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Executive summary

The current (public) document includes a report of the relevant impact evaluation criteria that are defined in order to measure the success of the COCOP implementations at the pilot sites of Boliden (copper production) and Sidenor (steel production). The title of this document is *Deliverable D2.2 Impact evaluation criteria* and it is produced during the six first months of the project within WP2 and in close co-operation with task *T2.1 Use case definition*. All project partners have contributed to this deliverable. Main responsible is Optimation (OPT) as T2.3 leader and Idener as WP2 lead beneficiary.

Background material is gathered from visits at the production plants of Sidenor and Boliden and by numerous meetings with plant and supplier representatives. Three different sets of Key Performance Indicators (KPI) are defined; *technical*, *social* and *development.* This differentiation brings a structure to the KPI definition and also simplifies the exchange of KPIs between different process industries and departments within these industries. As far as possible KPI's defined in ISO 22400 have been used, sometime modified to fit the needs of processes industry. For consistency each KPI is defined in a template.

Each defined KPI can contribute to one or several top level impacts achieved with the COCOP implementation (like energy usage or CO_2 emissions) and the KPI's can be viewed as clear and understandable process feed-back that contribute to the overall equipment effectiveness and environmental goals of the production process. In this deliverable we do not define numerical goals for the KPIs but rather provide how impact could be measured. The main receivers of D2.2 are WP6 where the impacts will be evaluated in real tests and WP5 where process models are developed.

Innehåll

Abbreviations

Abbreviation	Full name
FSF	Flash Smelting Furnace
PSC	Pierce-Smith Converter
AF	Anode Furnace
AC	Anode Casting
DCS	Distributed/Digital Control System
BOHA	Boliden Harjavalta, the copper pilot process
KPI	Key Performance Indicator
EAF	Electric Arc Furnace
LF	Ladle Furnace
VD	Vacuum Degassing
VAD	Vacuum Arc Degassing
CC	Continuous Casting
LF	Ladle Furnace
TBD	To be decided

1 Introduction

In the design and maintenance of plant-wide control and advisory systems measuring the performance is fundamental. Firstly, measurements are needed to design feedback loops and reliable and optimal recommendations to personnel and secondly it is important to be able to quantify the improvement obtained with the "system" in order to justify the investment. Using Key Performance Indicators (KPI's) as part of the plant wide control solution is gaining interest in the automatic control community. In a survey published by MESA (1, 2010) it is concluded that companies that manage to substantially increase their financial metrics, these companies are sometimes called "business movers", typically have very well defined KPIs, have informed employees and have IT-systems that support generation and distribution of KPI's to personnel that actually can act on the information. In another work presented by Bauer 2016 (2, 2016), KPI's are derived and used as the interface between production scheduling and control, i.e. integration using estimates from the planning system and comparing them with actual values from the control system. KPIs are calculated in both systems (production and control) and then fed back to each system for further action. The connection can be loose or strong depending on the application/process.

During the last years a standard for calculating KPI's has emerged, ISO 22400 (3, 2014). This ISO standard has been developed mainly for the manufacturing industry (also called discrete production) and not for process industries (also called continuous or batch). The ISO 22400 standard has however been used and modified, see (4, 2012), to fit the needs of continuous or batch processes and in this deliverable we have choose to follow the suggested KPI's in the ISO standard as much as possible.

Each KPI, which can be implemented online or offline, may contribute to one or several impacts as described in Figure **2**, KPI and Impact dependencies. Below the impacts that are planned to be used in the evaluation of the COCOP system are given. Each KPI can affect one or more of the impacts as described in Figure **2**.

- Productivity (better yield)
- Energy usage (per produced tonnage)
- CO_2 emissions (per produced tonnage)
- SO_2 emissions (per produced tonnage)
- Production cost (per produced tonnage)
- Economic impact (considering for example required man hours)
- Dust emission (per produced tonnage)
- Decrease of resource consumption raw material (oil gas, bricklayer lifetime)
- Generation of waste material and its potential in the reuse/recycling path

1.1 KPI definition

KPIs are defined as quantifiable and strategic measurements that reflect an enterprise's critical success factors. KPIs are very important for understanding and improving manufacturing performance, both from the lean manufacturing perspective of eliminating waste and from the corporate perspective of achieving strategic goals. Social dimension KPI's consist of two types: Process-oriented and results-oriented KPI's (impacts). They will be used as checking points throughout the project and/or in the final evaluation from the social perspective. See also D2.1 section 2.3 Key Performance Indicator (KPI) methodology.

1.1.1 KPI and impact Template

Each KPI and its impact is described with a template described below. Based on ISO standard 22400. The social dimension KPI's will be described using the same template as well.

KPI definition	
Content	
Name	Name of the KPI
ID	*KPI-**X**1**Y**,* ***X** stands for type of KPI* • Process/technical (**T**) • Social (**S**) • Development process (e.g. how often we meet stakeholders and do co-creation etc) (**D**). *and **Y** stands for pilot case (Copper or Steel)*
Description	A brief description of the KPI
Scope	Identification of the element that the KPI is relevant for, which can be work unit, work centre or production order, product or personnel.
Formula	The mathematical formula of the KPI specified in terms of elements
Unit of measure	The basic unit or dimension in which the KPI is expressed
Range	Specifies the upper and lower logical limits of the KPI
Trend	Is the information about the improvement direction, higher is better or lower is better
Context	
Timing	A KPI can be calculated either in • Real-time - after each new data acquisition event • On demand - after a specific data selection request • Periodically - done at a certain interval, e.g. once per day
Audience	Audience is the user group typically using this KPI. The user groups used in this part of • Operators – personnel responsible for the direct operation of the equipment • Supervisors – personnel responsible for directing the activities of the operators • Management – personnel responsible for the overall execution of production
Production methodology	Specifies the production methodology that the KPI is generally applicable for • Discrete • Batch • Continuous

Effect model diagram	The effect model diagram is a graphical representation of the dependencies of the KPI elements that can be used to drill down and understand the source of the element values. NOTE This is a quick analysis which supports rapid efficiency improvement by corrective actions, and thus reduces errors
Notes	Can contain additional information related to the KPI. Typical examples are • Constraints • Usage • Other information
Assessment	
Data source	Description of data source elements
Data availability	Frequency, storage, historical values, accuracy
Goal	Description of the KPI objective. For example *"10 % reduction"*
Notes	Can contain additional information related to the assessment
Impact	
Description	KPI impact evaluation description.
Calculation	Calculation of the KPI impact.
Evaluation method	Impact can be evaluated, for example • Relative to baseline • During testperiods • End of project. See Figure **1**, Impact evaluation method
Notes	Can contain additional information related to the impact.

Impact evaluation method

Relative to baseline

Impact evaluation can be done relative to a baseline. This baseline should be set during a period which is representative for the KPI status and impact evaluation prior of setting the optimisation system in use. Representative meaning normal production circumstances regarding the KPI without disturbances and with the same equipment. Impact evaluation is then done relative to the baseline during test periods or/and at the end of project when the optimisation system is in use.

During testperiods

Evaluation during test periods is done by altering the optimisation system between on-off modes for some time followed by an impact evaluation. Several test periods or cycles lead to a more accurate impact evaluation.

End of project

Impact evaluation of the KPI could also be done at the end of project when the optimisation system is commissioned for permanent use in operations.

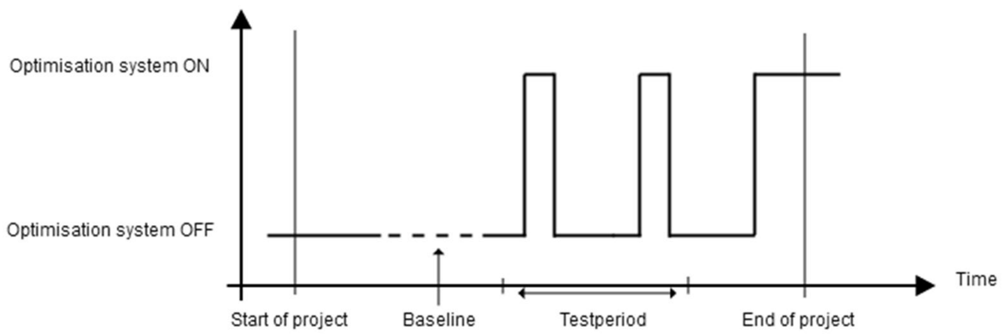

Figure 1, Impact evaluation method

KPI and impact dependencies

One KPI can have one direct impact or several impacts. For example KPI1 and KP2 can have the same impact as described in *Figure 2, KPI and Impact dependencies*. When evaluating these KPI's the project will sum up the impact from a test period or at the end of project. In some occasions the KPI correspond directly to an impact. This is done during COCOP project impact evaluation.

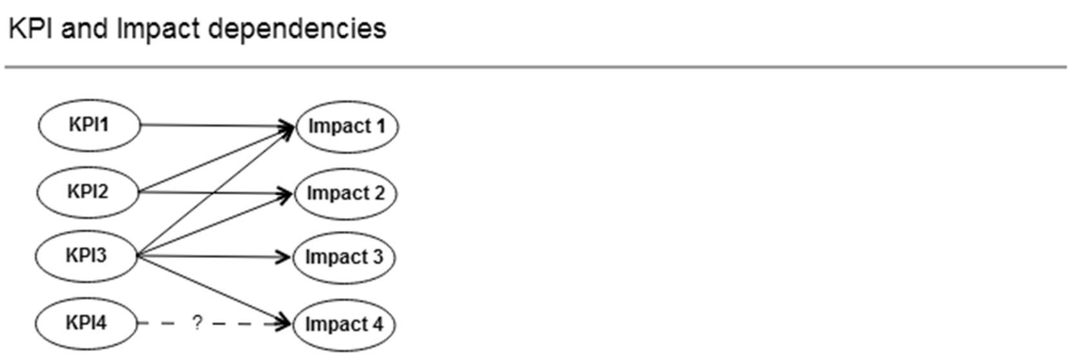

Figure 2, KPI and Impact dependencies

Online KPI and work procedure

An example of "Key Performance Indicators Used as Measurements Parameter for Plant-Wide Feedback Loops is described in Concept of plant wide control, see (2, 2016). Online indicators are suggested in D2.2 but needs to be analyzed in system design before implementation in the target system.

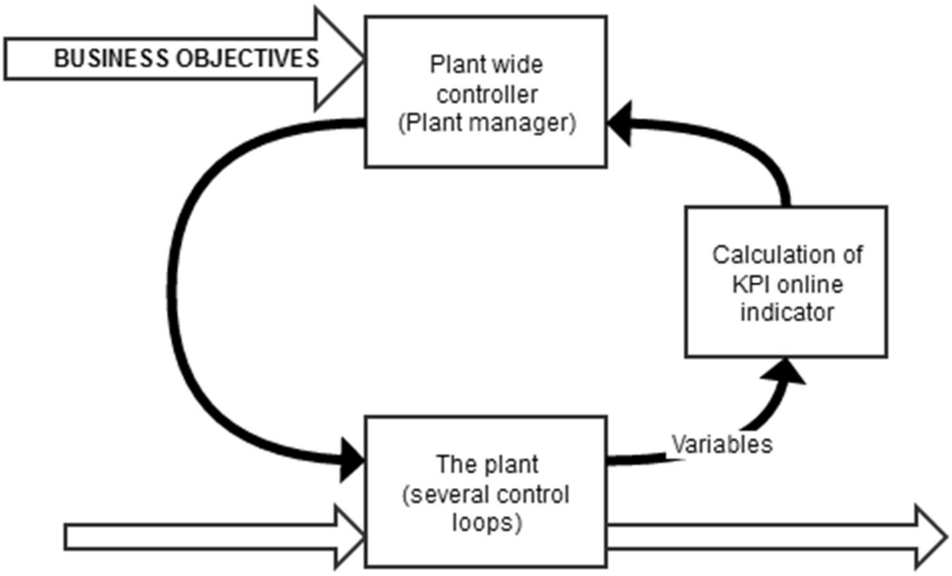

Figure 3, How to use and implement online indicators

A possible work procedure for plant wide control loops.

1. Select the control-parameter and the corresponding sensors i.e.
   select the variable that should be controlled (compare output signal) and select how it should be measured.
2. Select the manipulated-variable and the corresponding actuator, i.e. select the variable that should be used as control
   signal and select how it could be manipulated.
3. Construct the control loop, i.e. pair the manipulated-variable
   with the control-parameter
4. Select the type of controller, tune the controller parameters
   and search for an optimal set-point.

1.1.2 KPI from social point of view (operators, shift manager)

The social dimensions, mainly represented by the KPIs are closely interrelated, instead of single effect model diagrams we produced a common effect model diagram, Figure **4**, setting up and visualising the interrelations of all the social KPIs different levels, including the additional aspect of qualification and skills adjustment (if relevant).

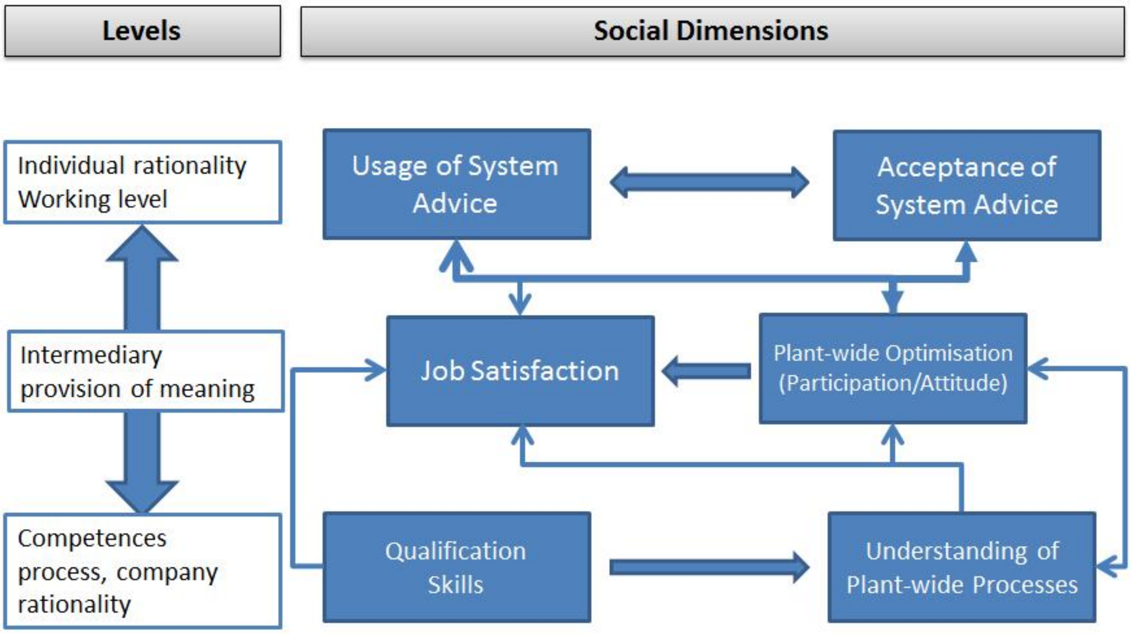

Figure 4, Effect model diagram KPI Social point of view

There is an interrelation between the individual and the company / process level. COCOP should open the individual (and work place related) rationality much more to a plant-wide and process related reference or mind-set for the own behavior, decisions and attitudes (a broader company rationality). For instance, at the work place more quality assuring activities might be seen as too much work, not relevant for the part the operators feels responsible for - from a process or company related perspective the worker feels responsible for a better quality at the end of the process and therefore is doing much more to ensure high quality. See also D2.1 section 2.3 Social Methodology.

2 Introduction Copper Case

At the Boliden copper plant increasing the production rate, lowering specific production cost and lowering specific emissions are constantly in focus. Utilizing the capacity of the FSF smelter is a priority since the FSF smelter is in many cases the bottle neck of the production plant. Based on discussions with Boliden and Outotec improvements of importance are:

- Maximize the FSF feed rate
- Maximize the copper cathode production (this is mainly related to copper electrolysis and out of COCOP scope)
- Maximize the amount of copper scrap (recycling) added to the converters and anode furnace (increase of copper amount from matte to anode copper)
- Increase the life time of the brick-lining in the PS converters
- Keep the SO_2 emissions under the legal limits and as low as possible
- Minimize oil usage in the anode furnaces and FSF
- Minimize propane usage at anode furnace
- Increase recovery of copper from slag
- Minimize the fluctuations in matte grade to facilitate production stability

These improvements are below turned into measurable KPI's and impacts.

2.1 KPI and Impacts Copper Case

Item	Notes
KPI Definition	The KPI's to be controlled along the project will be: • KPI-T1C: Equipment load ratio: Feed rate FSF • KPI-T2C: Stability FeedRate FSF • KPI-T3C: Copper content waste slag relative to baseline • KPI-T4C: Equipment load ratio: Acid plant • KPI-T5C: Stability Acid plant • KPI-T6C: Wear of bricklining (velocity) relative to produced bilister • KPI-T7C: Wear of bricklining (velocity) • KPI-T8C: Propan usage relative to produced copper • KPI-T9C: Amount of produced converter slag compared to optimal estimate from FSF matte analysis. • KPI-T10C: Stability Anode Composition • KPI-T11C: Scrap usage ratio • KPI-T12C: Oil usage in the anode furnaces and FSF
Impact	The improvements of the KPI's will generate impacts in different areas. The impacts to be evaluated during the project will be: • Productivity improvement Reduction of CO_2/SO_2 emissions • Reduction of energy use (heat production, reuse of heat energy) • Economic impact • Dust emissions • Decrease of Resource Consumption Raw material (oil gas, bricklayer lifetime) • Waste and its potential reuse/recycling The project will analyze the potential figures of these impacts of the COCOP project and if applicable also extrapolate the data to the whole production.

2.2 KPI and Impact Technical

In this section the technical KPIs for the copper case are defined.

2.2.1 KPI -T1C Equipment load ratio: Feed Rate FSF

KPI definition	
Content	
Name	Equipment load ratio: Feed Rate FSF
ID	KPI-T1C
Description	The equipment loss ratio considers the produced quantity (PQ) in relation to the equipment production capacity (EPC). Equipment production capacity is “rated”: • Rated equipment production capacity: the upper value of production rate where the equipment operate in a stable way.
Scope	Flash melting Furnace
Formula	PQ = Feed rate FSF , EPC = Rated maximum Feed rate FSF , Equipment load ratio = PQ / EPC.
Unit of measure	%
Range	Min: 0%, Max: 100%, > 100% if more is produced than specified as the rated equipment production capacity.
Trend	The higher, the better. A value > 100% may indicate a quality issue
Context	
Timing	Real-time - after each new data acquisition event
Audience	Operator, Supervisor
Production methodology	Continuous
Effect model diagram	See Figure **5**, Effect model diagram, Equipment load ratio, Feed rate FSF
Notes	Production capacity and the load rate of equipment are important indicators in a manufacturing enterprise. The equipment load ratio is an indicator to reflect the production state of equipment and production efficiency. It helps to reflect the technical performance and utilization of equipment and by researching the usage of equipment. The value of equipment load rate impacts the production costs and ultimately the profit level. A value > 100% may indicate an issue as it may impact the security and reliability of equipment when the produced quantity is above the rated equipment production capacity. There is also a lower limit of equipment load rate for some equipment, below which it cannot produce anymore.

Assessment	
Data source	Database information system (Wedge™, Savcor) Feed rate FSF Maximum Rated Feed rate FSF (rated)
Data availability	-
Goal	Increase by TBD %
Notes	Feed rate is an existing KPI in Boliden and maximum feed rate needs to be determined. Calculation of KPI needs to be implemented.
Impact	
Description	• Productivity improvement - less CO2 emissions per produced ton copper • Economical impact
Calculation	Evaluate production improvement and economical impact of whole plant.
Evaluation method	• Related to baseline • During testperiods
Notes	-

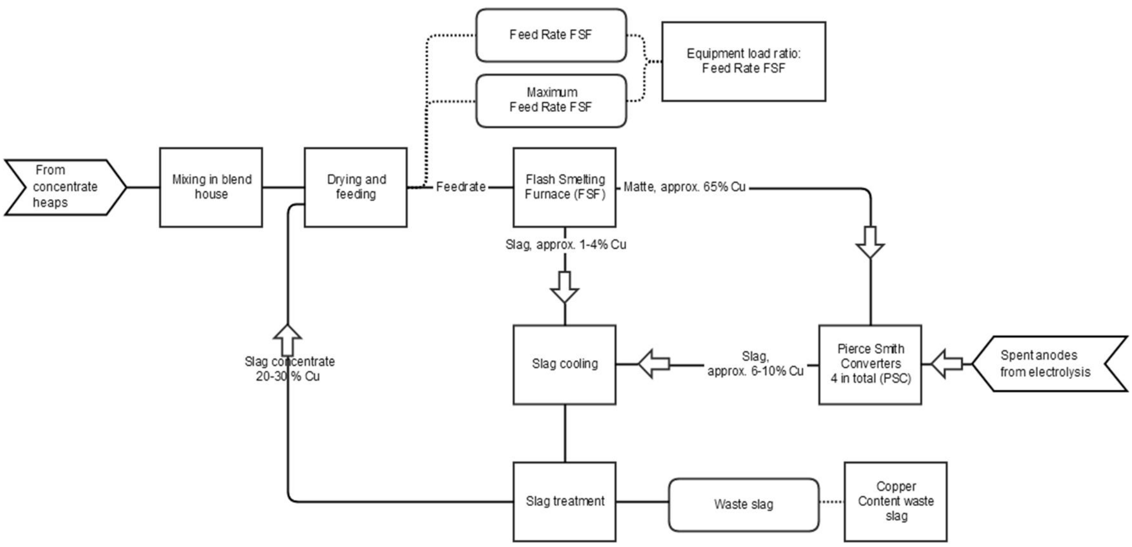

Figure 5, Effect model diagram, Equipment load ratio, Feed rate FSF

2.2.2 KPI-T2C Stability Feed Rate FSF

KPI definition	
Content	
Name	Stability Feed Rate FSF
ID	KPI-T2C
Description	Feedrate stability FSF low feedRate and using oil (no oil used or less oil). Stability leads to less emission even if higher Feed Rate.
Scope	FSF
Formula	Fr = Feed Rate FSF Stability Feed Rate FSF = Variance (Fr).
Unit of measure	-
Range	-
Trend	lower is better
Context	
Timing	Periodically - done at a certain interval, e.g. once per day, hour
Audience	Operator, Supervisor
Production methodology	Continuous
Effect model diagram	See Figure **5**, Effect model diagram, Equipment load ratio, Feed rate FSF
Notes	This KPI is important during periods, when feed is restricted due to converter or anode furnace capacity.
Assessment	
Data source	Database information system (Wedge™, Savcor) Feed rate FSF
Data availability	-
Goal	TBD
Notes	-
Impact	
Description	• Reduction of CO_2. Stability leads to less emission - (no oil used or less oil) • Economical impact
Calculation	-
Evaluation method	• Related to baseline • During testperiods
Notes	-

2.2.3 KPI-T3C Copper content in waste slag relative to baseline

KPI definition	
Content	
Name	Copper content in waste slag relative to baseline
ID	KPI-T3C
Description	Copper content in waste slag. Excluding influence of minor elements e.g. arsenic
Scope	Slag flotation
Formula	Cu_{ws} = Copper content waste slag $Cu_{ws\ baseline}$ = Copper content waste slag baseline $100 * (Cu_{ws} - Cu_{ws\ baseline}) / Cu_{ws\ baseline}$ exclude influence minor elements
Unit of measure	%
Range	min = -100 max = 100
Trend	Lower the better
Context	
Timing	On demand - after a specific data selection request
Audience	Operator, supervisor
Production methodology	Continuous
Effect model diagram	Figure 6, Effect Model Diagram Copper content waste slag
Notes	Bad slag from converters increases copper losses to waste slag.
Assessment	
Data source	Database information system (Wedge™, Savcor) Cu_{ws} = Copper content waste slag
Data availability	-
Goal	TBD
Impact:	
Description	• Productivity improvement - Better use of earth's natural resources because of better recovery of copper • Economic impact
Calculation	Calculate Copper losses and economical impact.
Evaluation method	• Relative to baseline • During testperiods
Notes	-

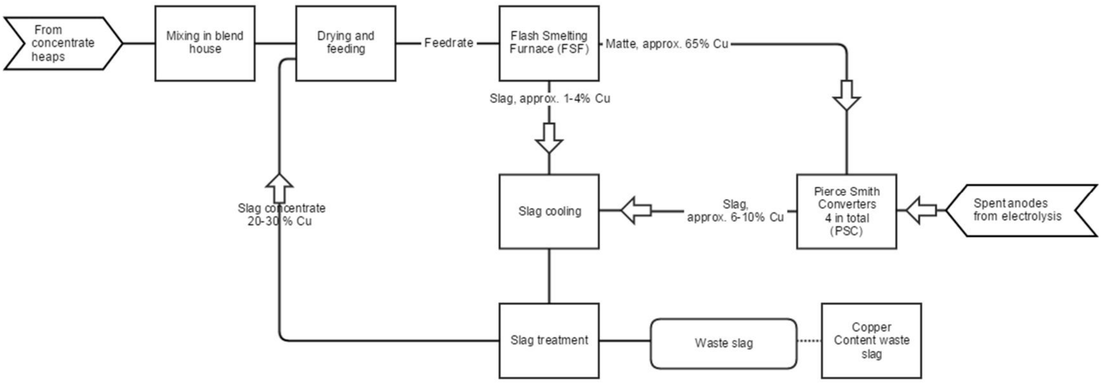

Figure 6, Effect Model Diagram Copper content waste slag

2.2.4 KPI-T4C Equipment load ratio: Acid plant

KPI definition	
Content	
Name	Equipment load ratio: Acid plant
ID	KPI-T4C
Description	The equipment load ratio acid plant considers the produced quantity in relation to the equipment production capacity. In this KPI we use pressure and fan speed as a measurement for produced quantity. The capacity is pressure and fan speed limits. Rated equipment production capacity: the upper limit value of production promised the stable operation of the equipment. If pressure limits in acid plant is reached or fan speed limit is reached then there is no guarantee for enough under pressure in the offgas-line which leads to off-gas leakage and increased SO_2 emission.
Scope	Acid plant
Formula	Suggested calculation of KPI. P_1 = Under Pressure before fan acid plant P_{1L}= Under Pressure limit before fan acid plant P_2 = Pressure after fan acid plant P_{2L}= Pressure limit after fan acid plant F_s = Fan speed F_L = Fan speed limit Equipment load ratio: Acid plant = 100 * max($P_1 > P_{1L}$; $P_2 > P_{2L}$; F_s / F_L) , where $P_1 > P_{1L} = 1$ and $P_1 < P_{1L} = 0$. There is a under pressure limit before the main blower of a acid plant and over pressure limit after the main blower (fan). (usually the under pressure limit comes first) The KPI calculations should measure the two acid plants in Boliden.
Unit of measure	%
Range	Min: 0 % Max: - %
Trend	< 100%
Context	
Timing	On-demand, periodically
Audience	Operator, supervisor, management
Production methodology	Continuous
Effect model diagram	Figure **7**, Effect model diagram equipment load ratio acid plant

Notes	There are two parallel acid plants in Boliden. One of the current acid plants will be replaced with a new one during the COCOP project. The main blower is located in the middle of the acid plant. (Washing & drying sections are operating in under pressure and acid converter is operating in over pressure.) Although, notable part of the gases come from nickel smelter. Note that actual equipment production capacity of acid plant is not constant since the pressure drop increases (with same gas amount) when a unit slowly gets dirty. Production capacity and the load rate of equipment are important indicators in a manufacturing. The equipment load ratio is an indicator to reflect the production state of equipment and production efficiency. It helps to reflect the technical performance and utilization of equipment and by researching the usage of equipment. The value of equipment load rate impacts the production costs and ultimately the profit level. A value > 100% may indicate an issue as is possible to impact the security and reliability of equipment when the produced quantity is above the rated equipment production capacity. There is also a lower limit of equipment load rate for some equipment, below which it cannot produce anymore
Assessment	
Data source	Database information system (Wedge™, Savcor) P_1 = Under Pressure before fan acid plant P_{1L}= Under Pressure limit before fan acid plant P_2 = Pressure after fan acid plant P_{2L}= Pressure limit after fan acid plant F_s = Fan speed F_L = Fan speed limit
Data availability	Historical values from database already measured in Boliden
Goal	<100% If acid plant is bottleneck equipment load ratio should be maximized. It is important not to hit to the limit due to emissions.
Notes	Calculate time above 100% and average equipment load ratio during e.g. day, week, year. Can be implemented as an Online indicator for operators.
Impact	
Description	Reduction of SO2 emissions
Calculation	Time exceeding 100% is calculated when optimisation system is in use compared to without optimisation system in use. Based on calculations reduction of SO2 emissions is to be estimated.
Evaluation method	• Related to baseline • During testperiods
Notes	Can contain additional information related to the impact.

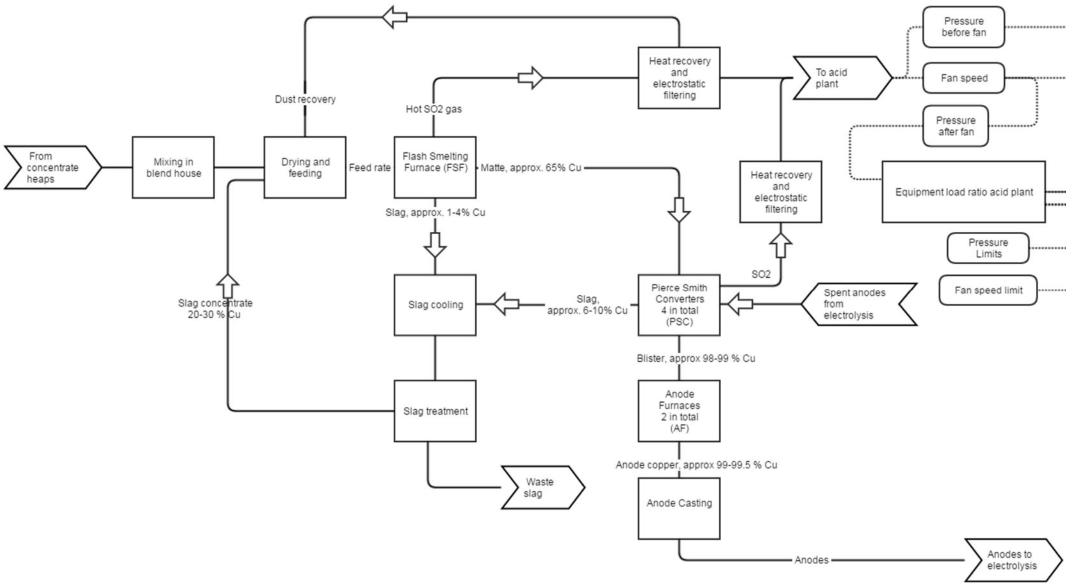

Figure 7, Effect model diagram equipment load ratio acid plant

2.2.5 KPI-T5C Stability Acid plant

KPI Definition	
Content	
Name	Stability Acid plant
ID	KPI-T5C
Description	Stability acid plant described by the variance of fan speed Acid plant.
Scope	Acid plant
Formula	F_s = Fan speed [rpm] Stability Acid plant = Variance (F_s) when Acid plant is running.
Unit of measure	rpm
Range	MIN = 0
Trend	Lower is better
Context	
Timing	Periodically - done at a certain interval, e.g. once per day, hour
Audience	Operator, Supervisor
Production methodology	Continuous
Effect model diagram	See, Figure 7, Effect model diagram equipment load ratio acid plant
Notes	-
Assessment	
Data source	Database information system (Wedge™, Savcor)
Data availability	-
Goal	TBD
Notes	There are two parallel acid plants.
Impact	
Description	• Reduction of energy use It is beneficial to have as stable (minimize fluctuations) gas-flow as possible. Stable production will result to savings in electricity and stable steam production. The electricity usage is higher if running an hour with low capacity and then a hour with large capacity or running the fan speed constantly up and down. Also the production of steam etc. is more stable if the off-gas amount is stable.
Calculation	-
Evaluation method	• Related to baseline • During test periods
Notes	-

2.2.6 KPI-T6C Wear of brick-lining relative to produced blister

KPI definition	
Content	
Name	Wear of brick-lining (velocity) relative to produced blister
ID	KPI-T6C
Description	Weekly measurement of the bricks to measure wear of brick-lining per ton blister produced.
Scope	PS Converters
Formula	Weekly measurement of the bricks per converter. ToB = Thickness of bricks [mm] P_B = Produced Blister [ton] Wear of bricklining (velocity) = (ToB_n - ToB_{n-1}) / P_B
Unit of measure	mm / ton
Range	-
Trend	Lower is better
Context	
Timing	Periodically - weekly
Audience	Operator, Supervisor
Production methodology	Batch
Effect model diagram	See, Figure 8, Effect Model Diagram Wear of brick-lining per ton produced
Notes	In the converter temperature control, scheduling less waiting times (cooling times) and slag chemistry play a central role for maximizing the bricklayer lifetime of the converters whose optimisation would lead to a decrease of resource consumption.
Assessment	
Data source	Needs to be implemented in info system. At the moment in excel data sheet.
Data availability	Weekly measurement
Goal	TBD % decrease
Notes	-
Impact	
Description	Decrease of Resource Consumption Raw material. Reduction of CO_2 emissions. The reduction of CO_2 is related to the manufacturing of raw material.
Calculation	Calculate reduction of CO_2 emissions from increased life time of brick-lining in the PS converters

Evaluation method	Related to baseline
Notes	-

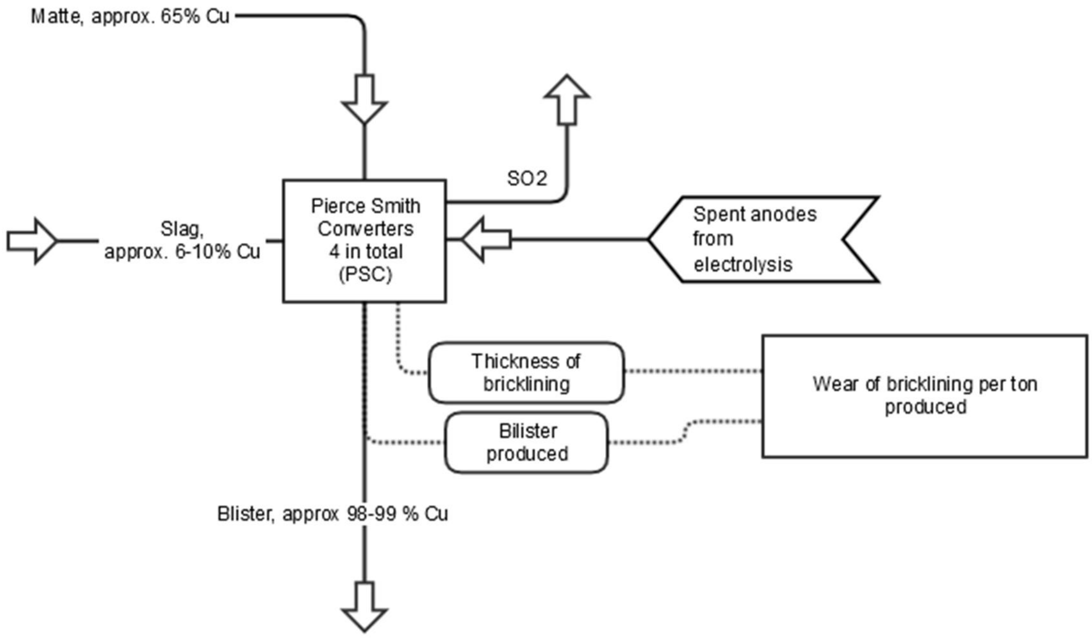

Figure 8, Effect Model Diagram Wear of brick-lining per ton produced

2.2.7 KPI-T7C Wear of bricklining (velocity)

KPI definition	
Content	
Name	Wear of bricklining (velocity)
ID	KPI-T7C
Description	Weekly measurement of the bricks to measure wear
Scope	PS Converters
Formula	Weekly measurement of the bricks per converter. ToB = Thickness of bricks [mm] Wear of bricklining (velocity) = $(ToB_{n} - ToB_{n-1})$
Unit of measure	mm / week
Range	-
Trend	Lower is better
Context	
Timing	Periodically - weekly
Audience	Operator, Supervisor
Production methodology	Batch
Effect model diagram	See Figure 8, Effect Model Diagram Wear of brick-lining per ton produced
Notes	Furthermore, in the converter temperature control, scheduling less waiting times (cooling times) and slag chemistry play a central role for maximizing the bricklayer lifetime of the converters whose optimisation would lead to a decrease of resource consumption.
Assessment	
Data source	Needs to be implemented in info system. At the moment in excel data sheet.
Data availability	Weekly measurement
Goal	TBD
Notes	-
Impact	
Impact description	Decrease of resource consumption raw material. Reduction of CO_2 emissions. The reduction of CO2 is related to the manufacturing of raw material.
Calculation	Calculate reduction of CO_2 emissions from increased life time of brick-lining in the PS converters
Evaluation method	Related to baseline
Notes	-

2.2.8 KPI-T8C Propane usage relative to amount produced copper

KPI definition	
Content	
Name	Propane usage relative to amount produced copper
ID	KPI-T5C
Description	Propane usage relative to amount produced copper
Scope	Anode Furnace
Formula	Pr = Propane usage [Nm^3/h] Pc = Produced Copper [ton] Propane usage relative to amount produced copper = Pr / Pc
Unit of measure	Nm^3ton/h
Range	-
Trend	Lower is better
Context	
Timing	Periodically - done at a certain interval, e.g. once per anode casting. (The anode copper amount is measured during the casting)
Audience	Operator, Supervisor, Management
Production methodology	Batch
Effect model diagram	See, Figure 9, Effect Model Diagram Propane usage relative amount of produced Copper
Notes	Currently the converter operators decide the endpoint of a converter batch by monitoring the SO2 measurement from the off-gas and OPC-curves (an optical monitoring system of the off-gas), a procedure that could be automatized. The end-point affects the propane usage operation time at the anode furnaces.
Assessment	
Data source	Pr = Propane usage [Nm^3/h] Pc = Produced Copper [ton]
Data availability	After each blow
Goal	TBD
Notes	
Impact	
Description	• Reduction of energy use • Economic impact

Calculation	Calculate Reduction of Propane.
Evaluation method	• Related to baseline • During testperiods
Notes	Can contain additional information related to the impact.

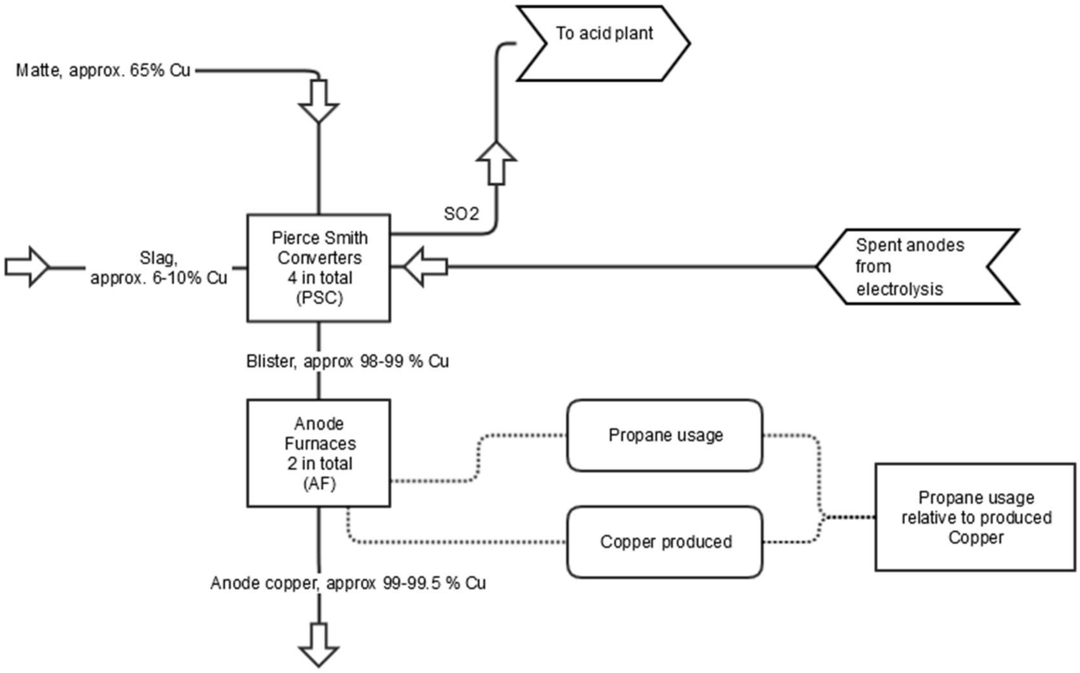

Figure 9, Effect Model Diagram Propane usage relative amount of produced Copper

2.2.9 KPI-T9C Amount of produced converter slag compared to optimal estimate from FSF matte analysis

KPI definition	
Content	
Name	Amount of produced converter slag compared to optimal estimate from FSF matte analysis
ID	KPI-T6C
Description	A correct silica usage reduces the slag amount and matte contamination in slag. A good slag contains less copper. Less unnecessary SiO_2, less matte contamination in PSC slag.
Scope	PS Converter
Formula	AoS = Amount of Slag [ton] OEoS = Optimal estimate from FSF matte analysis [ton] Amount of slag compared to estimate of slag matte analysis = AoS/OEoS
Unit of measure	%
Range	Min: 0%
Trend	Equal to 100 %
Context	
Timing	Periodically - done at a certain interval, e.g. once per batch
Audience	Operator, Supervisor
Production methodology	Batch
Effect model diagram	Figure 10, Effect Model Diagram Amount of slag compared to estimate of slag
Notes	PSC slag is not normally sampled/analyzed. That's why only amount can be used.
Assessment	
Data source	A relatively simple batch calculation model, which gives suggestion of blowing times and needed silica amount in slag blowing is used in BOHA. Data is available in DNA info or in wedge. Calculation made to DNA info system or to wedge.. The model needs to be updated with OEoS = Optimal estimate from FSF matte analysis [ton] AoS = Amount of Slag [ton]
Data availability	For every batch. Online KPI for operators.
Goal	Equal to 100 %
Notes	

Impact	
Description	Economic impact - less SiO_2
Calculation	-
Evaluation method	During test-periods
Notes	-

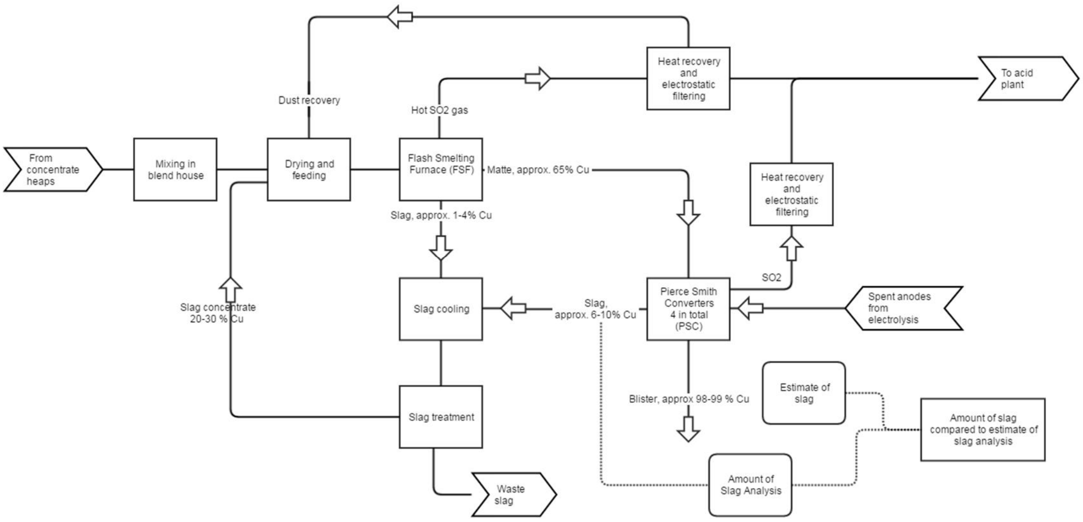

Figure 10, Effect Model Diagram Amount of slag compared to estimate of slag

2.2.10 KPI-T10C Stability Anode Composition due to advise tool

KPI definition	
Content	
Name	Stability Anode composition due to advise tool
ID	KPI-T10C
Description	Stable anode composition: Stability of anode composition excluding fluctuations in concentrate feed composition. This gives possibility to plan the concentrate blend so that everything is in the limits. The target is to operate converters and anode furnace in a standard way so that the operations do not cause fluctuations in the minor elements of anode copper e.g. Ni, As, Sb, Bi, Pb, etc. content. A minor element content in anode copper should only smoothly follow the minor element content in the concentrate (matte). This increases predictability of minor elements in anode copper. However, there is exceptions that if some minor element is too high, the operations in PSC and AF should reduce its content anode copper. High nickel concentrate is reduced by overblowing in every converting step and in the anode furnace. This results in slag absorbing more nickel. However, more propane is needed to reduce the excess oxygen from blister copper in the anode furnace. The developed online model simulates minor elements. The deviation of analysis from the simulated values is measured. Each minor element is weighted according to its importance.
Scope	PS converters and anode furnaces
Formula	Weighted Variance = Weight1 * Variance of ((Ni analysis anode copper) - (estimated Ni anode copper)) / (estimated Ni anode copper) + Weight2 * Variance of ((Pb anode or anode copper) - (estimated Pb anode copper)) / (estimated Pb anode copper) + Weight3 * Variance of ((As anode copper) - (estimated As anode copper)) / (estimated As anode copper) + Weight4 * Variance of ((Sb anode copper) - (estimated Sb anode copper)) / (estimated Sb anode copper) + Weight5 * Variance of ((Bi anode copper) - (estimated Bi anode copper)) / (estimated Bi anode copper))
Unit of measure	Variance
Range	Min = 0
Trend	Lower is better
Context	
Timing	Periodically - done at a certain interval, e.g. once per month
Audience	Operator, Supervisor
Production methodology	Batch

Effect model diagram	-
Notes	A sample is taken from every anode casting. The copper comes usually from two converters batches. Average analysis of matte samples should be used as base in the estimation.
Assessment	
Data source	Database information system, laboratory analysis, Developed online model
Data availability	-
Goal	Good fit in predictability
Notes	During the project developed online model simulates the minor element content in anode copper based on analysis in matte. The deviation of anode copper analysis from the simulated values is measured. Each minor element is weighted according to its importance.
Impact	
Description	Improved controllability of minor elements in anode copper. Possibility to utilize wider range of raw material Economical impact
Calculation	Calculate Economical impact based on possibility to utilize wider range of raw material.
Evaluation method	• Test periods • End of project
Notes	-

2.2.11 KPI-T11C Scrap usage ratio

KPI definition	
Content	
Name	Scrap usage ratio
ID	KPI-T11C
Description	Scrap is added to converter process and anode furnace process in order to cool the batch. Optimal temperature control has a clear effect. Using more circulated copper scrap in relation to copper concentrates improves resource utilisation.
Scope	Converters and anode furnace
Formula	[Used tons of scrap during period] / [Produced tons of anodes during period], suggested period is per week
Unit of measure	%
Range	Min = 0 Max = 100
Trend	The higher the better
Context	
Timing	A KPI can be calculated • periodically - done at a certain interval, e.g. once per week
Audience	Operator, Supervisor, Management
Production methodology	• Batch
Effect model diagram	See, Figure 11, Effect model diagram used scrap ratio
Notes	-
Assessment	
Data source	Database information system (Wedge™, Savcor) Scrap charged into the converters Scrap charged into the anode furnace Produced tons of anodes
Data availability	At each charging
Goal	TBD % increase
Notes	-
Impact	
Description	Economical impact. More re-circulated copper is used in relation with copper from concentrates. Increased scrap usage per produced tonne anode copper increase productivity and saves usage of raw material (FSF feed material).
Calculation	Evaluate production improvement and economical impact of whole plant.

Evaluation method	• Relative to baseline • During test-periods
Notes	-

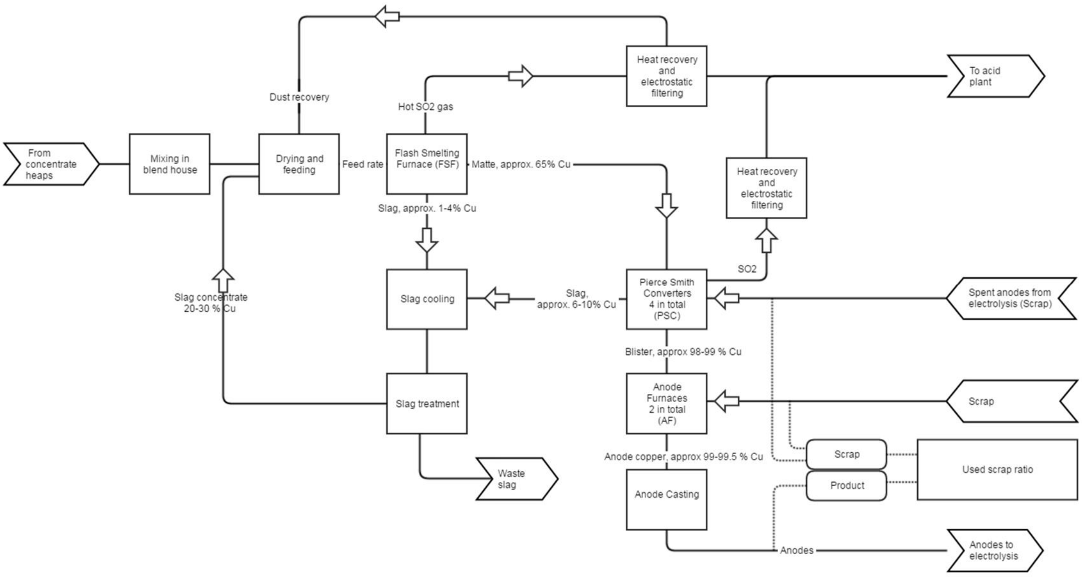

Figure 11, Effect model diagram used scrap ratio

2.2.12 KPI-T12C Oil usage in the anode furnaces and FSF

KPI definition	
Content	
Name	Oli usage in the anode furnace and FSF
ID	KPI-T12C
Description	Sum of Oil usage in the anode furnace and FSF
Scope	Anode furnace and FSF
Formula	Oil_{AF} = Oil usage Anode Furnace [m3/h] Oil_{FSF} = Oil usage FSF [m3/h] Oil usage anode furnace and FSF = Oil_{FSF} + Oil_{AF}
Unit of measure	m3/h
Range	-
Trend	Lower is better
Context	
Timing	Periodically - done at a certain interval, suggested once per week
Audience	Operator, Supervisor, Management
Production methodology	Continuous
Effect model diagram	
Notes	Use less oil by improved temperature control
Assessment	
Data source	Database information system (Wedge^{TM}, Savcor) Oil_{AF} = Oil usage Anode Furnace [m3/h] Oil_{FSF} = Oil usage FSF [m3/h] and total measurement
Data availability	-
Goal	TBD
Notes	-
Impact	
Description	Reduction of CO_2 emissions - less oil is used
Calculation	-
Evaluation method	• Related to baseline • During test periods
Notes	-

2.3 KPI from social point of view (operators, shift manager)

2.3.1 KPI-S1C Usage of system advice

KPI definition	
Content	
Name	Usage of system advice
ID	KPI-S1C
Description	How often does the plant personnel follow the advice given by the system
Scope	Work centre / whole site
Formula	Usage of system advice = number of accepted advice / total number of advice
Unit of measure	%
Range	Min: 0% Max: 100%
Trend	The higher, the better
Context	
Timing	On-demand and/or periodically
Audience	Supervisor, management
Production methodology	Continuous and/or discrete
Effect model diagram	Graphical overview of usage overtime, periodically or/and at critical milestones
Notes	The acceptance ratio should if possible be measured in the solution itself automatically. It should be a requirement to T2.2 when design of optimisation system. For e.g. by an acceptance button.
Assessment	
Data source	Number of presented advice Number of followed advice Generated in the COCOP solution.
Data availability	Frequency
Goal	High usage of the system
Notes	Quantitative and qualitative assessment of the usage. The usages could have quantitative (how often) and qualitative (improvement of the production activities) effects.

<table>
<tr><th colspan="2">Impact</th></tr>
<tr><td>Description</td><td>KPI impact evaluation description.
Productivity improvement
Reduction of energy use
Reduction of CO2/SO2 emissions
Economic impact
Oil usage due to low feed-rate
Increase of productivity and quality (quantitative and qualitative usage of the system advice)
Higher quality of the production and decrease of defects
Reduction of energy use and CO2 emissions
Economic advantages: cost effectiveness, lower costs</td></tr>
<tr><td>Calculation</td><td>Calculation of the KPI impact.</td></tr>
<tr><td>Evaluation method</td><td>Impact can be evaluated, for example
Related to baseline
During test periods
End of project.</td></tr>
<tr><td>Notes</td><td>Indirect impact, through lower amount of losses/emissions/energy consumption caused by minor operator errors.
This is based on the hypothesis, that the new system is having these technical based possibilities, effects.</td></tr>
</table>

2.3.2 KPI-S2C Acceptance of system advice

KPI definition	
Content	
Name	Acceptance of system advice
ID	KPI-S2C
Description	How accepted is the advice given by the system
Scope	Work centre/whole site
Formula	Acceptance of system advice: to be operationalised in a questionnaire, such as: Do you agree with the following statements: • The systems gives reliable advices • It makes decisions easier • It reduces workload • It is easy to handle • It is adaptable to individual requirements
Unit of measure	% of acceptance
Range	Min: Strongly disagree Max: Strongly agree
Trend	The higher the agreement, the better
Context	
Timing	On-demand, periodically
Audience	Supervisor, management
Production methodology	Continuous and Discrete
Effect model diagram	Graphs of the percentage of acceptance, based on the questionnaire results
Notes	Questionnaire: "Acceptance" will be operationalised by criteria of the system developers and the users of the system. Co-creation of the indicators for acceptance.
Assessment	
Data source	Questionnaire, interviews
Data availability	New data, primary data survey: interviews, questionnaires
Goal	High acceptance (mind-set)
Notes	Qualitative assessment of the system by the operators

Impact	
Description	Increase of Productivity and Quality (quantitative and qualitative usage of the system advice) Higher quality of the production and decrease of defects Reduction of energy use and CO2 emissions Economic advantages: cost effectiveness, lower costs. • Productivity improvement • Reduction of energy use • Reduction of CO2/SO2 emissions • Economic impact • Oil usage due to low feed rate
Calculation	Calculation of the KPI impact.
Evaluation method	Impact can be evaluated, for example • Related to baseline • During test periods • End of project.
Notes	Through a higher acceptance the usage of the system is improved, increasing (improving KPI-S1C)

2.3.3 KPI-S3C Plant-wide processes as part of operator training ratio relative to baseline

KPI definition	
Content	
Name	Plant-wide processes as part of operator training ratio relative to baseline
ID	KPI-S3C
Description	The share of plant-wide processes as part of operator training relative to baseline Objective: to integrate the plant-wide perspective and to assess if it is adopted as an integral part of training Methodology: document analysis of training material, questionnaire for operators/shift managers (is the perspective sufficiently considered in the training?), interview of training responsible persons (how is plant wide understanding provided in trainings)
Scope	Work centre/whole site
Formula	Document analysis: part of training material (yes/no; if yes, to what extent and in which form) Questionnaire: Statement "Plant-wide understanding is sufficiently considered in trainings." Range of answers: strongly agree - agree - indifferent - disagree - strongly disagree Interview: quantitative and qualitative aspects of training Measured in the beginning and in the end.
Unit of measure	Documents: training modules related to plant-wide processes, questionnaires/interviews of training responsible persons, operators
Range	Comparison of initial (existing training programme) and final situation (after system development)
Trend	The higher the approval, participation and knowledge improvement of operators and managers, the better
Context	
Timing	On-demand, periodically
Audience	Supervisor, management, personnel development responsible persons, operators
Production methodology	Continuous and Discrete
Notes	

Assessment	
Data source	Questionnaires, interviews Training programs and documents
Data availability	Training documents, primary data via survey
Goal	Integration of all relevant employees (operators, managers, etc.) in the training programm, improvement of knowledge about plant-wide processes
Notes	Indirect assessment through the attitudes of trainees, in combination with a document analysis of existing and new training programs target-performance comparison
Impact	
Description	Better understanding of plant-wide processes Awareness for training programs to get a plant-wide perspective Higher qualification of operators
Calculation	Results from questionnaire
Evaluation Method	Impact can be evaluated, for example • Related to baseline • During test periods • End of project.
Notes	Training as a human centered basis for plant-wide operation from a people perspective (in addition to the technical perspective) KPI-S3S is a basis for KPI-S4S (*Understanding* plant-wide processes)

2.3.4 KPI-S4C The level of understanding the plant-wide processes relative to baseline

KPI definition	
Content	
Name	The level of understanding the plant-wide processes of operators
ID	KPI-S4C
Description	The level of understanding the plant-wide processes of operators Objective: to assess whether the plant-wide optimization has truly enlarged operators' perspective on their work Methodology: operator questionnaire analysing the relation of own work to plant-wide processes
Scope	Work centre/whole site
Formula	The level of understanding the plant-wide processes of operators ratio, concerning the processes before and after the own working area. Statement such as: "I know the impact of my decisions on the product quality, assessed at quality control/finishing line." Adding some details, such as: • because of the new system • because of training • because of better communication with staff of other sub-processes Measured at different stages of the project (e.g. after providing prototypes, improved trainings or communication channels) Integration of plant-wide perspective contents/issues in everyday work (e.g. number of meetings with this issue)
Unit of measure	% of agreement, number of events accentuating plant-wide processes
Range	Min: Strongly disagree Max Strongly agree
Trend	The higher the agreement/accentuation, the better
Context	
Timing	On-demand, periodically
Audience	Supervisor, management
Production methodology	Continuous and Discrete
Notes	Mainly operationalised by a questionnaire, integrating numbers of events (operationalised in the questionnaire)
Assessment	
Data source	Questionnaires, interviews Training programs and documents
Data availability	Primary data: questionnaires, interviews

Goal	Improvement of understanding of plant-wide processes higher awareness of and responsibility for the whole production process
Notes	Other indicators to be assessed: e.g. number of meetings with plant-wide perspective contents, issues
Impact	
Description	Better understanding of and orientation at a plant-wide process perspective Optimisation of plant-wide processes by a human factor, leading to the improvement of the central impact indicators: • Increase of productivity and quality • Higher quality of the production and decrease of defects • Reduction of energy use and CO2 emissions • Economic advantages: cost effectiveness, lower costs • Productivity improvement • Reduction of energy use • Reduction of CO_2/SO_2 emissions • Economic impact • Oil usage due to low feed-rate
Calculation	Calculation of the KPI impact.
Evaluation method	Impact can be evaluated, for example • Related to baseline • During test periods • End of project.
Impact evaluation	Task where impacts are evaluated.
Notes	Indirect affecting the central indicators

2.3.5 KPI-S5C Operators' job satisfaction relative to baseline

KPI definition	
Content	
Name	Operators' job satisfaction
ID	KPI-S5C
Description	Operators' job satisfaction relative to baseline Objective: assessment of the effect of optimization on job satisfaction (e.g. its effects on work load, the meaning of reduced autonomy in deciding about operations, the effect of broader understanding of the plant-wide processes) Questionnaire with several questions related to the effect of optimization on job satisfaction - to be specified in relation to COCOP system and measures, operationalised along main dimensions, such as: satisfaction with (mental) workload
Scope	Work centre/whole site
Formula	Operators' job satisfaction ratio = average of questionnaires (0 -100%, relative to baseline) Measured in the beginning to get baseline, at critical events and/or periodically, in the end
Unit of measure	%
Range	Min: 0% Max 100%
Trend	The higher, the better
Context	
Timing	On-demand, periodically
Audience	Supervisor, management
Production methodology	Continuous and Discrete
Notes	Done by questionnaire, interviews
Assessment	
Data source	Primary data: survey, questionnaires, interviews
Data availability	Primary data: questionnaires, interviews
Goal	Higher job satisfaction, leading to a higher acceptance and usage of the system
Notes	Relevant: focus on the effects caused by the new system

Impact	
Description	higher job satisfaction leading to • Higher productivity and quality • Lower energy usage • Better cost-effectiveness
Calculation	Calculation of the KPI impact.
Evaluation method	Impact can be evaluated, for example • Related to baseline • During test periods • End of project.
Notes	This kind of secondary (indirect) impact based on higher job satisfaction could not be directly measured in a causal way indirect improvement of the central impact indicators of COCOP

2.4 KPI Development Process

2.4.1 KPI-D1C, Participation ratio: plant-wide optimization

KPI definition	
Content	
Name	Participation and attitude ratio in the plant-wide optimization
ID	KPI-D1C
Description	Participation of the key personnel and relevant stakeholders in the plant-wide optimization related innovation process Attitudes of key personnel and relevant stakeholders towards the development process for plant-wide optimization
Scope	Work centre/whole site
Formula	Participation ratio: • Number of involved (groups of) users / number of relevant groups of users (shift managers, foremen of hot mill, operators etc.) • Number of involved (groups of) stakeholders / number of relevant groups of stakeholders • Number of times users/stakeholders are involved in the development process / stages of system/measures development (e.g, first design ideas, mock-up, first prototype, ...) Indirect assessment of attitudes/perception of the development process with statements, such as: "I feel sufficiently involved in the development process of systems/measures for an plant-wide optimisation" or "I was involved in the following stages of the development: ..."
Unit of measure	% (ratio) / questionnaire
Range	Min: 0% (low integration) Max 100% (high integration)
Trend	The higher, the better resp. the more agreeing, the better
Context	
Timing	On-demand, periodically
Audience	Supervisor, management
Production methodology	Continuous and Discrete
Notes	Questionnaire users/stakeholders, (document) analysis of the process: Objective: are these persons truly involved in the innovation process or only in the beginning and at the end of the project (co-creation ratio) Attitudes and perception of key personnel and relevant stakeholders towards the process for plant-wide optimization

Assessment	
Data source	Questionnaire, document analysis (minutes of meetings, agreements, etc.)
Data availability	Primary data (survey), secondary data (minutes, etc.)
Goal	Comprehensive and effective involvement of users and stakeholders, co-creation process
Notes	
Impact	
Impact description	Effective and efficient process of plant-wide optimisation Reduction of feedback loops, adjustments afterwards and aberrations Integrating and considering impact from the users and stakeholders perspective.
Calculation	Calculation of the KPI impact.
Evaluation method	Impact can be evaluated, for example • Related to baseline • During test periods • End of project.
Notes	Can contain additional information related to the impact.

3 Introduction Steel Case

The Steel case will focus on the micro-alloyed steel grades family. This family represents around 30% of SIDENOR production and it is the most critical from the defects point of view

3.1 KPI and Impacts Steel Case

Item	Notes
KPI Definition	The KPI to be controlled along the project will be: • KPI-T1S: Percentage of rejection (kilograms) on the finishing line • KPI-T2S: Percentage of reworking (number of bars) on the finishing line • KPI-T3S: Percentage of rejection (kilograms) after Continuous Casting due to process parameters Due to confidentiality issues, the data provided in the deliverable documents will be the improvement percentage of the KPIs.
Impact	The improvements of the KPIs will generate impacts in different areas. The impacts to be evaluated during the project will be: • Productivity improvement in the finishing line • Reduction of energy use • Reduction of CO_2 emissions • Economic impact SIDENOR will analyze the potential figures of these impacts of the COCOP project (micro-alloyed steels) and will also extrapolate the data to the whole production.

3.1.1 KPI-T1S Relative Scrap ratio: Rejection on the finishing line relative to baseline due to surface quality

KPI definition	
Content	
Name	Relative Scrap ratio: Rejection on the finishing line relative to baseline due to surface quality
ID	KPI-T1S
Description	The Scrap Ratio represents production that is scrap due to surface quality. Scraped products are recycled to the EAF.
Scope	Percentage of rejection (kilograms) in the finishing line relative to baseline due to surface quality
Formula	Relative Scrap Ratio = Scrap Ratio / Scrap Ratio Baseline , Scrap Ratio = SQ / PQ SQ=scrap quantity [kilograms] , PQ=produced quantity in rolling mill [kilograms]
Unit of measure	%
Range	Min: 0% , Max 100%
Trend	The lower, the better
Context	
Timing	On-demand, periodically
Audience	Supervisor, management
Production methodology	Discrete
Effect model diagram	Figure **12**, Effect model diagram Scrap Ratio
Notes	All the bars are inspected automatically using Eddy Current technology. When the automated inspection detects surface cracks, the bar is classified as reworked (KPI-T2S) and an operator checks it. If the operator is not able to repair the cracks, it is rejected and scraped. The percentage of kilograms scraped with respect of kilograms controlled form this KPI.
Assessment	
Data source	SQ=scrap quantity for target product [kilograms]: PQ=produced quantity of target product in rolling mill [kilograms]:
Data availability	-
Goal	TBD % reduction in scrap ratio compared to baseline
Notes	Target product is micro alloyed grades 80-85mm bars

Impact	
Description / Calculation	Productivity impact is obtained from the resources lost in the whole process due to producing not useful material. The rejection effect is more than lineal because it can provoke suboptimal readjustments in planning. *Productivity loss* can be estimated in KPI-T1S * 1.2
	Energy usage: Energy needed for production of one ton of steel bar via electric arc furnace; considering steelmaking, rolling mill and finishing operation and excluding heats treatments, is in the *TBD* KWh range including electric energy and natural gas. This amount of energy is lost as a consequence of scraping one ton of product in finishing line.
	CO_2 emissions increment is a direct consequence of carbon emitting energy waste, natural gas and other carbonaceous materials. It can be estimated as TBD Kgr CO_2 per ton of steel.
	Economic impact: Economic impact is important too. Transformation costs in Steel Making shop, rolling mill and finishing line are included but also the amount of raw material not recoverable in the scrap (some ferroalloys that are oxidized in Electric Arc Furnace). It sums up to *TBD* Euros per ton.
Evaluation method	• Relative to baseline • During testperiods
Notes	Each ton of scraped material at the finishing line is a product that has been completely produced but becomes raw material again.

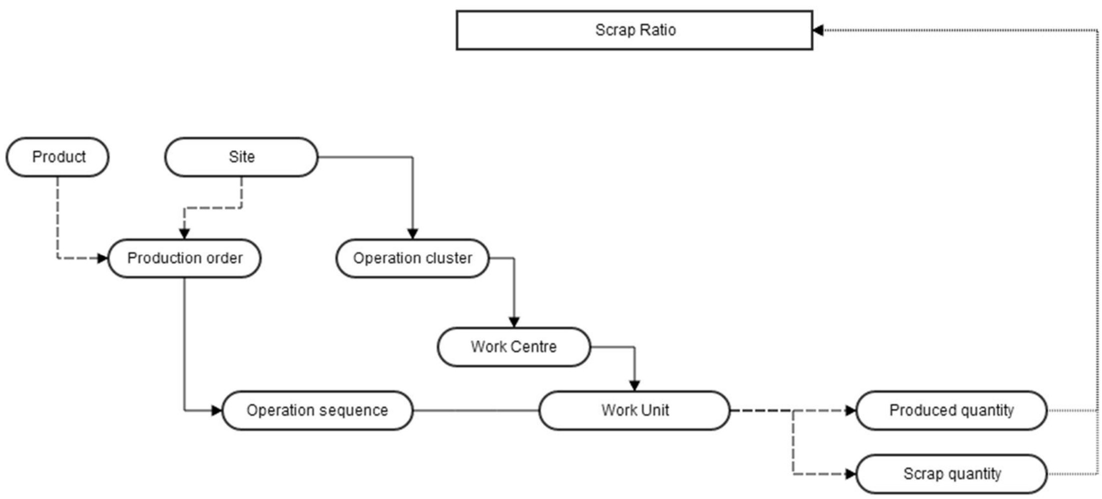

Figure 12, Effect model diagram Scrap Ratio

3.1.2 KPI-T2S Relative Rework Ratio: Reworking on the finishing line relative to baseline

KPI definition	
Content	
Name	Relative Rework ratio : Reworking on the finishing line relative to baseline
ID	KPI-T2S
Description	The rework ratio is the relationship between rework quantity (RQ) and produced quantity (PQ).
Scope	Work unit, product, production order, and defect type.
Formula	Relative Rework Ratio = Rework Ratio / Rework Ratio Baseline Rework ratio = RQ / PQ
Unit of measure	%
Range	Min: 0%, Max 100%
Trend	The lower, the better
Context	
Timing	On-demand, periodically, real time
Audience	Supervisor, management
Production methodology	Discrete
Effect model diagram	Figure **13**, Effect model diagram Rework Ratio
Notes	All the bars are inspected automatically using Eddy Current technology. When the automated inspection detects surface cracks, the bar is classified as reworked (KPI-T2S) and an operator checks it. If the operator is not able to repair the cracks, it is rejected and scraped if it is repaired fulfilling customer specification it is sent. The percentage of bars reworked with respect of controlled bars form this KPI.
Assessment	
Data source	RQ= rework quantity [number of bars] PQ= produced quantity [number of bars]
Data availability	-
Goal	*TBD* % reduction in rework ratio compared to baseline
Notes	Target product is micro alloyed grades 80-85mm bars

Impact	
Description / Calculation	Productivity: Concretely a TBD% improvement in reworking index is related with a productivity increase at the Finishing Shop: TBD% hours/Ton
	Energy usage: No
	CO_2: No
	Economic impact: Cost reduction from associated wastes (energy, raw material…): TBD% of the whole plant index
Evaluation method	• Relative to baseline • During test periods
Notes	Each ton of reworked material reduces productivity in the finishing line as it increases the work per ton of produced material.

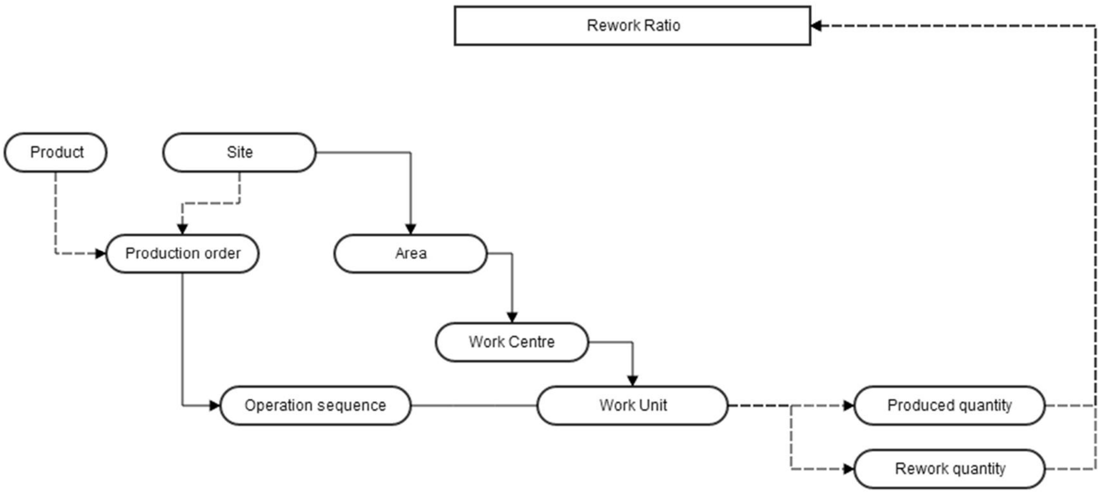

Figure 13, Effect model diagram Rework Ratio

3.1.3 KPI-T3S Relative scrap Ratio: Rejection in the continuous casting relative to baseline

KPI definition	
Content	
Name	Relative Scrap ratio: Rejection continuous casting relative to baseline due to surface quality
ID	KPI-T3S
Description	The Scrap Ratio represents production that is scrap due to surface quality. Scraped products are recycled to the EAF.
Scope	Percentage of rejection (kilograms) in the continuous casting relative to baseline due to surface quality
Formula	Relative Scrap Ratio = Scrap Ratio / Scrap Ratio Baseline Scrap Ratio = SQ / PQ SQ=scrap quantity in continuous casting [kilograms] PQ=produced quantity in continuous casting [kilograms]
Unit of measure	%
Range	Min: 0% Max 100%
Trend	The lower, the better
Context	
Timing	On-demand, periodically
Audience	Supervisor, management
Production methodology	Discrete
Effect model diagram	Figure **12**, Effect model diagram Scrap Ratio
Notes	There is no automated inspection device at the end of steel making process but Quality department checks all the heats' available critical variables and, if they find incorrect values, they scrap billets before they are sent to the rolling mill. The percentage of kilograms scraped with respect of kilograms controlled form this KPI.
Assessment	
Data source	SQ=scrap quantity for target product [kilograms]: PQ=produced quantity of target product in continuous casting [kilograms]:
Data availability	-
Goal	*TBD*% reduction in scrap ratio compared to baseline
Notes	Target product is micro alloyed grades 80-85mm bars

Impact	
Description / calculations	Each ton of scraped material at the steelmaking shop is a product that has gone through the steelmaking process but becomes raw material again. The waste is lower than in the case of KPI-T1S as rolling mill and finishing line process are not involved but involves the same concepts:
	Productivity: Productivity impact is obtained from the resources lost in the steelmaking process due to producing not useful material. The rejection effect is more than lineal because it can provoke suboptimal readjustments in planning. Productivity loss can be estimated in KPI-T3S * 1.2, e.g. reducing scrap ratio with a factor of one improves the productivity with a factor of 1.2.
	Energy usage: Energy needed for production of one ton of steel bar via electric arc furnace considering steel making, is in the TBD KWh range including electric energy and natural gas. This amount of energy is lost as a consequence of scraping one ton of billet in steel-making shop.
	CO2 emissions increment is a direct consequence of carbon emitting energy waste, natural gas and other carbonaceous materials. It can be estimated as TBD kg CO2 per ton of steel.
	Economic impact: Economic impact is important too. Transformation costs in Steel Making shop are included but also the amount of raw material not recoverable in the scrap (some ferroalloys that are oxidized in Electric Arc Furnace). It sums up to TBD Euros per ton.
Evaluation method	• Relative to baseline • During test periods
Notes	-

3.2 KPI from social point of view (operators, shift manager)

3.2.1 KPI-S1S, Usage of system advice

KPI definition	
Content	
Name	Usage of system advice
ID	KPI-S1S
Description	How often does the plant personnel follow the advice given by the system
Scope	Work centre/whole site
Formula	Usage of system advice = number of accepted advices / total number of advices
Unit of measure	%
Range	Min: 0% Max 100%
Trend	The higher, the better
Context	
Timing	On-demand and/or periodically
Audience	Supervisor, management
Production methodology	Continuous and/or discrete
Effect model diagram	Graphical overview of usage overtime, periodically or/and at critical milestones
Notes	The acceptance ratio must be measured in the solution itself. It should be a requirement to T2.2.
Assessment	
Data source	Number of presented advices Number of followed advices Generated in the COCOP solution.
Data availability	Frequency
Goal	High usage of the system
Notes	Quantitative and qualitative assessment of the usage. The usages could have quantitative (how often) and qualitative (improvement of the production activities) effects.

Impact	
Description / Calculations	Increase of productivity and quality (quantitative and qualitative usage of the system advices) Higher quality of the production and decrease of defects Reduction of energy use and CO2 emissions Economic advantages: cost effectiveness, lower costs
Evaluation Method	• During test periods
Notes	Indirect impact, through lower amount of losses/emissions/energy consumption caused by minor operator errors. This is based on the hypothesis, that the new system is having these technical based possibilities, effects.

3.2.2 KPI-S2S Acceptance of system advice

KPI definition	
Content	
Name	Acceptance of system advice
ID	KPI-S2S
Description	How accepted is the advice given by the system
Scope	Work centre/whole site
Formula	Acceptance of system advice: to be operationalised in a questionnaire, such as: Do you agree with the following statements: • The systems gives reliable advices • It makes decisions easier • It reduces workload • It is easy to handle • It is adaptable to individual requirements
Unit of measure	% of acceptance
Range	Min: Strongly disagree Max: Strongly agree
Trend	The higher the agreement, the better
Context	
Timing	On-demand, periodically
Audience	Supervisor, management
Production methodology	Continuous and Discrete
Effect model diagram	Graphs of the percentage of acceptance, based on the questionnaire results
Notes	Questionnaire: "Acceptance" will be operationalised by criteria of the system developers and the users of the system. Co-creation of the indicators for acceptance.
Assessment	
Data source	Questionnaire, interviews
Data availability	new data, primary data survey: interviews, questionnaires
Goal	High acceptance (mind-set)
Notes	Qualitative assessment of the system by the operators

Impact	
Description / Calculation	Increase of Productivity and Quality (quantitative and qualitative usage of the system advices) Higher quality of the production and decrease of defects Reduction of energy use and CO_2 emissions Economic advantages: cost effectiveness, lower costs
Evaluation method	• Relative to baseline • End of project
Notes	Through a higher acceptance the usage of the system is improved, increasing (improving KPI-S1S)

3.2.3 KPI-S3S Plant-wide processes as part of operator training ratio relative to baseline

KPI definition	
Content	
Name	Plant-wide processes as part of operator training ratio relative to baseline
ID	KPI-S3S
Description	The share of plant-wide processes as part of operator training relative to baseline Objective: to integrate the plant-wide perspective and to assess if it is adopted as an integral part of training Methodology: document analysis of training material, questionnaire for operators/shift managers (is the perspective sufficiently considered in the training?), interview of training responsible persons (how is plant wide understanding provided in trainings)
Scope	Work centre/ whole site
Formula	Document analysis: part of training material (yes/no; if yes, to what extent and in which form) Questionnaire: Statement "Plant-wide understanding is sufficiently considered in trainings." Range of answers: strongly agree - agree - indifferent - disagree - strongly disagree Interview: quantitative and qualitative aspects of training Measured in the beginning and in the end.
Unit of measure	Documents: training modules related to plant-wide processes, questionnaires/interviews of training responsible persons, operators
Range	Comparison of initial (existing training program) and final situation (after system development)
Trend	The higher the approval, participation and knowledge improvement of operators and managers, the better
Context	
Timing	On-demand, periodically
Audience	Supervisor, management, personnel development responsible persons, operators
Production methodology	Continuous and Discrete
Notes	
Assessment	
Data source	Questionnaires, interviews Training programs and documents
Data availability	Training documents, primary data via survey

Goal	Integration of all relevant employees (operators, managers, etc.) in the training program, improvement of knowledge about plant-wide processes
Notes	Indirect assessment through the attitudes of trainees, in combination with a document analysis of existing and new training programs target-performance comparison
Impact	
Description / Calculation	Better understanding of plant-wide processes Awareness for training programs to get a plant-wide perspective Higher qualification of operators
Evaluation method	• Relative to baseline • End of project
Notes	Training as a human centered basis for plant-wide operation from a people perspective (in addition to the technical perspective) KPI-S3S is a basis for KPI-S4S (*Understanding* plant-wide processes)

3.2.4 KPI-S4S The level of understanding the plant-wide processes relative to baseline

KPI definition	
Content	
Name	The level of understanding the plant-wide processes of operators
ID	KPI-S4S
Description	The level of understanding the plant-wide processes of operators Objective: to assess whether the plant-wide optimization has truly enlarged operators' perspective on their work Methodology: operator questionnaire analysing the relation of own work to plant-wide processes
Scope	Work centre/ whole site
Formula	The level of understanding the plant-wide processes of operators ratio, concerning the processes before and after the own working area. Statement such as: "I know the impact of my decisions on the product quality, assessed at quality control/finishing line." Adding some details, such as: • because of the new system • because of training • because of better communication with staff of other sub-processes • etc. Measured at different stages of the project (e.g. after providing prototypes, improved trainings or communication channels) Integration of plant-wide perspective contents/issues in everyday work (e.g. number of meetings with this issue)
Unit of measure	% of agreement, number of events accentuating plant-wide processes
Range	Min: Strongly disagree Max Strongly agree
Trend	The higher the agreement/accentuation, the better
Context	
Timing	On-demand, periodically
Audience	Supervisor, management
Production methodology	Continuous and Discrete
Notes	Mainly operationalised by a questionnaire, integrating numbers of events (operationalised in the questionnaire)
Assessment	
Data availability	Primary data: questionnaires, interviews

Goal	Improvement of understanding of plant-wide processes higher awareness of and responsibility for the whole production process
Notes	Other indicators to be assessed: e.g. number of meetings with plant-wide perspective contents, issues
Impact	
Description / Calculation	Better understanding of and orientation at a plant-wide process perspective Optimisation of plant-wide processes by a human factor, leading to the improvement of the central impact indicators: • Increase of productivity and quality • Higher quality of the production and decrease of defects • Reduction of energy use and CO2 emissions • Economic advantages: cost effectiveness, lower costs
Evaluation method	• Relative to baseline • End of project
Notes	Indirect affecting the central indicators

3.2.5 KPI-S5S Operators’ job satisfaction relative to baseline

KPI definition	
Content	
Name	Operators’ job satisfaction
ID	KPI-S5S
Description	Operators’ job satisfaction relative to baseline Objective: assessment of the effect of optimization on job satisfaction (e.g. its effects on work load, the meaning of reduced autonomy in deciding about operations, the effect of broader understanding of the plant-wide processes) Questionnaire with several questions related to the effect of optimization on job satisfaction - to be specified in relation to COCOP system and measures, operationalised along main dimensions, such as: satisfaction with (mental) workload
Scope	Work centre/whole site
Formula	Operators’ job satisfaction ratio = average of questionnaires (0 -100%, relative to baseline) Measured in the beginning to get baseline, at critical events and/or periodically, in the end
Unit of measure	%
Range	Min: 0% Max: 100%
Trend	The higher, the better
Context	
Timing	On-demand, periodically
Audience	Supervisor, management
Production methodology	Continuous and Discrete
Notes	Done by questionnaire, interviews
Assessment	
Data source	Primary data: survey, questionnaires, interviews
Data availability	Primary data: questionnaires, interviews
Goal	Higher job satisfaction, leading to a higher acceptance and usage of the system
Notes	Relevant: focus on the effects caused by the new system

Impact	
Description / Calculations	Higher job satisfaction leading to • Higher productivity and quality • Lower energy usage • Better cost-effectiveness
Evaluation method	• Relative to baseline • End of project
Notes	This kind of secondary (indirect) impact based on higher job satisfaction could not be directly measured in a causal way indirect improvement of the central impact indicators of COCOP

3.3 KPI Development Process

3.3.1 KPI-D1S Participation ratio: plant-wide optimization

<table>
<tr><th colspan="2">KPI definition</th></tr>
<tr><th colspan="2">Content</th></tr>
<tr><td>Name</td><td>Participation and attitude ratio in the plant-wide optimization</td></tr>
<tr><td>ID</td><td>KPI-D1S</td></tr>
<tr><td>Description</td><td>Participation of the key personnel and relevant stakeholders in the plant-wide optimization related innovation process
Attitudes of key personnel and relevant stakeholders towards the development process for plant-wide optimization</td></tr>
<tr><td>Scope</td><td>Work centre/whole site</td></tr>
<tr><td>Formula</td><td>Participation ratio:
• Number of involved (groups of) users / number of relevant groups of users (shift managers, foremen of hot mill, operators etc.)
• Number of involved (groups of) stakeholders / number of relevant groups of stakeholders
• Number of times users/stakeholders are involved in the development process / stages of system/measures development (e.g, first design ideas, mock-up, first prototype, ...)
Indirect assessment of attitudes/perception of the development process with statements, such as: "I feel sufficiently involved in the development process of systems/measures for a plant-wide optimisation"
or "I was involved in the following stages of the development: ..."</td></tr>
<tr><td>Unit of measure</td><td>% (ratio) / questionnaire</td></tr>
<tr><td>Range</td><td>Min: 0% (low integration)
Max: 100% (high integration)</td></tr>
<tr><td>Trend</td><td>The higher, the better resp. the more agreeing, the better</td></tr>
<tr><th colspan="2">Context</th></tr>
<tr><td>Timing</td><td>On-demand, periodically</td></tr>
<tr><td>Audience</td><td>Supervisor, management</td></tr>
<tr><td>Production methodology</td><td>Continuous and Discrete</td></tr>
<tr><td>Notes</td><td>Questionnaire users/stakeholders, (document) analysis of the process:
Objective: are these persons truly involved in the innovation process or only in the beginning and at the end of the project (co-creation ratio)
Attitudes and perception of key personnel and relevant stakeholders towards the process for plant-wide optimization</td></tr>
</table>

Assessment	
Data source	Questionnaire, document analysis (minutes of meetings, agreements, etc.)
Data availability	Primary data (survey), secondary data (minutes, etc.)
Goal	Comprehensive and effective involvement of users and stakeholders, co-creation process
Notes	
Impact	
Description / Calculations	Effective and efficient process of plant-wide optimisation Reduction of feedback loops, adjustments afterwards and aberrations Integrating and considering impact from the users and stakeholders perspective
Evaluation method	• Relative to baseline • End of project
Notes	

4 Referenser

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