FORCAM™ FORCE

Version 5.9

Energy Analysis

Manual

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Author:	**STernes**

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1 Concept

FORCAM FORCE™ can measure and present workplace energy consumption, whereby the data given is either for material or operating condition. These energy data are used as the basis for the preparation of reports.

Energy data are process data that represent the energy consumption of the workplace. The consumption represents certain energies distributed over workstations and operating states (electrical energy, compressed air, etc.).

The PLC collects process data from machines and writes it to a NoSQL database (MongoDB). It is then aggregated by the energy aggregation service (time controlled, triggered by a configurable CRON job). For each workstation, energy timelines are written to the relational database. The reporting process obtains data from this database and displays it graphically.

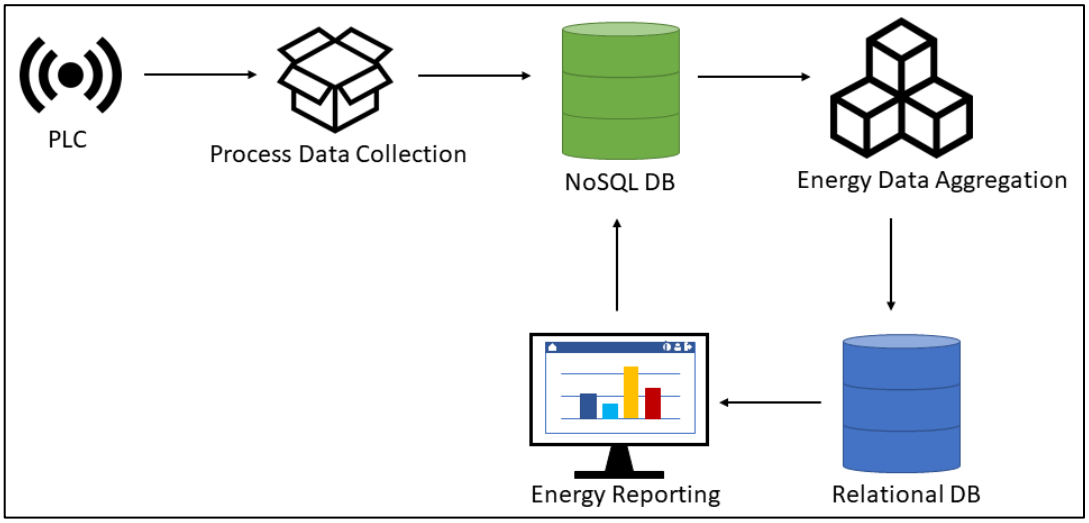


Fig. 1: Simple architecture of the energy analysis process

2 Reports

FORCAM FORCE™ can visualize energy data in several different ways.
The performance analysis provides reports received from **energy data acquisition** that show the energy consumption of workplaces, materials, and operating conditions. It is also possible to display those workstations that consume the most energy. For example, the energy consumption of a machine line displayed as a pie chart.

The process data visualization displays the values of process data. The limit values of the violation rules are also displayed.

2.1 Performance Analysis

2.1.1 Energy Consumption per Workplace

Path (Office): Performance Analysis > Reporting > Reports > Energy Data Acquisition > Energy Consumption per Workplace

This multi-report displays the energy consumption for each selected workplace as a column diagram or in table format.

Column diagram

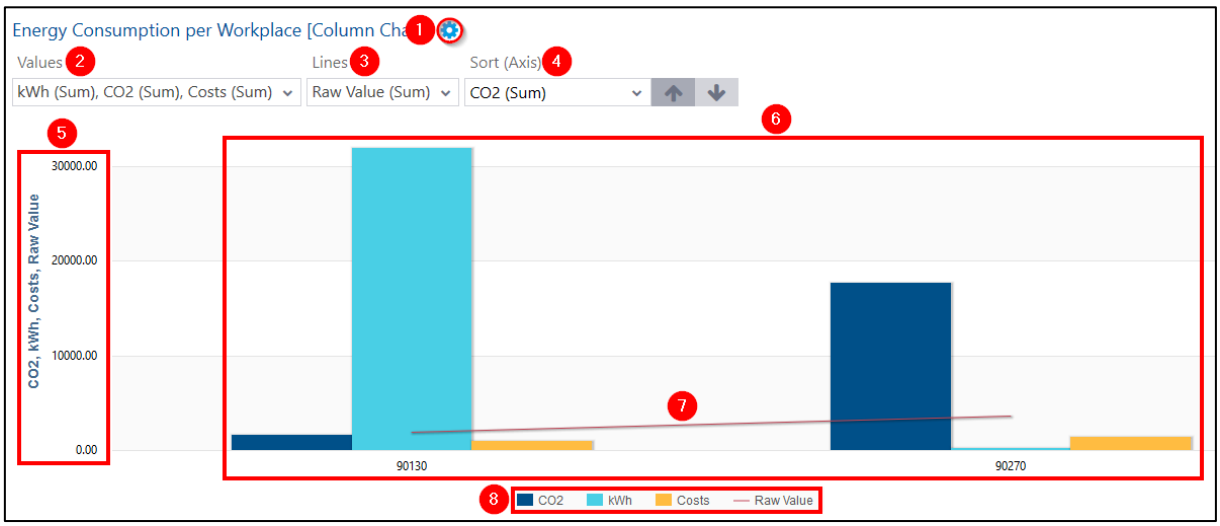


Fig. 2: Energy consumption per workplace displayed as a column diagram

(1) Shows filters for values, material or machine lines, and sorting

(2) Selection of one or more values to be displayed as a column (kWh, CO_2, etc.).
Each value can be displayed cumulative or non-cumulative (see chapter 2.1.1.1).

(3) Selection of a value that can be placed over workplaces to visualize a certain comparison or difference.
The line selection is only available where more than one workplace exists, as it is a tool for comparing lines. If more than one value is selected, then more than one line is displayed.

(4) Sorts the workplaces along the x-axis according to the selected value in ascending or descending order.
Example: If CO_2 is selected, the workplace with the lowest CO_2-value is positioned left on the x-axis, followed by the workplace with the next highest value next to it on the right.

(5) Y-axis for numbers that are referenced from the selected values.
Example: A workplace consumes 400 kWh electricity, 1700 Nm^3 CO_2 and accrues costs of $6000. The y-axis must be able to display all three values, and thus the numbers scale is from 0 to 6000.

(6) Consumption values displayed as columns for all selected workplaces.
Each bar represents a consumption value and is relationally sized. Thus, the column for electricity consumption of 400 kWh reaches to the number 400 on the y-axis.

(7) A line displayed over more than one workplace to depict an additional value as a comparison (see (3)).

(8) Legend of the column diagram.
Each entry represents a consumption value represented by a column. By clicking on that entry, all corresponding columns are shown or hidden.

Table

Energy Consumption per Workplace [Table]

Workplace	Consumption Type	Costs %	CO2 %	kWh %
90130	Consumption of electricity	37.86%	8.72%	98.09%
90130	Consumption of water	3.56%	0.02%	0.8%
90270	Consumption of electricity	43.42%	23.34%	0.7%
90270	Consumption of water	15.16%	67.92%	0.41%
		100%	100%	100%

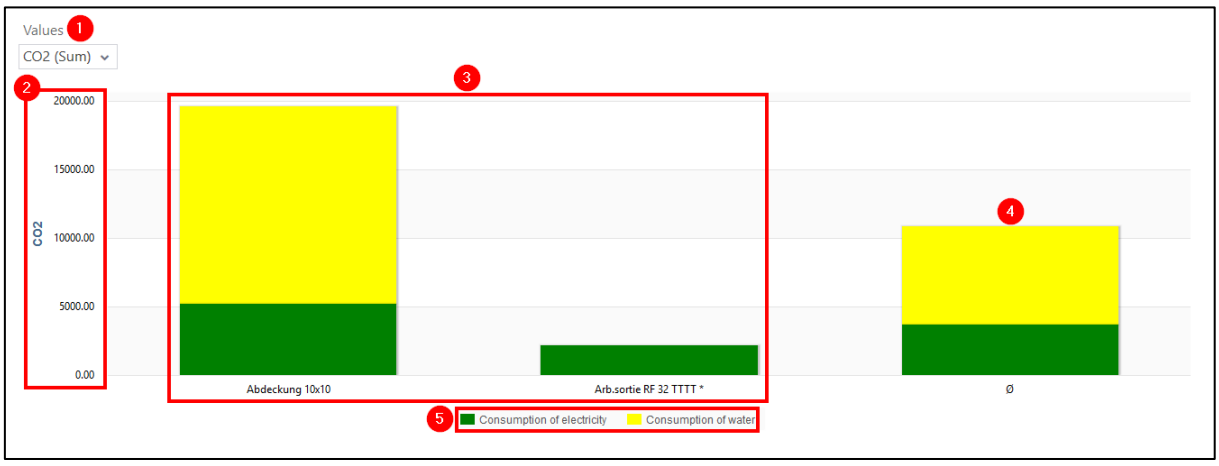


Fig. 3: Energy consumption per workplace as a table

Each row of the table shows the energy consumption of *one* workplace for a consumption type. However, the workplace can also represent a workplace line (workstation). The values given are configured for each energy type (see section 3.1).
The individual columns are displayed or hidden using the icon at the top right corner of the table. Each column of the table can be either displayed or not via the icon on the right upper corner of the table.

2.1.1.1 Concept of Cumulation

Cumulation here means that individual values are totaled up in the display.
Example: 12 energy units are consumed at time 1; 14 units are consumed at time 2, and 16 units are consumed at time 3.
The chart shows the corresponding value per point in time as a column. The curve line does not just reflect the mere values, but their cumulation: One value represents time 1, and the curve is on the column. Time 2 has another value represented by the second column with a value of 14. The curve cumulates this value, i.e. it accumulates the two previous values and thus reaches a value of 26 (12 + 14). This corresponds to the total value (total consumption) at that point in time. Another value is added in time 3, the curve increases again by also accumulating this value. The curve reaches the value 42 (26 + 16), which corresponds to the total value at time 3.

ⓘ The cumulation is carried out as part of the SQL statement of this report and is purely optical.

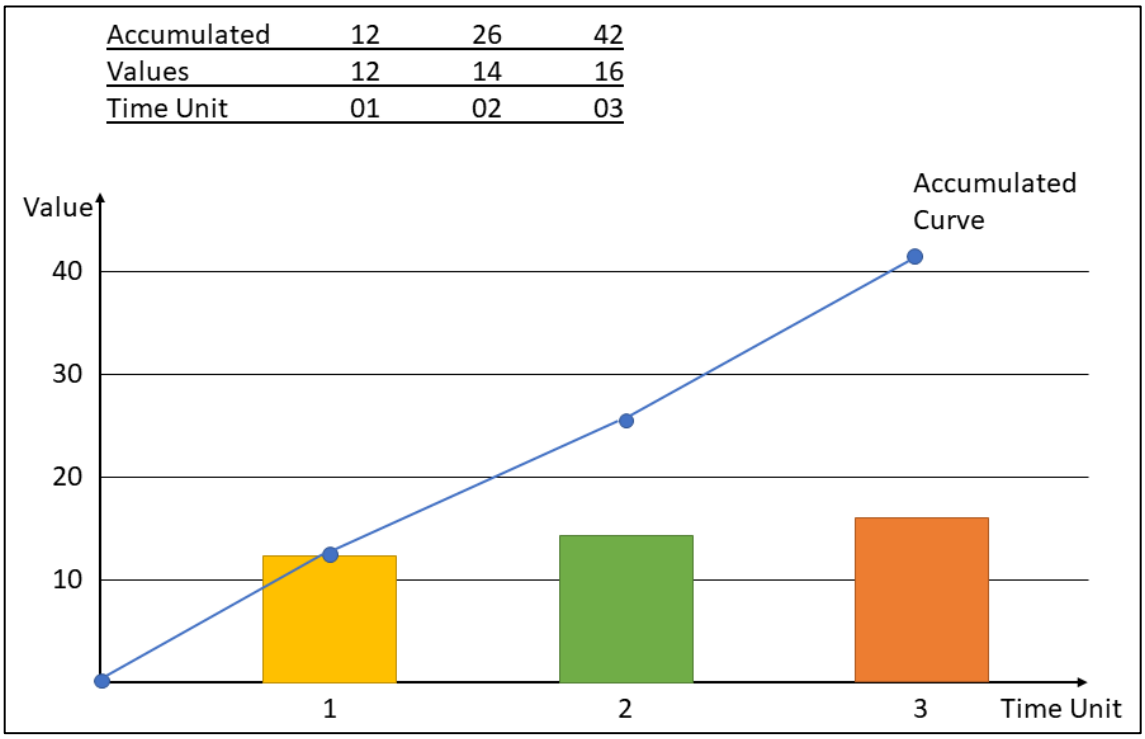


Fig. 4: Cumulation concept

2.1.2 Energy Consumption per Material

Path (Office): Performance analysis > Reporting > Reports > Energy data acquisition > Energy consumption per material

This multi-report displays the energy consumption for each selected material as a column diagram or a table.

Column diagram

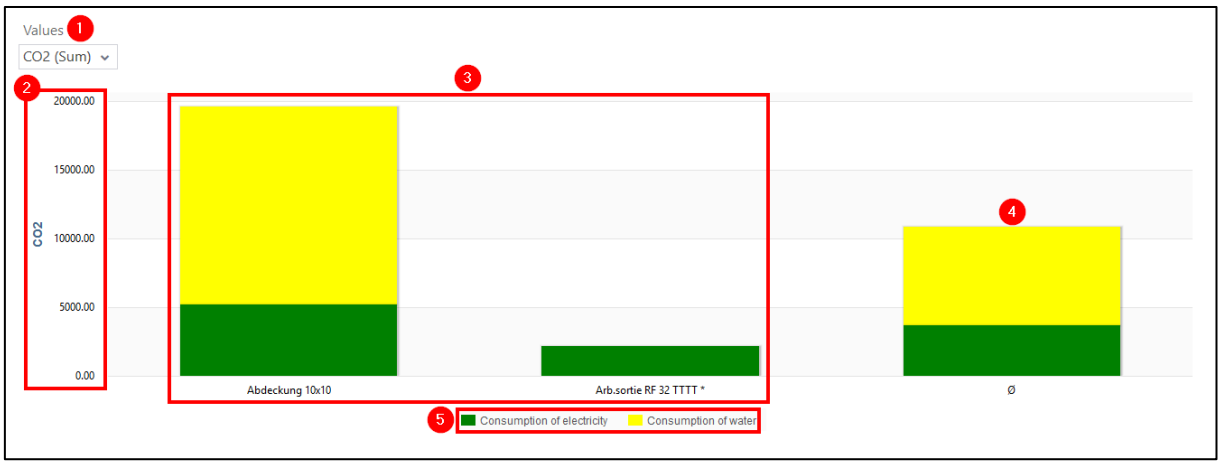


Fig. 5: Energy consumption per material displayed as a column diagram

(1) Selection of a value to be displayed as a column diagram (i.e. kWh, CO_2 etc.).
(2) Y-axis with numbers referenced to the selected value.
(3) Consumption values as columns for all selected workplaces.
Each column is composed of several consumption types (if available) divided proportionally. Example: A material has a total CO_2 consumption of 10,000 Nm^3. Of this, 2.500 Nm^3 is attributed to electricity consumption and 7,500 Nm^3 to water consumption. The column for this material then consists of 1/3 electricity consumption and 2/3 water consumption.
(4) Column with the average value of all selected materials.
(5) Legend of the column diagram.
Each entry represents an energy type. By clicking on an entry, the corresponding energy type is either shown or hidden.

Table

Material	Consumption Type	Costs	CO2	kWh	Raw Value
Arb.sortie RF 32 TTTT *	Consumption of e...	1289.56	2210.67	41450.00	1842.22
Abdeckung 10x10	Consumption of e...	1316.48	5265.93	263.30	2632.97
Arb.sortie RF 32 TTTT *	Consumption of w...	120.31	6.02	336.88	601.57
Abdeckung 10x10	Consumption of w...	431.53	14384.20	143.84	1438.42

Fig. 6: Energy consumption per material as table

Each row of the table shows the energy consumption of a material for *one* consumption type. The values shown are configured for each energy type (see section 3.1).
The individual columns are either shown or hidden via the icon at the top right corner of the table.

2.1.3 Energy Consumption per Operating State

Path (Office): Performance Analysis > Reporting > Reports > Energy data acquisition > Energy Consumption per operating state

This multi-report displays the energy consumption for each selected operating state as a column diagram or a hitlist.

Column diagram

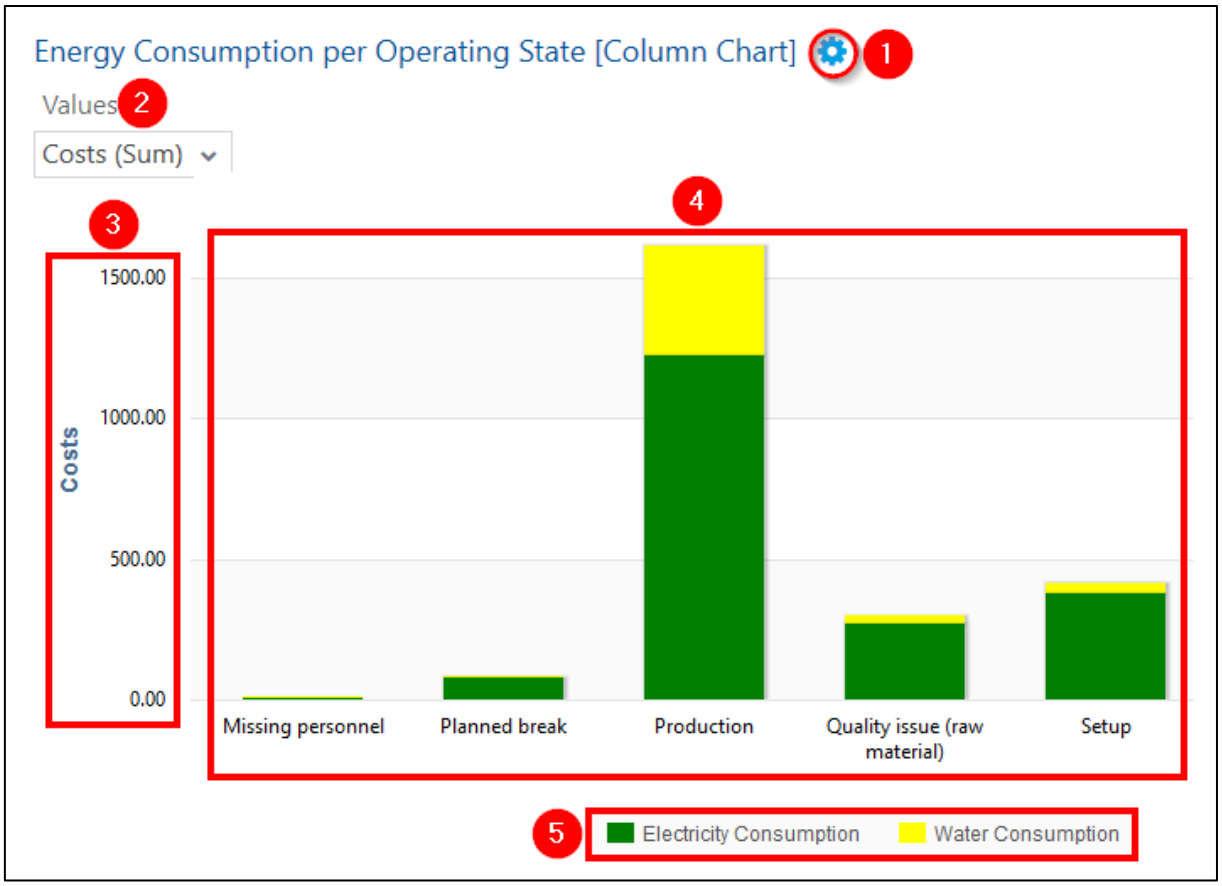


Fig. 7: Energy consumption per operating state as a column diagram

(1) Shows the additional filter for values
(2) Selection of a value to be displayed as a column (kWh, CO_2 etc.)
(3) Y-axis with numbers referenced to the selected value.
(4) Consumption values displayed as columns for all selected operating states.
Each column consists of several consumption types (if available) divided proportionally.
Example: An operating state causes costs of $1600. Of these, $1200 is attributed to electric consumption and $400 to water consumption. Thus, the column for this operating state consists of 1/3 water consumption and 2/3 electrical consumption.
(5) Legend of the column diagram.
Each entry represents an energy type. The corresponding energy type is either shown or hidden by clicking on an entry.

Hitlist

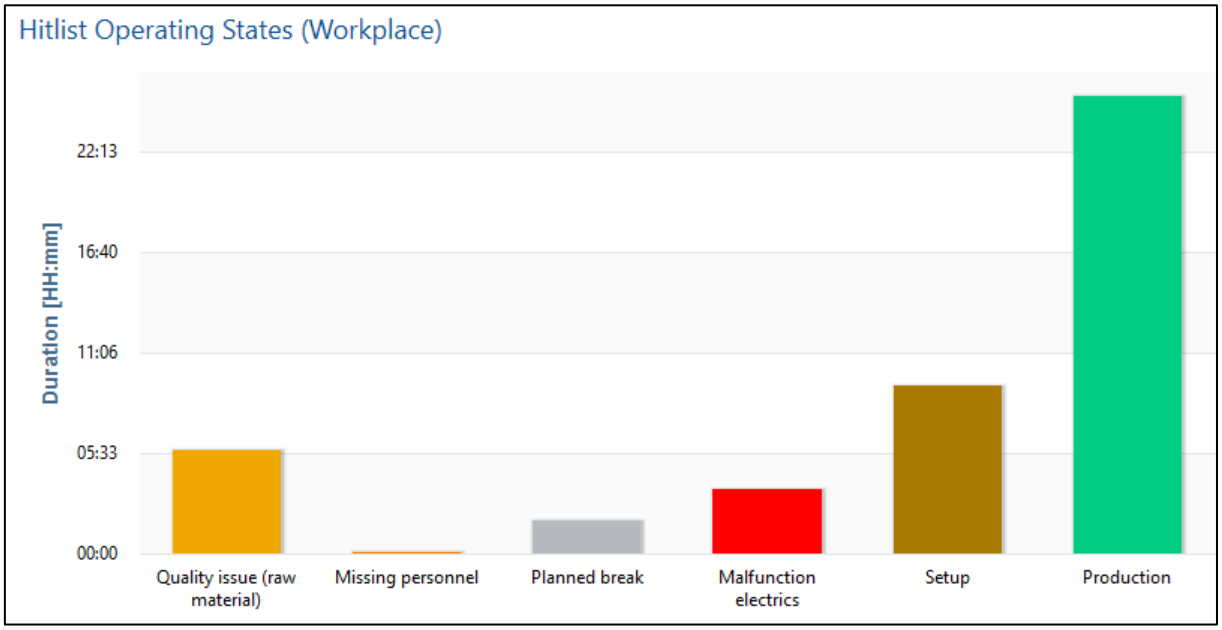


Fig. 8: Energy consumption per operating state displayed as a hitlist

In the hitlist, each column represents an operating state. The duration of an operating state determines the height of the column. The longer the operating state lasts, the higher the column. The user can therefore quickly see which operating states dominate.

2.1.4 Workplaces with the Highest Consumption

Path (Office): Performance Analysis > Reporting > Reports > Energy Consumption Data Sources > Workplaces with Highest Consumption

This multi-report compares the energy consumption of several workstations in a pie chart. The selected value is displayed proportionally for each workplace.
Additionally, a table summarizes the consumption for each workplace.

ⓘ The pie chart will fit to scale seamlessly in the browser window by zooming in or out.

Pie chart

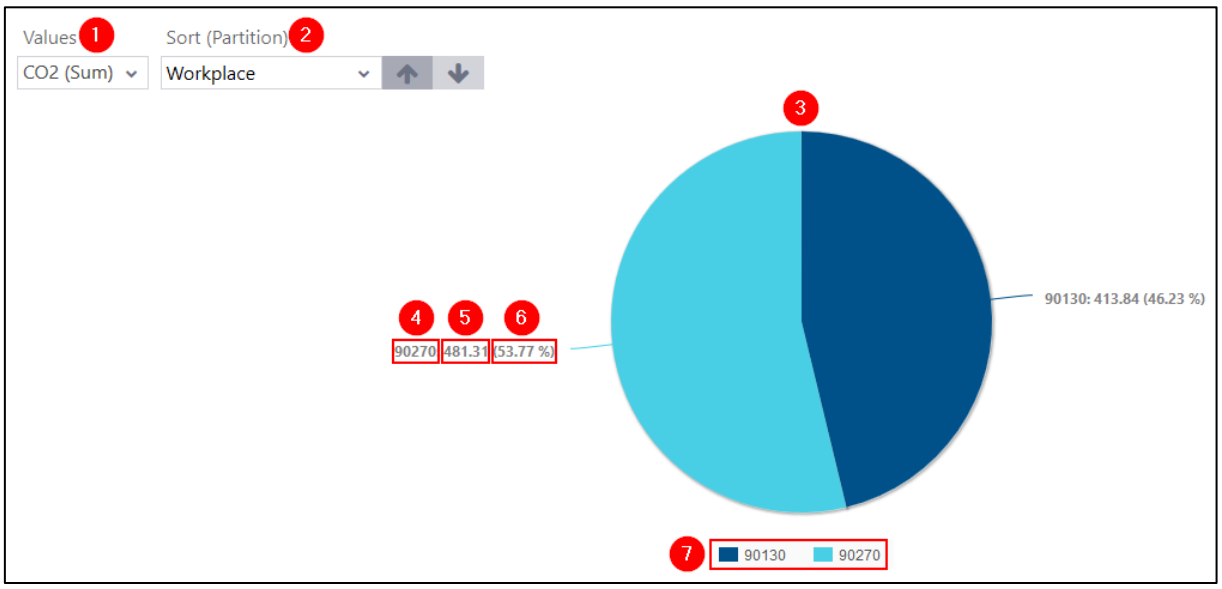


Fig. 9: High consumption workplaces displayed as pie chart

(1) Selection of a value to be displayed in the pie chart (kWh, CO_2 etc.).

(2) Sorts the selected workplaces displayed in the pie chart either in ascending or descending order. For example, if ascending is selected, the workplace with the smaller value will be positioned on the right.

(3) Pie chart showing the selected value for all workplaces.
The selected value is displayed proportionally for each workplace. This means that each workplace takes up as much space in the pie chart as it consumes in the comparison.
Example: In the comparison between the workplaces 90130 and 90270, together they have a total consumption of 895.15 Nm³ CO2. 90270 has a consumption of 481.31 Nm³, which amounts to 53.77%. This workplace therefore occupies 53.77% of the diagram's space.

(4) Name of the workplace

(5) Consumption value of the workplace

(6) Proportionate percentage consumption of each workplace measured from the total consumption of all workplaces.

(7) Legend of pie chart.
Each entry represents one workplace. Selecting an entry either shows or hides the workplace.

Table

Workplace	Consumption Type	Costs %	CO2 %	kWh %
90130	Consumption of electricity	37.86%	8.72%	98.09%
90130	Consumption of water	3.56%	0.02%	0.8%
90270	Consumption of electricity	43.42%	23.34%	0.7%
90270	Consumption of water	15.16%	67.92%	0.41%
		100%	100%	100%

Fig. 10: Energy consumption per workplace displayed as a table

Each row of the table shows the energy consumption of a workplace for one energy consumption type. However, the workplace can also represent a workstation line. The values given are configured for each energy type (see section 3.1)
Using the icon at the top right corner of the table either shows or hides the individual columns of the table.

2.1.5 Load Curve

Path (Office): Performance Analysis > Reporting > Reports > Energy Consumption Data Sources > Load Curve

This report displays the energy consumption of workplaces as a column diagram over a certain time-period.

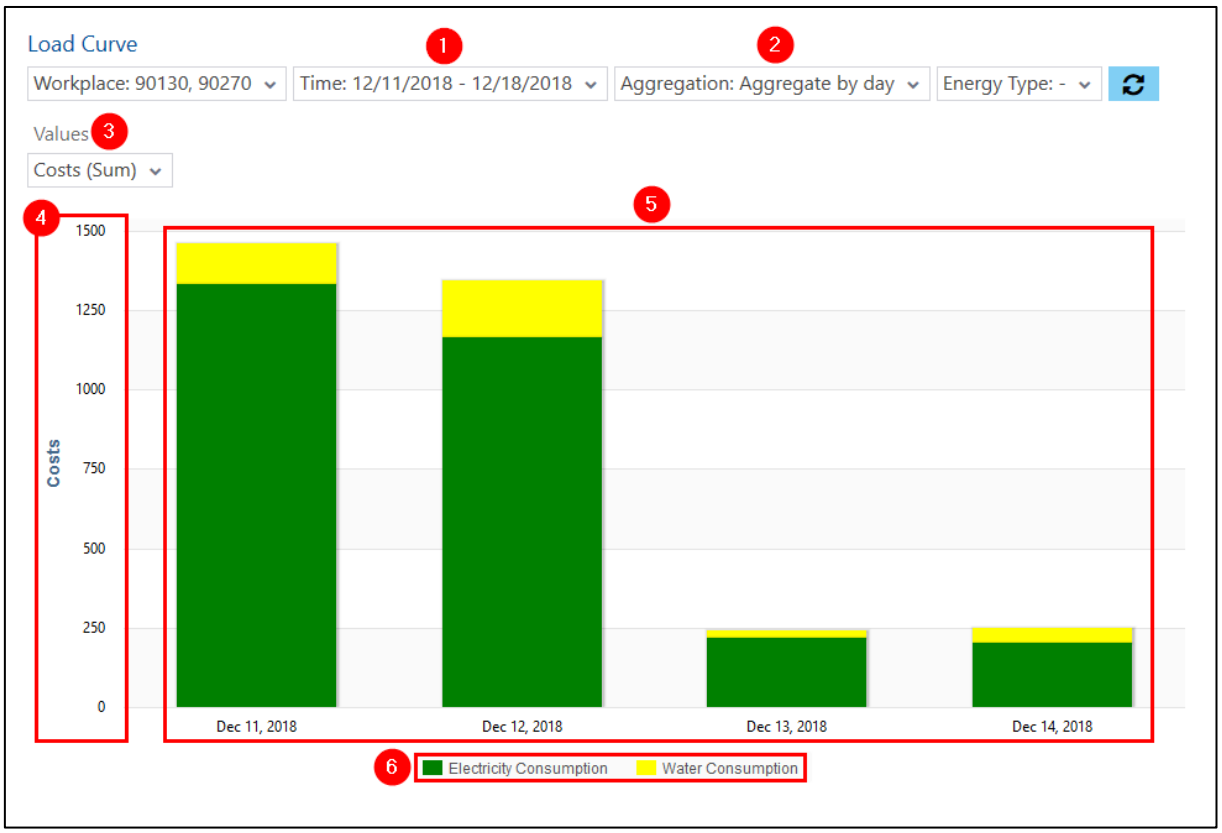


Fig. 11: Load curve

(1) Time filter.
The selection for displaying the load curve of a time-period.
(2) Aggregation filter.
The energy consumption can be aggregated over diverse time-periods (minutes, weeks, months, etc.).
(3) Selection of a value for displaying as a column (kWh, CO_2 etc.).
(4) Y-axis with numbers referenced to the selected value.
(5) Consumption values displayed as columns for the selected time-period, that consist of several consumption types (if available) distributed proportionately.
Example: On 12.12.2018, the energy consumption for the selected workplaces sums up to $1347. $1168 of this went to electric consumption, and $179 went to water consumption. Therefore, the column for this day consists 7/8 out of the electrical consumption, and 1/8 out of the water consumption.
(6) Legend of the column diagram.
Each entry represents an energy type. The energy type is either shown or hidden in the diagram by selecting an entry.

2.2 Process Data Visualization

Path (Office): Track & Trace > Reporting > General Reporting > Process Data Chart

The process data chart displays the values for the process data. Additionally, the limit values of the violation rules are displayed in this chart, which show when values have gone over the limit rules.

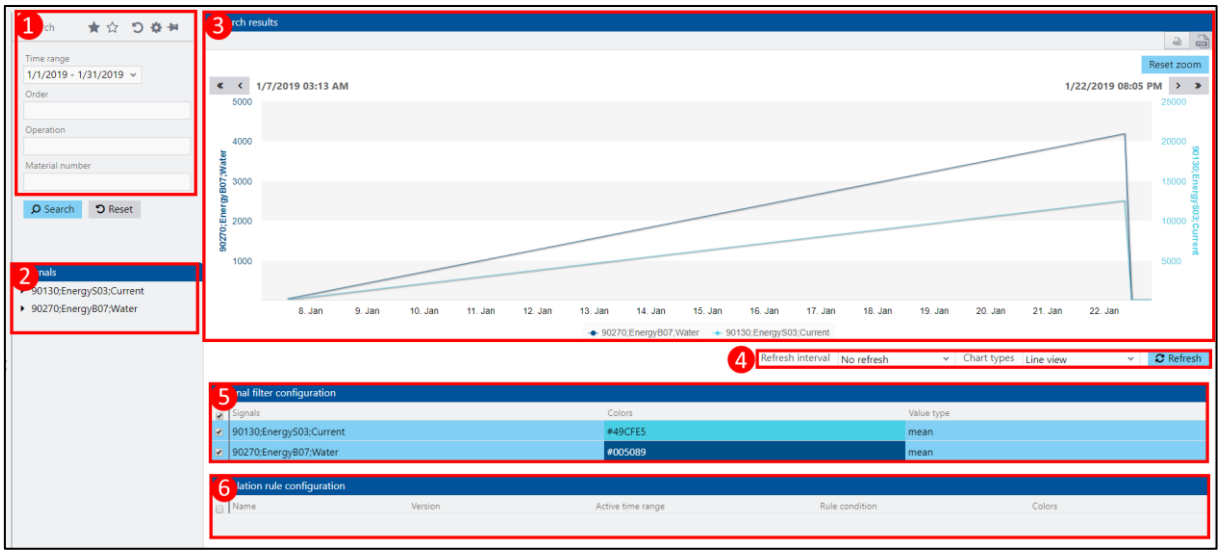


Fig. 12: Process data visualization

(1) Search filter for entering search parameters
Time-period is a mandatory field.

(2) Signal filter for defining process data values
A right click here makes it possible to add up to two signals, whereby one workplace and the desired data to be displayed may be selected.

(3) Graphic section of the display area
Displays the process data with the desired values selected. Additionally, lines displaying values that have violated the limit rules are shown.
Moving the mouse curser over a certain point in the graphic, shows a tooltip with the values for that point. If the curser is over a point where two lines intersect, the values of both lines are displayed in a tooltip.
Holding down the mouse and dragging an area zooms in on that area in the graph.

(4) Display options of the graphic shown
Enables an automatic update of the graph after a desired time.
It is also possible to select various display types. After selecting an update interval or a different display type, refreshing the graphic reflects the changes.
The following graphic types are available:

- Line view
  The values are depicted through a straight line comprised from a direct connection of the measuring points.
- Spline view
  The values are depicted as an interpolated curve.
- Series view
  Several curves are displayed, making a direct comparison possible. This view will be integrated into the line view with the next release version, thus omitted here.

(5) Signal filter configuration
Shows all the configured signals. Double-clicking on a signal makes it possible to change color and value type.

(6) Violation rule configuration
Clicking on a signal prompts the display of a violation rule, if one is available. A double-click on a rule makes it possible to change color.
If a violation rule has more than one version, these are also shown. This allows the user to see all the changes (i.e. when the limit value of a rule has changed).

2.2.1 Calling up the Process Data Visualization Via a Button

Path (Workbench): Configurations > Shop Floor Terminal > Templates-Editor

The Shop Floor Terminal can show a process data chart. To do this, a button must be configured that calls up the chart in a pop-up window. The chart keeps all functionality in the pop-up window, such as update intervals, color selection, etc.

The button needs the activity steps **Construct and/or call up a URL with parameters** and **Displaying HTML content**.

ⓘ The table below only lists all the required configurations. Specific parameters such as execution condition, size, etc. are not included.

Table 1: Configuration of the step „Construct and/or call up a URL with parameters"

Designator	Value	
Input parameter	Workplace (WPL) → Workplace (WPL)	
Output parameter	Parameter (URL) ← Created URL (URL)	
Mode	Create URL	
Base-URL	URL of the process data chart	
List of URL parameters	4 list elements	
URL-Parameter	Name	Language
	Value	Language
URL-Parameter	Name	Time zone
	Value	Time zone
URL-Parameter	Name	Key
	Value	Authentication token
URL-Parameter	Name	Search filter
	Value	today

Table 2: Configurating the step „Displaying HTML content“

Designator	Value
Input parameter	Parameter (URL) → URL (URL)
Mode	URL call-up
Display URL	Yes
Display the close button	Yes

2.2.2 Integration into the start page of the SFT

Path (Workbench): Configurations > Shop Floor Terminal > Template Editor

The process data chart can be imbedded into the Shop Floor Terminal (Operation view/OP mask). If an update interval is set in the chart, it will automatically update independently of the start page, even if no update was configured for the start page.

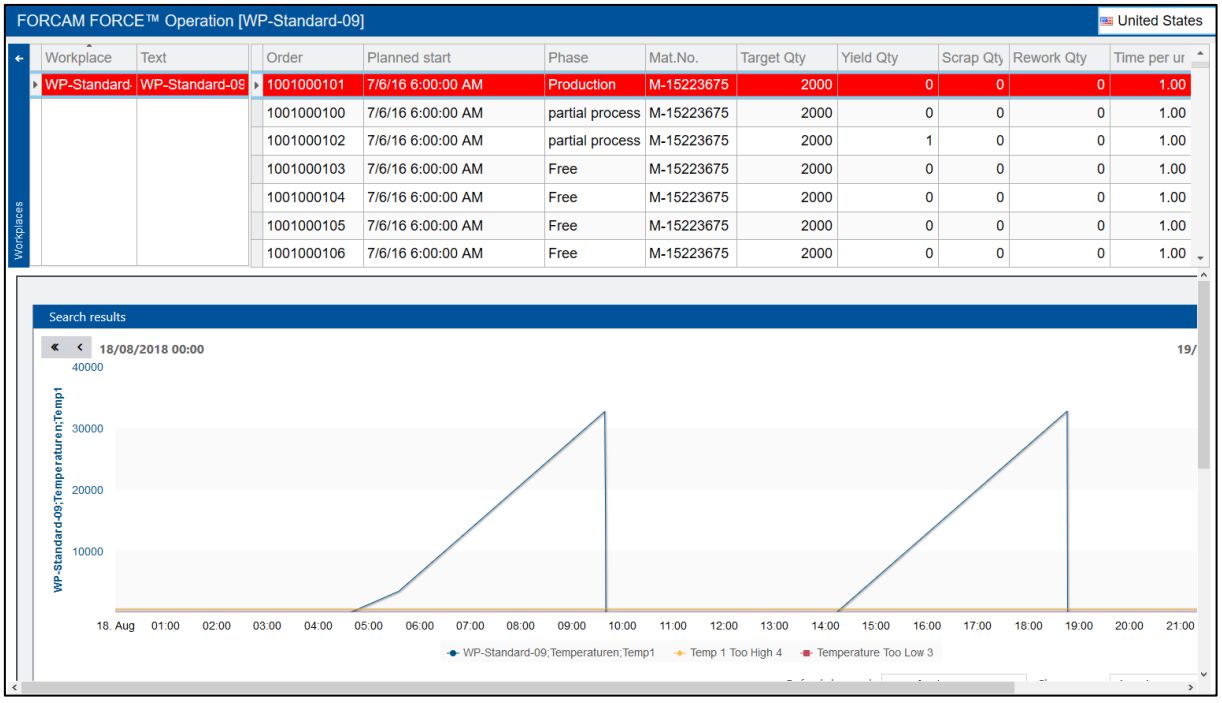


Fig. 13: Process data chart in the Shop Floor Terminal

An iframe added to the SFT configuration in the template editor displays the chart in the terminal. The report is displayed within the iframe. The iframe must be included in the template of the HTML configuration:

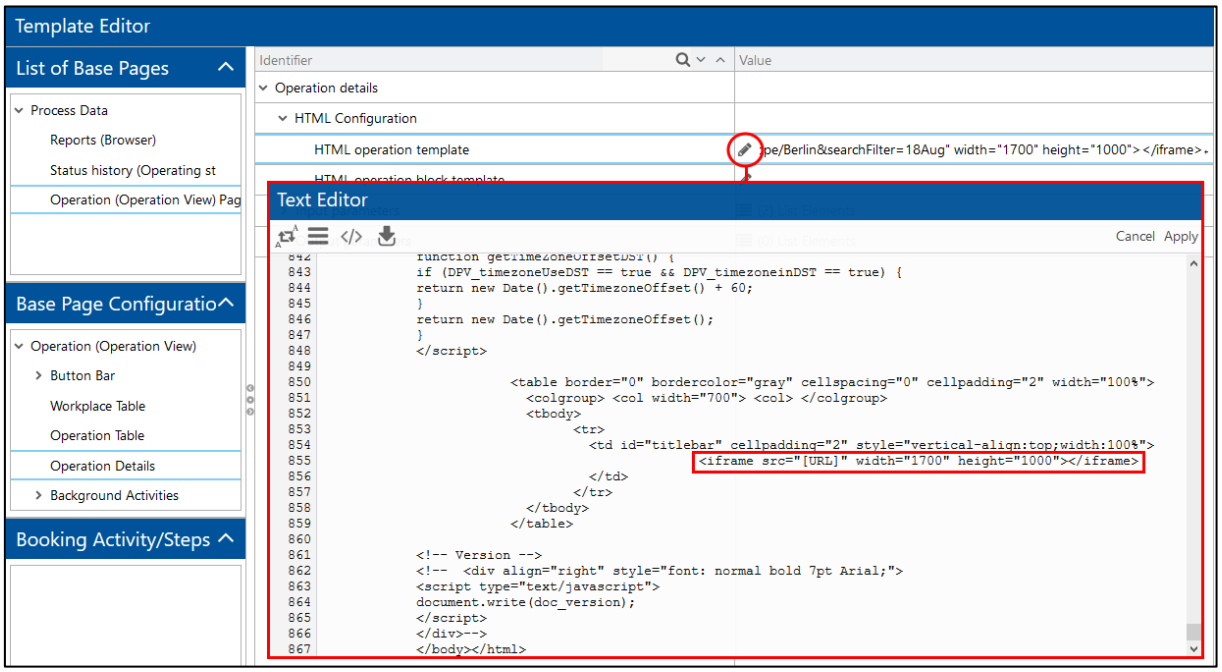


Fig. 14: iframe in the HTML template of the start page

The iframe has the following attributes:

Table 3: iframe attributes for displaying the chart in the terminal

Attribute	Description
src	URL of the trace reports to be shown (this example: process data chart). The URL must contain all the required parameters, so the report can be called-up and displayed.
Width	Width of the report in pixels
Height	Height of the report in pixels
Example	<iframe src="[URL]" width="1700" height="1000"></iframe>

3 Configuration

3.1 Energy Type Configuration

Path (Office): Track & Trace > Configuration > Energy Type Configuration

Energy types are data types that divide the energy consumption into specific classifications. There are four different classifications predefined as a default:

- Electricity consumption (kWh)
- Gas consumption (Nm³)
- Water consumption (m³)
- Compressed air consumption (Nm³)

It is possible to display or edit existing energy types. It is also possible to define your own energy types.

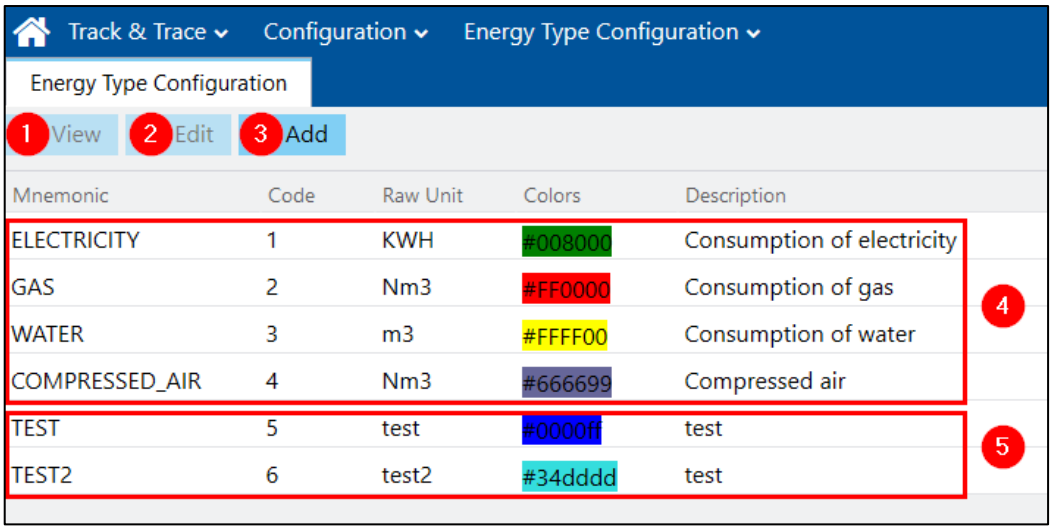


Fig. 15: Configuration page for energy types

(1) Shows the selected energy type in a follow-up window.
The data is only viewable, edits are not possible.
(2) Shows the selected energy type in a follow-up window.
Edits are possible.
(3) Adds a new energy type.
Fields depicted with a star are mandatory fields.
(4) Default energy types.
(5) Individually configurated energy types.

3.2 Signal Configuration

Any signal values from machines can be received via the DCU and written into the FORCAM FORCE™ database. These values can be used for energy analysis, among other things.
First, a signal is configured in the controller configuration. Its value is interpreted as energy consumption value in the context of energy data compression.

ⓘ See the manual **Master Data and System Configuration** for a detailed explanation of the configuration of a controller.

3.2.1 Controller Configuration

Path (Workbench): Master Data > Workplace > Workplace Configuration > Controller Configuration

The configuration of a controller can vary due to technical reasons. Below is an example workplace configuration for the controller **Welding1** with the signals **Gun Vacuum** and **HV Demand**.

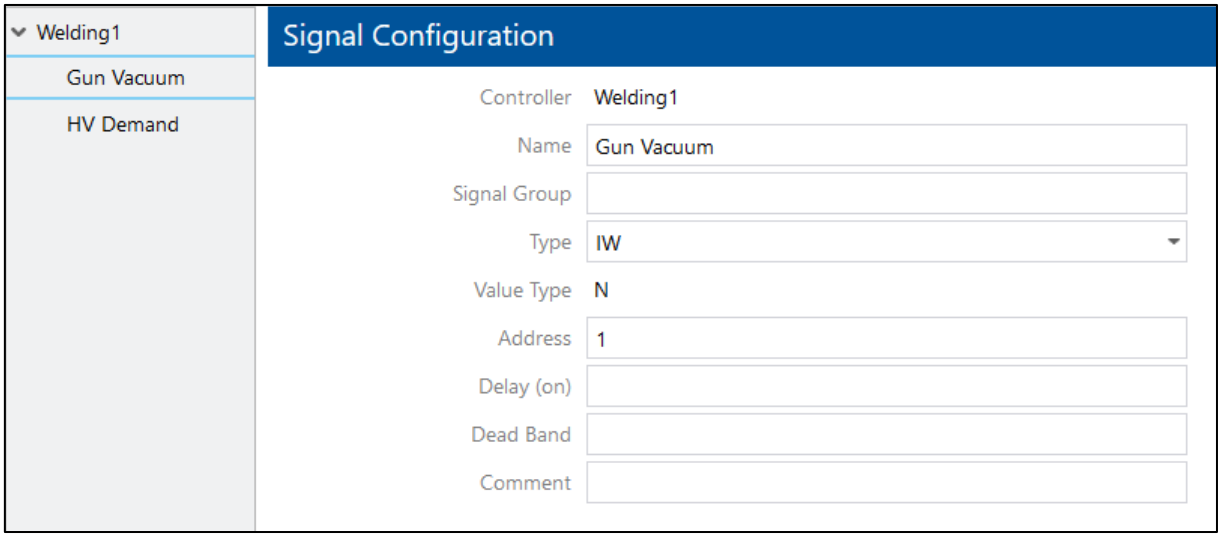
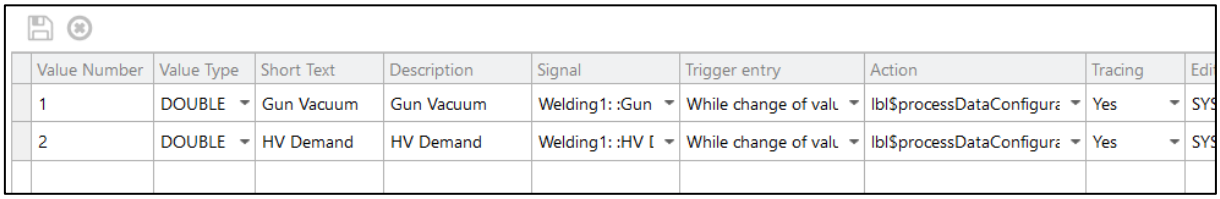


Fig. 16: Example of a configuration of signals

3.2.2 Process Data Acquisition

Path (Workbench): Master Data > Workplace > Workplace Configuration > Process Data

The configuration of the process data acquisition defines which values will be given out to the trace module.



Value Number	Value Type	Short Text	Description	Signal	Trigger entry	Action	Tracing	Edi
1	DOUBLE	Gun Vacuum	Gun Vacuum	Welding1: :Gun	While change of valu	lbl$processDataConfigura	Yes	SYS
2	DOUBLE	HV Demand	HV Demand	Welding1: :HV [	While change of valu	lbl$processDataConfigura	Yes	SYS

Fig. 17: Configuration of the process data acquisition

The following table describes the configuration parameters:

Table 4: Configuration parameters of the process data acquisition

Parameter	Description
Value number	Unique, consecutive ID number for identifying the configured process date to be forwarded to the trace module.
Value type	Type of signal value. No longer used after FORCAM FORCE™ version 5.9.
Short text	Value short text. No longer used after FORCAM FORCE™ version 5.9.
Description	Description of the value. No longer used after FORCAM FORCE™ version 5.9.
Signal	Selection of a signal that was pre-configured for this workplace. (see chapter 3.2.1)
Trigger entry	Determines what will trigger the data transfer to the Trace-module. No longer used after FORCAM FORCE™ version 5.10. – When the value is changed (every value change) – Every X minute (set cycle) – When signal X has been changed (change of a certain signal)
Action	Determines how the signal values will be stored. No longer used after FORCAM FORCE™ version 5.10. – Global configuration: Writes the current value and the signal value history to the database. – Current values: Writes only the current values to the database. – Logging the values: Writes only the signal value history to the database. – Send: Sending a value (only for FORCAM FORCE™ Version 4)
Tracing	Only relevant if Track & Trace is used: If **yes** is selected, the signal value is also written to the Trace database. No longer used after FORCAM FORCE™ version 5.10.
Editor	Additional metadata
Created	

Parameter	Description
Changed	

Each defined signal value is automatically available as a formula in the visualization. All values can be found under the name space **PR_VALUE** and entered in every visualization.

ⓘ To configure a visualization, see the manual **Performance Data**.

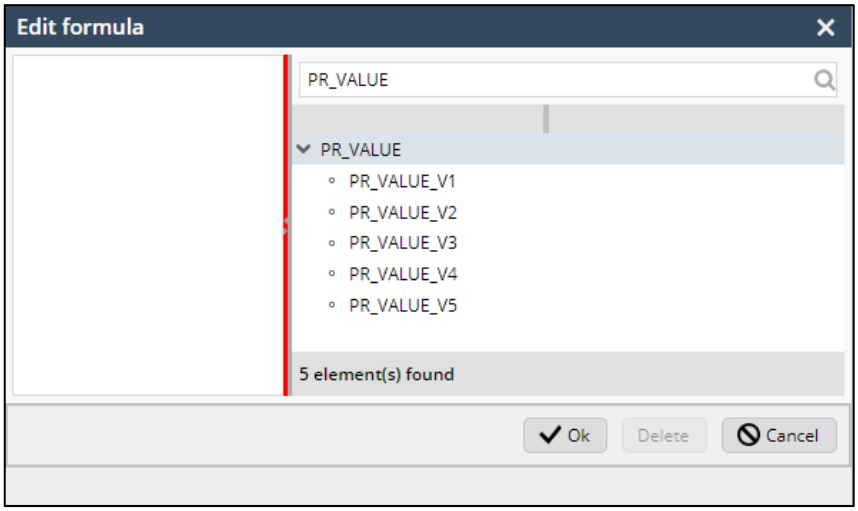


Fig. 18: Signal values as formulas in the visualization

3.3 Process Data

Process data are certain process values continuously generated and collected (24/7), such as temperature or pressure.

FORCAM FORCE™ uses these generated process data in its **Track & Trace** module. Based on a specific trigger, the Track & Trace module (=trace data) simultaneously collects process data. Trace data directly refer to certain trace objects (e.g. single pieces with a serial number). Trace data also has a reference to other process data from the same data entry point (DEP). A specific trace object and time are the basis for the relationship.

Other than trace data, pure process data are independent values. They do not interface with Trace objects. Process data are also not connected to other process data, except via time interface. Meaning different data occur and are captured simultaneously, however, they do not influence each other.

Example:
The Trace data capturing captures the following data:

- Piece 1
  - Serial number: S147
  - Temperature: 45.89
  - Pressure: 223.6
- Piece 2
  - Serial number: S186
  - Temperature: 67.8
  - Pressure: 376.1

Here, the values are referenced directly to a piece. The values are in this relation to each other: This temperature value and this pressure value occurred to produce the piece with this serial number.

The process data acquisition collects the following data:

- Temperature:
  - 45.56
  - 45.89
  - 67.8
  - 67.4
  - 23.7
- Pressure:
  - 200.1
  - 223.6
  - 245.8
  - 256.4
  - 342.8
  - 376.1

The values for temperature and pressure are not related in any way. These process data have no relation to each other, whether between each other, nor to a certain piece.

3.3.1 Data Capturing Point

Path (Office): Track & Trace > Configuration > Virtual Process Image

A data capturing point (DCP) describes the structure of the process data. With Trace data, the DCP describes a „data package" of related process data that describe a technical procedure (e.g. welding procedure). Since the workplace carries out and captures more than one technical procedure, there can be more than one DCP, such as welding, drilling, milling.

When creating a new DCP, the system prompts an initial inquiry about the requested data capturing. The energy analysis references the type **process data capturing (24/7)**.

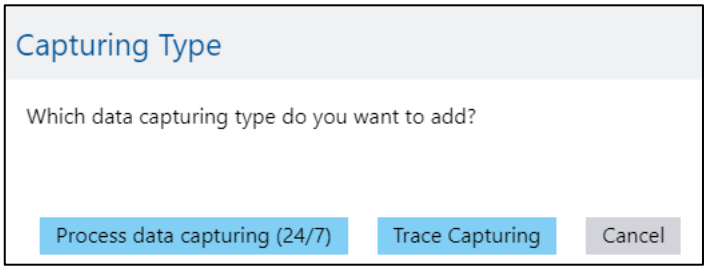


Fig. 19: Selecting the capturing type

The following table summarizes all the configuration parameters of a DCP.

Table5: Configuration parameters of a data capturing point

Parameter	Explanation
ID	ID of the DCP. This is automatically generated and cannot be edited.
Name	Name of the DCP
Workplace	Selection of the workplace for which the DCP is to be configurated
Description	Description of the DCP
Literal	Defines how the value of a report will be displayed
Data capturing point type	Type of capturing that was pre-selected
Machine type	All structurally identical DCPs are combined into one machine type. For example: A welding robot compiles all welding robots of several workstations. A machine type should have a fixed structure, both syntax and semantics of the data are important. In the example in section 3.3, the first process data element is a temperature with a data type **Double** (= floating point number).
External capturing point name	Name of a DCP (or "data package") from an external application. Only relevant if the data are captured via the Trace Exchange Interface, CAQ, or a Web Service Interface.
Deactivated	Checking this option deactivates the DCP.
Region schematic	Only relevant if the DCU delivers the data as a data string and will be converted to another data type (e.g. Double). In this case, the region schematic determines the data string region format (German, English etc.).
External capturing point?	Activates or deactivates the input field for defining the external capturing point name.

3.3.2 Adding a Process Data Element

Process data element tab

A process data element (PDE) is part of a DEP. A PDE is often assigned to a signal of a controller. However, if an external application is to capture the PDE, it is possible to assign it to an external acquisition element. It is also possible to manually enter the value of a PDE via a dialog in the Shop Floor Terminal, so that neither an assignment to a signal nor to an external acquisition element name is necessary.

The following table summarizes all the configuration parameters of a PDE:

Table 6: Configuration parameter of a process data element

Parameter	Explanation
Object type	Defines the type and processing of the PDE
ID	ID of the PDE. This is automatically issued and cannot be edited.
Name	Name of the PDE
Description	Description of the PDE
Workplace	Selection of the workplace for which the PDE will be configured
Literal	Defines how the PDE will be displayed in a report
Data type	With process data acquisition (24/7), and particularly energy data processing, the data type for a PDE must be numerical (long, integer, etc.). The reason for this limitation is that, principally, aggregation of non-numeric values or their visualization in a line diagram is unsuitable.
Signal	The signal from the DCU
Data conversion	Defines whether a data conversion is to take place, such as from String to Double. This is not relevant for process data acquisition.
Data type pattern	Defines the pattern for the data type conversion if the delivered value of a PDE (e.g. character string) is to be converted into a numerical value. See **docs.oracle.com** for a detailed description of the possible translation patterns.
Signal mode	Type of value where the signal is to be displayed: – Absolute value: The values are absolute values and are stored as such. – Incremental value: The values are stored as [previous value + current value] when a new value comes in.
External acquisition element name	Name of a PDE (or “data packet element”) from an external application. Only relevant if capturing data via the Trace Exchange Interface, CAQ, or a Web Service Interface.
Timestamp	Specifies that this value will show up in a report as a timestamp, which indicates the DEP recording time of the process data. This is necessary because there can be several timestamps in a DEP; and in the upstream search, only one timestamp from the DEP should show for a process date (e.g. temperature).

Parameter	Explanation
Timestamp format	Format of the timestamp (e.g. hh:mm:ss). This is necessary for calculating a timestamp from a character string.
Seconds until data expires	If a Trace type DEP is captured, it will contain a definition of a trigger that describes the DEP resolve time and then forwarded as a "data packet" to the update unit of the trace module for further processing. The Trace module can also process these data packages later. The value configured here specifies the number of seconds after which such a data packet should not post-process.
Deactivated	Checking this option deactivates the PDE.
Colors	Determines the standard colors with which these process data are displayed in the report. The predetermined colors from the energy type configuration are used to visualize the energy data reports. (see chapter 3.1)
Limit value violation rule	Determines which value is a limit value and what shall occur when the limit value is reached. (see chapter 3.3.2.1)
Energy value aggregation	The option to additionally aggregate these process data as energy data. (see chapter 3.4)

Tab Energy Value Aggregation

Table 7: Configuration parameter of energy value aggregation

Parameter	Explanation
Energy value	Checking this option, additionally processes the PDE as an energy value. This means, a process date is stored in the database, and as result of this, it owns full functionality (e.g. visualization, violation rule, etc.).
Aggregation column	Selection of an energy type (see chapter 3.1)
CO_2-Equivalent	The equivalents are determined from the raw value by multiplying it with a configurable factor. Example: An electricity consumption of 25 kWh is converted with a factor of 0.527 in kg CO_2. The result is a CO_2-equivalent of 13 kg CO_2. Parallel to converting the energy raw value into a CO_2-equivalent, the raw value can be converted with another factor into a monetary value (costs) or kWh-equivalent.
Cost converter	
kWh Equivalent	

3.3.2.1 Limit Value Violation Rule

Any number of limit value violation rules can be created for a data entry point. In doing so, it determines a value to compare with the value of the DEP. It is possible to configure sending a notification when a limit value has exceeded an upper/lower limit.

The following table summarizes all the configuration parameters of a violation rule:

Table 8: Configuration parameters of a limit value violation rule

Parameter	Explanation
ID	ID of the rule. This is automatically given and cannot be edited. The ID is only exclusive to this DEP.
Name	Name of the rule. This shows up in the lower part of the configuration page of a PDE. (see Table 6)
Version	Rules are revised. Hence, new versions are created to comprehend or reproduce when a condition of a certain upper/lower limit was active.
Colors	Each rule has a standard color used for displaying in a report.
Violation level	Each rule can have one of the violation levels listed below. Use the level together with the priority to filter messages to the SFT for example. – Info – Success message – Warning – Error
Priority	Each rule can have one of the priorities listed below. Use the priority together with the level to filter messages to the SFT for example. – Blocker – Critical – Serious
Range	Determines the comparison operator with which the current or new process data value compares with the set signal value entered below (e.g. process data value = signal value, process data value > signal value, etc.).
Signal value	Entering a signal value for comparing the current or new process data value (see above explanation).
SFT-message	Determines what happens after a limit value violation occurs. This option sends a corresponding notification to the SFT or per email (or both). Additional configurations are required to receive the notification at the SFT. (see chapter 3.3.2.2).
Email-message	
Time between messages (in minutes)	Violation rules are reviewed whenever capturing process data values. The time between two messages can be configured to prevent the same message from sending over and over in a short time span. Then, if a new violation occurs shortly after receiving a message, the second message is suppressed until this configured time expires. The suppressed message is not sent. A new message will be sent only after the next limit value violation.
Usable wildcards in email subject line and text	Wildcards for a message text. In the actual message, the wildcards are replaced with corresponding values. Example text: „The current value **$actualValue$** on workplace **$workplaceName$** has exceeded the limit value **$upperBound$**.”

Parameter	Explanation
Recipient	Determines the recipient of the email message. Email groups and users are added in the system configuration (see the manual Performance Analysis). Email addresses are entered directly.
Subject	Email subject line
Text	Email text
Deactivated	Checking this deactivates the violation rule.

3.3.2.2 Receiving Messages on the Shop Floor Terminal

Path (Workbench): Master Data > Workplace Configuration > Template Configuration > Message Parameter

The Shop Floor Terminal can display messages of a limit value violation. This requires configuring the activity step **Show terminal message on status bar**. This step displays the message of the rule as a pop-up dialog. It is also possible to display the message in the status bar of the terminal.
The step obtains all output information of the violation rule as input parameters.

Table 9: Configuring the activity step „Show terminal message on status bar"

Designator	Value	Explanation
Input parameter	Parameter (EVERY) → Terminal message source (EVERY)	
Input parameter	Parameter 2 (EVERY) → Terminal message event type (EVERY)	
Input parameter	Parameter 3 (EVERY) → Terminal message priority (EVERY)	
Input parameter	Parameter 4 (EVERY) → Literal key for short text (EVERY)	
Input parameter	Parameter 5 (EVERY) → Literal key for long text (EVERY)	
Input parameter	Parameter 6 (EVERY) → Parameters for short text (EVERY)	
Input parameter	Parameter 7 (EVERY) → Parameters for long text (EVERY)	
Show messages on local message bar		Check this to display a message on the status line of the terminal.
Sources	Trace	The step filters to the sources Trace, DACQ, and runtime. The source Trace is set to the violation rule.

Designator	Value	Explanation
Message types	– Success message – Error – Info – Warning	Only these selected message types will show up. All message types selected in the violation rule must also be selected here for them to show up in the display.
Priorities	– Blocker – Critical – Serious	Only the messages with these selected priorities are shown. All priorities selected in the violation rule must also be selected here for them to show up.
Time value for auto close [ms]	5000 (Standard)	When a message is received, the pop-up dialog opens automatically. The dialog stays open for the time (ms) specified here.

3.4 Energy Aggregation Service

Process data values are received in reoccurring time ranges. The energy aggregation service (EAS) processes a time range that comprises several timestamps and process data values.
During the first aggregation cycle, the EAS generates energy slots that calculate the energy distribution. These slots are then further broken down for each workplace to process timelines and workplace timelines.

3.4.1 Distributing the Energy Consumption Values to Time Ranges

In the following figure, time ranges with a maximum length of 5 minutes are displayed. The time ranges can be shorter if the workplace status changes or a new energy consumption value is received from the machine or the energy measuring unit.
The green bar shows the consolidated energy consumption values of a workplace.
The orange colored bar shows what takes place during a “Recoding”. Recoding means a re-calculation/aggregation of energy consumption values for previously captured values.

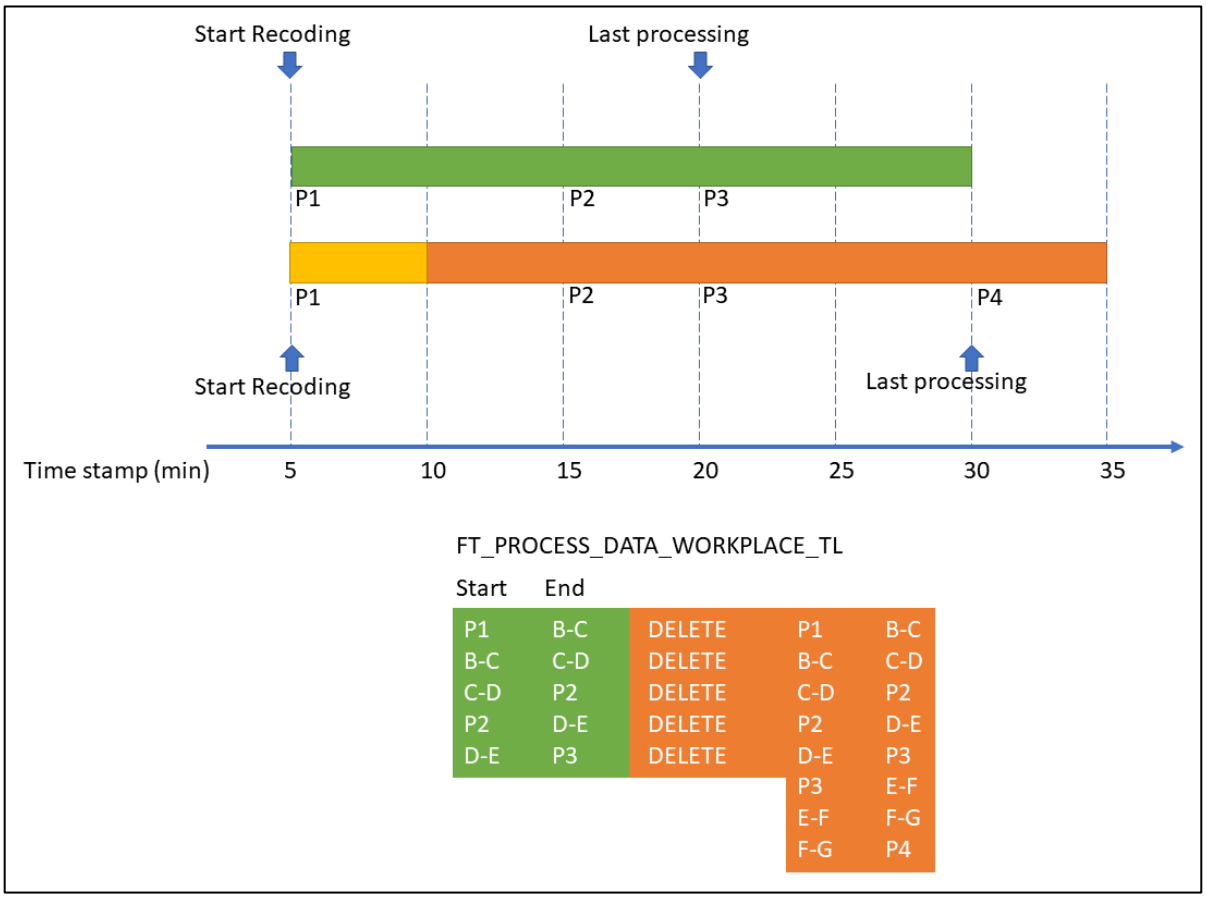


Fig. 20: EAS Recoding

The EAS finds the process data values P1, P2, and P3 for this time range in the process data collection of the MongoDB. They are recorded as normal process data here. In this example, P1, P2, and P3 are values for electrical consumption. These values are absolute values of an energy measuring device that increases strictly monotone. P1, P2, and P3 all lie between the timestamps.

Now, the following energy slots are generated as an example:
P1 to B-C, that means a time range from timestamp P1 to timestamp B-C.
The energy consumption with the amount P2-P1 distributes to the following time slots:
P1 to B-C, B-C to C-D, and C-D to P2.

In the second energy aggregation cycle (orange colored column), the process data values P1, P2, P3, and P4 are processed. Adding the value P1 covers a minimum time span of 60 minutes. The delete/input principle is the basis for the energy aggregation cycle. That means, the timelines P1 to P3 are deleted, and the timelines P1 to P4 are newly created.

Recoding is necessary because the status of the machine timeline or the operation timeline may have changed. For example, a worker can recode an unfounded standstill to indicate the actual reason for the standstill. A standstill can also be split into different times for specifying other status details.

The goal of the EAS is to correctly distribute the energy consumption values to the individual workplace phases or work process phases. Only this aggregation and distribution of the energy consumption values enables targeted and concise reports.

3.4.2 Distributing the Energy Consumption Values to Several Work Procedures

The following figure shows an example of the distribution of a workplace's energy values to several parallel running production orders.

Assuming that every 5 minutes, 100 kWh are to be distributed. Thus, the workplace (or the machines associated with the workplace in FORCAM FORCE™) consumes 100 kWh of electrical energy every 5 minutes. This energy consumption distributes among the active operations of the registered production orders per energy data slot, a maximum of 5 minutes long. The intention is to distribute the energy consumption according to the source of consumption.

Energy consumption values are only distributed to an operation/production order if the corresponding operation is in an active phase. For example, an operation in the **setup** phase does not consume energy until it is in an active phase (usually **production**).
If no active work processes in a time slot, the energy consumption records anonymously - i.e. without reference to a production order at the workplace.

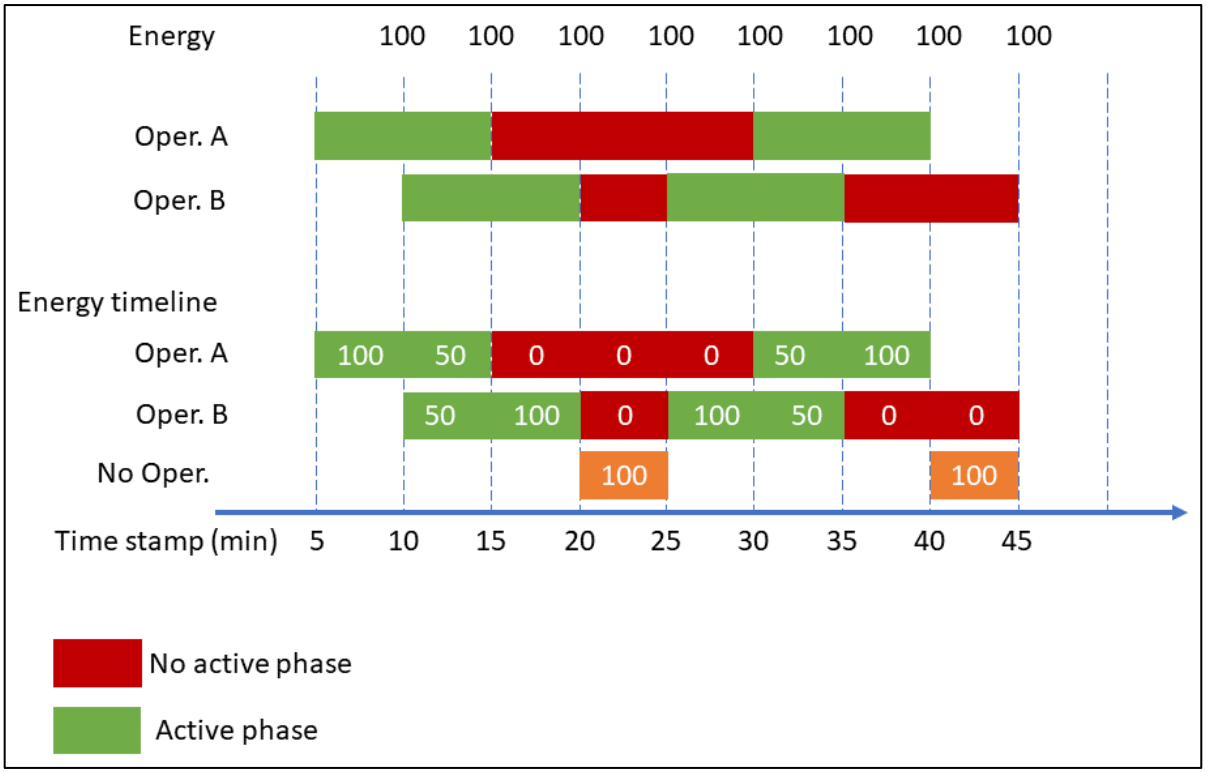


Fig. 21: Distributing the energy consumption values to several processes

3.4.3 Aggregating Energy Consumption Values of a Machine Line

In some production processes, components are manufactured on machine lines. FORCAM FORCE™ models a machine line with its own workplace that represents the machine line. The participants of the machine line are also modeled as workplaces and assigned to a common workstation hierarchy.

The energy consumption values are distributed to the individual workplaces as described before. Additionally, the sum of the energy consumption values of each workplace allocates to that workplace that represents the machine line.

3.4.4 Deactivating / Activating EAS

Path (Workbench): Configurations > System > FORCAM FORCE™ > Configurations > Modules > Tracing > Energy aggregation

The energy aggregation service is activated or deactivated in the workbench. The calculation of the EAS is the basis for aggregation. As a default, the calculation runs every 5 minutes, whereby the values of the last hour are calculated.

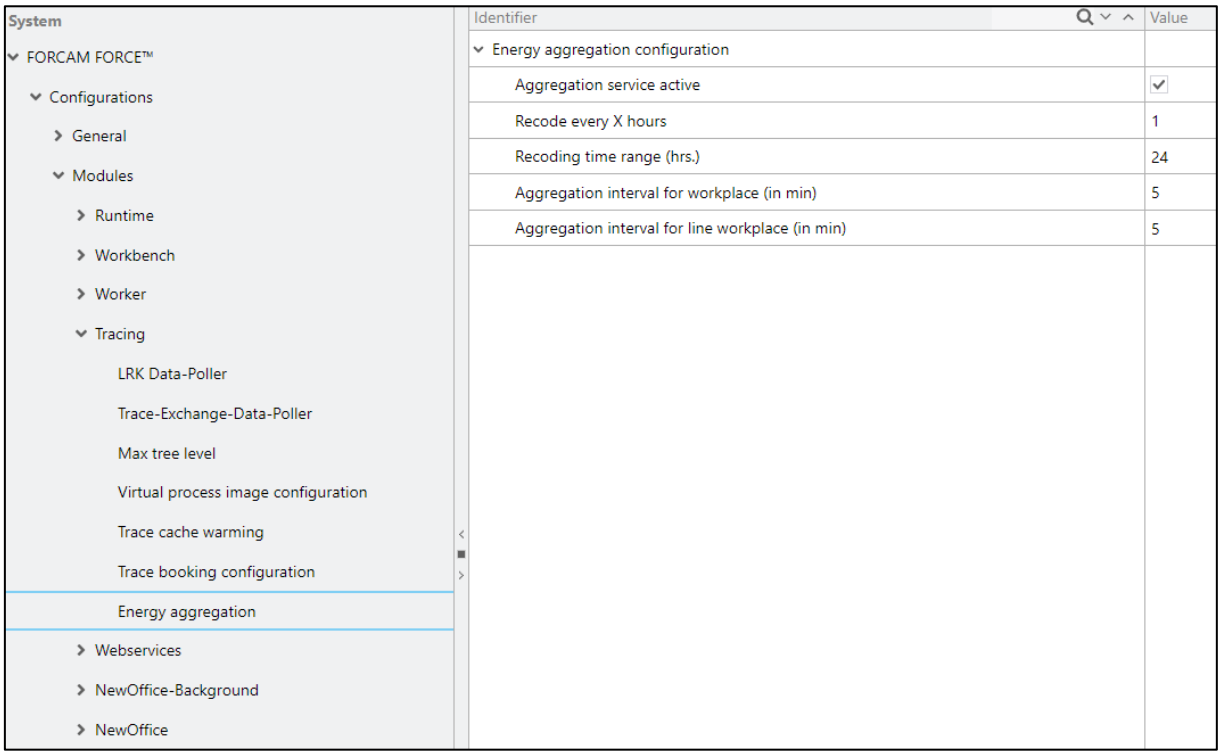


Fig. 22: Configuration of energy aggregation in the workbench

Table 10: Configuration parameter of the energy aggregation service

Parameter	Explanation
Aggregation service active	Checking this activates the EAS.
Recode every X hours	Determines the time interval in hours after which the values are to be recoded (default = 1). This means that usually the last 24 hours are calculated hourly.
Time range for recoding (hrs.)	Determines the time range to be recoded in hours (default = 24)
Aggregation interval for workplace (minutes)	Determines the time, after how many minutes the distribution of the new energy consumption values since the last distribution for a single workplace takes place.
Aggregation interval for line workplace (minutes)	Determines the time, after how many minutes the distribution of the new energy consumption values since the last distribution for a line workplace takes place.

3.4.5 Aggregation of Line Workplaces

Path (Workbench): Master Data > Workplace Configuration > Workplace Hierarchy

The EAS can calculate the energy consumption of line workplaces. The line workplace itself has no energy consumption because it is a virtual workplace that doesn't exist physically. It merely represents the line as a unit.
Aggregating a line workplace adds up each workplace consumption of the line. The sum of all consumption values for the individual workplaces calculates as the consumption of the line.

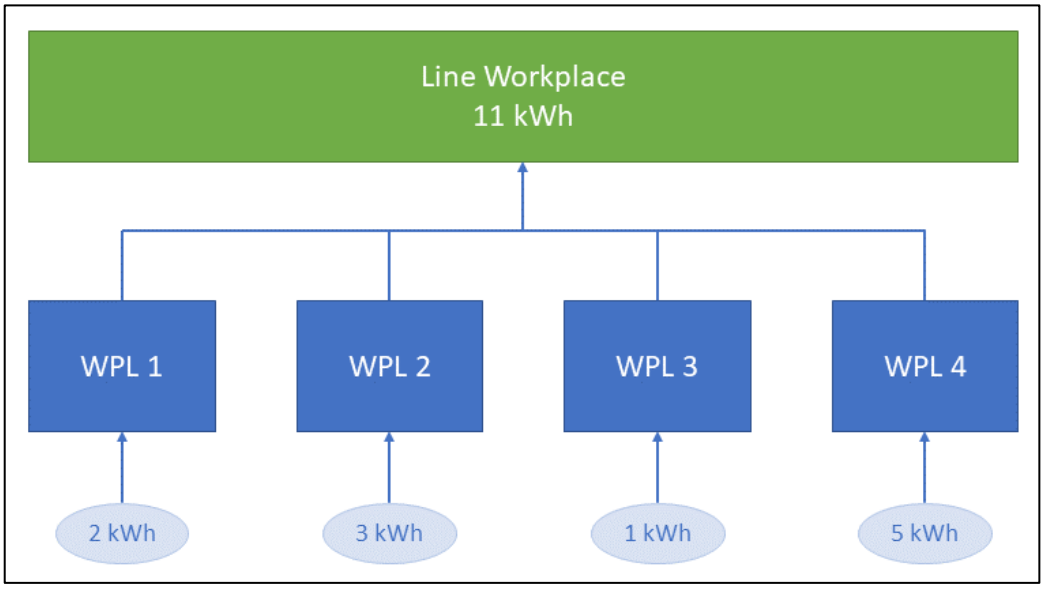


Fig. 23: Aggregation at a line workplace

To enable the calculation of a workplace timeline or process timeline, it must first be defined as a workplace in the workplace hierarchy.

ⓘ More information on configuring a workplace or a hierarchy is in the manual **Master Data and System Configuration**.

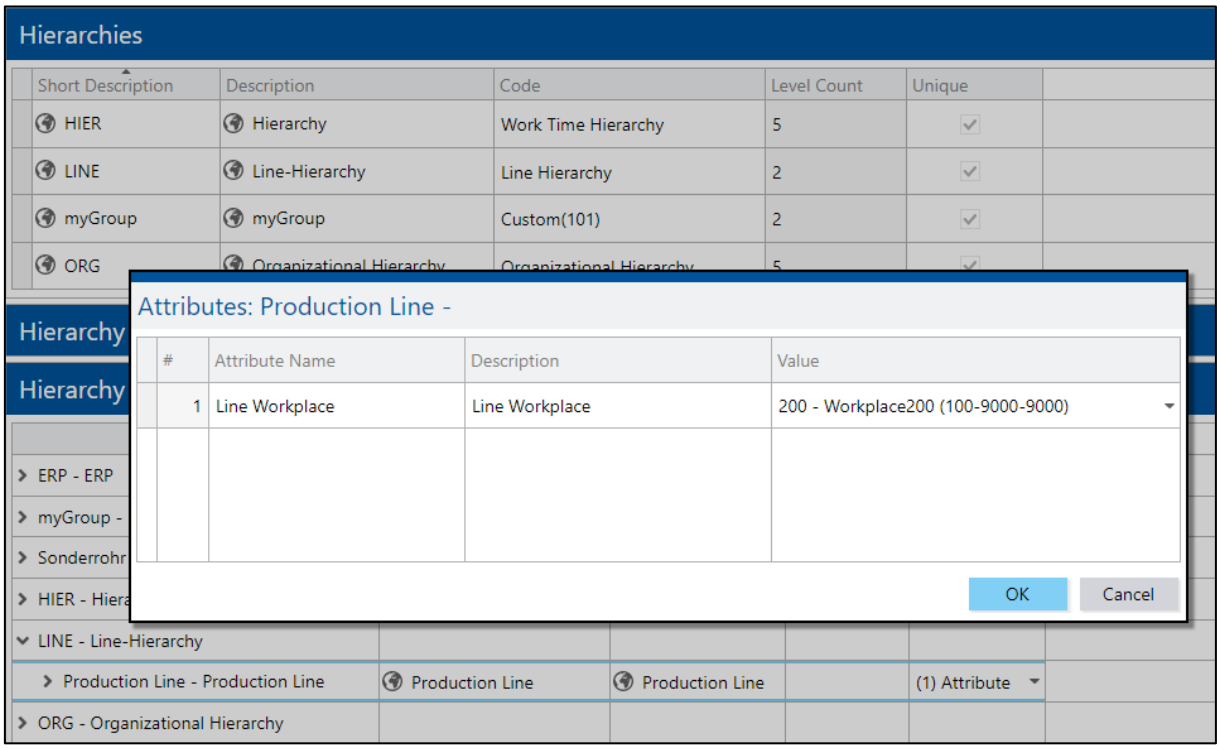


Fig. 24: Configuration of a line hierarchy

4 Appendix

4.1 Abbreviations

Table 11: Abbreviations used

Abbreviation	Description
WPL	Workplace
CO_2	Carbon dioxide
DB	Database
DCU	Data collection unit
DEP	Data entry point
EAS	Energy aggregation service
kWh	Kilowatt hour
m^3	Cubic meter
ms	Milliseconds
Nm^3	Normal cubic meter
PDE	Process data element
SPS (PLC)	Programmable logic controller
SFT	Shop floor terminal

4.2 Table of Figures