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Report of scenario and sensitivity analyses results on the effect of biomass exploitation on material and energy flows

Deliverable D2.2

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1 Introduction

1.1 Purpose and scope of the present document

During GreenHeatEAF, simulations are considered powerful tools to assist industrial trials and to expand the investigation horizon related to the effects of the use of alternative C-source in EAF to replace fossil carbon. Therefore, SSSA and BFI models, respectively, stationary and dynamic, which had been adapted and extended in Task 3.1, were used (and are still being used in the project for its entire duration) for different kinds of scenarios investigations and for sensitivity analyses. In addition, some analyses of preliminary Sidenor industrial tests were carried out.

This document presents the analyses that were carried-out and explains the main results that were achieved concerning the behaviour of the process and the effect of the use of alternative C-bearing materials on the products.

1.2 Structure of the document

The document is organised as follows:

- Section 2 introduces the analyses that were carried out and presents the results that were obtained concerning the statistical evaluation of first trial data with biochar usage at the Sidenor EAF.
- Section 3 depicts and explains the results of stationary and dynamic simulations.
- Section 4 provides some concluding remarks as well as ideas for further investigations.

2 Overview of Sensitivity and Scenario Analyses

In this section the carried-out investigations are introduced and a statistical analysis of first Sidenor trials with the use of biochar at 5th hole are presented.

2.1 Investigations with EAF route flowsheet stationary model

The flowsheet model by SSSA, developed in Aspen Plus V11 environment, adapted during GreenHeatEAF and described in the Deliverable D3.1, was used to perform scenario analyses and evaluate the effect of the substitution of fossil carbon sources used in EAF with alternative ones. These scenario analyses are complementary to the industrial tests, with the objective to extend the industrial trials (e.g. considering more C-sources, also the ones that cannot satisfy supply capacity and therefore cannot be tested on field, or that from their carbon content below 70-80% are preferable to not be used in infield tests but that through simulations can provide useful information and/or making different investigations) and/or guiding them.

Among all the C-sources reported in Deliverable D2.1 and modelled as described in Deliverable D3.1, the ones reported in Table 1 were considered in the flowsheet stationary model investigations. They correspond to the alternative C-sources having a content of Fixed C higher than 40 wt-%; only tires are outside these constraints but since the Carbon content in the volatile part is pretty high, they are also considered of particular interest and for this reason included in the investigations.

Biochar No. 4 of the supplier CPL INDUSTRIES was considered the reference C-source because adopted by Sidenor for the preliminary industrial trials involving 278 heats where it was used in place of anthracite fed at 5th hole for the starting of foaming slag formation.

Table 1 Available and calculated features of considered C-materials (see D2.1 and 3.1)

ID	Supplier	Material	Fixed C	S	N	H (from model)	O (from model)	Moisture	Volatile	Ash	HHV
			wt%								kcal/kg
1	FERROSADIM	Biochar	87.7	0	0	3.45	6.35	32.6	9.8	2.5	8048
2	FERROSADIM	Biochar	62.2	0	0	4.92	13.38	12.9	18.3	19.5	6090
3	PRECO	Biochar	64	0	0	2.67	9.33	0	0	24	6000
4	CPL INDUSTRIES	Biochar	80	0.8	2	0	9.2	13	12	8	6360
5	CPL INDUSTRIES	Biochar	70	0.85	2	1.57	18.08	13	21	7.5	5776
6	ARBAFLAME	Biochar	41.3	0.26	0	8.61	16.03	0	24.9	33.8	5259
10	AIREX	Biochar	80	0.03	0	3.36	12.45	7	8.9	4.16	7214
11	ENVIGAS	Biochar	95	0.01	0.29	1.55	1.74	0.8	3	1.4	8264
12	SIGNUS	Tires	28.70	1.80	0.54	27.02	34.64	0.49	64	7.29	8938
13	IBLU	Plastics	97.2	0.03	0	0.2	0	0.15	0.23	2.57	9715
14	AGBAR	Charcoal	48	0.08	0.58	5.81	32.03	5.3	69.3	13.5	4691

2.1.1 Description of scenario analyses

Three different typologies of scenario were analyzed through SSSA flowsheet model simulations and described in the following subsections. All the scenario analyses were conducted for 4 steel families (groups of steel grades with similar characteristics): Alloyed Case Hardening, Alloyed Q&T, Free Cutting, Carbon Case Hardening. The simulation results were used to calculate the following Key Performance Indicators (KPIs):

- Consumption of electrical energy in EAF [kWh/t_{liquid_steel}].
- CO_2 emissions of the EAF [kg/t_{liquid_steel}].
- Content of C and S in the tapped metal [w/w].
- Metallic yield [$kg_{metal\_material}$/t_{liquid_steel}].
- EAF slag [kg/tliquid_steel].

In addition, secondary metallurgy was monitored.

2.1.1.1 Scenario 1: Substitution of fossil carbon injected in the EAF through the 5th hole (partial substitution of the whole fossil carbon).

The idea of the first scenario is simulating some heats by reproducing the preliminary SID industrial trials that tested the substitution of a part of the whole fossil carbon used in EAF (i.e. the anthracite fed through the 5th hole) with alternative carbon sources. The replacement corresponds to less than 15% of the whole used fossil carbon. As reported above, the first industrial tests only regarded the use of Biochar No. 4 used as a reference in the simulations, therefore the simulations expand the investigations by testing all the alternative C-sources listed in Table 1. In addition, for allowing comparisons, also anthracite was considered as a source of C (although fossil); its features are the following: fixed C 84% w/w, S 1% w/w, N 1.20% w/w, H 5.21 % w/w, O 0.59 % w/w, moisture 6.00 % w/w, volatile 8.00 % w/w, ash 8.00 % w/w and HHV of 8250 kcal/kg

The simulations were carried out in two alternative ways:

- **Scenario 1.a** by adding an amount of C-material ensuring the same amount of fed fixed C through the 5th hole
- **Scenario 1.b** by adding an amount of C-material ensuring the same quantity of energy supplied through the 5th hole
-

2.1.1.2 Scenario 2: Sensitivity analyses by changing the content of the main compounds of the reference biochar fed in the EAF 5th hole

The concept of the second scenario is to analyse the effects of the content of the main compounds of biochar, i.e. C, S, Moisture, on the considered KPIs. Also in this case, it is considered a partial substitution of fossil C-source (i.e. the one fed in the EAF through the 5th hole and corresponding to less than 15% of the whole fossil carbon) according to the preliminary industrial trials. The sensitivity analysis was conducted taking into account the reference biochar (i.e. Biochar No. 4 in Table 1) by changing respectively the content of fixed-C (**Scenario 2.a**), S (**Scenario 2.b**) and Moisture (**Scenario 3.b**) in the range of ±25%. Of course, the content of other compounds is adjusted accordingly.

2.1.1.3 Scenario 3: Total substitution of fossil carbon in the EAF

The third scenario involves the replacement of the overall amount of fossil carbon used into the EAF with the Biochar No. 4 in Table 1). Similarly to Scenario 1, also Scenario 3 was carried out in the following two alternative ways:

- **Scenario 3.a** by adding an amount of C-material ensuring the same amount of the overall fed fixed C
- **Scenario 3.b** by adding an amount of C-material ensuring the same quantity of energy supplied

2.2 Tests with dynamic EAF model

Sidenor performed first industrial trials with biochar material, which should substitute the anthracite addition via the 5th hole to start the slag foaming process.

For these trial heats, also dynamic EAF process data were recorded, so that an evaluation of the trials with the dynamic EAF model, as it is described in Deliverable D3.1, were performed. The results are reported in Section 3.2.

In addition, BFI evaluated the trial data with biochar usage at the Sidenor EAF with statistical methods, to investigate if it has an effect on the chemical composition of critical elements like sulphur and phosphorus, or on the consumption figures of electrical energy as well as blown oxygen and carbon.

For this purpose, a comparison of the results of the 270 trial heats with the heats produced under standard conditions before and after the trial campaign was performed.

Figure 1 shows that the amount of biochar added via the 5th hole is more or less the same as the anthracite which has been added in standard production.

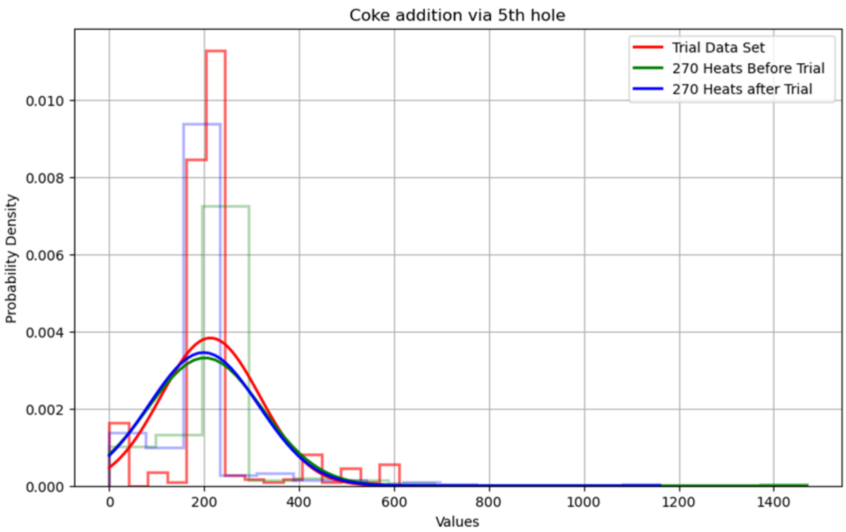

Figure 1 Statistical distribution of coal addition via the fifth hole for trial heats with biochar and standard heats with anthracite

As can be seen in the following two figures Figure 2 and Figure 3, no clear effect of the biochar usage on the liquid steel composition at EAF tapping regarding the elements sulphur and phosphorus can be found. This means that the use of biochar seems to have no critical effect on the liquid steel quality.

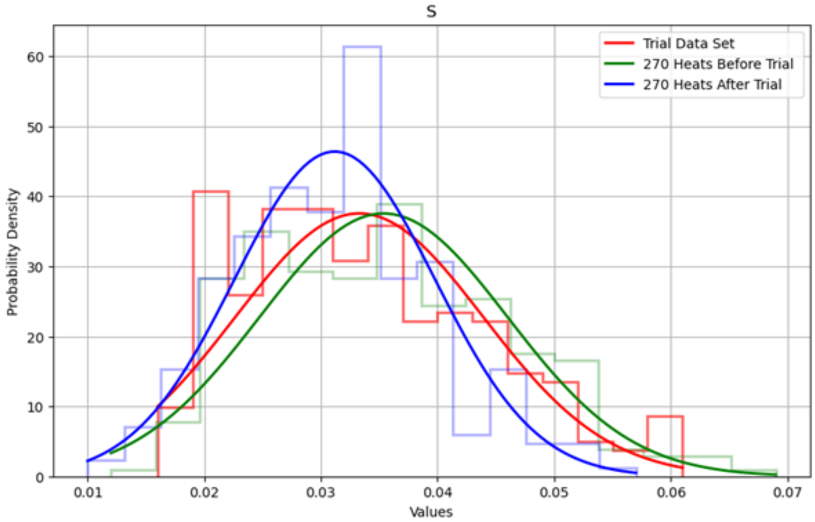

Figure 2 Statistical distribution of sulphur content for trial heats with biochar and standard heats with anthracite

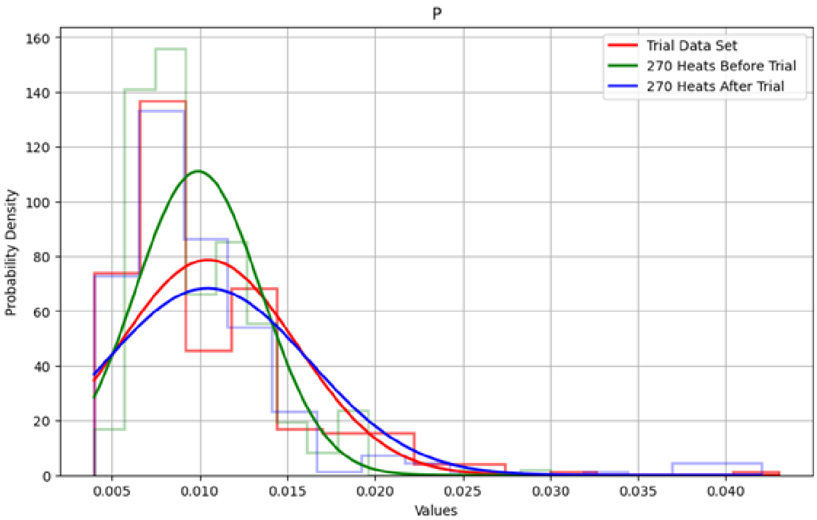

Figure 3 Statistical distribution of phosphorus content for trial heats with biochar and standard heats with anthracite

Furthermore, a comparison of the energetic parameters of the furnace operation has been performed. Figure 4 and Figure 5 show the electrical energy consumption and the oxygen consumption for standard and trial heats.

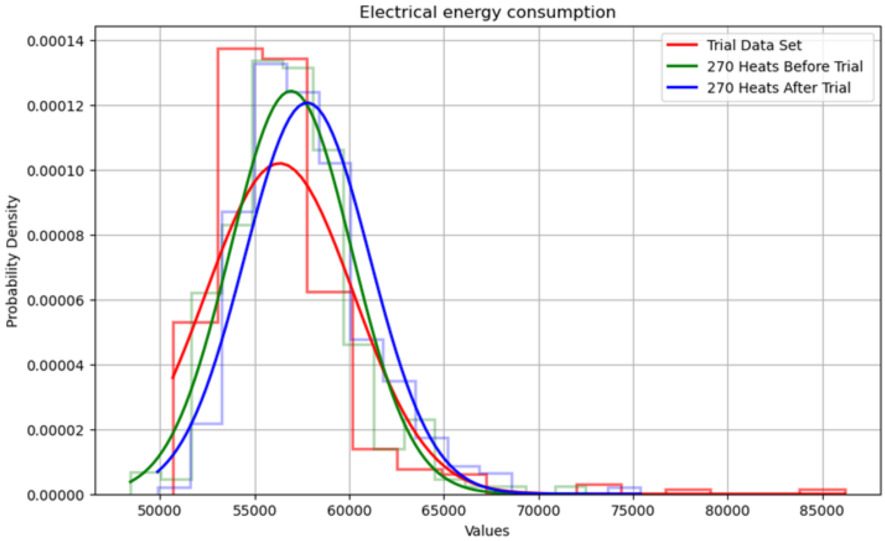

Figure 4 Statistical distribution of electrical energy consumption for trial heats with biochar and standard heats with anthracite

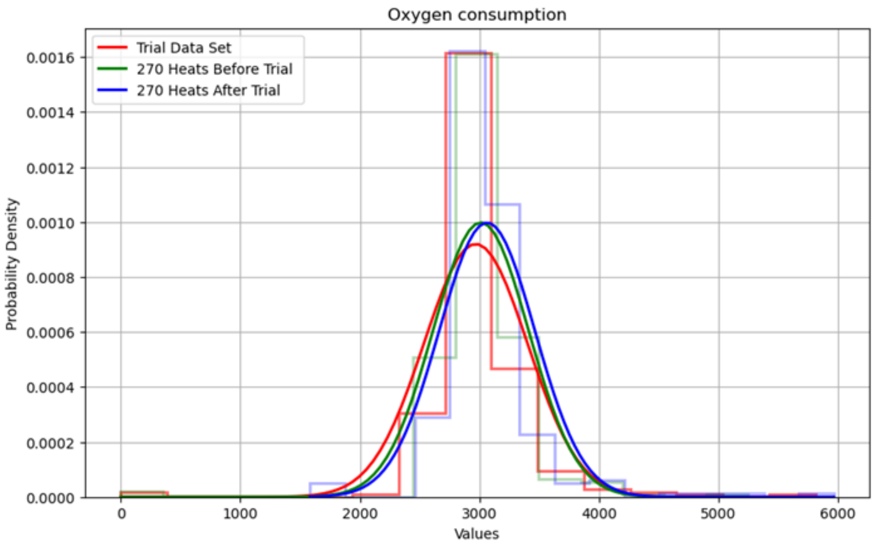

Figure 5 Statistical distribution of oxygen consumption for trial heats with biochar and standard heats with anthracite

Regarding the amount of blowing coke, it can be seen from Figure 6 that less carbon was used before the biochar trials, but almost the same amount in the period after the trials.

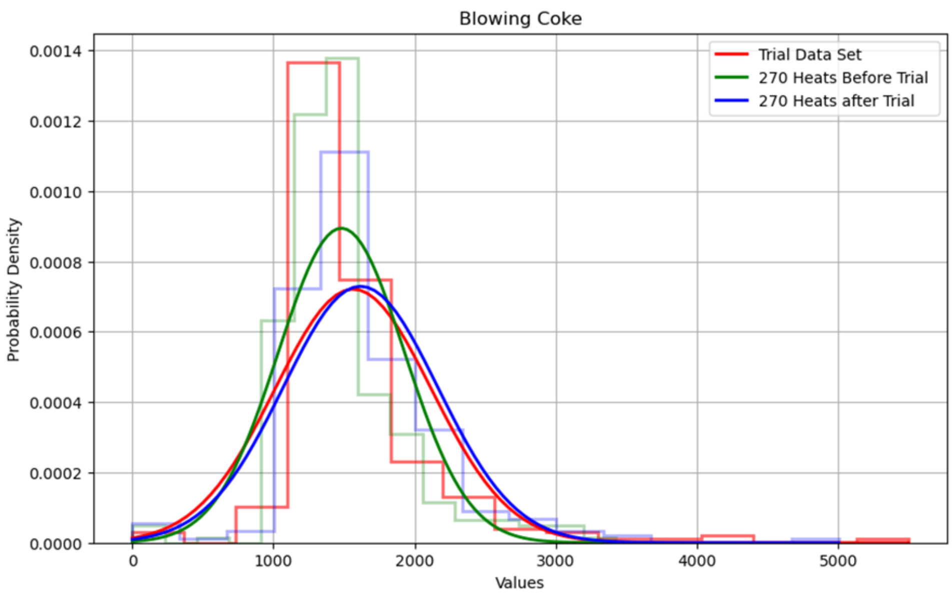

Figure 6 Statistical distribution of blowing carbon consumption for trial heats with biochar and standard heats with anthracite

To evaluate more objectively if the use of biochar has an effect on the energetic performance of the EAF, in addition, a statistical model for the electrical energy demand was used, which was previously developed by BFI [1]. With this statistical model, variations of electrical energy consumption at an EAF can be analysed. The formula for calculating the electrical energy demand of EAFs with the parameter values determined in [1] is shown in Figure 7.

$$\frac{W_R}{kWh\ /t} = 375 + 400 \cdot \left[\frac{G_E}{G_A} - 1\right] + 80 \cdot \frac{G_{DRI\,/\,HBI}}{G_A} - 50 \cdot \frac{G_{Shr}}{G_A} - 350 \cdot \frac{G_{HM}}{G_A} + 1000 \cdot \frac{G_Z}{G_A}$$

$$+ 0.3 \cdot \left[\frac{T_A}{°C} - 1600\right] + 1 \cdot \frac{t_S + t_N}{min} - 8 \cdot \frac{M_G}{m^3/t} - 4.3 \cdot \frac{M_L}{m^3/t} - 2.8 \cdot \frac{M_N}{m^3/t}$$

G_A	Tap weight	t_S	Power-on time
G_E	Metallic charge weight	t_N	Power-off time
G_{DRI}	DRI	M_G	Burner gas
G_{HBI}	HBI	M_L	Lance oxygen
G_{Shr}	Shredder-Scrap	$M_{LJ1\text{-}3}$	Injector oxygen
G_{HM}	Hot metal	M_N	PC oxygen
G_Z	Slag formers	W_R	Required electrical energy
T_A	Tapping temperature		

Figure 7 BFI formula for electrical energy demand of EAFs

The statistical model considers the specific consumption of total and several individual ferrous materials, slag formers, burner gas, oxygen for blowing by lances and injectors as well as for post-combustion, temperature before tapping and tap-to-tap time. All consumption values - also the actual electrical energy consumption W_E for comparison with the calculated demand W_R - are related to the tap weight. In Table 2 the average input values for the BFI statistical model are compiled for the trial campaign with biochar and the periods before and after which were performed under standard operating practice.

Table 2 Average input values of Sidenor EAF for BFI model for three periods

	W_R	W_E	T_A	t_{TTT}	G_E/G_A	G_Z	M_G	M_J	M_{Coke}	$M_{C5th\ hole}$
	kWh/t	kWh/t	°C	min		kg/t	m³/t	m³/t	kg/t	kg
Standard operation 1	426.2	439.5	1647	60	1.116	21.4	1.3	20.6	11.4	203
Trial campaign	424.4	438.4	1647	63	**1.112**	21.6	1.3	20.5	12.1	**227**
Standard operation 2	427.1	446.8	1645	60	1.122	21.3	1.3	20.9	12.5	196

From the table it can be seen that the operational figures of standard operation and with biochar usage differ not very much. Interesting is that with the use of biochar a slightly better metallic yield (G_E/G_A) was achieved. Regarding the assessment of the overall energetic performance the calculated electrical energy demand is plotted versus the actual electrical energy consumption in Figure 8. The mean deviation is an indication of the energetic performance compared to an ideal EAF. In this sense it can be noted that the standard production after the biochar trials has a slightly lower energetic performance than in the phases before. Furthermore, it can be clearly seen by the lower standard deviation that the trials with biochar were performed under better controlled conditions.

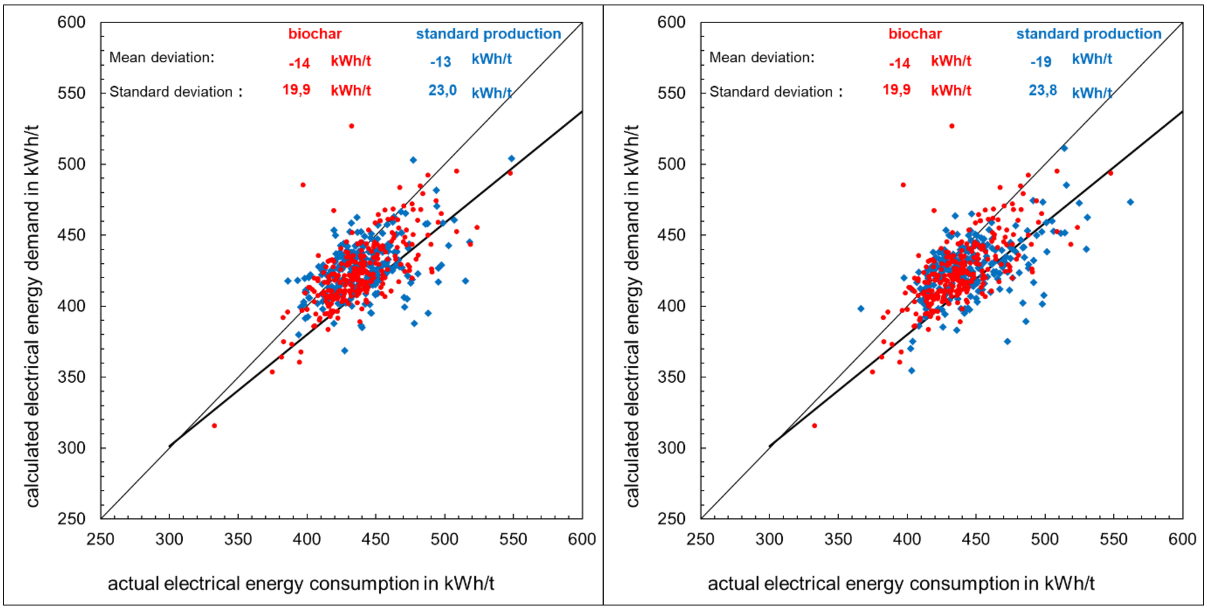

Figure 8 Calculated electrical energy demand versus actual electrical energy consumption for trial heats with biochar, compared with standard heats directly before (left) and directly after (right) the trial campaign

Overall, it can be said that the use of biochar instead of anthracite does not influence negatively the energetic and yield performance of the Sidenor furnace, which is a good result towards a green steel production.

3 Simulation Results

The aim of this section is to discuss the obtained results during the simulations and the sensitivity analyses described in the Section 2.

3.1 Stationary simulations

In this section the results are presented of the three simulated scenarios described in Section 2.1.

3.1.1 Scenarios 1

Main results of Scenarios 1.a (Section 2.1.1.1) are depicted from Figure 9 to Figure 14, where radar diagrams show the normalized values of each considered KPIs (i.e. EAF electrical energy, EAF CO_2 emissions, C content in tapped metal, S content in tapped metal, EAF metallic efficiency, EAF slag) with respect to the reference heat where Biochar No. 4 of Table 1 is used (value 1 of each KPI corresponds to it). The amount of Fixed C in the considered C-sources increase in the Figures in counterclockwise direction.

Figure 9 shows that tires provide the highest decrease of required EAF electric energy. Due the low amount of fixed carbon contained in tires, high tires amount is required to reach the desired fixed C fed and, consequently, higher chemical energy is provided also considering their significant HHV (i.e. 8938 kcal/kg). From the Figure 10 it is clear that anthracite increases CO_2 emissions, and these emissions are fossil. While from the plots in Figure 11 it emerges that there is no clear correlation between C-bearing material and C content in tapped metal. However, it is evident how the variations are limited. The results reported in Figure 12 show that tires lead to highest S content in tapped metal because of their highest S content with respect to the other C-sources and their significant amount for ensuring the fed fixed C. From the graphs in Figure 13 it can be observed that there are small changes in terms of metallic efficiency, without a clear correlation. Finally, the radar diagrams in Figure 14 show that similar behaviour was observed for the different C-sources with respect to EAF slag amount. Only Tires leads to an evident decrease of EAF slag.

Figure 15 to Figure 16 depict the main results related to Scenarios 1.b (2.1.1.2) in a similar way of Scenarios 1.a. The amount of HHV of the considered C-sources increases in the figures in clockwise direction.

From Figure 15 there is no clear general correlation between C-bearing material and EAF electric energy consumption. While EAF CO_2 emissions are almost similar for all the considered C-sources (Figure 16) apart for anthracite that again leads to the highest CO_2 emissions. It is important to remark one time more that these emissions are fossil. In scenarios 1.b, the C content in tapped metal is lower in case tires are used as alternative C-source, as can be seen in Figure 17. This can be explained from their lowest fixed-C content (despite its high content in the volatile part) and from the fact that low amount of tires are fed for achieving the desired energy contribution because of their high HHV. In addition, as in Scenarios 1.a, also in this case, tires (C-bearing material with highest S content) increase S content in tapped metal (Figure 18). Figure 19 shows that there is no clear general correlation between C-bearing material and EAF metallic efficiency. However, the variations are very limited between the different cases. Finally, the radar diagrams in Figure 20 depict that, generally, tires and anthracite lead respectively to a decrease and an increase of EAF slag.

Lastly, it is important to underline that due to the no significant changes in tapped metal by using alternative C-sources, no important changes in secondary metallurgy were observed.

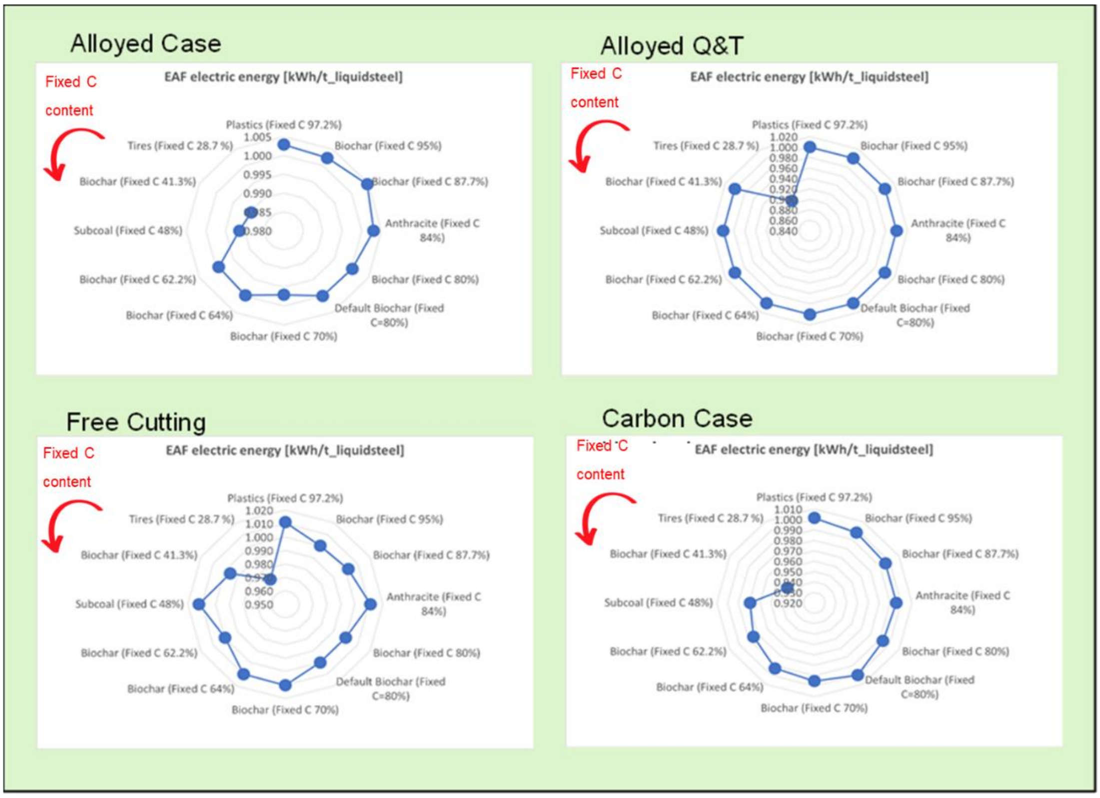

Figure 9 Scenario 1.a results – EAF Electric Energy. The values are normalized (1 refers to default heat). Missing points are related to unconverged simulations

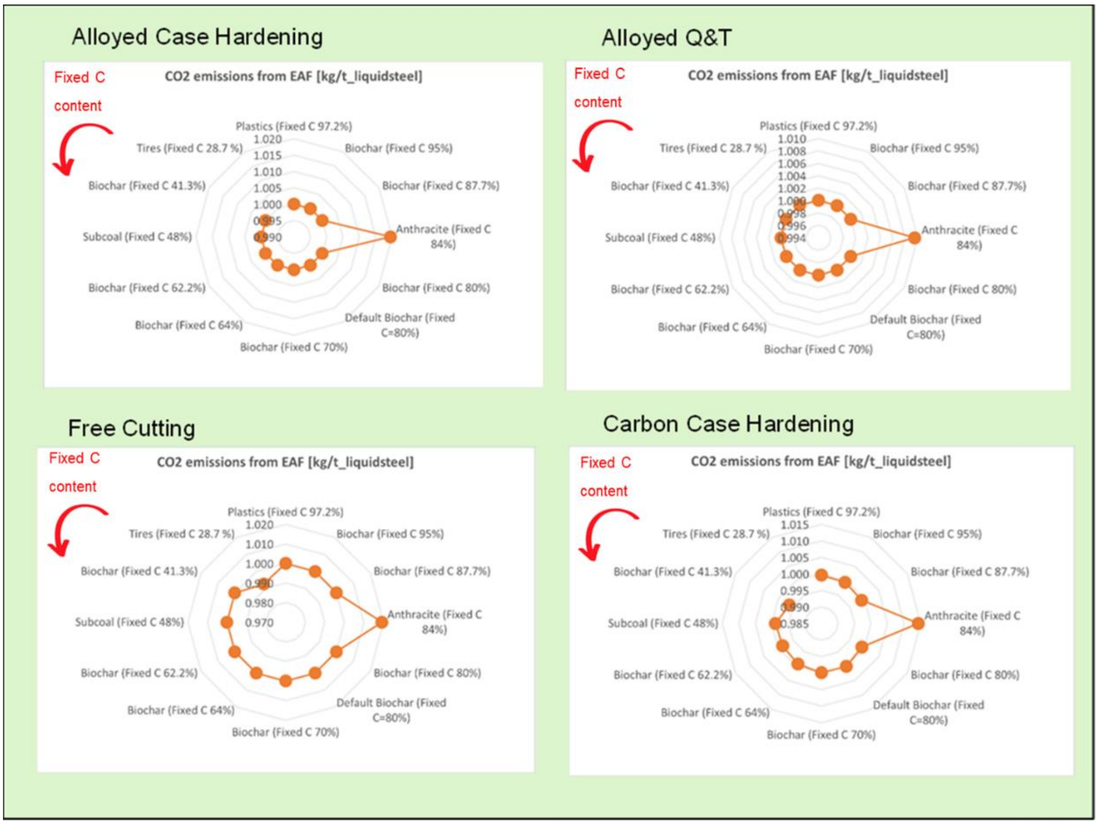

Figure 10 Scenario 1.a results – CO_2 emissions from the EAF. The values are normalized (1 refers to default heat). Missing points are related to unconverged simulations

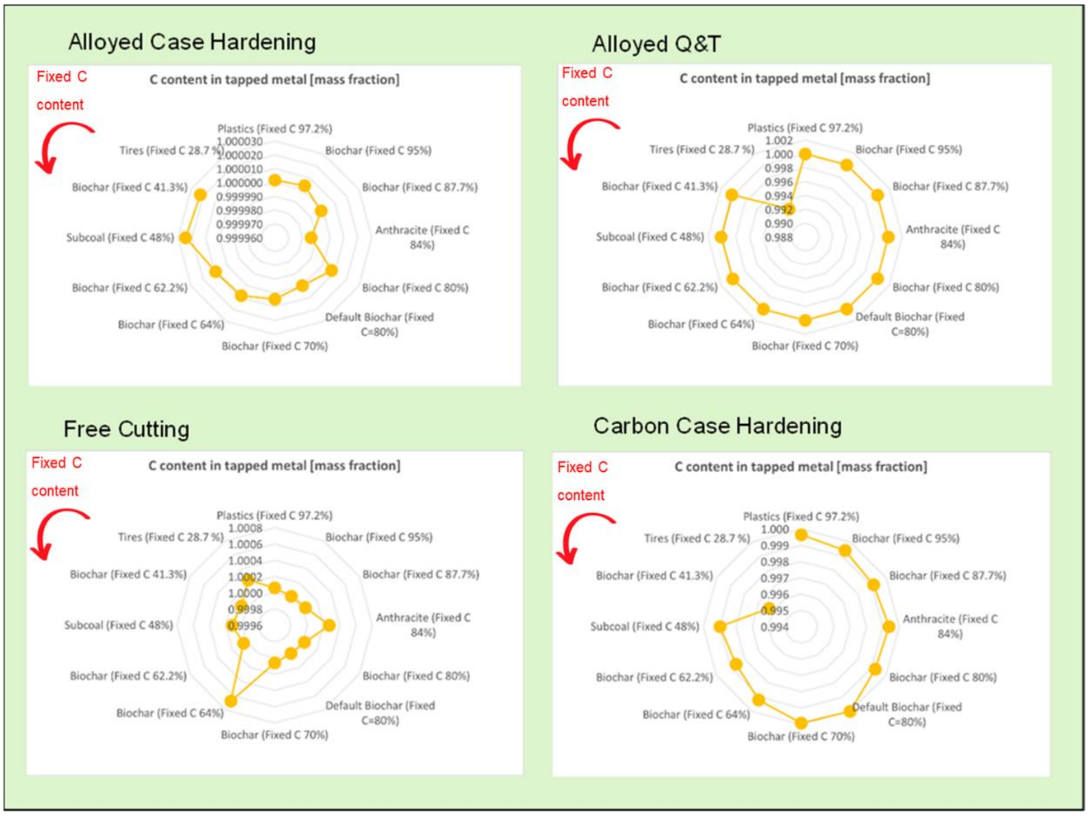

Figure 11 Scenario 1.a results – C content in tapped metal. The values are normalized (1 refers to default heat). Missing points are related to unconverged simulations

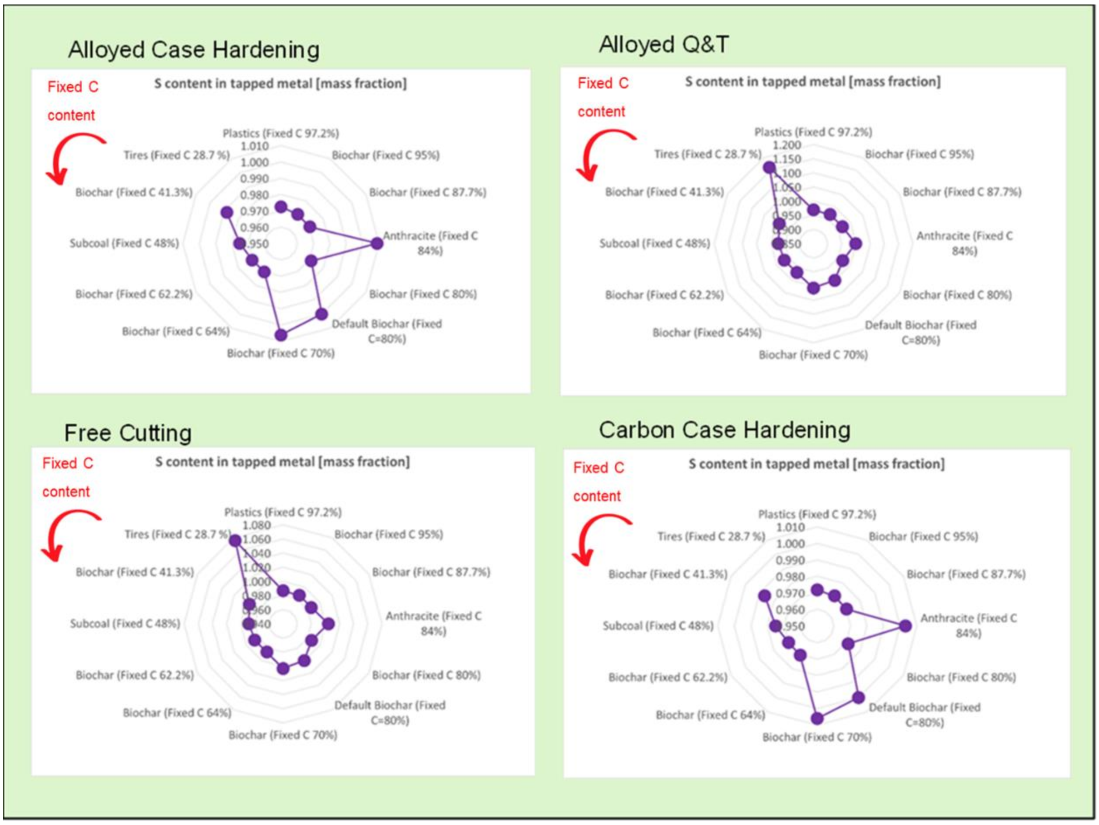

Figure 12 Scenario 1.a results – S content in tapped metal. The values are normalized (1 refers to default heat). Missing points are related to unconverged simulations

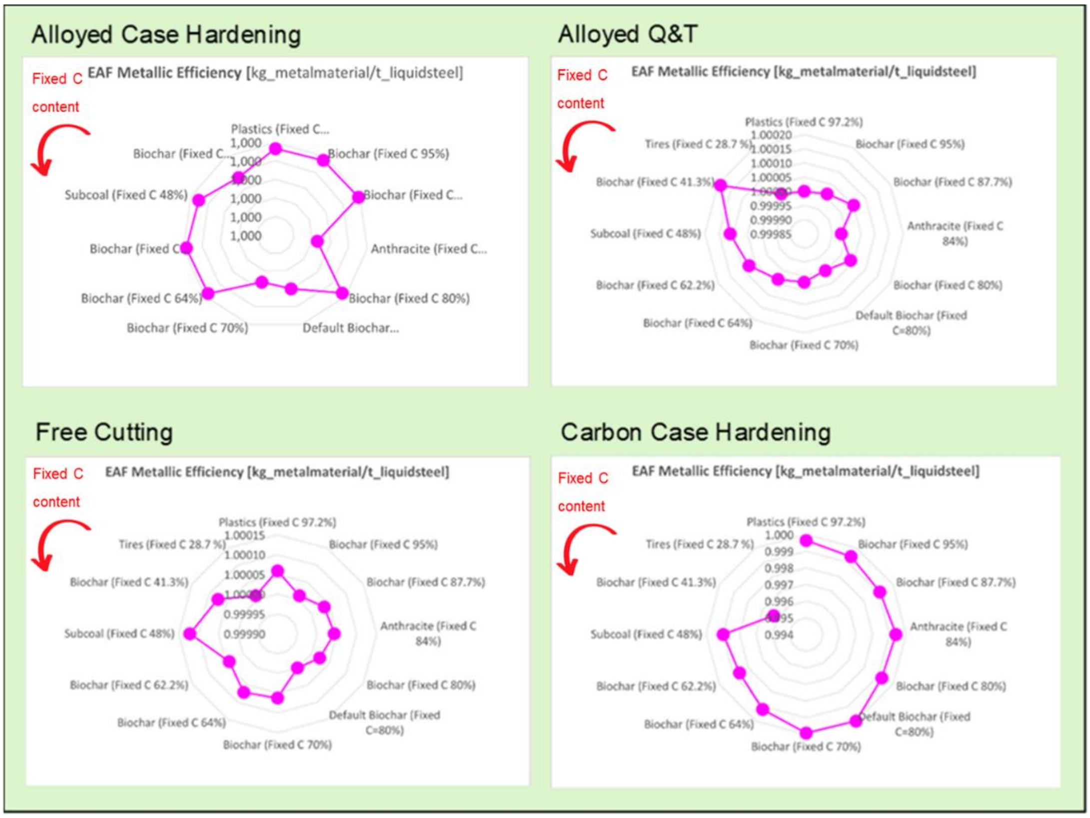

Figure 13 Scenario 1.a results – EAF Metallic Efficiency. The values are normalized (1 refers to default heat). Missing points are related to unconverged simulations

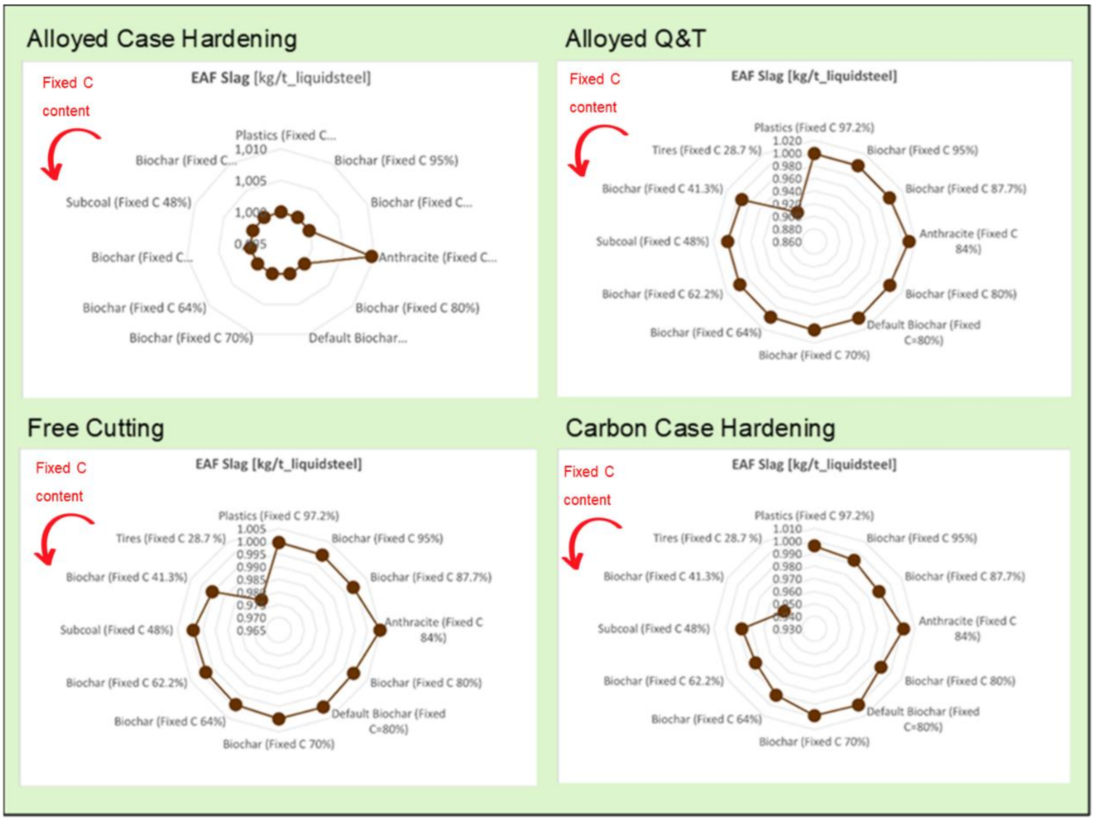

Figure 14 Scenario 1.a results – EAF Slag. The values are normalized (1 refers to default heat). Missing points are related to unconverged simulations

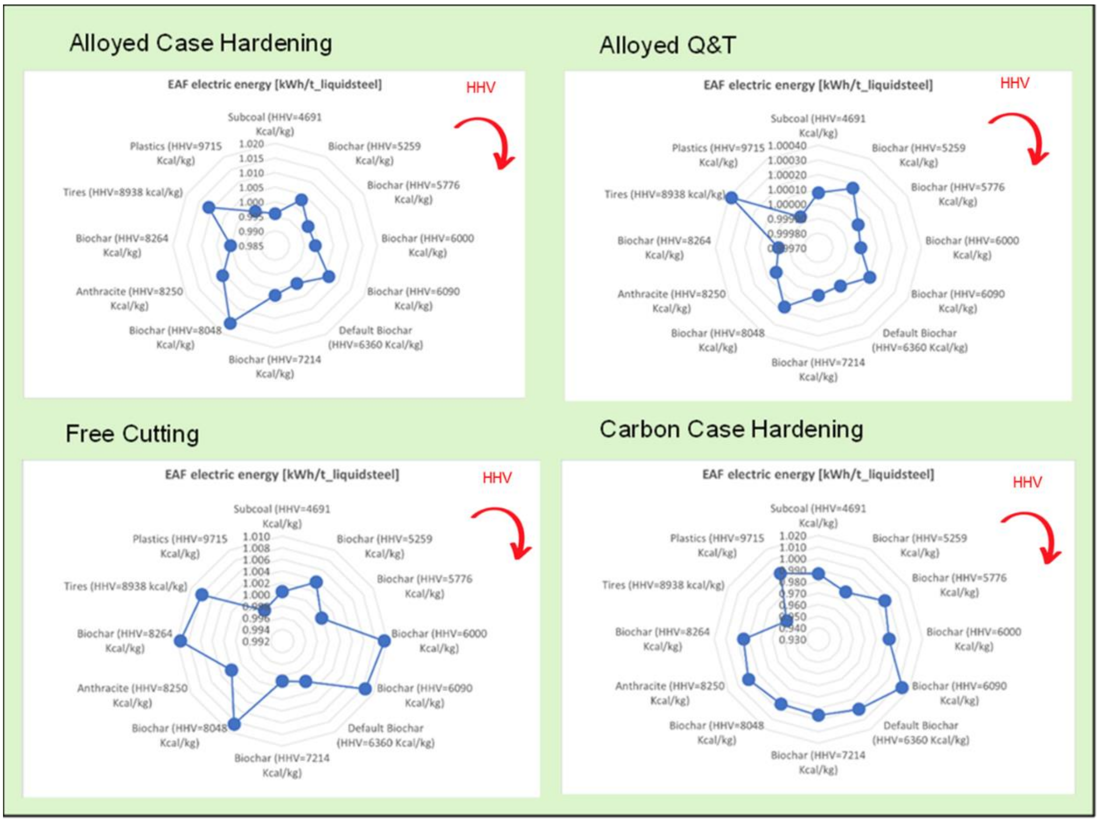

Figure 15 Scenario 1.b results – EAF Electric Energy. The values are normalized (1 refers to default heat)

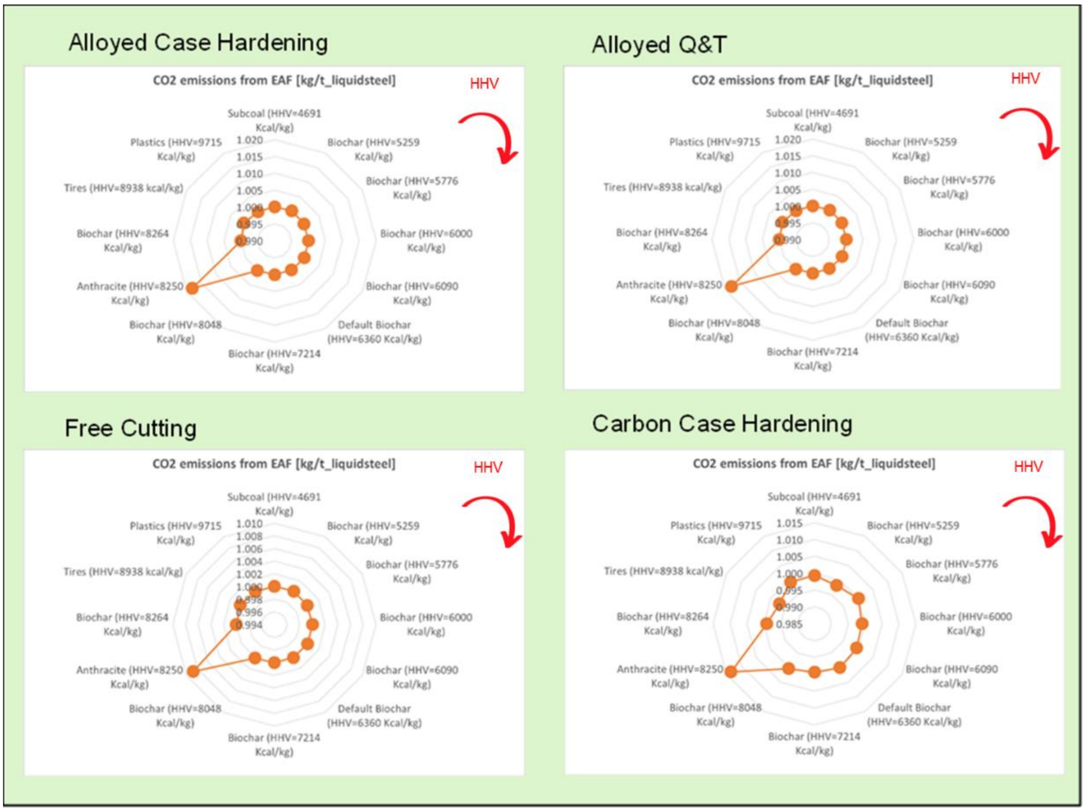

Figure 16 Scenario 1.b results – CO_2 emissions from the EAF. The values are normalized (1 refers to default heat)

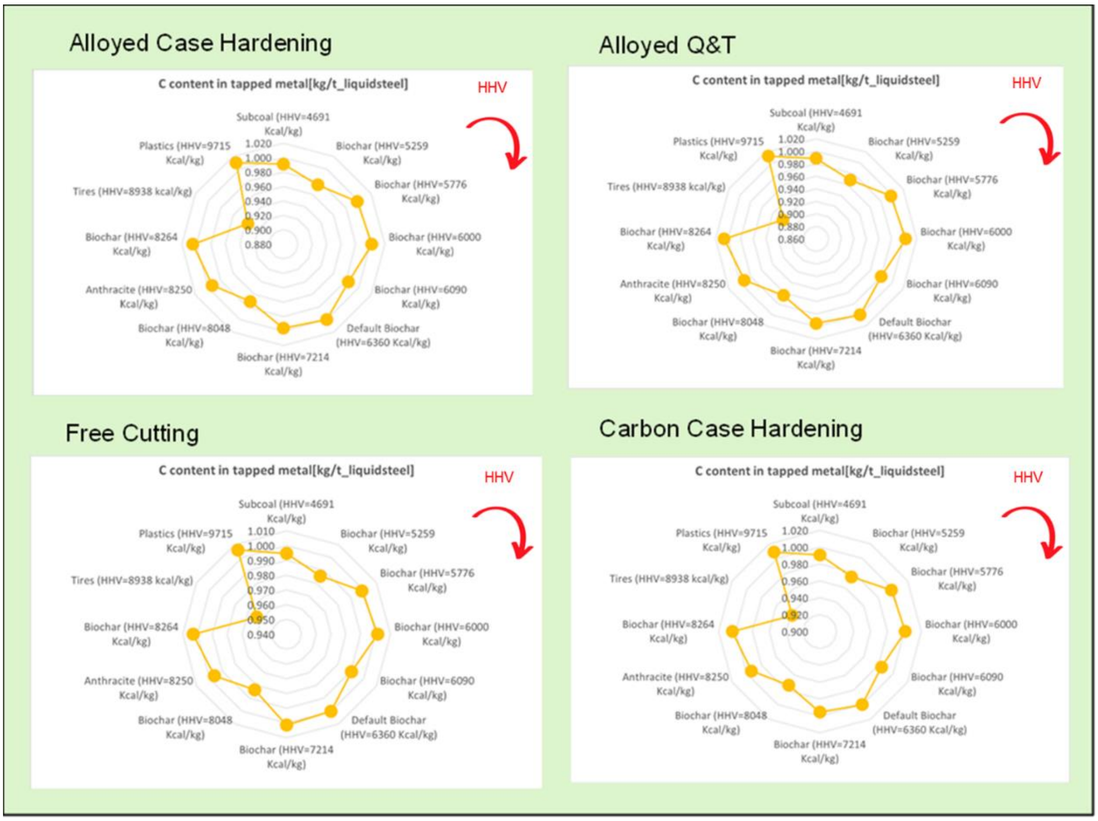

Figure 17 Scenario 1.b results – C content in tapped metal. The values are normalized (1 refers to default heat)

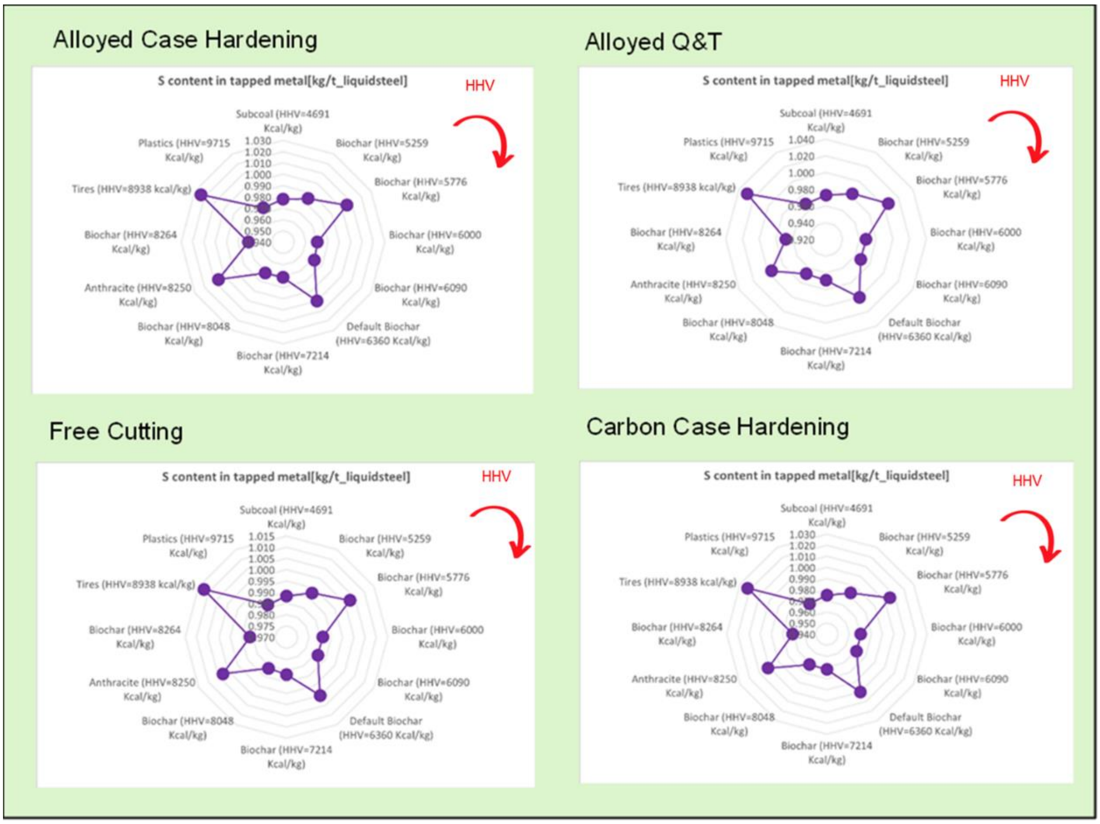

Figure 18 Scenario 1.b results – S content in tapped metal. The values are normalized (1 refers to default heat)

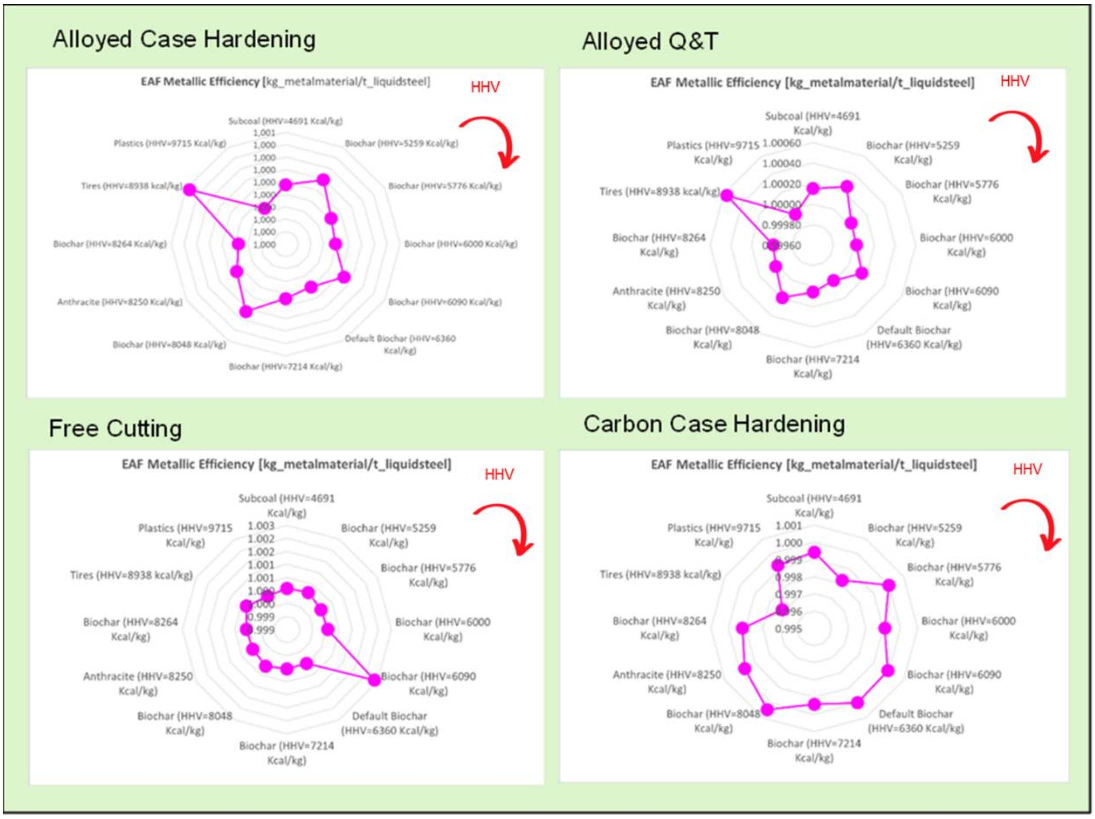

Figure 19 Scenario 1.b results – EAF Metallic Efficiency. The values are normalized (1 refers to default heat)

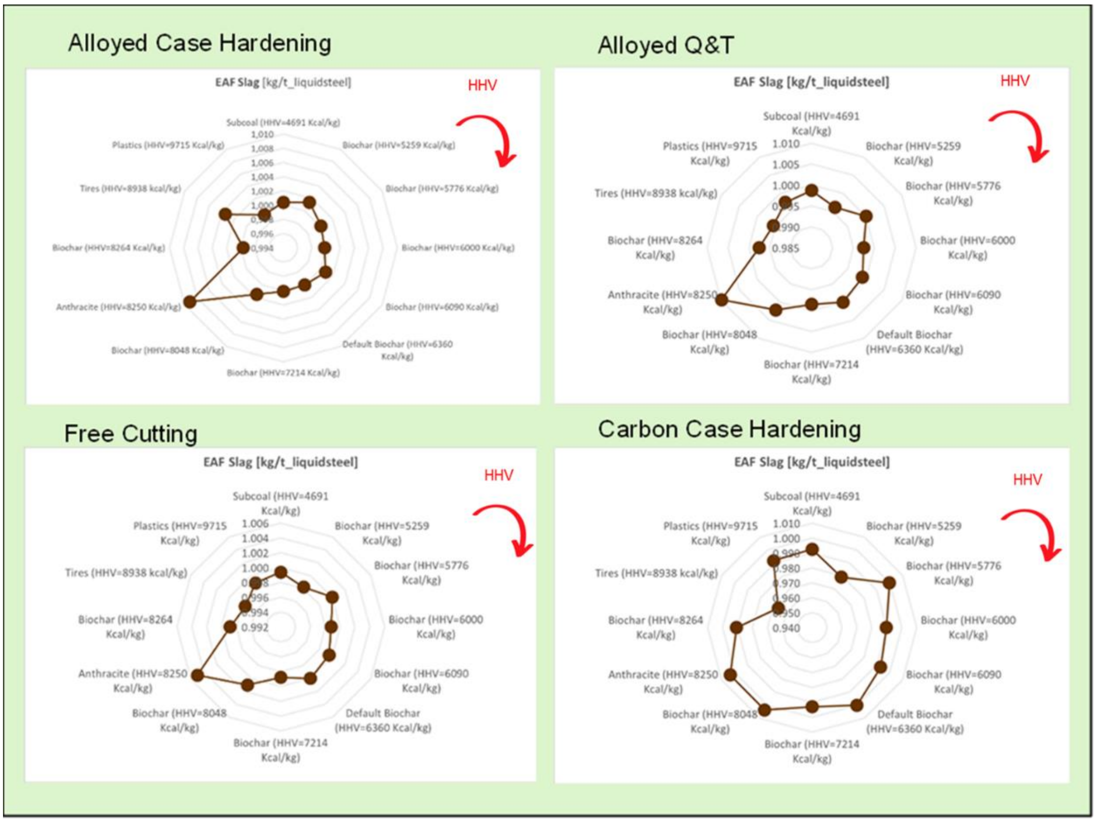

Figure 20 Scenario 1.b results – EAF Slag. The values are normalized (1 refers to default heat)

3.1.2 Scenarios 2

As mentioned in Section 2.1.1.2, Scenarios 2 refers to the sensitivity analyses carried out by varying some features of Biochar No. 4 (see Table 1) that was added at the 5th hole in first Sidenor industrial trials.

During the sensitivity analyses done by varying the C content (Scenarios 2.a) in the considered biochar, the effects on EAF electric energy, C content in tapped metal, EAF slag, EAF CO_2 emissions and metallic yield were monitored. Most significant results are reported in Figure 21, Figure 22 and Figure 23. The reported graphs show that there are almost linear behaviors of monitored parameters in function of fixed-C content in the alternative C-source. In general, limited observed variations are obtained due to the small amount of fossil carbon substitution (between about 5% and 13%). However, as expected, the increase of fixed-C content in biochar leads to:

- a decrease of EAF electric energy;
- an increase of C content in the tapped metal.

In addition, a decrease of slag amount was observed and negligible changes in CO_2 emissions and in metallic yield (these last two monitored variables were not reported in Figures).

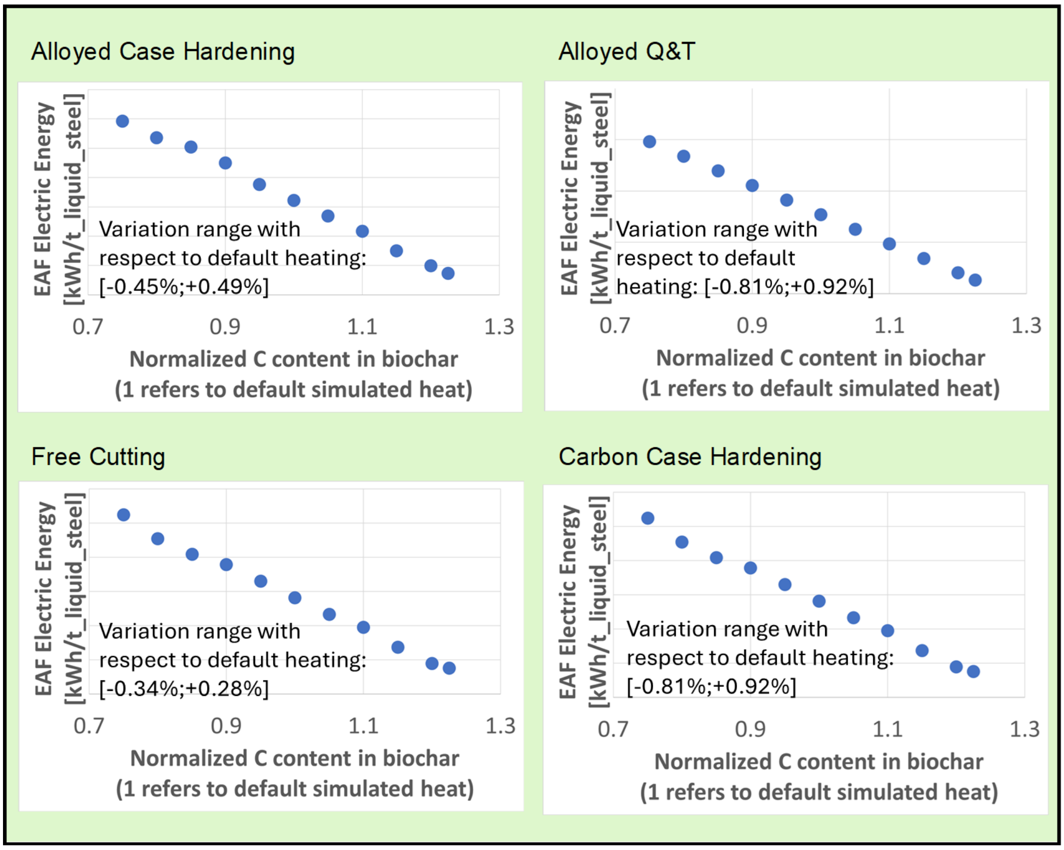

Figure 21 Scenario 2.a results – EAF Electric Energy. The values are normalized (1 refers to default heat). Ordinate values are not shown for confidentiality reasons.

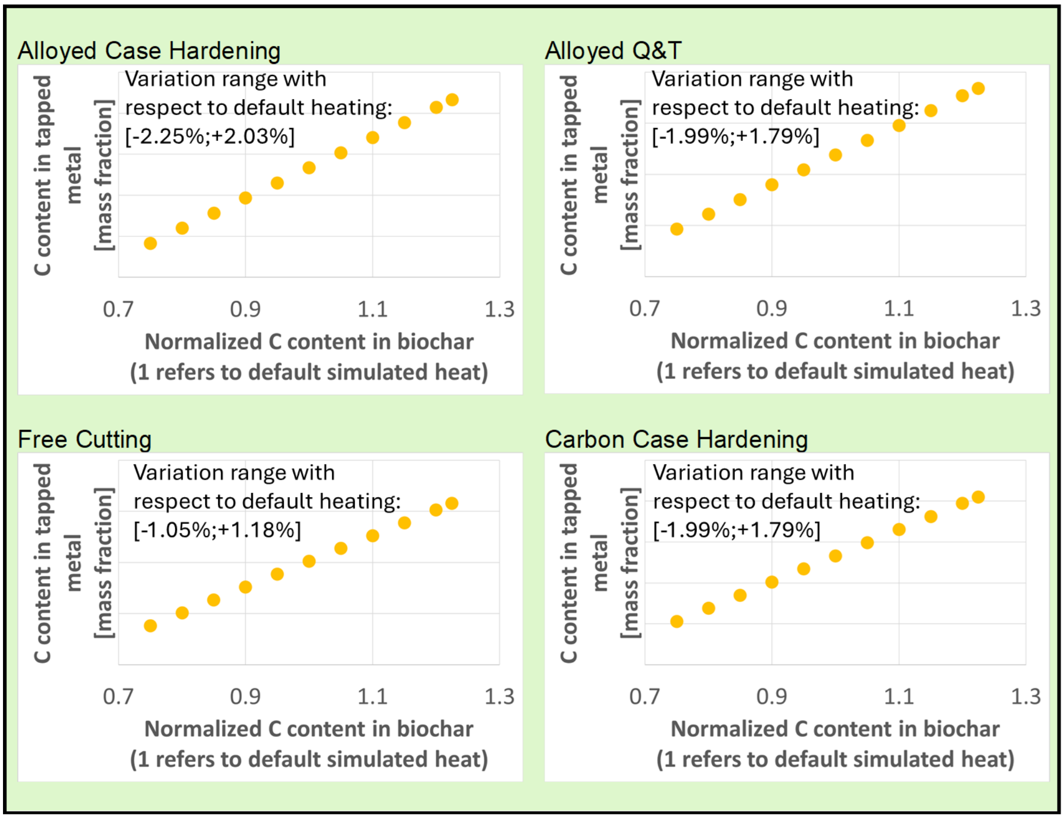

Figure 22 Scenario 2.a results – C content in tapped metal. The values are normalized (1 refers to default heat). Ordinate values are not shown for confidentiality reasons.

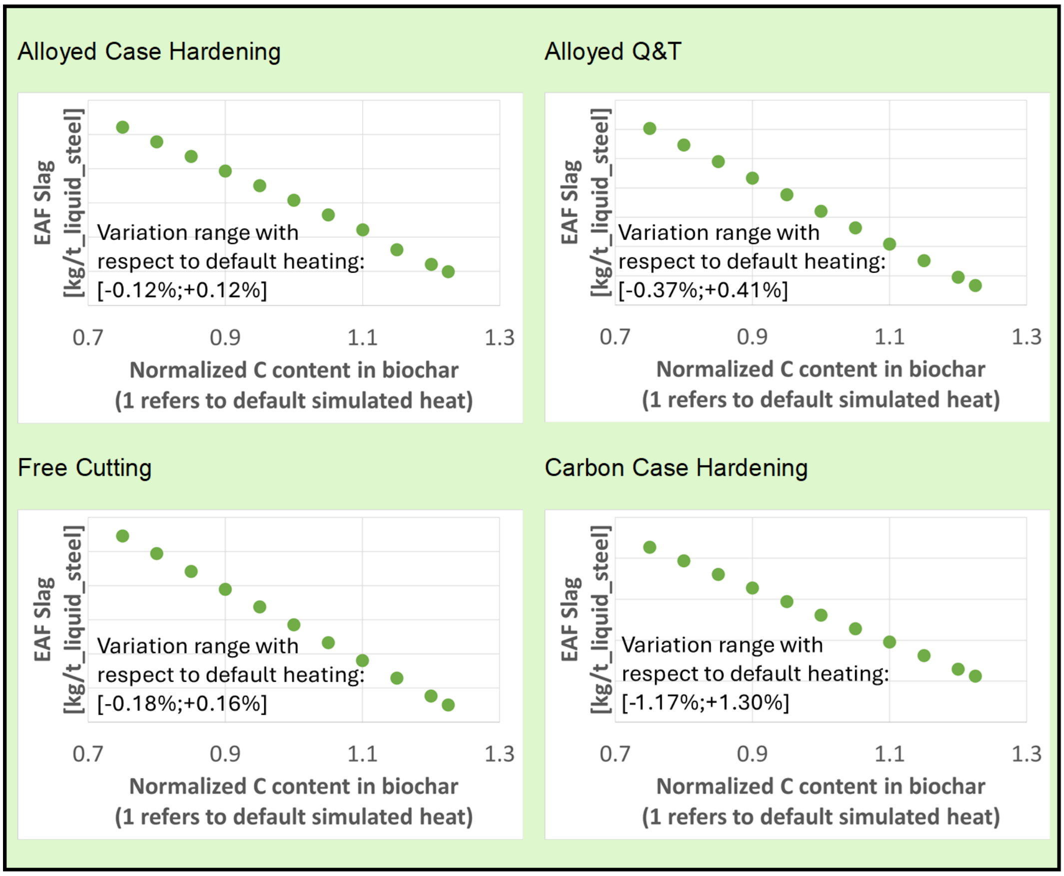

Figure 23 Scenario 2.a results – Slag produced by the EAF. The values are normalized (1 refers to default heat). Ordinate values are not shown for confidentiality reasons.

During simulations of Scenarios 2.b, where S content in biochar was varied, only the behaviour of S content in tapped metal was shown in Figure 24. As expected, it is evident that higher S content in biochar leads to higher S content in tapped metal: there appears to be an almost linear correlation. The observed variations obviously are limited due to the small amount of fossil carbon substitution (between about 5% and 13%). The other KPIs were not affected significantly.

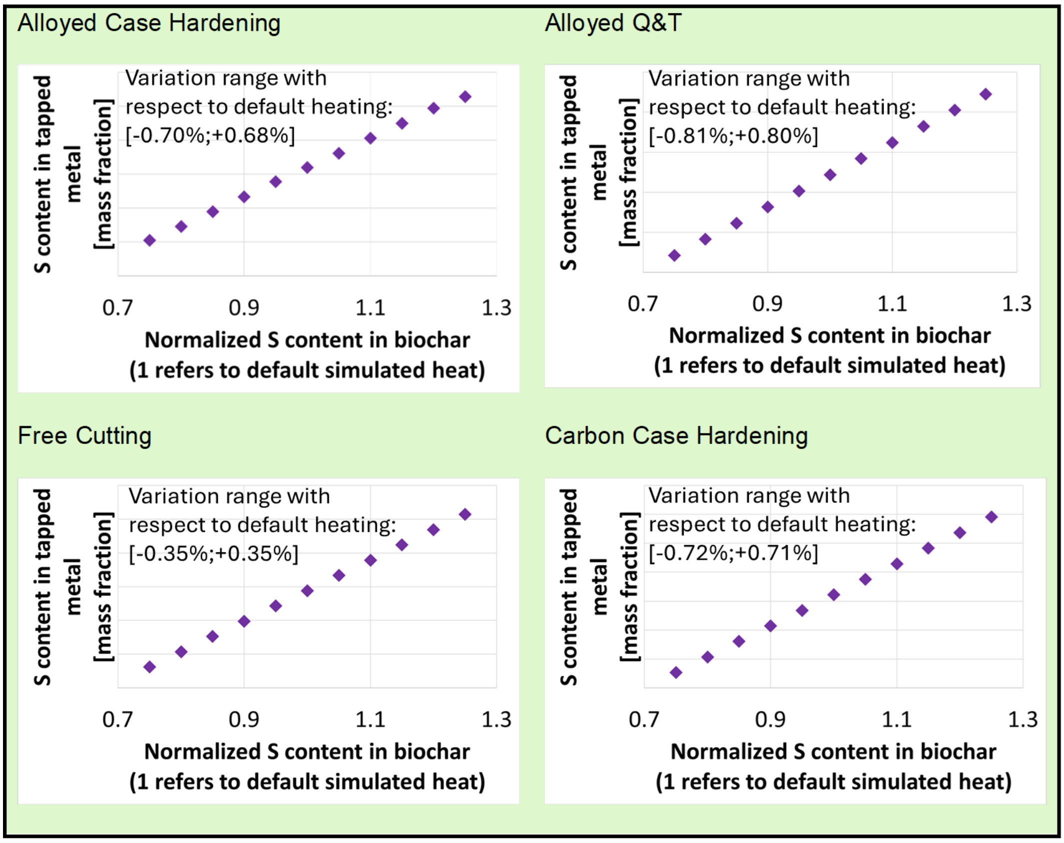

Figure 24 Scenario 2.b results - S content in tapped metal [mass fraction]. The values are normalized (1 refers to default heat). Ordinate values are not shown for confidentiality reasons.

Finally, the main results of Scenarios 2.c, related to the investigations of the effects of moisture content change in biochar, are depicted in Figure 25 and Figure 26. They refer to the behaviour of EAF electric energy and EAF slag respectively. Small almost linear variations for EAF electric energy and EAF slag are observed with the variation of moisture content in biochar. In particular, as expected, the increase of moisture increases the request of energy due to its evaporation; therefore, small amounts of moisture are preferable. Concerning the other monitored variables, their effects are not reported because they are affected negligibly.

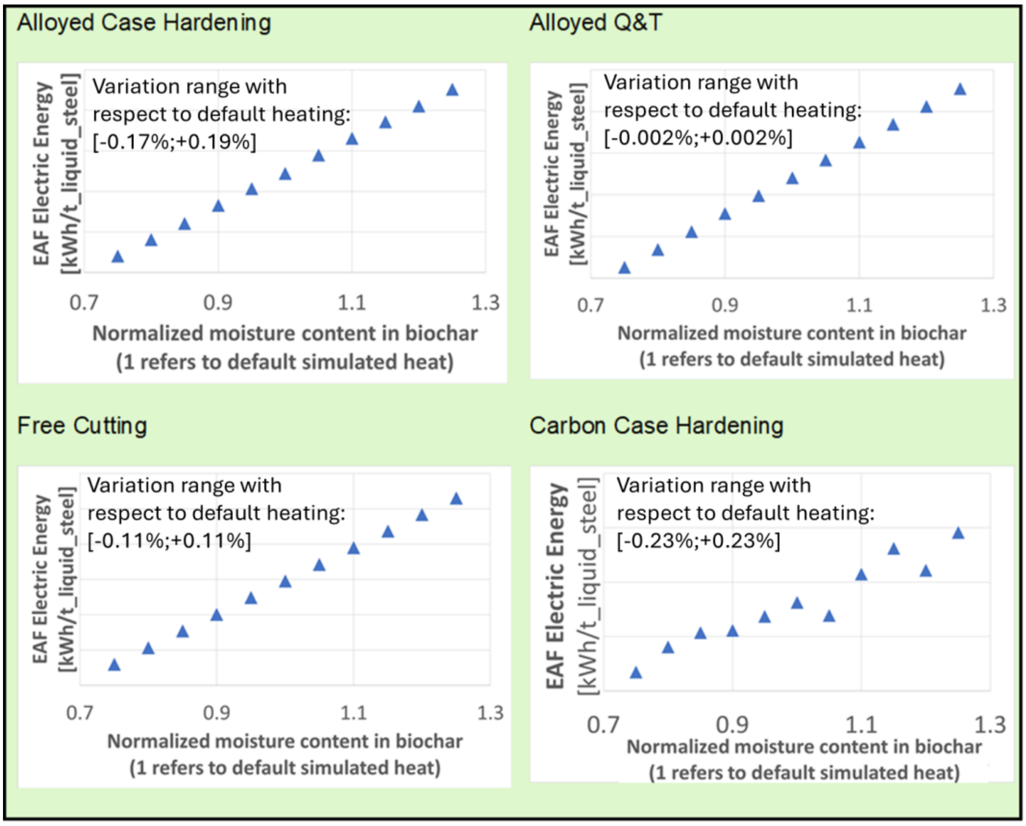

Figure 25 Scenario 2.c results – EAF Electric Energy. The values are normalized (1 refers to default heat). Ordinate values are not shown for confidentiality reasons.

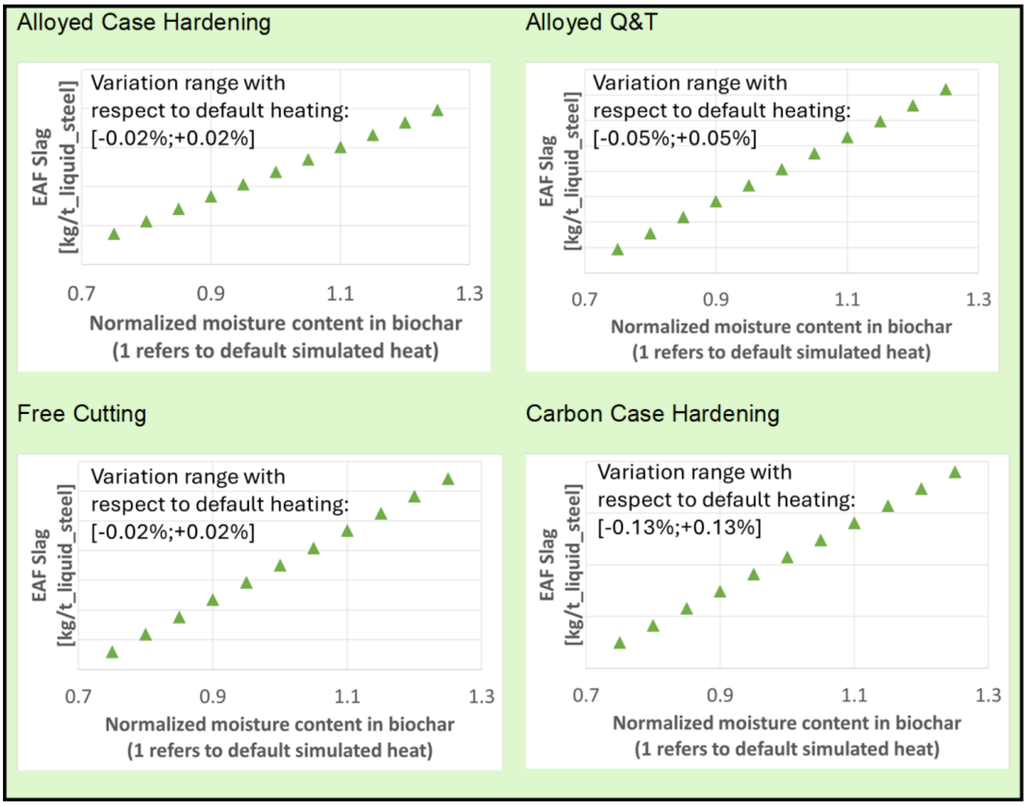

Figure 26 Scenario 2.c results – Slag produced by the EAF. The values are normalized (1 refers to default heat). Ordinate values are not shown for confidentiality reasons.

3.1.3 Scenarios 3

Scenarios 3 (see Section 2.1.1.3) concern the substitution of the whole fossil C used in EAF with Biochar No.4 (see Table 1). For both the subscenarios (i.e. at constant fixed-C fed and at constant energy supplied with the alternative C-source), the following KPIs were monitored: EAF Electric Energy, CO_2 emissions from EAF, C and S content in tapped metal, EAF metallic yield, Slag produced by EAF. Results are listed in Table 3 and Table 4 in terms of KPIs variations respectively for Scenarios 3.a and Scenarios 3.b.

Table 3 Scenarios 3.a results

	UoM	Alloyed Case Hardening	Alloyed Q&T	Free Cutting	Carbon Case Hardening
EAF Electric Energy	kWh/t_{liquid_steel}	-0.27%	+1.95%	-0.26%	+8.31%
EAF CO_2 emissions	kg/t_{liquid_steel}	-19.22%	-14.75%	-15,77%	-15.31%
C content in tapped metal	w/w	+0.01%	+0.03%	+0.01%	+0.42%
S content in tapped metal	w/w	-12.50%	-10.29%	-10.63%	-8.22%
EAF metallic efficiency	$kg_{metal\_material}/kg_{liquid\_steel}$	+0.01%	+0.02%	+0.01%	+0.40%
EAF slag	kg/kg_{liquid_steel}	-8.22%	-6.58%	-6.69%	-3.20%

The results reported in Table 3 indicates that the complete substitution of fossil carbon keeping constant the fed fixed-C with biochar No.4 leads especially to:

- a significant decrease of CO_2 emissions;
- a significant decrease of S content in tapped metal;
- a decrease of EAF slag.

Other variables are negligibly affected.

Table 4 Scenarios 3.b results

	UoM	Alloyed Case Hardening	Alloyed Q&T	Free Cutting	Carbon Case Hardening
EAF Electric Energy	kWh/t_{liquid_steel}	-1.14%	-0.01%	n.a.	+7.86%
EAF CO_2 emissions	kg/t_{liquid_steel}	-19.12%	-14.64%	n.a.	-15.25%
C content in tapped metal	w/w	+1.97%	+2.06%	n.a.	+2.29%
S content in tapped metal	w/w	-11.84%	-9.68%	n.a.	-7.62%
EAF metallic efficiency	$kg_{metal\_material}/kg_{liquid\_steel}$	-0.01%	0%	n.a.	+0.37%
EAF slag	kg/kg_{liquid_steel}	-8.33%	-6.72%	n.a.	-3,90%

Similar results are obtained also in case of Scenarios 3.b. The main difference is related to free cutting family where the simulation was not converged. The possible reason is the fact that for ensuring the energy previously supplied with fossil-C by using Biochar No.4 (as expected in

Scenario 3.b) means adding a higher amount of Biochar No.4 with respect to fossil-C because of Biochar No.4 lower HHV. Therefore, more fixed-C is available, and this can lead to higher C content in free cutting steel (see Section 3.1.2) not respecting its specifications.

Finally, in both cases no significant changes were necessary in the secondary metallurgy.

3.2 Dynamic simulations

The Sidenor trial heats with biochar usage were evaluated with the dynamic EAF model of BFI, which was described in detail in Deliverable D3.1. In total, 278 heats with biochar usage were compared to 301 standard heats with anthracite addition.

The biochar and anthracite materials were both charged via the 5th hole of the furnace. The charging was performed at the beginning of the refining phase. Figure 27 shows the dynamically simulated evolution of the carbon content for two example heats, in the top a standard heat and in the bottom a trial heat with biochar addition.

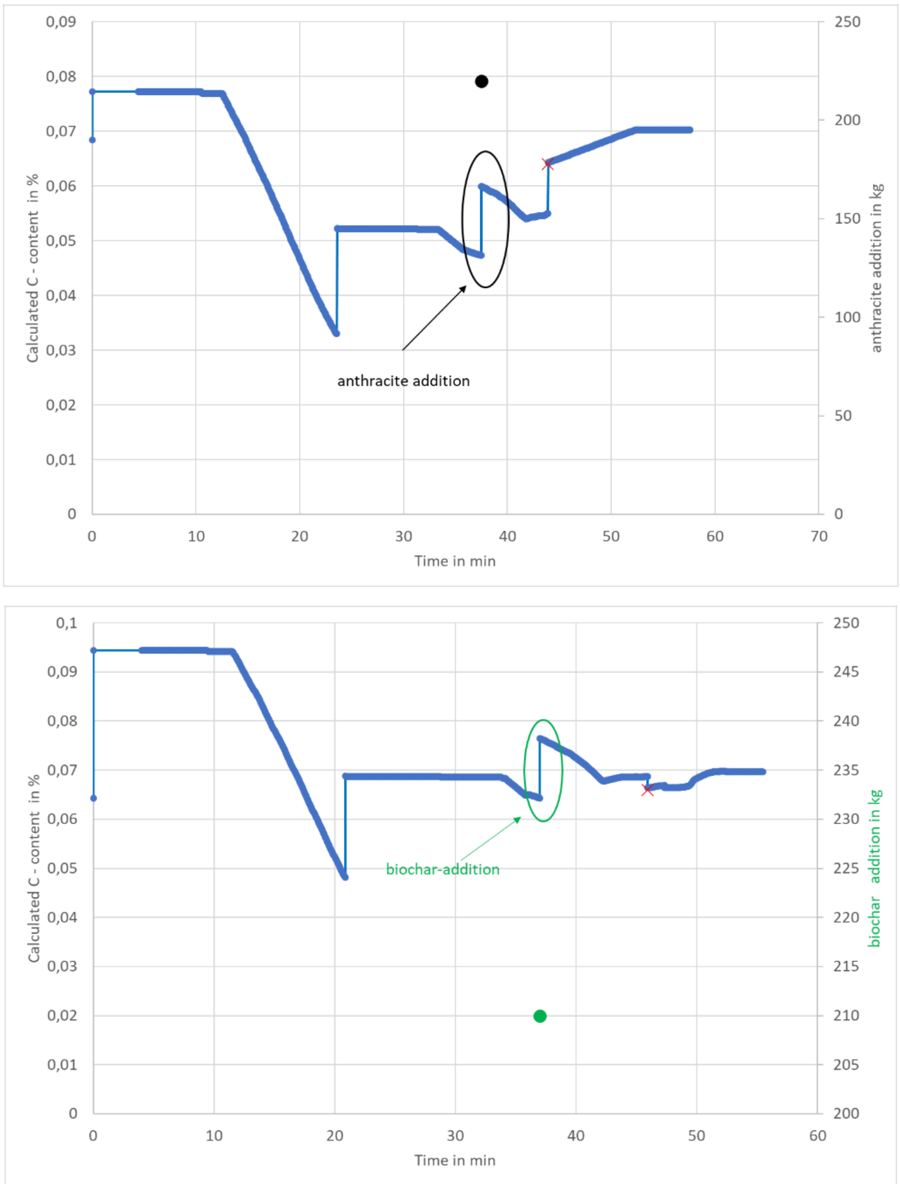

Figure 27 Calculated carbon content for standard heat (top) and trial heat with biochar (bottom)

The carbon input by anthracite results in a little bit higher increase in carbon content compared to the biochar material, which corresponds to its slightly higher carbon content. The red cross indicates the analysed carbon content in a steel sample, to which the model calculation is adapted.

When comparing the calculated carbon content to the analysed value at the time of sampling, an almost similar scatter in the modelling result can be found, as can be seen in Figure 28.

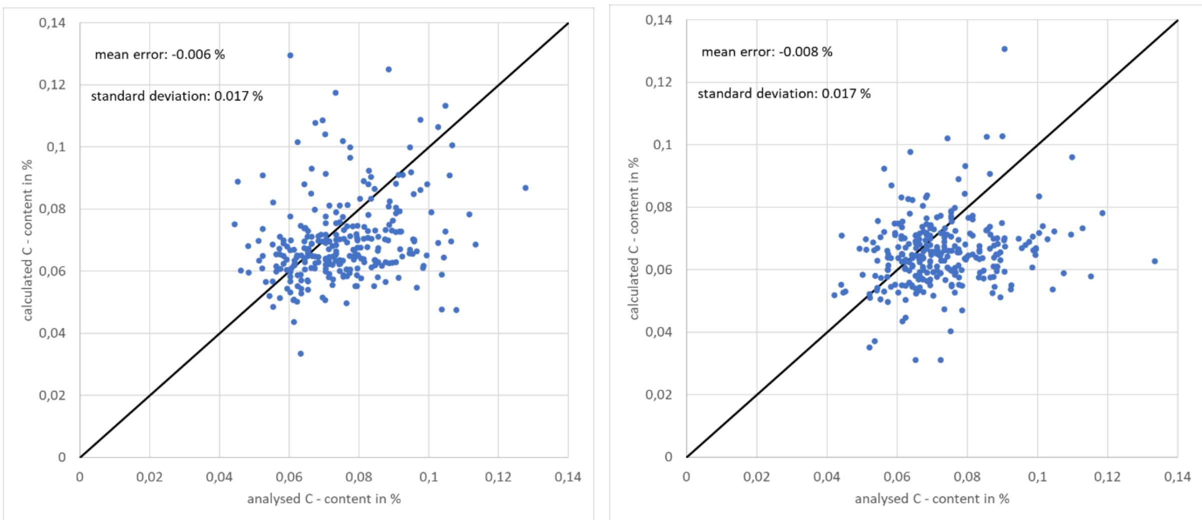

Figure 28 Calculated versus analysed carbon content for trial heats with biochar (left) and anthracite usage (right)

It can be seen that the modelling accuracy is almost equal in both cases, which shows that the use of biochar does not have a negative impact on the reproducibility of the process performance. As Figure 29 shows for the results of the melt temperature, this can also be stated regarding the energetic performance of the furnace.

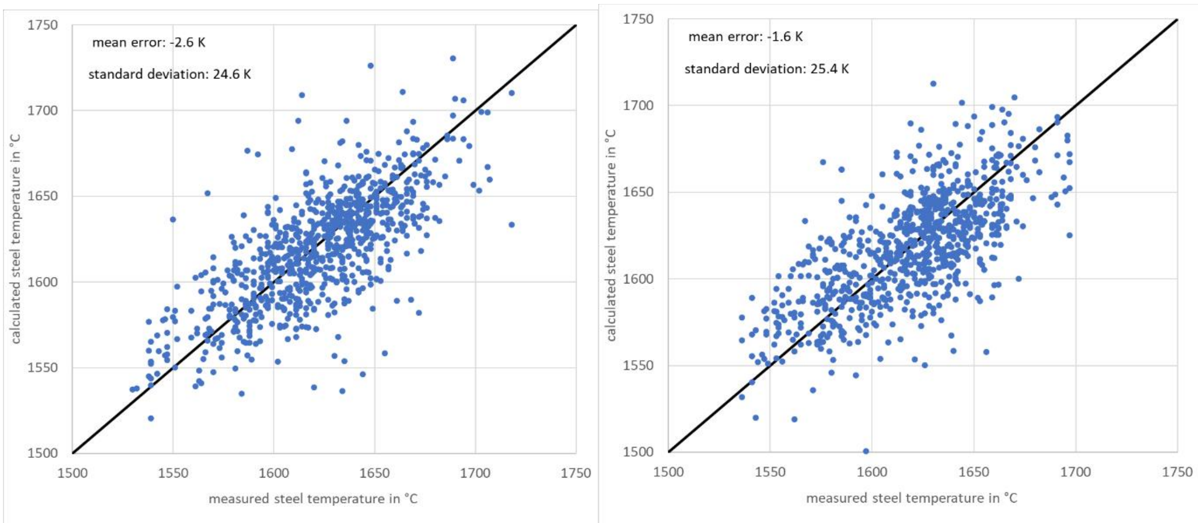

Figure 29 Calculated versus measured melt temperature for trial heats with biochar (left) and anthracite usage (right)

4 Conclusions

Different kinds of investigations were done for researching the effects of the use of alternative C-bearing materials in EAF to replace fossil C. The investigations consist in statistical analyses of preliminary Sidenor test data, stationary and dynamic simulations by exploiting respectively the SSSA and BFI models presented in Deliverable D3.1. In addition, both partial and global fossil carbon replacement were analysed. The results are complementary to the ones that will be obtained with further infield tests.

It was observed that alternative C-sources didn't affect always clearly the different monitored process parameters and that only in some cases more evident behaviours can be observed. This is the case for instance of tires; its use seems leading generally to a decrease of required electric energy and of produced EAF slag but to highest S content and lowest C content in tapped metal. However, further related simulations will be done for understanding the effect of their partial usage together for instance with anthracite and/or with other alternative non-fossil C-sources. In addition, it is highlighted that anthracite leads to the highest CO_2 (fossil) emissions.

In addition, there appears to be almost linear correlations between main monitored KPIs and C, S and moisture content in biochar.

However, globally, it can be concluded that alternative C-materials generally didn't affect negatively the Sidenor process (e.g. concerning energy and yields) and product (e.g. regarding C and S content) but can lead for instance to significant fossil CO_2 reduction, paving the way for a more sustainable production.

Obviously, further simulations will be carried out during the project for confirming what observed until now, for having together the industrial trials a global view of what are the effects of the use of alternative C-sources to the EAF process and to its product, and for providing a guidance to their exploitations.

5 List of Figures

6 List of Tables

7 List of acronyms and abbreviations

Acronym	Full Name
BFI	Betriebsforschungsinstitut
EAF	Electric Arc Furnace
KPI	Key Performance Indicator
Q&T	Quenched & Tempered
SID	Sidenor
SSSA	Scuola Superiore Sant'Anna
UoM	Unit of Measurement

8 References

[1]. Köhle, S.: Recent improvements in modelling energy consumption of electric arc furnaces. Proc. 7th European Electric Steelmaking Conf., Venice, 2002, p. 1.305 – 1.314