SUSTAINABLE steel production for the 2030s: the vision of the European Steel Technology Platform's Strategic Research Agenda (ESTEP's SRA)

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ABSTRACT

ESTEP's SRA vision is to manage a smooth cooperation between the anthroposphere and the bio/ecosphere, with the mutual respect of the different players, and the challenges that the sector faces in terms of R&I in relation to SUSTAINABLE steel production. The focus is on reducing the environmental footprint of steel production and steel solutions by reducing resource consumption, fostering the use of secondary raw materials and thus accelerating the move towards a more closed-loop economy, by implementing energy efficiency, saving exergy, implementing process integration and ecodesign approaches. It also means reducing emissions and addressing complex issues such as climate change with ambitious targets or the preservation of biodiversity by internalizing the value of ecosystem services in business models.

Keywords: steel, sustainability, social value, environment

1 INTRODUCTION

The European Steel Technology Platform (ESTEP), which represents the Steel sector and its value chain, upstream and downstream of its core activities, as well as the research and academic communities related to steel plus some other stakeholders, is the think tank, which generates a foresight vision of what Steel is to become in the middle and long term and of how it can get there. This work is presented in ESTEP's revised its Strategic Research Agenda (SRA), a revised version of which was published in 2013.

Steel is ubiquitous, even if it often remains invisible underneath decorative, protective or functional layers of other materials. This is due to the fact that steel is directly linked to human activities, for example through a consumption intensity per capita (217 kg/cap in the world in 2012 and 278 in the EU) and its importance grows with population, standard of living and quality of life. The core business of the steel industry is thus to organize the recovery of iron from natural or anthropogenic resources, in order to make possible the construction and the maintenance of the structure of the anthroposphere (technosphere) and of its artifacts. This means that large amounts of raw materials, primary and secondary (32/68 % BOF/EAF routes, close to the virgin iron/scrap ratio), of energy (18.5 GJ/t steel) and of logistics (more than 2 t of raw materials per ton produced in an integrated steel mill) have to be marshaled in complex and professional ways, literally at the global scale of the planet (60% of the iron ore consumption and 80% of the coal are traded internationally). This also requires the contribution of millions of people (2 million jobs, worldwide) and creates a GDP footprint that extends far beyond that of the steel sector (2%), along the value chain and the life cycle of steel (20%).

Steel is thus deeply and subtly interwoven with the environment, the whole planet and society. The natural and the economic worlds, the ecosphere of the planet and the anthroposphere of human society, are intersecting. This happens at a very deep level and the former descriptions of industry as having simply to comply with environmental regulations does not tell the whole story any longer: what is taking place is no longer a collision between antagonistic worlds, but rather a cooperation that can be described as a kind of metabolism, the emergence of which has been induced by the size of the world population and the extent of urbanization.

ESTEP's SRA explores how to manage this cooperation as smoothly as possible in its section devoted to environmental issues [1]. Adapting to changes in environmental regulations involves incremental change that is handled by incremental research. But it is also necessary to prepare for the larger evolution that will take the sector in this direction further than ever before: the present paper focuses in these.

2 LIFE CYCLE ASSESSMENT (LCA) AND LIFE CYCLE THINKING (LCT)

The status of LCA is somewhat paradoxical, as it is both ignored, in matters where it would be readily used, and over-extended, in areas where it contributes to deleterious rebound effects. This distorts the picture of reality in general, and the image of steel in particular.

There are important areas where LCA is not yet properly used or not used at all, like in the case of EU rules and regulations for construction, which favor a concept called "recycled content" rather than a recycling ratio, which amounts to a deep misunderstanding of the nature of time (past vs future) in life cycle methodology. In another example related to transport, tail pipe emissions are used to grade the performance of commercial vehicles, while the proper indicator ought to be life cycle emissions: this confusion puts on a pillar the rule of light weighting, which is not always a worthy objective when pursuing low GHG emissions. Moreover, it gives a predominant weight to climate change without considering other issues and may thus be creating difficulties elsewhere. This would be the case when diesel engines are preferred in spite of their fine dust emissions. Generally speaking, LCA ought to be the privileged yardstick for setting regulatory rules.

There are also instances, where LCA is overused. This may lead to odd or inadequate optimizations for society. Thus, when an LCA study concludes that electrical steel (EAF route) should be used rather than integrated mill steel to minimize the environmental footprint, this solution cannot be implemented at a large scale as the amount of steel produced by EAF is entirely controlled by the amount of existing scrap and is already almost fully recycled. LCA, which is a tool related to micro-economics, cannot take on board issues related to macro-economics (cf. Table 1).

	2010	2015	2020
Crude steel production	1,417	1,639	1,953
EAF share	29.0%	32.1%	33.9%
EAF crude steel production	411	526	662
EAF metallics required	452	579	729
Metallics sources:			
Captive DRI	56.3	91.1	113.2
Merchant DRI/HBI	11.9	11.1	10.7
sub-total DRI/HBI	68.2	102.2	123.9
Merchant pig iron	22.6	28.1	31.9
Hot metal	15.3	17.7	21.1
Scrap [by difference]	346	431	552

Figures do not include pig iron used in foundries and DRI/HBI used in BF and BOF.

Table 1 – Metallic balance [OECD Steel Committee Raw Materials Workshop, 2011]

Life Cycle Thinking (LCT), the approach behind LCA, is a worldview that is beneficial to society in general and European Steel wishes to promote it. But, this ought to be done within reason, because the present methodology only provides part of the answers and other methodologies are needed to complement it.

3 BEYOND LIFE CYCLE THINKING

LCT needs to progress beyond its present statue-of-the-art and this will involve other disciplines extending "beyond LCA". This is needed to get a more exact description of the connection of economic activity with the ecosphere and to update it continuously to incorporate new knowledge and new global issues.

The present most common kind of LCA is *attributional LCA*. A different method, describing more closely how the real world ticks, is *consequential LCA,* but it is still rarely used. More forward looking methodologies are under development, such as foresight LCA, dynamic LCA, social LCA, Life Cycle Costing (LCC), introduction of end-of-life and recycling into LCA and the Steel sector ought to pioneer their development to jump start them. To move away from the micro-economic description of the economy related to choosing the functional unit as the central concept of LCA, one should open the scope to macro-economic thinking with Material Flow Analysis (MFA) or Energy Flow Analysis, etc., which lie at the core of the analysis of recycling, a major issue for steel and metals in general and many other materials. This might not be sufficient, however, to deal with the main open issues and challenges: therefore, more ambitious methodologies, going beyond LCA and MFA have to be developed, or, rather, their development has to be further encouraged. In the steel and structural material sectors, this is called the SOVAMAT initiative [2], which puts forward the concept of "social value", which is close in its attempts at being more holistic to some general definition of sustainability; the LCA Community is exploring the idea of functionality, beyond that of functional unit, etc. The steel sectors needs to be at the forefront of methodological innovation in this area, in order to create a dynamics that would open up to interdisciplinary cooperation, from sociology, socio-economics to scientific ecology by encompassing the various communities of LCA, MFA, economic global modelers, etc.

4 RESOURCE ISSUES DUE TO ENERGY AND RAW MATERIALS SUPPLY

Europe, not the richest mining region in the world, imports most of its primary raw materials. That raises many issues related to access to resources, security of supply, scarcity, criticity, sustainability of material-based activities, and simple economic and logistical issues. The EU Commission has become aware of the underlying threats and launched a large initiative, framed as a European Innovation Partnership, the *EIP on Raw Materials* [3].

The approach focuses on the finiteness of the ecosphere and on the need to preserve its resources for future generations. However, this is only part of the story. A leaner economy, based on increased energy and raw materials efficiencies, is called for, as is an acceleration of the pace at which the economy will be relying on close-loop operation. In simple words, this means industrial ecology and synergies between industries, cities and communities, and a reinfor-cement of reuse and of recycling.

Steel has been recycled at a high level estimated around 85%; steel mills are moving towards "zero residues" (zero waste) in a credible way; energy use is one of the most efficient among Energy Intensive Industries (EII). However, the steel sector has to progress further and to imagine solutions for turning into a leaner sector. Furthermore, transversal, through-process issues are essential to acknowledge in a holistic approach, as well as the quick integration of new technologies developed outside of the sector and cooperation with other economic players.

5 STEEL & NEW ENERGY FRONTIERS

The steel sector can "green" its energy sources, starting from demonstration projects, where factory roofs are covered by solar panels or wind turbines are erected on the extended piece of lands on which steel mills are installed.

A steel mill based on renewable energy alone will probably never make sense, because of the large energy needs of making steel. However, if renewable are inter-mediated by an energy vector, electricity today and possibly hydrogen tomorrow, then the transition can be as high as the renewable content of the grid. This is fairly obvious for EAF steelmaking, which melts scrap, but an electricity-based route directly using iron ore is being developed as part of the carbon-lean technologies like ULCOS' (ULCOWIN, ULCOLYSIS). The sector should try to understand when a switch to such technology will start being meaningful in a middle-term future.

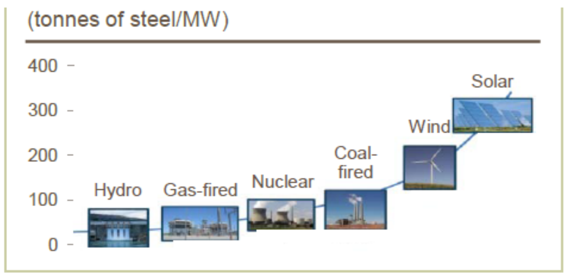

Figure 1 - Steel intensity of different power technologies [OECD Steel Committee Raw Materials Workshop, 2011]

It should also be stressed that steel, as a universal and global structural material, is at the core of new energy efforts, in wind turbines, especially giant ones, solar farms, geothermal projects, sea turbines, etc. (cf. Table 1). Steel is also the almost exclusive material for the extensive grids of pipes, which will transport natural gas, shale gas and shale oil, hydrogen and CO_2 from fields to urban-industrial consumption areas or to geostorage sites.

6 CARBON-LEAN STEELMAKING

The European Steel sector and ESTEP have been strongly backing the ULCOS program, which is the largest and most ambitious program in the world to propose solution for making steel with a major cut in GHG emissions, typically more than 50% at the very least [4].

Beyond the breakthrough solutions of the ULCOS family, more incremental innovations like near-shape-casting also need significant development effort, to extend their product capability (thin slab casting) or more simply to move them out of niches, where strip casting is still confined for example.

This effort should be accompanied by a communication campaign that would show how steel is not simply cleaning its own house but also delivering solutions that make all other sectors become energy and carbon-lean. The amount of CO_2 avoided in this manner is actually an order of magnitude higher than the direct emissions of the sector 5.

7 STEEL & SYNERGIES WITH NEIGHBORING COMMUNITIES

The technosphere is part of the anthroposphere, to the point that the two expressions are sometimes used synonymously. In the case of steel, this means that the Steel sector is immersed in the economy and society, in various ways: the value chain and the life-cycle dimensions have already been stressed, but various other synergies are at play and operate in a transversal manner. A steel mill is at the center of a huge logistical hub, where more than 5 tons of matter and scores of energy are handled, transformed, exchanged and sometimes dissipated or landfilled per ton of steel. This puts large demands on logistics, which ought to be considered as a resource akin to raw materials, except that it is a more abstract one, based on seaways, harbors, rail tracks, roads and bridges on the one hand and on ships, cranes, trains and trucks on the other hand.

The steel mill also connects with other economic sectors and with local communities in a horizontal manner, i.e. not through the logics of the value chain but with that of industrial ecology. Indeed, waste heat and residues can be used elsewhere and the mill itself can, in principle, use those of neighboring industrial sites. This is usually a mesoscale effect, as opposed to the macro-scale of international trade. The field is not virgin, as supplying heat to city districts has been practiced for decades; similarly, much of blast furnace slag is used as raw material for the cement industry, the rest being turned into roadbed material. The expectation today is that more can be done in the future to save energy and raw materials globally, across value chains, thus increasing energy and material savings.

8 STEEL & SYNERGIES WITH NATURE

The synergy of the Steel sector with Nature is mainly related today to its use of natural resources. In the future, biomass is likely to replace some of its fossil fuel consumption in most of its major reactors, from coke ovens to steelmaking and reheating furnaces. Biomass would most probably need to be converted by a high temperature treatment like pyrolysis to produce charcoal or char as well as synthetic gas. The industrial use of biomass competes with other sectors (e.g. paper mills vs steel mills) and with agriculture, in terms of land use. It also might threaten some ecosystem services.

More challenging is the threat to biodiversity, mainly related to the increase of the footprint of mankind on land and ocean, of which the steel industry is only a very small part. However, the destruction of biodiversity is now analyzed in terms of a reduction in ecosystem services: in a global view of the world, where ecosphere and techno-sphere are analyzed as a holistic system, the steel sector offers global ecosystem services, which compensate for part of biodiversity destruction; fairly simply put, the eco-system services offered by steel are their role as structural materials organizing the boundary between natural space (the biosphere) and

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human space (the anthroposphere) [6]. This is part of what is sometimes called the social value of steel or its sustainability value.

The downside of steel activities in terms of their impact on BES (Biodiversity and Ecosystem Services) needs also to be taken on board, as regulators are being more and more precise on what they expect of industrial operators in this area, which translates in new requirements when licenses to operate are requested or renewed. This is usually confined to the micro-scale of the steel mill itself but it might be extended to the mesoscale in the future, through the large call on logistics of one mill.

Last but not least, the steel sector can offer products and services, not simply ecological services, which can help maintain or restore biodiversity. For example, biodiversity corridors are likely to request new specific infrastructures, which will need large amounts of structural materials, including steels.

9 MOVING SMOOTHLY INTO A CLOSE-LOOPED ECONOMY

Steel claims rightly to be the most recycled material in the world and this is often taken to mean that it is part of a closed-loop economy. This is a subtle & complex concept, as an economy can be close-looped for some material and not for others and it can be partially or totally closed (weak and strong meaning). Steel, today, is part of a partial closed-loop economy related to the generation and reuse of scrap but also to the reuse of steel without remelting it, as is commonly practiced for rails or pile sheets.

This practice will be enduring in the future, because the steel sector has organized with specialized steel mills, EAF mills, which have been erected to take care of using scrap. Moreover, the collection of scrap and its treatment to turn it into a true secondary raw material competing with ore on an equal footing is mostly a profitable, value-creating business: this is actually the main reason why steel is recycled to a high level. In the future, the proportion of scrap and iron ore is expected to increase, as the steel produced in the past and especially since the large increase of production that has taken place since 2000 will be coming back in the economy as scrap. This will raise delicate issues of adjusting the balance between integrated and scrap process routes, especially in China, which has invested heavily in integrated mills. But it will also call on new technology to sort scrap more effectively and to purify it after sorting.

10 GLOBAL THREATS AND FUTURE ENVIRONMENTAL DEMANDS

The environment has long been perceived as an externality in the economy, but global environmental issues are gaining strength, as they are becoming threats and grand challenges for mankind. The ozone layer and climate change were the major global threats perceived until recently, but more issues are becoming global, like acidification, eutrophication of fresh and ocean waters and biodiversity (BES) issues.

Projections of demands for the middle of the century show that environment in general will be posting limits on various emissions, which will be as demanding as the ones for CO_2 today (a factor 4 reduction). From a practical standpoint, this will mean demands for steel on dust emissions, NO_X and Sox, for example, which are far beyond what is achieved or even achievable today [6]. Therefore, this calls on deep research and development work to arrive in time at technological solutions, which are not simply waiting on the shelf today.

11 CONCLUSIONS

The Steel sector produces a material that has been essential to society for historical times and has proven its resilience in remaining at the core of the technological episteme evolving and shifting regularly: in today's world, steel is a KET (Key Enabling Technology), part of the Advanced Materials KET. Moreover, it is ubiquitous and most artifacts are either made of steel, in part or in all, or are manufactured from machines and tools made of steel! It is thus deeply embedded in the anthroposphere, it serves as its backbone, but it also calls on large amounts of resources, energy, raw materials and logistics, generates emissions to air, soil and water, and thus interacts with the geosphere and the biosphere in an intimate way. Environmental issues, long considered as externalities in the economy, business and metallurgy, are not simply boundary conditions expressed by bothersome regulation any more, but an integral part of an holistic system, where nature and society, geo-, bio and anthropo-spheres interact at a complex level.

The future of the Steel sector is thus deeply related to these environmental issues. In ESTEP, the working group that analyzes them is aptly called "Planet". This means that holistic, transverse, cross-cultural and cross-sectoral approaches are the standard vial to move forward. Steel is not starting from a clean slate, as these issues have been embedded in its practice and culture for a long time (recycling, energy efficiency, zero waste, carbon-lean steel production processes, steel as an enabler of a leaner economy, etc.), but the pace of change should not slacken and it might even have to accelerate, because the world is become more populated, more compact and more demanding.

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