FUTURE VIEWS

Emission reduced steel production

How can a steel plant strive towards net-zero targets and reduce costs at the same time?

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GREENSTEEL – what are we talking about?

Summary

What is GreenSteel and where does the term come from? Questions that are not be answered in this article because we do not know. But what we do know is that the world is in turmoil and that things are getting worse.

Nowadays, it is hard to be positive with a war in the neighbourhood, with inflation eating up wages and savings, with refugees knocking on the door, with devasting weather phenomena, with a financial system that destroys values, with economies that spend money they don't have, and finally information systems that can no longer be trusted.

Despite all these problems we face today, the mood remains positive because we know that the god will win. But we know that the first thing we have to worry about is climate change, because if we don't get a grip on climate change soon, all the other problems and worries will be nothing compared to what will happen then.

Everyone can do something – no one is exempt, nobody. We must work together to ensure that global warming remains at a low level. The effects are of long-term concern even with a warming of 1.5°C, but if the atmosphere warms by more than thin 1.5°C, which is to be feared at the current level of emissions, the effects will be drastic. Everyone can make a difference, even if its just a drop in the ocean – but many drops ultimately make an ocean.

On the following pages we discuss the purpose of GreenSteel and show that every single steel mill can and must do something not to saw off the branch on which it lives.

Then we define the requirements for the future electric steel mill – requirements to maintain or even increase performance, secure its economic basis and achieve the net-zero targets. Because only if everyone works on it, we will achieve the net-zero goals and we can even achieve them with profit.

To underscore the gravity of the situation and support efforts to halt climate change, we are making an offer worth keeping an eye on.

Roland V. Müller, owner of eco-e AG, Consultant for Environmental and Energy Issues

GreenSteel – a marketing game?

GreenSteel is on everybody's lips – but green steel is in nobody's hands!

What is GreenSteel or green steel? Is GreenSteel synonymous with steel produced with renewable (green) energy? Or is it another word for steel that is ecologically (green) valuable? Or is it called 'GreenSteel' just because the steel is produced with fewer greenhouse gas (GHG) emissions? Or is it just a marketing game?

I am certainly not the first to ask about the source of GreenSteel!

There is almost no steel mill that does not announce that it will produce 'GreenSteel'. Steel which looks exactly as before, steel that has the same behavior as before, steel that has the same physical properties as before, is suddenly 'GreenSteel' without visible changes. This leads to the assumption that 'GreenSteel' is just a marketing game or a trendy reassurance of the public to allay their fear of the coming climate change.

Undoubtedly, the electric steelworks (secondary steel production) produce less greenhouse gases than the production of steel from ore (primary steel production), and this would give the justification to declare secondary production as 'greener steel', but the comparison of processes and results is not so simple.

Steel produced by the primary route is clean steel, steel with fewer inclusions and trace elements, so a greener steel when green is synonymous with clean, valuable and environmentally friendly.

But if GreenSteel is steel to be produced with renewable energy, then GreenSteel will exist at some point in the future; if GreenSteel is clean steel, then the choice falls in steel from the integrated plant; but if GreenSteel is the steel produced with the lowest greenhouse gas emissions, then those who say they produce green steel could still improve.

Steel itself cannot be green – steel is grey, not even with shades of grey. But the production process could be what we mean by 'green'. What we are aiming for is not green steel, what we are aiming for is low-emission steel, and that is what we, Clesid Lorber and eco-e, offer, equipment and processes that help to reduce emissions such as CO2, NO_x, heat, and toxic combustion products, and also reduce the 'emission of money' the production costs.

Fig. 1 / Logo of Clesid Lorber and eco-e AG

Well, reduced-emission steel is not only limited to melting steel, but also includes the secondary metallurgy, ladle furnce steel treatment and vacuum degassing.

The facts

World steel production in 2021:		1952 Mio tons
Raw material:	Iron ore	1952 Mio tons
	Coke (metallurgical carbon)	1088 Mio tons
	Limestone	393 Mio tons
	Scrap	646 Mio tons
	DRI	113 Mio tons
Energy:	Electrical energy	789 TWh
	Natural gas (10 kWh/Sm^3)	267 TWh
Primary route (Blast furnace – basic oxygen furnace)		1387 Mio tons
Secondary route	(electric steel production)	565 Mio tons
	(100% scrap)	339 Mio tons
	(50% scrap/50% DRI (100% NG))	75 Mio tons
	(30% scrap/70% DRI (100% NG) Induction)	100 Mio tons
	(70% scrap /30% PI)	50 Mio tons

Global hydrogen production in 2021		
	(78% by fossil fuels	
	(22% by By-products):	94 Mio tons
	(The hydrogen is almost exclusively used for finishing and industrial apps)	

CO2 emissions Total		3563 Mio tons
Specific emission (total)		1825 $kg/t_{hot\ metal}$
Primary route		2223 $kg/t_{hot\ metal}$
Secondary route:	100% scrap	713 $kg/t_{hot\ metal}$
	50% scrap / 50% DRI	1003 $kg/t_{hot\ metal}$
	30% scrap / 70% DRI (induction)	1115 $kg/t_{hot\ metal}$
	70% scrap / 30% PI	995 $kg//t_{hot\ metal}$

The assumptions

World steel production in 2030[i]		2030 Mio tons
Global hydrogen production in 2030:		180 Mio tons
	By fossil fuels without CCUS	72 Mio tons
	By fossil fuels with CCUS	33 Mio tons
	By by-products (biomass)	13 Mio tons
	By electricity (electrolyser)	62 Mio tons

A glance at the reality

To produce 62 million tons of hydrogen, 4.960 GWh are needed (the efficiency of an electrolyser is assumed to be 80%). Currently, there are projects for electrolysers that should be ready for 2030, with a total capacity of about 90 GWelectric! An interesting detail: Hydrogen production currently produces 10g CO_2/g H_2 (comparison: 2.2g CO_2/g steel). Emissions should be reduced to 4g CO_2/g H_2 in 2030 (with green energy).

By 2030, the global production of green hydrogen will be 10% of the required amount on the way to the net-zero scenario 2050!

The outlook

In order to effectively reduce GHG emissions, the primary route must be changed by replacing the blast furnaces with plants for a direct reduction of iron ore. Since most blast furnaces are still quite young and the service life of a furnace (furnace journey) is about 10 years, it will take a while until the systems are replaced. The blast furnace is the heart of an integrated steel plant, and an integrated steelworks is a socially important employer and often the centre of its surroundings – this is an obligation. A blast furnace and its ancillary facilities represent a very large investment. Investments are based on a return calculation, which means that the calculation is based on a time frame. In this case, the time frame is the furnace life. For the investor the calculation is crucial and only a buy-out or a bond from a third party, e.g., the state, can change its schedule. This means, that the high CO_2 emissions associated with primary steel production will not decrease in the next 10 years if the state (taxpayer) does not intervene. The decarbonisation of steel is not a local, but a global issue, with all the "small" local problems significantly hampering the realisation of this adaptation process.

There are many questions surrounding the replacement of blast furnace by DRI reactors. Compared to the blast furnace, which can produce pig iron from almost any iron ore quality, the DRI process requires a high iron ore quality. The better the ore quality, the better the DRI metallization. From an economic point of view, only very good qualities are suitable for the DRI process, because low-quality DRI increases the cost at the EAF enormously.

Due to the increase of collected and end-of-life scrap the amount of available scrap will increase over the next 10 years, leading to a decline in primary steel production assuming stable production over the next decade. This decline is also absorbed by the end of the furnace life of the older blast furnaces. CO_2 emissions will gradually fall from an average of 1825 kg/$t_{hot\ metal}$ to 1630 kg/$t_{hot\ metal}$, but this is far from the intermediate target of 1150 kg/ $t_{hot\ metal}$.

In addition, DRI production will increase. The IEA forecasts production of 178 Mio tons of DRI by 2030. The DRI produced at the integrated steel plants that have already been converted does not count as this production is absorbed internally.

Since the entire decarburization process depends on the 'super-abundance' of renewables and a rapid conversion of the integrated steel mills, the plan to meet the interim targets of 2030 seems far away, at least for the 8% of the CO_2 emitted by the steel industry.

The core problem of the hesitant decarburization is philosophy, that can be summarized as follows:

'What can I achieve on my own?' half of humanity wondered.

Hesitation and self-apology are the real inhibiting factors, it is not the level of investment costs, not the lack of financial incentives, not the insufficient availability of renewable energy, not the lack of hydrogen, it is the inability and lack of self-confidence that reduce the momentum.

Everyone is called upon to contribute to the decarburization and to the reduction of the CO_2 emissions, everyone can!

Every steel mill can help reduce CO_2 emissions by realistically reducing its emissions. Making 'GreenSteel' is good and sounds good, or using 'green' hydropower is also good, but not yet an active reduction compared to the current state.

The reality:

We have learned that the integrated steelworks need to replace their blast furnaces; we have also found that the substitution of these plants is not possible overnight. A major steel producer that operates several integrated steel mills around the world has agreed with the governments of various countries that they (taxpayers) will participate in its efforts to modernize its blast furnaces. Well done – but the steel producer in question is a global player and does not care about local suppliers, national conditions such as taxes, duties, custom duties, etc. it has its own supply chains and strategies. The market will solve it – but haven't we talked about the danger of globalisation and dependence? By the way, the new 'world's first commercial steel mill producing steel with green hydrogen' will initially run on natural gas (until hydrogen (H_2) is available at a **low** price!) and the natural gas will be supplied by the government[ii].

And what do the electric steelworks do? They produce green steel – of course, as we know, they produce steel with much lower CO_2 emissions. Now, as well as yesterday and the day before yesterday! So, we are back to 'field zero', but far away from net-zero.

The proposal:

In the previous article[iii], we saw that steel produced with hot DRI would reduce CO_2 emissions, but only with a high metallization DRI with low C content made with a mixture of natural gas (NG) and hydrogen (H_2). Since the transport of hot DRI is not without risks[iv], hot DRI will only be available at integrated steel mills or nearby steel mills and steel mils with their own DRI reactor.

Steel production with cold DRI is more energy intensive unless the DRI is preheated in a suitable atmosphere. The preheating of DRI must be flameless and in an inert atmosphere, otherwise the risk of spontaneous combustion is very high.

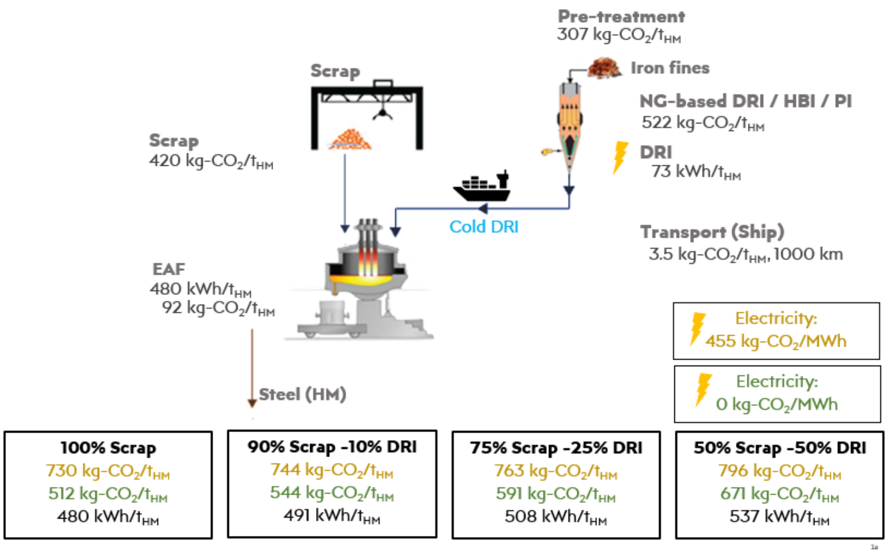


Fig. 2 / CO2 emission and energy input of the actual secondary route (EAF with or without DR/HBI/PI) [1a]

The picture above shows traditional electric steel production with HBI, pig iron, or DRI. Reported CO_2 emissions include total emissions from steel production: these include pre-treatment of iron ore, emissions from the DRI shaft reactor, emissions from scrap handling, emissions from arc furnaces and emissions from DRI transport from mine to furnace. The brown figures are based on a traditional energy mix, the green ones on an energy mix based on renewable energies. The reported energy consumption is usually limited to the energy consumption at the electric arc furnace and downstream equipment, as the upstream energy consumption is included in the DRI selling price.

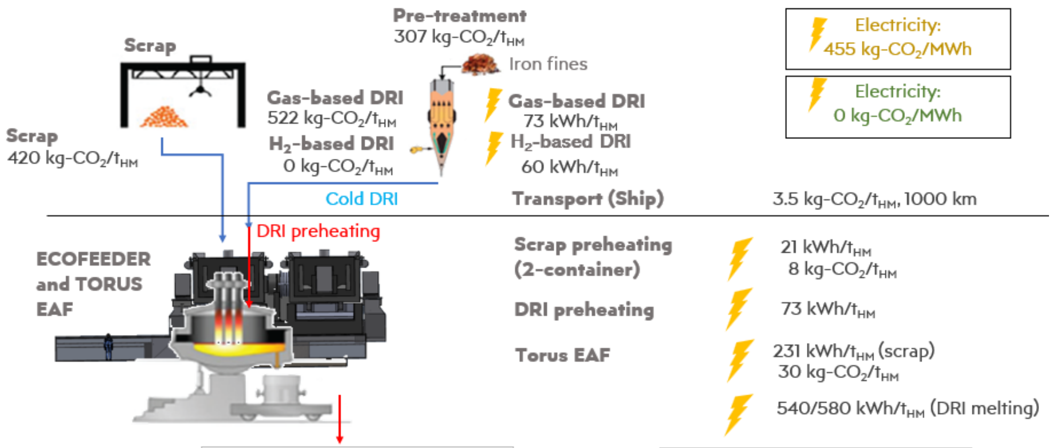
This is a realistic picture of the steel production in a traditional electric steelwork. The key to a real reduction in emissions is the availability of renewable energy. In addition to renewable energy, what are the requirements to reduce the emissions and production cost at the same time? The requirements are: versatility, flexibility, less dependency, ecology and economy.

- Versatility: the steelworks must be able to produce all types of qualities except stainless steels and deep-drawing steels, i.e., clear and clean differentiation of the scrap heap and scrap preheating
- Flexibility: the steel mill must be able to achieve a high degree of flexibility in productivity while at the same time achieving a high degree of specialisation, i.e., flexible process times and operation values
- Independency means freedom from constraints and restrictions, Restrictions and obligations relating to raw materials, energy supply, energy choice and production time.
- Ecology: the plants and processes must be able to minimize emissions such as CO_2, NO_x, aromatic and toxic exhaust gases, and heat releases.
- Economy: Energy will always be a strategic matter. As long as there is no fusion reactor that can provide unlimited electricity, there are dependencies, dependence on the supplier, policy, source and security. Energy is expensive, so it is important to reduce energy consumption and recover as much as possible.

T**<u>he steelworks</u>**, more precisely the electric arc furnace, **<u>must therefore meet all these requirements</u>**! Of course, there are also many downstream plants that can be optimized or upgraded, such as the vacuum treatment which could benefit of a mechanical vacuum generation instead of a environmentally harmful and maintenance-intensive steam ejector (we supply the engineering for such plants), the continuous caster, where the energy of more than 385 kWh/t is released into the atmosphere largely unused – there are ways to recover some of this energy – etc. The answer is 'eco-e tech'.

Eco-e tech is a joint technology between Clesid Lorber and eco-e, two companies that share a common vision, ready to tackle upcoming challenges with environmentally friendly solutions and energy-saving concepts engineered with a fast and efficient design team. Local partners, optimized procurement, efficient project management as well as forward-looking and task-oriented commitment are the key to success. Ask us and you will get answers – answers to your questions and suggestions based on your installations and no general clichés.

The next picture (Figure 3) shows the details in CO_2 emissions and energy consumption of an eco-e tech installation.



	DRI 2.5% C (45% NG / 55% H_2)			DRI 1.0% C (25% NG / 75% H_2)		
EAF-Scrap	90/10 Scrap/DRI	75/25 Scrap/DRI	50/50 Scrap/DRI	90/10 Scrap/DRI	75/25 Scrap/DRI	50/50 Scrap/DRI
635 kg-CO_2/t_{HM}	648 kg-CO_2/t_{HM}	669 kg-CO_2/t_{HM}	687 kg-CO_2/t_{HM}	641 kg-CO_2/t_{HM}	651 kg-CO_2/t_{HM}	668 kg-CO_2/t_{HM}
520 kg-CO_2/t_{HM}	520 kg-CO_2/t_{HM}	518 kg-CO_2/t_{HM}	517 kg-CO_2/t_{HM}	515 kg-CO_2/t_{HM}	504 kg-CO_2/t_{HM}	488 kg-CO_2/t_{HM}
252 kWh/t_{HM}	282 kWh/t_{HM}	326 kWh/t_{HM}	401 kWh/t_{HM}	286 kWh/t_{HM}	336 kWh/t_{HM}	421 kWh/t_{HM}

Fig. 3 / CO2 emission and energy consumption with eco-e tech [11d]

The picture above shows the versatility and flexibility of the eco-e tech electric steel production with DRI but also with HBI, or pig iron and a wide variety of different scrap densities and qualities. The CO_2 emissions shown include total emissions from steel production: these include pre-treatment of iron ore, emissions from the DRI shaft reactor, emissions from scrap handling, emissions from DRI transport from mine to furnace, emissions from the scrap preheating (burners), and emission from the arc furnace (torus type). The figures in brown base on a traditional energy mix and the ones in green on renewable energy. The energy consumption shown is usually limited to the melt shop which is the energy consumed at the scrap preheating (hydraulic system, electric drives, registers, etc), at the DRI preheating (assumption) and at the arc furnace (torus type). In addition, a distinction is made between the energy used to melt scrap and to melt DRI. Upstream energy consumption is included in the DRI selling price. Here, too, the green emission values can be significantly reduced, as the use of renewable energy has not yet been taken into account in the upstream processes.

The versatility makes it possible to use and combine a variety of different raw material qualities and degrees of preheating, e.g., DRI can be preheated to a very high temperature before being fed into the furnace. In this way, high DRI concentrations can be added without "producing" icebergs and other melting problems. Different scrap qualities can be preheated without mixing and stored longer, as the containers are designed like the tundish of the continuous caster.

The flexibility is reflected in the unique ability to store preheated scrap on demand (problem with a downstream plant, unforeseen maintenance break, quality change, production stop or planned interruption). Whatever happens, the scrap once preheated stays hot for hours.

Emissions are maximized by optimizing the process flow, furnace atmosphere control, and a unique application of Carbon Capture and Use (CCU), where CO_2 is used to cool down the electrode tip through an endothermal process while increasing foam formation, foam stability and foam viscosity. Another brilliant technology of 'eco-e tech'.

Preventive maintenance is one way to reduce production cost, use and repair is a better way to reduce unexpected production breaks.

Eco-e tech is as flexible as your existing furnace, there is no change in process operations, but there is more freedom because there is no slag door which causes problems, no cold spots in the furnace, no side-wall burners with their backfire, no bears and scrap domes and a greater variety in raw material choice, all this with lower production costs and with lowest emission values, as shown in the following table.

Table 1 / Ranking in GHG emission and energy consumption

CO_2 emissions and energy input; CO_2 emission ranking

Process	Addition	%C	DRI	Mix [%]	Energy	kg-CO_2/t_{HM}	kWh/t_{HM}
EAF- DRI		1.00%	Hot	50/50	Renewable	473	495
eco-e tech	DRI preh.	1.00%	Cold	50/50	Renewable	488	421
EAF- DRI		1.00%	Hot	75/25	Renewable	492	488
SAF-DRI	H_2	0.00%	Hot	0/100	Renewable	500	547
eco-e tech	DRI preh.	1.00%	Cold	75/25	Renewable	504	336
EAF- DRI		1.00%	Hot	90/10	Renewable	504	483
EAF			no	100/0	Renewable	512	480
EAF- DRI		2.50%	Hot	90/10	Renewable	513	479
eco-e tech	DRI preh.	1.00%	Cold	90/10	Renewable	515	286
EAF- DRI		2.50%	Hot	75/25	Renewable	515	478
eco-e tech	DRI preh.	2.50%	Cold	50/50	Renewable	517	401
EAF- DRI		2.50%	Hot	50/50	Renewable	518	475
eco-e tech	DRI preh.	2.50%	Cold	75/25	Renewable	518	326
eco-e tech			no	100/0	Renewable	520	252
eco-e tech	DRI preh.	2.50%	Cold	90/10	Renewable	520	282
EAF- DRI		3.50%	Hot	90/10	Renewable	544	477
EAF- DRI		3.50%	Hot	75/25	Renewable	591	473
EAF-DRI		1.00%	Cold	50/50	Traditional mix	598	567
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EAF- DRI		1.00%	Cold	75/25	Traditional mix	664	523
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EAF- DRI		2.50%	Cold	90/10	Traditional mix	713	493
EAF- DRI		1.00%	Cold	90/10	Traditional mix	713	497
EAF			no	100/0	Traditional mix	730	480
EAF- DRI		3.50%	Hot	90/10	Traditional mix	744	477
EAF- DRI		3.50%	Cold	90/10	Traditional mix	744	491
SAF-DRI	H_2	0.00%	Hot	0/100	Traditional mix	752	547
EAF- DRI		3.50%	Hot	75/25	Traditional mix	763	473
EAF- DRI		3.50%	Cold	75/25	Traditional mix	763	508
EAF- DRI		3.50%	Hot	50/50	Traditional mix	796	465
EAF- DRI		3.50%	Cold	50/50	Traditional mix	796	537
SAF-DRI	CH_4	2.50%	Hot	0/100	Renewable	1022	560
SAF-DRI	CH_4	2.50%	Hot	0/100	Traditional mix	1280	560
SAF-DRI	Coal	4.00%	Hot	0/100	Renewable	1548	587
SAF-DRI	Coal	4.00%	Hot	0/100	Traditional mix	1818	587
BF-BOF				-	Renewable	2061	356
BF-BOF				-	Traditional mix	2225	356

CO_2 emissions and energy input; energy ranking

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SAF-DRI	Coal	4.00%	Hot	0/100	Traditional mix	1818	587

Note: 1. In terms of emissions, the eco-e tech is beaten only by electric arc furnaces running on hot DRI and the traditional EAF using 100% scrap. In terms of energy, eco-e tech plants are unbeaten. 2. Electric arc furnaces with shaft preheating and horizontal conveyors are not considered due to poor GHG emission and energy consumption values.

In doing so, we have answered the question 'How can steelworks strive towards net-zero targets and reduce production cost at the same time?'. To underline our commitment to what has been said, we make the following offer:

In order to support global efforts to combat the climate change and actively contribute to the reduction of greenhouse gas emissions, we offer a discount of 15% on our best price after negotiation for the first 3 orders for a combined TORUS-ECOFEEDER installation (excluding our two diamond technologies: 'DRI preheating' and 'cool electrode') as described here below:

Eco-e tech, the versatile and easy-to-install scrap preheating unit in combination with the new torus-off gas system, turns a normal traditional EAF with 4th hole and post-combustion chamber, an energy saver and emission killer that beats all other melting combinations. Note that converting a normal, traditional furnace into an eco-e tech system does not require new buildings, no change in the shape of the furnace, no change in tilting motion, no change in electrode lifting and no change in the electrical system, such as transformer, control system, etc. The scrap preheating unit usually corresponds to the size of the existing post-combustion chamber, the torus encloses the furnace and can be easily lifted off for access to the panels. Thanks to the new off-gas flow, radiation from the arc to the panels is reduced while melting, resulting in fewer leakages and subsequent maintenance interruptions. Further information and a questionnaire can be found on our homepage: www.eco-eag.com.

On request we provide you with a realisation study and a tailormade offer based on your melt shop layout. Ask us for detailed information.

eco-e Tech is: Your existing furnace with an improved use of exhaust energy! The amount of scrap preheating or preheating temperature depends on the furnace operation. Existing experience, resp. furnace modes are taken over, and can be adapted step by step depending on the objective.

Think green!

www.clesid.com

www.eco-eag.com

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[i] IEA, "Steel – tracking report 2022", 2022
[ii] Leigh Collins, Hydrogen insight, 2022
[iii] 20220920_DRI_-_the_food_of_future_electric_arc_furnace-E.pdf, 2022
[iv] Noel, N et al; „Shipping of DRI – 'The Nu-Iron Experience'", 2014