, whose emissions from preparation is low, are an explanation of this.

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WAYS TO REDUCE CO2-EMISSIONS AT SSAB LULEÅ WORKS

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WAYS TO REDUCE CO₂-EMISSIONS AT SSAB LULEÅ WORKS

by

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Key words: CO₂-emissions, steelmaking, ironmaking, blast furnace, energy efficiency, alternative iron- and steelmaking

ABSTRACT

Possibilities to reduce the CO₂-emissions from SSAB Tunnplåt AB’s ore based steel production in Luleå, have been studied, looking at alternative process routes as well as potential reduction in today’s production system.

The CO₂-emissions from Luleå Works are in general lower than from other ore based steel plants. This is partly due to lower emissions in the pellet production and high iron content in the pellets, resulting in exceptional low slag rates in the blast furnace operation.

There are today no new smelting reduction processes, either established or under development, that will lead to a substantial reduction of carbon dioxide emissions from the iron- and steelmaking. New process concepts under development are mainly focusing on usage of cheaper raw materials.

An analysis of potential possibilities to reduce CO₂-emission from the steel production system in Luleå shows that improvements in process optimisation, improved balance in liquid flow and higher yields, gives the strongest effect. Slag granulation, followed by slag cement production would substantially decrease the emissions. This reduction will take place at the location of the cement producer.

SSAB Tunnplåt AB has a product programme with a high percentage of high strength steels. A great part of the products are for vehicles, containers, cranes, e.g. where the high strength steel contributes to a low energy consumption, and low CO₂-emissions, in the usage of the final product.
1 INTRODUCTION

In the year 2004, the annual global production of steel will, for the first time, exceed 1000 million tonnes. During the last 30 years the steel production has been quite constant in Europe and Japan and slightly declined in North America. The last couple of years, steel production has increased in Asia, especially in China where 222 million tonnes were produced in 2003, i.e. 41 million tonnes more than 2002. Chinese experts estimate that the steel production will continuously increase for some years in the near future, based on a huge domestic market. The estimated production of steel in China for 2004 is 260 million tonnes, which is still 20 million tonnes lower than the domestic consumption [1].

The rapid increase in steel production in China has had a strong influence on the market for raw materials, resulting in a high price for coal, coke, scrap and iron ore. At some location there is a lack of metallurgical coke, which to some extent has become a strategic raw material.

There are basically two different production systems dominating, i.e. the integrated route (iron ore based) and electro steel (scrap based). For the integrated plants the blast furnace and basic oxygen furnace will keep their strong position for a foreseeable future. Roughly 35% of the steel is produced in electric arc furnaces, based on recirculated scrap and electricity.

According to the Kyoto protocol, the emissions of green house gases, especially carbon dioxide, is one of the major problems for the future of mankind. Globally, 7% of the emissions of carbon dioxide originate from the production of steel, mainly due to the usage of coal and coke as reductant in the iron ore based production. The European joint research will strongly focus on identification of methods to substantially reduce the CO2-emissions from the steel production, especially through the ULCOS-project, aiming at cutting the emissions from steel production by 50%. Similar programs will also start in other parts of the world.

This paper deals with an investigation of possibilities to reduce the CO2-emissions from SSAB Tunnplåt AB’s ore based steel production in Luleå, looking at alternative process routes as well as potential reduction in today’s production system.

2 STEELMAKING AT SSAB TUNNPLÅT AB

![Fig 1. Lay out of SSAB Works in Luleå.](image)
A layout of the production units at SSAB Works in Luleå is shown in Fig 1. In the year 2000, SSAB stopped the operation in two old blast furnaces and all the hot metal production was concentrated to one new 11.4 m (hearth diameter) furnace. Just some years earlier a new coal injection plant was erected, replacing the earlier one, erected in 1985. Coal injection capacity is in the range of 160-180 kg per tonne of hot metal, depending on production level. Coke is produced in an own coke oven plant from 1975, which has been revamped in 2003. Additionally 15 % of imported coke is used.

The sintering plant in Luleå was taken out of operation already 1978, due to old equipment and strict environmental regulations. Since then the hot metal production is based on 100 % pellets. After the introduction and optimisation of olivine pellets (MPBO, KPBO) from LKAB in the mid 80’s, the slag volume has been in the range of 150-170 kg per tonne hot metal, and the reductant rate among the lowest in the world. In plant fines are recirculated to the blast furnace as cement bounded briquettes, to a volume of ~50 kg per tonne of hot metal. Some operational data from 2003 are shown in Table 1.

Table 1. Averages of operational data of BF No 3 in Luleå 2004 January-May.

<table>
<thead>
<tr>
<th>Pellet ratio</th>
<th>100</th>
<th>wt%</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPBO</td>
<td>57</td>
<td>wt%</td>
</tr>
<tr>
<td>KPBO</td>
<td>43</td>
<td>wt%</td>
</tr>
<tr>
<td>Additives</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lime stone</td>
<td>41</td>
<td>kg/ tHM</td>
</tr>
<tr>
<td>BOF slag</td>
<td>46</td>
<td>kg/ tHM</td>
</tr>
<tr>
<td>Manganese slag</td>
<td>5</td>
<td>kg/ tHM</td>
</tr>
<tr>
<td>Dust briquettes</td>
<td>37</td>
<td>kg/ tHM</td>
</tr>
<tr>
<td>Reducing agents</td>
<td>468</td>
<td>kg/ tHM</td>
</tr>
<tr>
<td>Coke</td>
<td>327</td>
<td>kg/ tHM</td>
</tr>
<tr>
<td>PCI</td>
<td>141</td>
<td>kg/ tHM</td>
</tr>
<tr>
<td>Blast</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific volume</td>
<td>938</td>
<td>m³/tHM</td>
</tr>
<tr>
<td>Blast temp.</td>
<td>1118</td>
<td>°C</td>
</tr>
<tr>
<td>O₂ content of blast</td>
<td>23.8</td>
<td>Volume%</td>
</tr>
<tr>
<td>Productivity</td>
<td>2.51</td>
<td>tonnes/m³/24h</td>
</tr>
<tr>
<td>Hot metal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>4.75</td>
<td>wt %</td>
</tr>
<tr>
<td>Si</td>
<td>0.36</td>
<td>wt %</td>
</tr>
<tr>
<td>Si std dev</td>
<td>0.119</td>
<td>wt %</td>
</tr>
<tr>
<td>S</td>
<td>0.039</td>
<td>wt %</td>
</tr>
<tr>
<td>Temperature</td>
<td>1482</td>
<td>°C</td>
</tr>
<tr>
<td>Slag</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amount</td>
<td>163</td>
<td>kg/ tHM</td>
</tr>
<tr>
<td>B2 CaO/SiO₂</td>
<td>0.98</td>
<td></td>
</tr>
<tr>
<td>MgO</td>
<td>17.8</td>
<td>wt %</td>
</tr>
</tbody>
</table>

Desulphurisation of the hot metal is made in the ladle, before charging into the two LD-converters (2*107 t). The crude steel is further treated in the alloying processes CASOB and RH-vacuum oven. The steelmaking is followed by two slab casters. The slabs produced in Luleå are transported 800 km south to Borlänge, where the rolling mill is located.
SSAB Tunnplåt AB has a product programme with a high percentage of high strength steel. A great part of the products are for vehicles, containers, cranes, e g where the high strength steel, from a CO₂-perspective, contributes to a low energy consumption in the usage of the final product.

3 ALTERNATIVE IRON- AND STEELMAKING PROCESSES [3]

An alternative to the BF / BOF route is the electric arc furnaces (EAF), where scrap is recirculated. The EAF can also be operated by use of direct reduced iron (DRI / HBI) or with a mixture of DRI and scrap. The main energy source is electric power.

The DRI / HBI are produced by reducing iron ore in solid state. The reduction is normally made by natural gas or coal. There are three types of reactors, e g shaft furnace, fluidized bed and rotary hearth. The shaft processes (Midrex, Hyl) are the most developed and accounts for almost 85 % of all DRI production. The fluid bed reactors are normally operated with natural gas (Finmet, Circored), but can also be coal based (Circofer). Processes based on rotary hearth technology are coal based (Fastmet, Itmk3, Sidcomet). In this study, only processes demonstrated in industrial or pilot plant scale are considered.

For production of liquid hot metal from iron ore, Corex is so far the only process that has come to a commercial use. Four units, all of the size C-2000 (2000 tonnes per day), are in operation at 3 different sites. Corex is today a well developed process, but the coal consumption is high and a sophisticated usage of the energy rich export gas is necessary, to justify the process. This is today made through production of electricity, combination with direct reduced iron (DRI) production, and could be combined with blast furnace tuyere gas injection.

Several smelting reduction processes are under development and some of them will be demonstrated in pilot plant or industrial scale. As far as can be seen today, none of them will, in the present stage of development, lead to a substantial decrease in CO₂-emissions.

4 COMPUTER MODEL AND CALCULATION PRINCIPLES FOR ESTIMATION OF CO₂-EMISSIONS

The analysis of CO₂-emissions was conducted in a mathematical simulation model, derived for the steel plant system of SSAB Luleå Works. It consists of one process module calculating the mass- and energy flows in the system, and one CO₂-module using the mass- and heat balance to calculate the CO₂-emissions, Fig 2.

The process module includes simulation models for the different process units in the existing production system. New alternative processes can be included by a mass balance sheet. All models are governed by an interface controlling the different sub models. For the study of new alternative technologies, process data have been adapted to fit into the existing steel plant system.
Fig 2. Analysis model used in the study.

In an industrial energy and production system, such as the integrated steel plant, the different processes are connected by primary and secondary products, affecting each other. Raw materials used for the iron- and steelmaking have generated CO₂-emissions in their preparation. There are processes generating CO₂-emissions inside the steel plant border that is emitted in by-products (e.g. process gases) outside the steel plant border. The use of by-products might also result in a global decrease of the CO₂-emissions, due to replacement of fossil fuels. There are principally three ways of making the analysis (Fig 3):

- as an inventory analysis, including only direct emissions from the system.
- as an effect-oriented analysis, also including indirect upstream emissions from raw material preparation or products used in the production, as well as downstream emissions related to by-product use.
- as an LCA analysis, taking into consideration the total emissions during the total life cycle of the product.

Fig 3. Different philosophies for calculation.

In order to take the specific aspects of the current system into consideration, an effect-oriented calculation philosophy is chosen. The LCA analysis is not applicable since the life cycle emission of
the product is of no relevance to this study. The analysis methodology is based on the method proposed by Aichinger et al [2], and is based upon the following principles:

- **Relevance**: the system boundary chosen should appropriately reflect the greenhouse gas emission from the system.
- **Completeness**: the calculation should include all emission sources and activities within the system.
- **Consistency**: the result should allow for meaningful comparisons of emission performance over time.
- **Transparency**: the analysis should be conducted in a factual and coherent manner, based on a clear audit trail.
- **Accuracy**: the emission calculations should have the precision needed for the intended use, and provide reasonable assurance on the integrity of the calculated emission.

Besides the direct emissions within the system, the indirect emissions from the preparation of raw materials and the use of process gases in the combined heat and power plant (CHP) are included. The specific CO2-emission from the process step divided by the production volume from each primary process product is calculated stepwise. The CO2-emission is calculated as the carbon entering the system subtracted by the carbon leaving the system in products and compounds other than the primary and carbon dioxide. The indirect emissions are then added by multiplying the actual material use by its specific emission, Table 2. This implies that the first process in the production chain is calculated first (i.e. the coke oven) and gradually the other processes are calculated on the basis of the earlier calculated emissions.

Table 2. CO2 emission factors used for indirect emissions from processes outside the system boundary (kg CO2/t).

<table>
<thead>
<tr>
<th>Material/energy</th>
<th>Specific emission</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pellet (hematite ore)</td>
<td>154</td>
<td>kg CO2/tonne</td>
</tr>
<tr>
<td>Pellet (magnetite ore)</td>
<td>51</td>
<td>“</td>
</tr>
<tr>
<td>Ore</td>
<td>26</td>
<td>“</td>
</tr>
<tr>
<td>DRI, Carbon based</td>
<td>1790</td>
<td>“</td>
</tr>
<tr>
<td>DRI, Natural gas based</td>
<td>586</td>
<td>“</td>
</tr>
<tr>
<td>Scrap</td>
<td>18.7</td>
<td>“</td>
</tr>
<tr>
<td>Burned Lime</td>
<td>1346</td>
<td>“</td>
</tr>
<tr>
<td>BOF slag</td>
<td>149</td>
<td>“</td>
</tr>
<tr>
<td>Limestone</td>
<td>428</td>
<td>“</td>
</tr>
<tr>
<td>Oxygen</td>
<td>1283</td>
<td>“</td>
</tr>
<tr>
<td>Steam</td>
<td>224</td>
<td>“</td>
</tr>
<tr>
<td>Power</td>
<td>0.6</td>
<td>kg CO2/kWh</td>
</tr>
</tbody>
</table>

**Transports**

<table>
<thead>
<tr>
<th>Material/energy</th>
<th>Specific emission</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boat (coal/coke)</td>
<td>51.4</td>
<td>kg CO2/tonne</td>
</tr>
<tr>
<td>Truck</td>
<td>0.072</td>
<td>kg CO2/tonkm</td>
</tr>
<tr>
<td>Train</td>
<td>0.020</td>
<td>“</td>
</tr>
</tbody>
</table>

For carbon, leaving the system in other forms than CO2, a credit is given in the analysis. The carbon is therefore only debited the process where it is used. For re-circulated materials, credits are given if they replace materials with a related CO2-emission. The electricity produced in the CHP is credited the system. Since the blast furnace slag is not granulated, this has not been included as a credit in the analysis. The stepwise calculation gives the total accumulated emission for all processes in the Luleå Works system.
5 CO₂-EMISSIONS FROM SSAB LULEÅ WORKS

Comparison with other integrated steel plants

Aichinger et al presented in 1999 a study of CO₂-emissions related to ore based steel production for three modern European plants [2]. The average emission was 1640 kg per tonne of hot metal. The much lower value compared to other studies is caused by the credit given for energy in the blast furnace top gas, as well as for the usage of granulated blast furnace slag for cement production.

By using the same calculation principle, as earlier described, the emissions for SSAB Luleå Works is 1385 kg per tonne of hot metal, Fig 4. The major difference is the usage of 100 % high quality pellets from LKAB, based on a magnetite type iron ore, which needs much less energy for induration, compared to hematite based pellets, or sinter, Fig 5. Another difference is the usage of 100 % coke oven gas for firing of the coke oven battery.

When comparing emissions per tonne of crude steel the difference is smaller, mainly due to lower scrap rate in the BOF at SSAB.

![Fig 4. CO₂-emissions from SSAB Luleå Works, compared to some European plants. (Alchinger et al).](image1)

![Fig 5. CO₂-emissions from sintering respective pelletising. (Source: LKAB).](image2)
Comparison with EAF steelmaking

If the BF / BOF at Luleå Works are replaced by EAF’s the total emission, using the same calculation method as described above, the total CO2-emission will be 320 kg per tonne of liquid steel, in case of 100 % scrap charging. Charging of 50 % DRI would increase the emissions to 700 kg.

From a strict logical point of view it is not correct to look upon scrap melting as an alternative to ore based metallurgy. Instead they are different steps in the same process chain; an iron unit is created by ore based metallurgy, then scrap is recovered and melted again, e.g using EAF. As a calculation example look upon one tonne steel that is first created from ore with a specific emission of 1400 kg CO2. Assume that 75 % of the steel can be recovered as scrap and re-melted with a CO2 emission of 320 kg CO2. Then in the second life cycle we will get 0.75 tonne and a total emission of 0.75*320 =240 kg CO2, in the third life cycle we get 0.56 tonne steel and 180 kg CO2, etc. If all remelting cycles are summed up (using standard formula for geometric series) they give back 3 tonne of steel and 960 kg CO2. Totally in all life cycles 4 tonnes of steel and 2360 kg CO2 are produced, i.e, the mean for the sum of all life cycles is 590 kg CO2/tonne steel. If the recovery rate is lower the emission is higher, e.g, 50 % recovery would give a mean emission for all life cycles of 860 kg CO2/tonne steel.

Comparison with alternative technologies

Corex is so far the only alternative to the blast furnace for production of liquid hot metal. If the blast furnace in Luleå is replaced by a Corex plant the CO2-emissions will be around 2170 kg per tonne of liquid steel, if high quality raw materials are used. With poor raw materials the emissions will be more than 3000 kg. Combination of Corex with other processes might lower the emissions to some extent, although not down to the same level as the blast furnace.

All the smelting reduction process under development seem to have an estimated coal consumption higher than the blast furnace, or in the same range, which make them less attractive from an CO2-emission perspective. Many of the ideas that are now being realised originate from the 80’s, when there was no focus on CO2-emissions and the major objective was to use less expensive raw materials. Calculations for the Sidcomet process show emissions slightly higher than for the blast furnace. The reason for choosing Sidcomet as a representative for rotary hearth processes is that it was close to be industrialised during the time when this study was initiated, and consumption figures were available, estimated from pilot plant operation.

Potential CO2 reduction for SSAB Luleå Works

An analysis has been made to identify possible potential ways of reducing the CO2-emissions, without replacing any of the production units at Luleå Works. The results are as follows:

- *Increased iron yield.* If the yield from hot metal to liquid steel can increase by 1 %, the CO2-emissions are reduced by 14 kg per tonne.

- *Increased crude steel yield.* If the yield from liquid steel can be increased by 1 % (for example through reduced slag losses, reduced slopping from the BOF or reduced losses from the continuous casting), CO2-emissions can be lowered by 21 kg per tonne.

- *Improved balance in the liquid flow.* During process disturbances in the steelmaking, pig iron is cast as an alternative to modification of the hot metal production. The solid pig iron is later charged to the BOF. The method reduces the yield from hot metal to liquid steel and is also reducing the usage of external scrap, causing higher CO2-emissions. If pig casting could be com-
pletely avoided emissions would be reduced by 88 kg per tonne. On the other hand, changing the production level of the blast furnace, to avoid pig casting, is not a good solution, as emissions will increase due to an increased blast furnace reductant rate.

- **Increased ratio of external scrap.** For each percentage of scrap charged to the BOF, CO$_2$-emissions are decreased by 11 kg per tonne. Initially, scrap can be charged as a coolant instead of iron ore, and for higher ratios scrap can be preheated. An increased charging of external scrap will probably not reduce CO$_2$-emissions globally, as an increased scrap ratio at SSAB will lead to a reduced scrap charging in another plant, due to limited available amount of scrap.

- **Coal injection into the blast furnace.** At BF No 3 in Luleå normally 140 kg of pulverised coal is injected per tonne of hot metal. Process calculations show that when going from all coke operation to an injection level of 60 kg, CO$_2$-emissions are substantially reduced. Above this level the effect of higher PC rate is marginal. The reason is that below 60 kg PC, moisture is added to the hot blast for flame temperature control. Above 60 kg, oxygen is added for the same reason, Fig 6.

![Fig 6. Effect of coal injection rate (PCI) in Luleå BF without credit for BF-gas (upper) and with credit for BF-gas (lower).](image)

- **Reduced reductant rate in the blast furnace.** If the coke rate is reduced by 20 kg per tonne of hot metal, CO$_2$-emissions are reduced by 66 kg per tonne of liquid steel. It should be pointed out that the reductant rate at SSAB has been more or less unchanged since the mid 80’s, and is among the lowest in the world. Although there are theoretically options, like using coke and coal with a substantially lower ash content.

- **Recirculation.** SSAB is already applying recirculation of BOF-slag into the blast furnace. The BOF-slag has a fairly high iron content and the chemical composition is almost ideal for the blast furnace process. BOF-slag reduces the need for limestone and has been given a credit of 142 kg CO$_2$ per tonne of slag.

- **Reduced flaring of process gases.** Because of unbalance in gas production and gas utilisation, sometimes the process gases are flared. Through an improved planning of the total energy system a reduction of the gas flaring is possible. It is important to make sure how to use the gases when there is a low need for hot water production.

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2nd International Conference & Exhibition on New Developments in Metallurgical Process Technology,
Riva del Garda – Italy, 19-21 September 2004
- *Firing of the coke oven battery*. More efficient firing of the coke oven battery can reduce CO$_2$-emissions to some extent.

- *Heat exchangers for the hot stoves*. By heat exchanging of the off gases from the hot stoves to the combustion air, energy consumption can be reduced. Although, the effect on CO$_2$-emissions is not very high.

- *Top pressure recovery turbine*. Installation of a turbine to recover the top pressure from the Luleå blast furnace would reduce CO$_2$-emissions by 10 kg per tonne of steel.

- *Slagcement*. Granulated blast furnace slag is, to a great extent, used as a raw material for the cement industry in Europe. CO$_2$-emissions are reduced by one tonne per tonne of granulated slag, according to a German study. In Sweden the structure of the cement market is such that slag cement production is very limited. For an increased production of slag cement, a close cooperation with the cement industry is needed. If all blast furnace slag produced in Luleå would be used for cement production it would result in reduced CO$_2$-emissions by 165 kg per tonne of hot metal. The reduced emissions will not take place at SSAB, but at the site of the cement producer.

- *Improved hot water balance*. A problem for the energy recovery is a positive hot water balance, e.g., the usage of recovered energy is limited. By connecting the hot water net to the net of another community, near by, the balance can be improved. A potential reduction of CO$_2$-emissions is estimated to 22 kg CO$_2$ per tonne.

The potential theoretical reduction of CO$_2$-emissions from SSAB Luleå Works for different modifications and improvement in the steel production is shown in Fig 7.

![Fig 7. Potential reduction of CO$_2$-emissions kg/t crude steel for SSAB Luleå Works. Some clarification to Fig 7 are made below:](image-url)
- for estimating the effect of slag granulation, 165 kg slag per tonne of hot metal and 100 % yield from liquid slag to cement is considered.
- it is estimated that the recirculation of BOF-slag can be increased by 5 kg per tonne of hot metal.
- a prerequisite for balance in the liquid flow is that all hot metal is charged as liquid into the BOF.
- scrap charging into the BOF is increased up to the level where cooling with iron ore is avoided, e.g. to a scrap rate of 26 %.

**Product quality aspects**

The development of steel products is moving towards higher and more narrow strength. This means that steel constructions become lighter, leading to a reduced environmental impact. From an environmental perspective, including CO$_2$-emissions, it is important to consider all different steps in steel production as well as for the usage of the final steel products. Important steps are:

- production of raw materials and energy generation.
- production of steel.
- transportation of raw materials, products and wastes.
- production, usage and recirculation of final products.
- deposition of wastes.

Birat et al [4] have reported the energy consumption for a car during a ten years life cycle, divided into manufacturing of the car, production of components for the car, production and transportation of gasoline and usage of the car during the life cycle, Fig 8.

![Fig 8. Energy consumption during the life of a car. (Source: Birat et al).](image)

The major energy consumption is the gasoline, and its production (90 %). This motivates the great efforts being made in car manufacturing to reduce the weight and produce more efficient engines. SSAB is participating in the ULSAB-project (Ultra Light Steel Auto Body), which has inspired the company strategy towards a higher ratio of high strength steels.

SSAB Tunnplåt is to a great extent utilising the possibilities given by the very pure Swedish iron ore. The strategy to increase the ratio of high strength steels, being energy efficient in its utilisation, is well supported by existing process route. The localisation, close to the ore mines and far from highly populated areas where scrap is generated, are strong arguments to continue with the ore
based steel production. Internal scrap, as well as external local scrap is today re-circulated via addition into the BOF, without any negative influence on product quality, minimising transportation of iron units. The virgin scrap, from the first life cycle of the SSAB products, also gives pure iron units when being recovered in European EAF’s, close to the customers.

Long term solutions

Long term solutions to the global CO₂-emission problem can hopefully be developed in the joint European ULCOS project. Of special interest for SSAB are:

- Full oxygen blast furnace operation, combined with CO₂-washing of the top gas and recirculation of reducing gas. The proposed process has a potential to substantially reduce CO₂-emissions from the blast furnace and also opens up for capture and storage of the isolated carbon dioxide.

- Production of pre reduced iron by natural gas, close to the gas field, opens up a great possibility for capture and storage of carbon dioxide within the gas field. The pre reduced iron, almost without any CO₂ backpack, can be used in EAF, BOF or BF, leading to substantially reduced CO₂-emissions.

6 DISCUSSION AND CONCLUSIONS

There are today no new smelting reduction processes, either established or under development, that will lead to a substantial reduction of carbon dioxide emissions from the iron- and steelmaking. New process concepts under development are mainly focusing on usage of cheaper raw materials.

A change towards scrap based production would strongly reduce the emissions of carbon dioxide. On the other hand, EAF-steelmaking in Luleå is not possible, due to the production of high strength steels, as well as a limited availability of scrap.

Among integrated steel plants, SSAB Luleå Works has the lowest CO₂-emissions, mainly due to usage of 100 % LKAB-pellets, which have low emissions in their production, due to the chemical energy in magnetite ore, and gives an energy efficient blast furnace operation, with an outstanding low slag volume.

Energy saving investments, like hot stove preheating or top pressure recovery, have only marginal effects on CO₂-emissions.

An analysis of potential possibilities to reduce CO₂-emission from the steel production in Luleå shows that improvements in process optimisation, improved balance in liquid flow and higher yields, gives the strongest effect. Slag granulation, followed by slag cement production would substantially decrease the emissions. This reduction will take place at the location of the cement producer.

For the long term solution to the problem with huge emissions of carbon dioxide from the steel production, a giant joint European research program is starting up, involving almost the whole European steel industry, in cooperation with suppliers, research institutes and universities.
REFERENCES


