Iron & Steel is the second major industry in terms of energy consumption (See figure 1). Energy constitutes a significant portion of the cost of steel production, ranging from 20% to 40% depending on process, local conditions, etc. Thus, improvements in energy efficiency result in reduced production costs and thereby improved competitiveness.

The Iron & Steel industry has already gone a long way in the direction of efficiency; sophisticated energy management systems ensure efficient use and recovery of energy throughout the whole steelmaking process.

On the environmental side, CO₂ emissions intensity (t of CO₂/t of crude steel) also vary from plant to plant, and country to country.

As a whole, the Iron & Steel industry is an important source of GHG emissions, accounting for 6.8% of world carbon dioxide (CO₂) emissions and 3.0% of GHG emissions (see table 1). It is the third largest industrial source of GHG after chemical and cement sector (Baumert, 2005).

Out of the sector’s estimated total emissions of 2.507Mt CO1 Unless specified otherwise, all CO₂ and GHG emissions figures in this paper include both direct (on-site) emissions from fuel combustion and the use of coal and lime as feedstock and indirect emissions from generation of the purchased electricity.

In 16 years time (1990 – 2006) CO₁ Unless specified otherwise, all CO₂ and GHG emissions figures in this paper include both direct (on-site) emissions from fuel combustion and the use of coal and lime as feedstock and indirect emissions from generation of the electric power and heat used in the steelmaking processes. per tonne of crude steel decreased by 7%, from 2.2 t of CO₂ in 1990 to 2.0 t in 2006 (see table 1).

Also in this field, the industry is not sparing efforts to limit its footprint and, on average, today, 1.9 t of CO₂ are emitted for every t of steel produced.

CO₂ emissions intensities vary from plant to plant due to differences in the technologies used, finished products, plant operating efficiencies, plant maintenance, quality or iron ore and coal and the carbon intensity of the electricity. The strongest factor affecting emissions intensity is the overall processing method.

Today there are two main steel making processes that account for 98% of the world steel production: the integrated blast furnace-basic oxygen furnace (BF-BOF) route and the scrap/DRI-based electric arc furnace (EAF) route (see figure 2).

The BF-BOF steelmaking process is more emission intensive than the scrap/DRI-EAF route, though estimates vary considerably (see table 2).

The international effort to mitigate and adapt to climate change is coordinated and regulated by the Kyoto Protocol (negotiated in 1997 and entered into force in February 2005) and Copenhagen Conference (2009). The efforts established are not prescriptive and do not set out binding GHG targets.
In parallel to the Kyoto Protocol and Copenhagen Conference, Governments of every country have issued national primary policies aiming at mitigating GHG emissions. On average, Kyoto Protocol and Copenhagen Conference’s target, to be achieved on a worldwide basis, is to reduce GHG gases by 15–20% by 2020 vs. 1990 levels (range depending on countries). In 2009, total global CO2 emissions increased to 31.3bn t, almost 40% since 1990, the base year of the Kyoto Protocol (see figure 3).

The assessment excludes CO2 emissions from deforestation and logging, forest and peat fires, from post-burn decay of remaining above-ground biomass, and from decomposition of organic carbon in drained peat soils.

Collectively, the countries that signed the Kyoto Protocol reduced CO2 and greenhouse gas emissions in 2009 by 7% compared to 1990, the base year for the Protocol. Most of the decrease, though, has taken place due to the financial crisis. Greenhouse gas emissions could rapidly increase toward pre-recession levels as industrialized countries grow out of recession.

In November 2011, the United Nations Climate Change Conference took place in Durban, South Africa. The most important achievement was the adoption of a mandate for parties to the UN Framework Convention on Climate Change to negotiate a new legal agreement by 2015. The new agreement would take effect from 2020. In the last January 2012 the State Council of China published a work plan for emissions control of GHG by 2015.

Considering all the above:

- Climate change is a global environmental challenge which can be addressed only with a strong global action. Durban made a significant breakthrough with the past;
- The iron and steel industry will play an important role;
- Innovation will give a fundamental contribution and Tenova is fully committed, in the value chain steps where active, with R&D activities and efforts in order to give an important portion.
- Tenova’s new technologies meet the most updated environmental requirements and at the same time focus on processes competitiveness and flexibility.

In the next pages, the most important innovations of our technologies in the field of energy efficiency, CO2 and NOx emissions abatement are described.

**DIRECT REDUCTION**

CO2 abatement

In 2006, a strategic alliance was formed by Tenova and Danieli & C. for the design and construction of gas-based DR plants under the new ENERGIRON trademark. ENERGIRON® is the innovative HYL direct reduction technology jointly developed by Tenova and Danieli, and whose name derives from the unique DRI product which distinguishes this technology from other available processes. The ENERGIRON® technology is characterized by a significant environmental contribution in terms of CO2 abatement.

ENERGIRON ZR DR process is the most advanced Tenova HYL technology, based on zero reforming (reductants are generated by “in-situ” reforming inside the shaft furnace). Figure 4 represents the process flow sheet.

The selective CO2 removal, based on chemical absorption (amines, hot carbonates solutions) which is inherent with the ZR DR process, becomes a real GHG abatement if the removed CO2 is commercialized.

A new development of the ZR DR process, recently patented and referred to as the...
“Minimal CO₂ Emission Scheme” (see figure 5), assures the possibility to remove up to 80% of total carbon input as selective CO₂. By the incorporation of a PSA-type Physical Adsorption System, the carbonaceous compounds are separated from the recycling gas (after CO₂ absorption), feeding them back to the reduction circuit and using the separated H₂ as fuel instead of tail and/or natural gas.

For example, using this new scheme for a recently proposed project for a 1.6 Mt/y DR plant in Europe, only 19% of carbon emissions would be non-selective CO₂ vented to the atmosphere instead of the 30% in the conventional case without PSA. The unique CO₂ emission reduction which is proper to the ZR process can be also key to reduce emissions in the traditional BF-BOF route by charging pre-reduced DRI into the BF-BOF. For a 23% - 38% DRI charge, production increase is about 20% - 28%, respectively and with 23% lower CO₂ emissions.

Energy efficiency
Specifically the ZR scheme is the most energy efficient DR technology available; in fact in terms of energy savings this technology has been refined over the years to what is now the lowest consumption of energy per ton of DRI of any DR process on the market.

The overall energy efficiency of the process is optimized by:
- the higher operating pressure (6-8 bar A), which optimizes the power consumption;
- the higher reduction temperature (above 1050°C), which increases the reduction process kinetics;
- “in-situ” reforming inside the shaft furnace, which avoids an external energy consumer (reformer);
- the various energy recovery units in the plant.

Therefore, the DRI product takes most of the energy supplied to the process, with minimum energy losses to the environment. The overall energy efficiency of the ZR process is around 87%, compared with less than 75% for other DRI technologies. For natural gas-based plants, the requirements (including selective CO₂ removal and production of high metalized and high-carbon DRI) are now only 9,84GJ and 70 kWh per t of DRI.

More importantly, the process provides even greater energy savings for the steelmaking process, thanks to its inherent ability to produce highly metalized DRI in excess of 94% with high carbon content in the form of iron carbide. Furthermore, the product can be continuously transported from the DR plant to the electric arc furnace using the reliable Tenova HYL HYTEMP® System for pneumatic hot transport and feeding to the EAF. This retains the inherent heat from the DR process of around 600°C, delivering the product already hot to the furnace.

The combination of hot DRI and its high carbon content in excess of 3.5% provides chemical energy to the melting process, thus reducing power-on-time from around 44 minutes for cold DRI to around 31 minutes, and reducing electrical energy requirements in the EAF from 530 to around 380 kWh per ton of liquid steel. The benefits provided to steelmakers by hot charging a high-carbon DRI product represent millions of dollars in annual operating cost savings by reduced energy costs, as well as increased productivity in the furnace.

Flexibility in using different energy source
Tenova HYL DRI technology also allows the use of Coke Oven Gas (COG) and Syn-Gas (gas from coal gasification). In both cases the basic ZR scheme can be used without any modification. For example, considering that COG has about 25% methane, while natural gas has +95% hydrocarbons, therefore the use of COG makes the process even easier. For coke oven gas-based plants, ZR DR process consumption per ton of DRI needs are only 10,05GJ and 90 kWh, including COG compression and for Syn-Gas-based plants 9,42GJ and 70-90 kWh.

Tenova HYL started the execution of a project for Jindal Steel & Power Ltd in India for a production of 2.5 Mt/y of hot and cold DRI, using a mixture of syngas and COG in any proportion. This project is a breakthrough in the DR industry for using a mixture of coal based energy sources, while transporting hot DRI to adjacent EAF’s with the HYTEMP system.

The plant is designed to produce both hot and cold DRI in any combination; furthermore, it will also use syngas from coal gasification and Coke Oven Gas as sources of reducing gas and also in any proportion.

The energy consumption for the plant will be on the order of only 2.2 Gcal/ton of DRI. As a further example of energy efficiency, the plant will also use BOF gases for fuel to the DR Process Gas Heater and other users.

Adding to the excellent flexibility of the ZR process is the fact that this very versatile plant being built for JSPL uses the same basic process scheme characteristic of any ENERGIRON ZR plant, whether natural gas based or other. Thanks to the above benefits, ZR direct reduction technology has had dramatic success in the past seven years. Since 2005, nine new plants have been or are currently being built for a total new capacity of 13.65Mt per year. Two additional projects for conversion of existing plants to the ZR process scheme will add another 0.80Mt of incremental capacity, for an overall total of 14.5 Mt with this technology in such a short time span.

Among the most recent references Emirates Steel Industry, located in Abu Dhabi (see figure 7), is one of the world’s largest projects to date with DRI production of more than 3.2 Mt/y in two new plants. The technology now exists to be able to build ZR DR modules of 2.5Mt/y in a single unit;
STEELMAKING
Tenova’s approach to steelmaking optimization and control provides great potential for improving steel quality, increasing productivity, lowering operational costs, improved environmental performance and safety.

Due to the development of novel sensors, mathematical models and process improvements, Tenova makes it possible to obtain more efficient operations in the electric arc furnace and in the oxygen converter.

Tenova is working in two main directions to achieve these targets:
1) Process optimization to reduce/improve the energy efficiency of the melting process:
   - Continuous feeding and preheating system (Consteel®).
   - Holistic process optimization based on real time measurement (EFSOP®) of off-gas composition;
   - Dynamic process control based on off-gas analysis and other novel sensor, and process optimization models (iEAF®);
2) Energy recovery from off-gas:
   - An efficient solution for off-gas heat recovery to produce steam/electrical energy (iRECOVERY®); A steel plant of 1 Mt/y production with top charge EAF 100% scrap (150 t/h productivity) equipped with Tenova technologies is capable to cut CO₂ emissions by about 65,500 t/y (see table 3).

The synergic integration of our technologies in the EAF route is the new Consteel Evolution™ which is able to achieve overall CO₂ reduction of 80,000 t/y of CO₂ (-15.4%). A short overview of all the above Tenova innovative technologies.

Table 3 – CO₂ emission related to a 1Mt/y steel plant with top charge EAF equipped with Tenova technologies.

<table>
<thead>
<tr>
<th></th>
<th>tons of CO₂ emissions (direct &amp; indirect) per year</th>
<th>CO₂ %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional EAF</td>
<td>518,000</td>
<td>0.0%</td>
</tr>
<tr>
<td>with EFSOP®</td>
<td>-7,400</td>
<td>-1.4%</td>
</tr>
<tr>
<td>with iEAF®</td>
<td>-7,400</td>
<td>-1.4%</td>
</tr>
<tr>
<td>with iRecovery®</td>
<td>-20,700</td>
<td>-4.0%</td>
</tr>
<tr>
<td>with Consteel®</td>
<td>-30,000</td>
<td>-5.8%</td>
</tr>
<tr>
<td>Total reduction</td>
<td>-65,500</td>
<td>-12.6%</td>
</tr>
</tbody>
</table>

Fig. 8 – EFSOP® operating results (/t of good billet).

Fig. 9 – iEAF® scheme.

Fig. 10 – iBOF® scheme.

EFSOP®
In the last decade, real-time off-gas analysis was the approach taken to optimize the energy input in the EAF, due in part to its use in post-combustion control and in the enhanced understanding of process dynamics provided by off-gas composition profiles. The reliability and effectiveness of the EFSOP® system has been demonstrated by the successes achieved in over 60 installations; world-wide. Typical results are presented in figure 8.

iEAF®
Tenova’s “Intelligent Electric Arc Furnace” the iEAF®, was the result of a tremendous collaborative effort between Tenova, Toronto University, CSM Research Centre and Tenaris Dalmine. The iEAF® is an innovative dynamic process control system for the real-time management of arc furnace melting, that is based on EFSOP® off-gas analysis, and other novel sensors, and dynamic real-time models of the EAF process. The iEAF® makes it possible to align chemical and electrical energy usage during the melting phase and to pace the process so that both optimal tapping temperature and carbon content (see figure 11) can be achieved simultaneously.

The benefits demonstrated by the 3 installations of the iEAF® that have been operating since the beginning of 2010 show process improvements which are roughly double those previously achieved by the EFSOP® system alone. Four new installations, in Italy, Mexico and Canada, are currently underway.

iBOF®
Two issues that affect yield and productivity in BOF steelmaking are the ability to accurately predict end-point and the miti-
Tenova employs an off-gas analysis system (EFSOP®), along with other measured process variables, as inputs to a non-linear dynamic model that is used to predict mass, temperature & compositions of the metal, slag and gas phases. This is a real time dynamic indicator of the bath carbon and temperature concentrations alerting the operator of his progress towards the end of the heat. The Tenova’s patented slop-detection technology gives operators advanced warning of the onset and severity of potential slopping, in the converter. High rate sampling and analysis of the vibration of the oxygen lance in a converter is a good predictor of the onset of slopping.

iRECOVERY®

Even in an extremely high efficient EAF provided with all the above technologies a lot of energy (about 30%) is lost in the off gas. Figure 13 shows the energy balance in a traditional top charge EAF (kWh/t). An amount ranging up to 30% of it can be recovered with this technology. The Tenova iRecovery technology, a development of the former Evaporative Cooling System (ECS) well known for reheating furnaces, has proven the massive potential of heat recovery at the 140t/h EAF of Georgsmarienhütte, Germany (see figure 14).

Since 2009 in this plant the off gas energy is turned into steam; this steam is used for vacuum degassing, oxygen production and for heating purposes in winter. The elimination of the gas consumed by the formerly used boiler house, grants savings higher than 1.000.000 €/y (in the new Georgsmarienhütte installation the total energy recovery achieved is in the high side of the range reaching the 30%). During the first quarter of 2012, the interest for this technology is widely spread in the world and 3 important contracts have been awarded in Germany and Korea.

Tenova R&D activities are in an advanced stage in order to increase the percentage of energy recovered from the off gas and dust and we consider achievable a recovery up to 70%.

An iRecovery waste gas duct works with pressurized water at the boiling point which is led through the piping. The nearly boiling water absorbs the energy from the waste gas by evaporation. In a steam drum steam and remaining water get separated. One of the enhancements of iRecovery is the continuous availability of steam also for batch mode furnaces like the EAF.

Consteel Evolution™ Process technology

Consteel® is a well known long term proved technology: 32 references already in operation since 1989 and 8 under way (see figure 13). Starting from the impressive results obtained, Tenova is continuously working in improving its innovative sustainable technologies, last development being Consteel Evolution™ (see figure 14). The new system subdivides the pre-heating tunnel in two sections: the first contains high-efficiency burners (developed by Tenova LOI Italimpianti) while the second completes the combustion of the off-gas leaving the furnace. The two gas flows merge in an intermediate section, where they are extracted at high temperature. With this innovative solution, CO₂ emissions related to the use of very high efficiency combustion systems, are more than balanced by the reduction in CO₂ associated to the less electric energy needed in
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Table 4 - Reports an expected performance level achievable with a Consteel Evolution furnace.

<table>
<thead>
<tr>
<th>Heat size (t/h)</th>
<th>Power on (min)</th>
<th>Power off (min)</th>
<th>Electric Energy (kWh/t/h)</th>
<th>Oxygen (Nm³/t/h)</th>
<th>Natural gas (Nm³/t/h)</th>
<th>Coal (Kg/t/h)</th>
<th>Electrode (Kg/t/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>33</td>
<td>7</td>
<td>297</td>
<td>33</td>
<td>8.5</td>
<td>20</td>
<td>1</td>
</tr>
</tbody>
</table>

Consteel Evolution™ vs. in the traditional Consteel®.

CO₂ savings depend on countries and in particular on how the electric energy is produced (nuclear, hydro, coal or gas based). Table 4 reports an expected performance level achievable with a Consteel Evolution furnace.

REHEATING FURNACE

In the last years Tenova LOI Italimpianti R&D efforts were oriented to a drastic reduction of NOₓ emissions and the significant result of less than 60 ppm @ 3% O₂ has been achieved. One of the most recent references are the three 420 t/h walking beams Reheating Furnaces (RHF) for TKS new mill in Calvert Alabama (see figure 15).

NOₓ emissions measured during performance tests, conducted under the EPA methodology, were 56 ppm @ 3% O₂ far below the legal limit of 71 ppm @ 3% O₂ established by ADEM (Alabama Department of Environmental Management). In parallel, recent R&D efforts have been focalized on the reduction of energy consumption with the design of a new type of regenerative and flameless burners whose performances allow two fundamental advantages: energy saving due to a better thermal efficiency and even lower NOₓ emissions. Even modern reheating furnaces are characterized by huge energy consumption, comparable to those of apparently far and distant machines such as big aircrafts. In the figure 16 energy consumption of the new A380 aircraft and a high capacity traditional walking beam furnace (>400 t/h) are compared showing similar rates and highlighting how energy intensive is slab/bloom reheating.

The most modern high capacity slab reheating furnaces equipped with Full Regenerative Flameless Burners will have, on a Europe cost basis, an overall annual cost of 47.6M€ (see figure 17). In this case, the fuel consumption reduction can be in the range of 10%-20% compared with a traditional furnace in the same operating conditions. Range depends on the furnace configuration and conditions. An example of successful result of this type of burner is the revamping of Tenaris Dalmine medium-pipe rotary hearth furnace (see figure 18).

Tenaris Dalmine rotary hearth furnace revamping had the main goal of charging larger blooms (up to 5.300 mm) and to improve productivity by about 35%. At the same time a significant energy saving in fuel consumption has been achieved corresponding to about 15%.

In this case the chosen combustion system included the installation of 55 TRGX LOI Italimpianti Full Regenerative Flameless Burners with very low NOₓ emissions well below the legal limits. Furthermore nowadays the energy saving concept is strongly related to the utilization/recovery of low calorific value fuels such as Blast Furnace Gas (BFG) that is widely available in the integral cycle steel plants often with coke oven gas (COG). While COG, due to its relatively high heating value (18 MJ/Nm³), is commonly used in reheating furnaces as substitute of natural gas.

Fig. 15 – Walking Beam furnace at TKS plant in Calvert Alabama.

Fig. 16 – Energy consumption comparison between the new A380 aircraft and a high capacity traditional walking beam furnace.

Fig. 17 – Annual total cost for a full regenerative flameless reheating furnace.

Fig. 18 – Medium-pipe rotary hearth furnace at Tenaris Dalmine plant in Italy.
gas (NG) with heating value 36 MJ/Nm³,
BFG with heating value 3.1-3.3 MJ/Nm³ is
normally:
• burnt in the flares basically wasting an
energy source;
• burnt in boiler or gas turbine for power
generation with an efficiency of 35-
40%, while reheating furnaces efficien-
cy is 55-60%;
• mixed with other more energetic fuels
such as COG and/or NG for feeding re-
heating furnaces.
The trend to reduce coke plants in Europe
forces to maximize the use of BFG as sub-
stitute of COG. Since BFG combustion sy-
stems based on European technology that
overcome the underline limits are not
commercially available and in any case world-
wide the BFG technology have not yet be-
come state of the art in reheating furnace
engineering, a specific development is
necessary with the goal to:
• maintain furnace throughputs;
• obtain better flexibility in use of availa-
bale gaseous fuels;
• achieve higher efficiency (>60%) and sub-
sequently reduce CO₂ emissions re-
duction in terms of massive CFD computing and
trials.
HEAT TREATMENT FURNACES
Tenova LOI Italimpianti is applying in its
heat treatment furnaces the most updated
technologies and thanks to its R&D efforts
has reached very impressive results in
terms of CO₂ savings. In the modern HPH® bell-type annealing furnaces (HPH = High Performance Hydrogen) hydrogen
is used as protective atmosphere in com-
bination with high convection for better
energy transfer purposes and in order to meet the Customers quality requirements.
Tenova LOI Italimpianti, thanks to its
R&D efforts, has obtained in these plants im-
pressive results for the improvement of
energy saving.
The most important adopted measures to
save energy and increase efficiency are:
- Exhaust heat utilization through higher
air preheating
- Stack heat recovery during cooling
- Exhaust heat usage by preheating of coils
- Stack heat usage for hot water/electricity
generation.
One of the last innovations introduced in
our HPH® bell-type furnaces is a new
heating hood (see Fig.20).
Stack heat recovery during cooling
To date, BYPASS cooling systems of this
type have been installed separately for each
base. As the charge is cooled by heat ex-
changers, the heat transferred to the char-
ge during heating is then transferred to the
cooling water. However, it is also possible
to couple two neighbouring annealing ba-
ses and to transfer waste heat from the hot
stack of base (A) to the cold stack of base
(B) (Fig.21). This approach is only possible
if the two bases are no longer operated indi-
dividually but as a pair, which reduces the
flexibility of the overall plant. Although the
BYPASS cooling systems of the two bases
could be coupled directly, an indirect link via
an additional heat exchanger is prefere-
rable because this prevents the controlled
atmospheres of the two neighbouring an-
Table 5 - Comparison between a
traditional 420t/h RHF with a rege-
erative RHF fed with natural gas
and BFG.

<table>
<thead>
<tr>
<th></th>
<th>Traditional RHF fed with Natural Gas</th>
<th>RHF fed with Blast Furnace Gas and Natural Gas (70%-30%)</th>
<th>Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calorific value, MJ/Nm³</td>
<td>35,6</td>
<td>12,8</td>
<td>-22,8</td>
</tr>
<tr>
<td>Net CO₂ emission, ty</td>
<td>362,000</td>
<td>329,000</td>
<td>-63,000</td>
</tr>
<tr>
<td>Natural Gas cost, €/y</td>
<td>48</td>
<td>30,5</td>
<td>-9,5</td>
</tr>
</tbody>
</table>

Fig. 19 - CFD simula-
tion of a proto-
type burner.

Fig. 20 - Energy saving Ultra-Low-NOx
Heating Hood for BAF
- Higher Air preheating temperature
t(=550 °C) due to extremely enlarged re-
cupersators
- 12 % energy saving
- New combustion technology (Flame-
less Oxidation, patent pending)
- NOₓ < 100 mg/m³
- No hot spots on inner cover
- Successful in operation more than 10
months.

It combines a new combustion technology
with flameless oxidation with an increased
air preheating at the same time.
The results are NOₓ emissions in flameless
mode < 50 mg/m³ @ 5% O₂ and 12% fuel gas
reduction at approx. 550°C preheated
combustion air with extended inner cover
durability by decreased temperature load
on the burner affected areas of the inner
cover. Over the whole annealing cycle incl.
flame & flameless mode an average
NOₓ-emission of less than 100 mg/m³ @ 5
% O₂ can be reached compared to 250-350
mg/m³ with conventional combustion te-
chnology.
nealing bases from becoming mixed. In every day operation, the coupling of two neighbouring bases reduces the plant throughput by about 15%, resulting in a slight increase in specific power requirements (by about 1.6 kWh/t). At the same time, a fuel saving of about 20% is achieved.

A further energy saving can be obtained in some cases with a BYPASS cooling as hot water generator (Fig. 22). This is an annealing cycle with heating + soaking, slow cooling and fast cooling. The slow cooling could be already used for charge preheating at the neighbour base. In fast cooling there is only a potential to gain low temperature heat. During the first 4 hours of fast (BYPASS) cooling, it is possible to heat the cooling water up to 80 °C without any drop in cooling performance. This represents an average heat flow of 500 kW, resulting in 2000 kWh recuperated energy per cycle. This energy can be used for heating or for electricity generation. This heat recovery system is only available with BYPASS cooling technology. The heat recovery amounts to approx. 22.5 kWh/t in case of an 88.8 t stack. Using this new technology in a HPH® bell-type annealing plant with 12 bases the energy saving amounts of nearly 3.8 GWh per year.

CONCLUSION
In the last 30 years the steel industry has reduced its energy consumption per tonne of steel produced by 50% (see figure 23). A similar reduction has also been achieved in the impact that the industry has on the environment. However, due to this dramatic improvement in energy efficiency, there is now only room for marginal further improvement on the basis of the existing technology. This fits with R&D approach of Tenova that is oriented to a continuous improvement of its technologies for achieving the best performances in terms of energy efficiency and environmental sustainability.