Addressing the Climate Change challenge:

ULCOS Breakthrough Program

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1.Introduction

Since 2002, the Ultra Low CO_2 Steelmaking (ULCOS) initiative has brought together most of the European Steel Industry, its partners in the value chain of steel and a broad group of research organizations in an effort to search for breakthrough solutions for producing steel with a large cut in specific CO_2 emissions, typically more than 50% of today's best routes. This has led to a large research program, supported by 3 EU projects in the RFCS (ULCOS & IDEOGAS) and the 6th Framework Programs (ULCOS): the 6-year ULCOS program is now running in its 5th year and involves 48 organizations from 15 European countries, under the coordination of ArcelorMittal and with major input from the main Integrated Steel Producers in Europe. This is one of the largest on-going European programs in terms of size of the partnership and budget (59 M€). It has also been, for a long time, the largest endeavor of the Steel Industry worldwide to look proactively for solutions to the grand challenge of Global Warming in a sectoral context (1).

This paper presents a progress report of this Program, which has passed a number of major milestones and is now moving towards the conclusion of its first step. It is also getting ready to launch its second step, ULCOS II, to follow up on the present program, ULCOS I.

2. ULCOS program's targets & structure

ULCOS is a "concept development" program that fairly extensively explores a wide array of steelmaking routes with a high potential for CO_2 mitigation. The approach calls for breakthrough innovation in the steel industry's context, as extensive research & development are needed to allow the new process routes to mature into commercial ones, which ought to be fully developed by the end of the 2010's. These routes should be in a position to be rolled out into production plants 15 to 20 years from now. Beyond the present ULCOS I program, a further step should thus lead to the scale-up (ULCOS II) and then to the deployment (ULCOS III) of ULCOS technologies in the post-Kyoto period.

The CO_2 emissions of the Steel Industry are mostly generated during the reduction of iron ore into metallic iron, a step that is very intensive in chemical and thermal energies delivered jointly by the reducing agents. Coal, natural gas and electricity are thus currently used at a high level (18GJ/tsteel). The ULCOS program examines how the structure of the energy mix of a Steel Mill should be reshuffled to decrease CO_2 emissions. However, the energy intensity of the Industry today is close to the physical requirements of thermodynamics, reaction kinetics and heat transfer physics and cannot, therefore, be decreased very much below the level achieved by the best performers in the sector: ULCOS thus investigates specific technologies that purposely and specifically reduce emissions, thus uncoupling the search for energy efficiency from CO_2 mitigation. Of course, these routes remain constrained by the necessity to maintain low energy consumption and to produce the same sophisticated and changing material that steel has become at competitive prices.

In the first phase of ULCOS I, seventy different process routes were investigated with the level of scrutiny necessary to build route flowsheets and to inform them in terms of raw materials and energy needs and of CO_2 emissions. This called for imagination for designing the routes, modeling them and carrying out small scale laboratory experiments.

The program is organized in subprojects (SPs), which bring routes into families (figure 1): carbon-based ironmaking, focused on the Blast Furnace modified to collect CO_2 and store it – the Top Gas Recycling Blast Furnace (TGR-BF) – or on Smelting Reduction with a Bath Smelter fed by a Cyclone Reactor, using pure oxygen and storing the off-gas composed mainly of CO_2 – the Hisarna Process developed in connection with

HIsmelt; natural gas-based (or syngas-based from coal gasification) DRI production in a new flowsheet using pure oxygen and capturing CO_2 for further storage – the ULCORED process; electrolysis of iron ore, a process developed almost from scratch in the present program; hydrogen-based steelmaking and use of charcoal as a coal/coke substitute produced from eucalyptus trees grown in sustainable plantations.

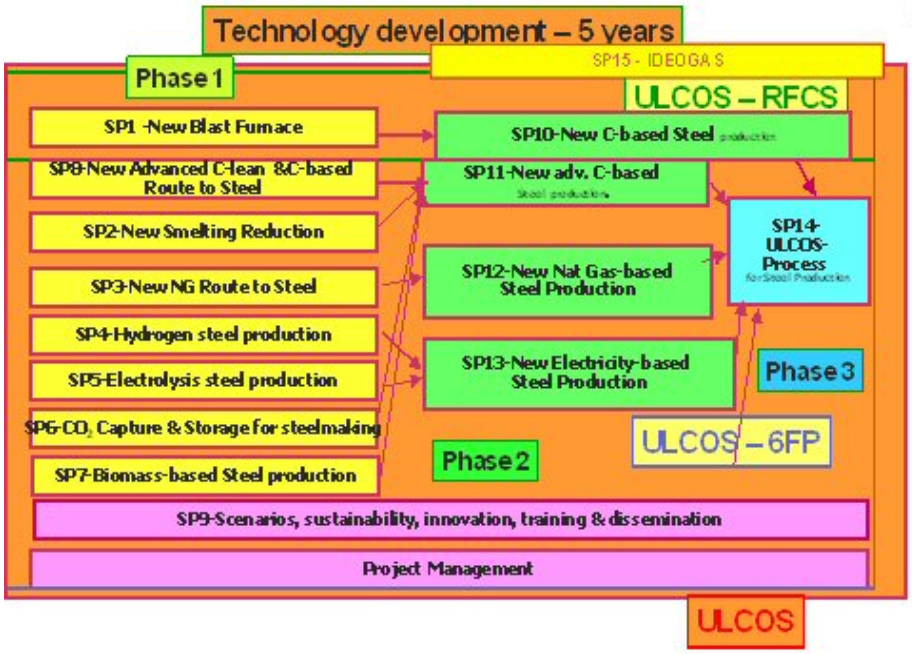

Fig. 1 ULCOS' program structure

3. Conclusions of phase I

The various process routes developed in phase I were compared on the basis of their flowsheets, energy consumption, CO_2 emissions and cost of making steel. A set of scenarios was developed, in which to carry out this comparison, as well as dedicated tools for doing this (e.g. a CO_2 calculation tool, etc.). Other tools have been developed for use in phase 2 (LCA, KPIs, local impacts).

The scenarios were at the core of a future study led by LEPII and based on the WETO and IPCC scenarios for the future (2000, 2015, 2030 & 2050) with various carbon constraints (BAU, 10-50, factor 2, F2 and factor 4, F4). LEPII modeled the energy futures using the POLES model with the support of IPTS. Roughly 70 routes and 1050 scenario cases were investigated at ArcelorMittal.

Most solutions examined in the 1st phase of ULCOS I bring about CO_2 reduction that range from 20 to 100% and can even become negative (thus storing CO_2, for example if CCS and biomass are used together). Applying CCS to the TGR-BF is one of the most powerful solutions. Smelting Reduction is also a strong one. Prereduction with CCS and low-C electricity is also attractive, using natural gas, hydrogen and even more so biogas. Electrolysis is also a strong option with low-C electricity (figure 5), as is plasma in the BF, although it does not outperform the TGRBF with storage. CCS can always be used, even in conjunction with electrolysis (negative emissions), but is a necessity with coal to reach at least a 50% reduction target. Note that energy consumption is not a discriminatory parameter, as it does not vary much among the various routes.

Cost wise, the picture is more complex and uncertain. The scenario modeling shows, however, that the ULCOS routes are not competitive today with the baseline BF route and that only a positive carbon value will make them attractive. In the longer term, when the cost of carbon increases, they all, more or less, become competitive, often at an early stage (2015). In the longer term and under strong carbon constraints, the order of merit of energies will have changed and electricity may by then hold a special status and be able to compete with coal and natural gas on a cost basis.

4. On-going research work in ULCOS I

Work on the TGRBF route has been focused on an extensive experimental campaign carried out on the EBF of LKAB during a 6-week campaign in the Fall of 2007. The test started with conventional BF operation. The top gas was decarbonized in a special VPSA unit designed and built by Air Liquide. After stabilizing the furnace operation, the decarbonized gas was gradually injected in the 3 bottom tuyeres with a 2-week operation under stable conditions and then the stream was divided into two and injected as well at another row of new tuyeres, placed at the bottom of the shaft. Stable operation was also reached in this case until the end of the campaign where the furnace was stopped and quenched. The CO_2 stream out of the VPSA was not stored during these tests.