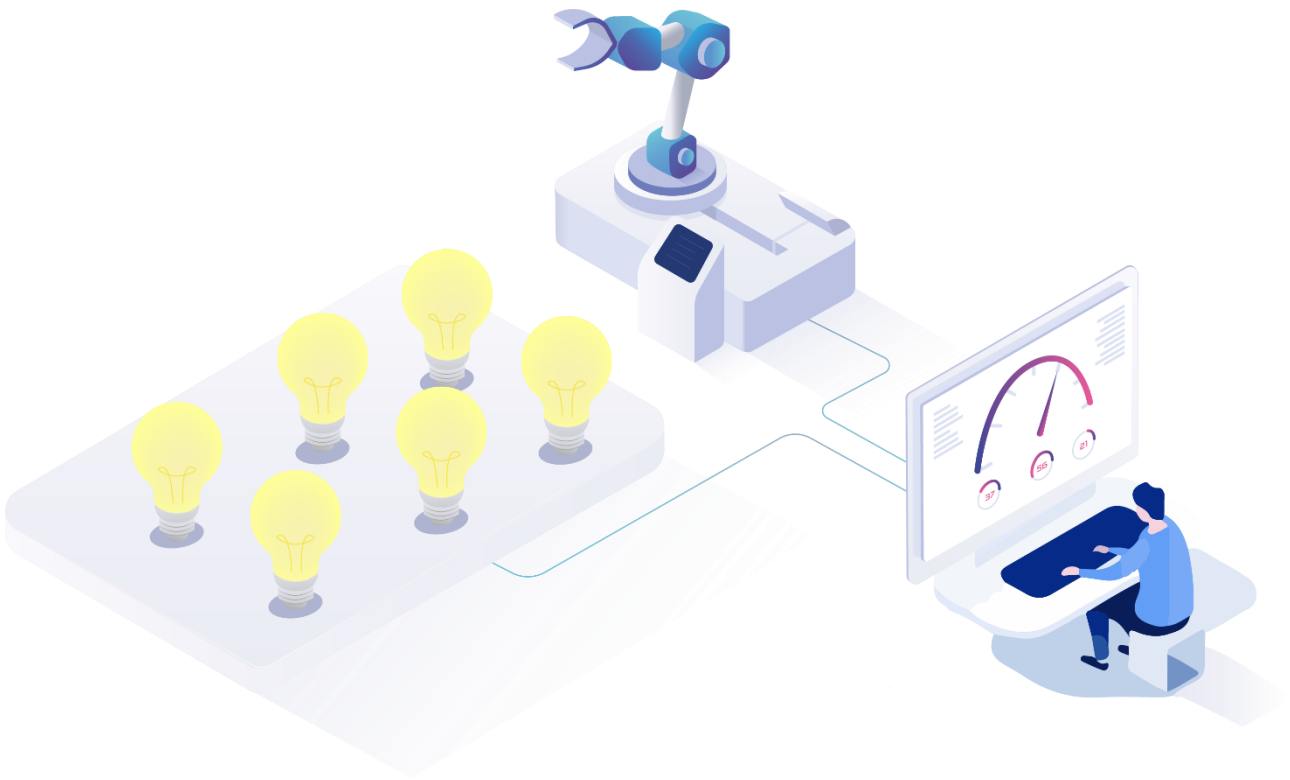
FORCAM FORCE



Energy Analysis

Version 5.12

Manual

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Content

1 Concept

FORCAM FORCE IIOT 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.

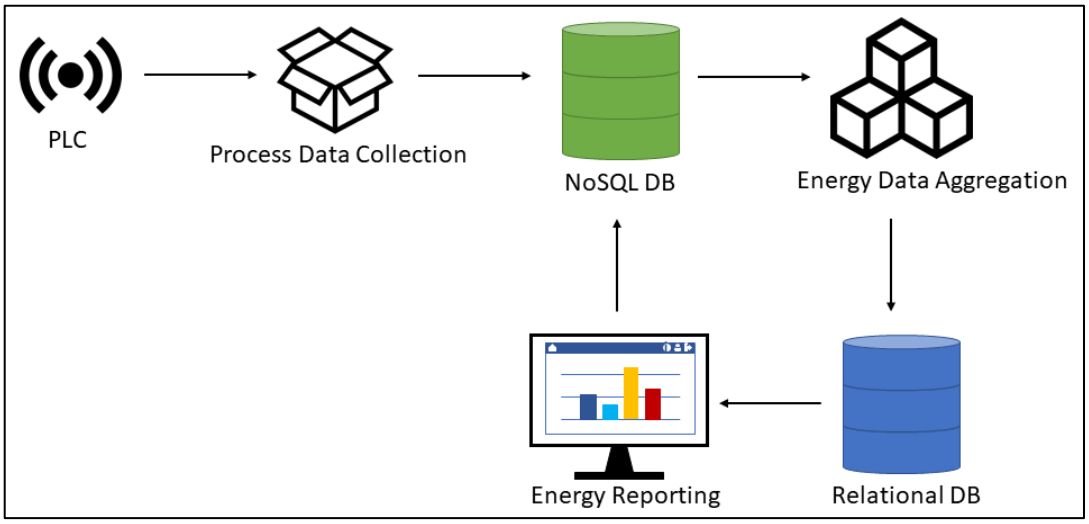

Fig. 1: Simple architecture of the energy analysis process

2 Reports

FORCAM FORCE IIOT 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

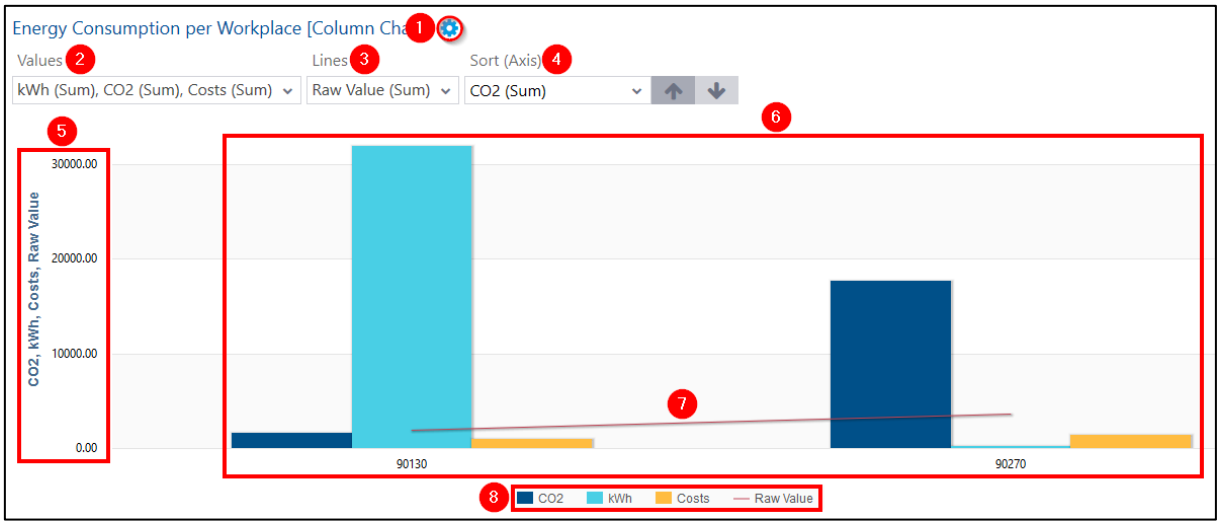

Fig. 2: Energy consumption per workplace displayed as a column diagram

(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.

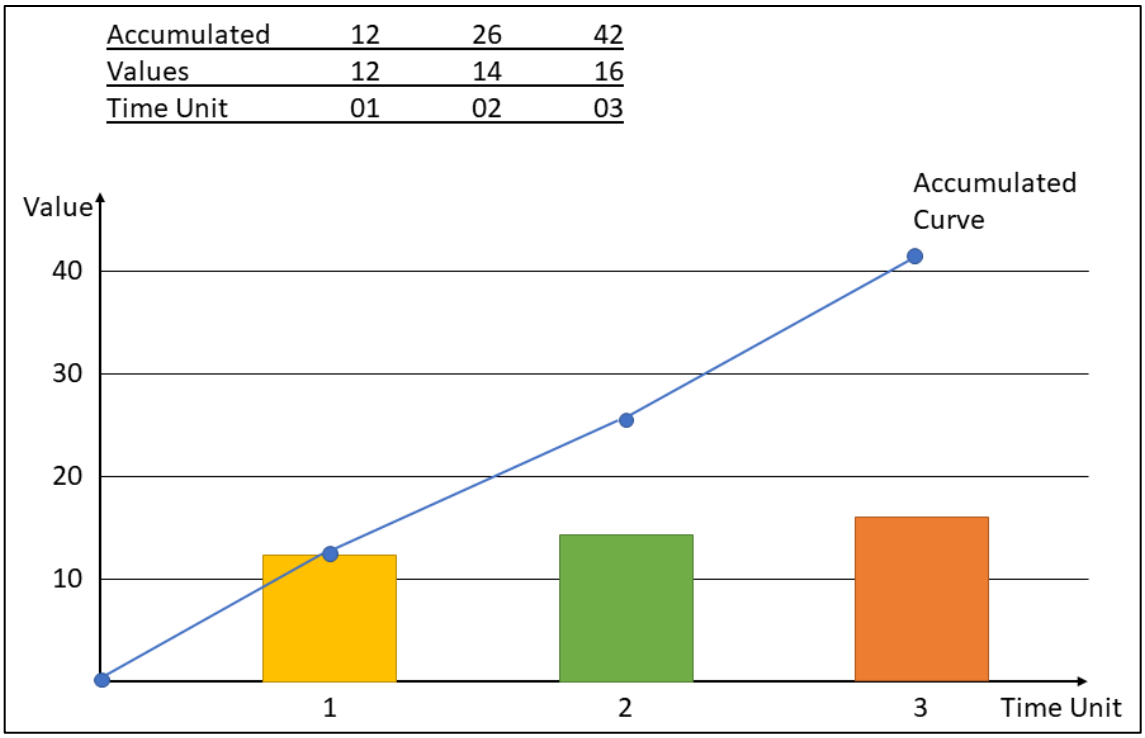

Fig. 4: Cumulation concept

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

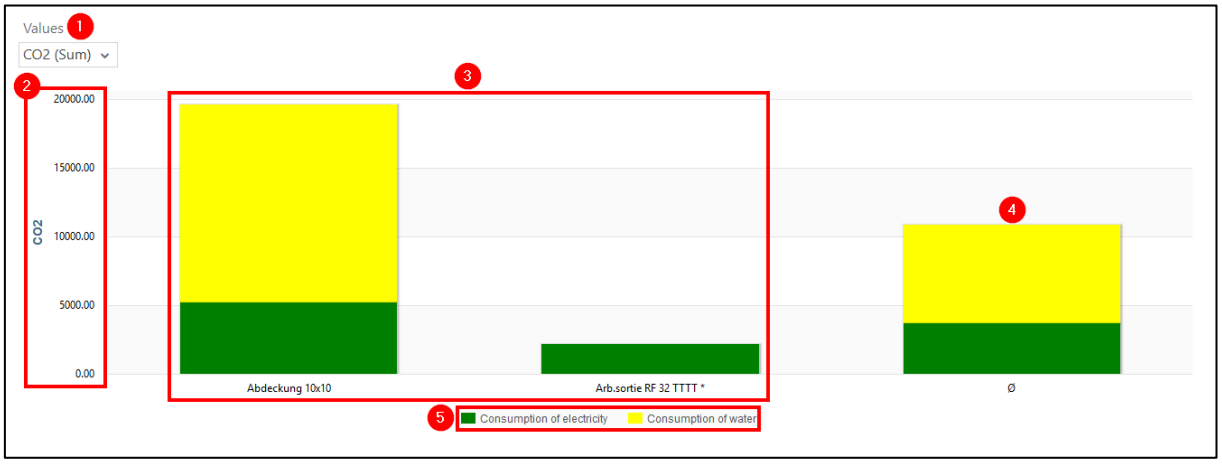

Fig. 5: Energy consumption per material displayed as a column diagram

(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

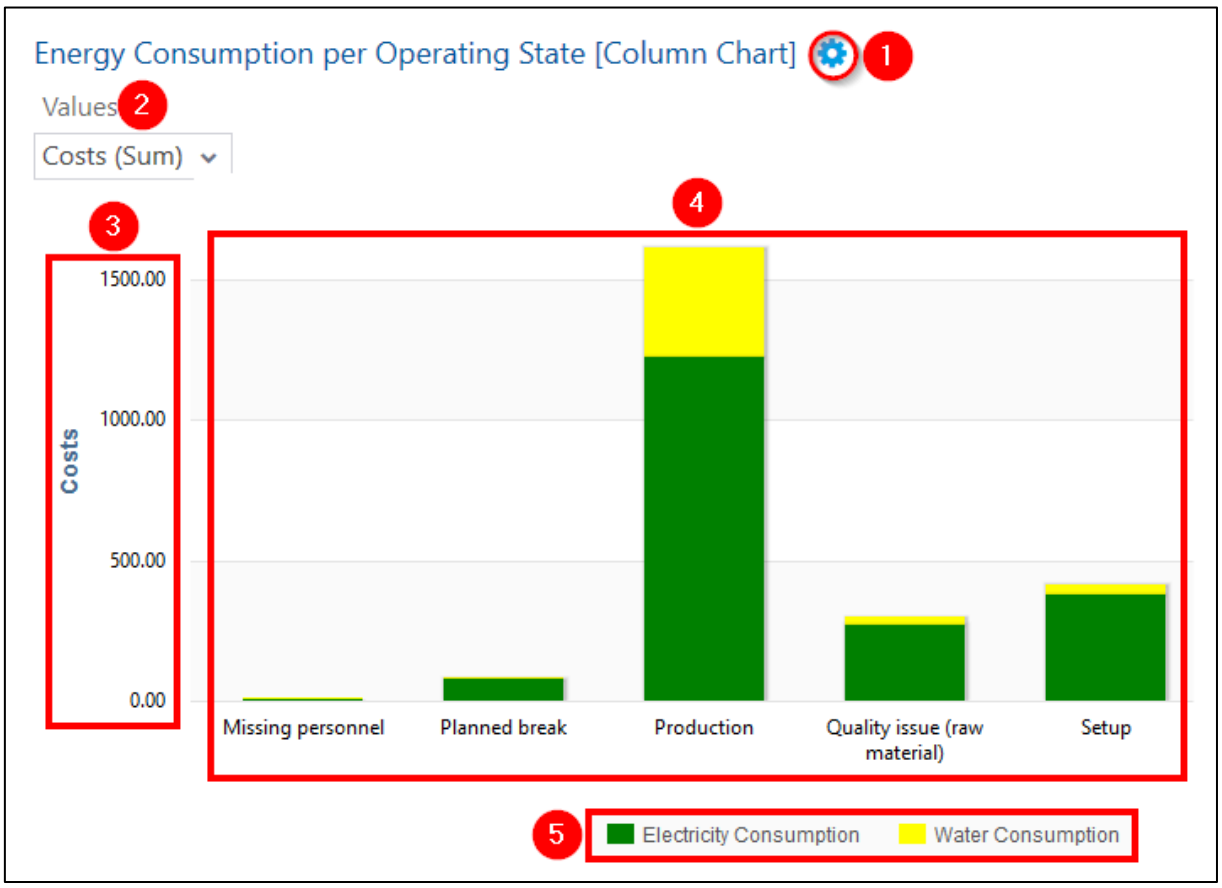

Fig. 7: Energy consumption per operating state as a column diagram

(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

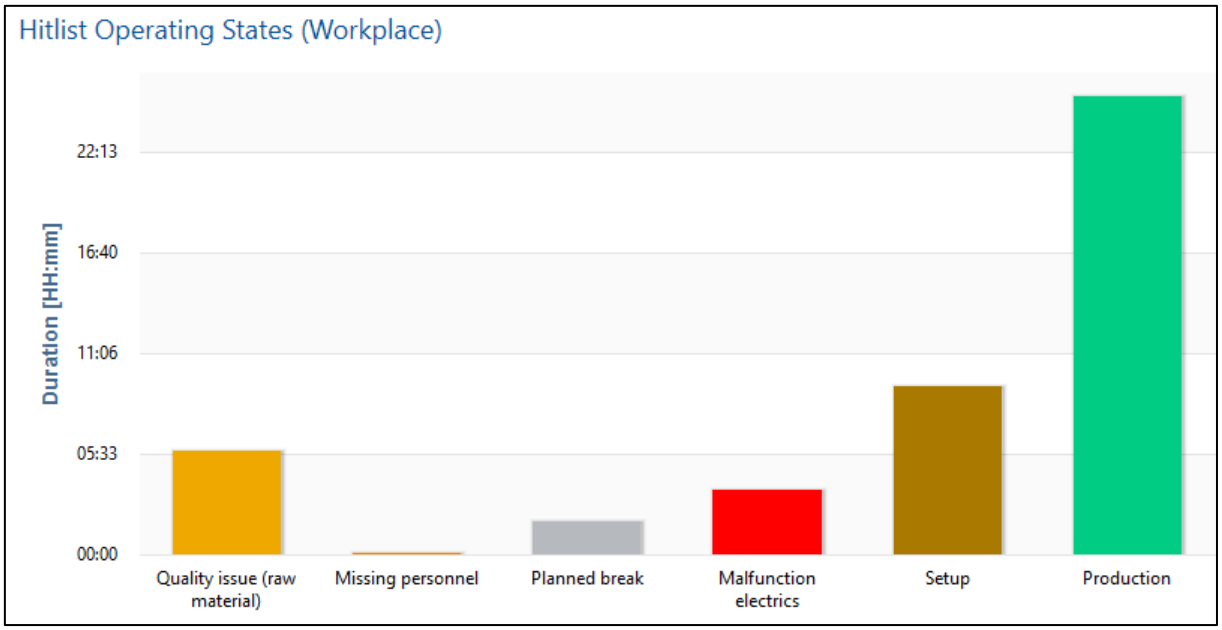

Fig. 8: Energy consumption per operating state displayed as a hitlist

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

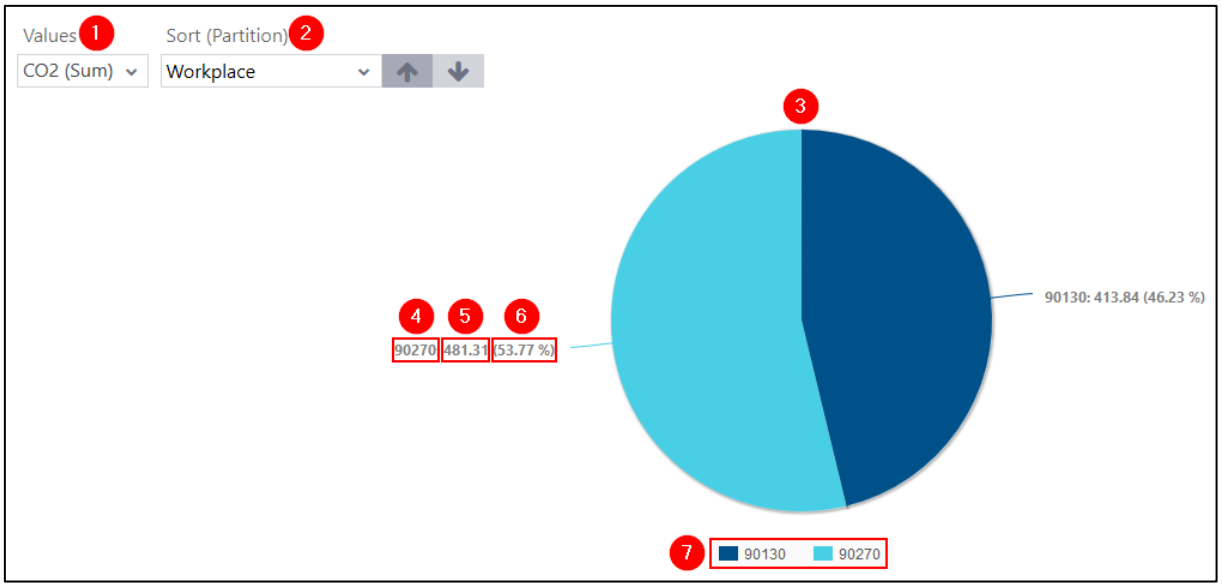

Fig. 9: High consumption workplaces displayed as pie chart

(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 Nm^3 CO2. **90270** has a consumption of 481.31 Nm^3, 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.

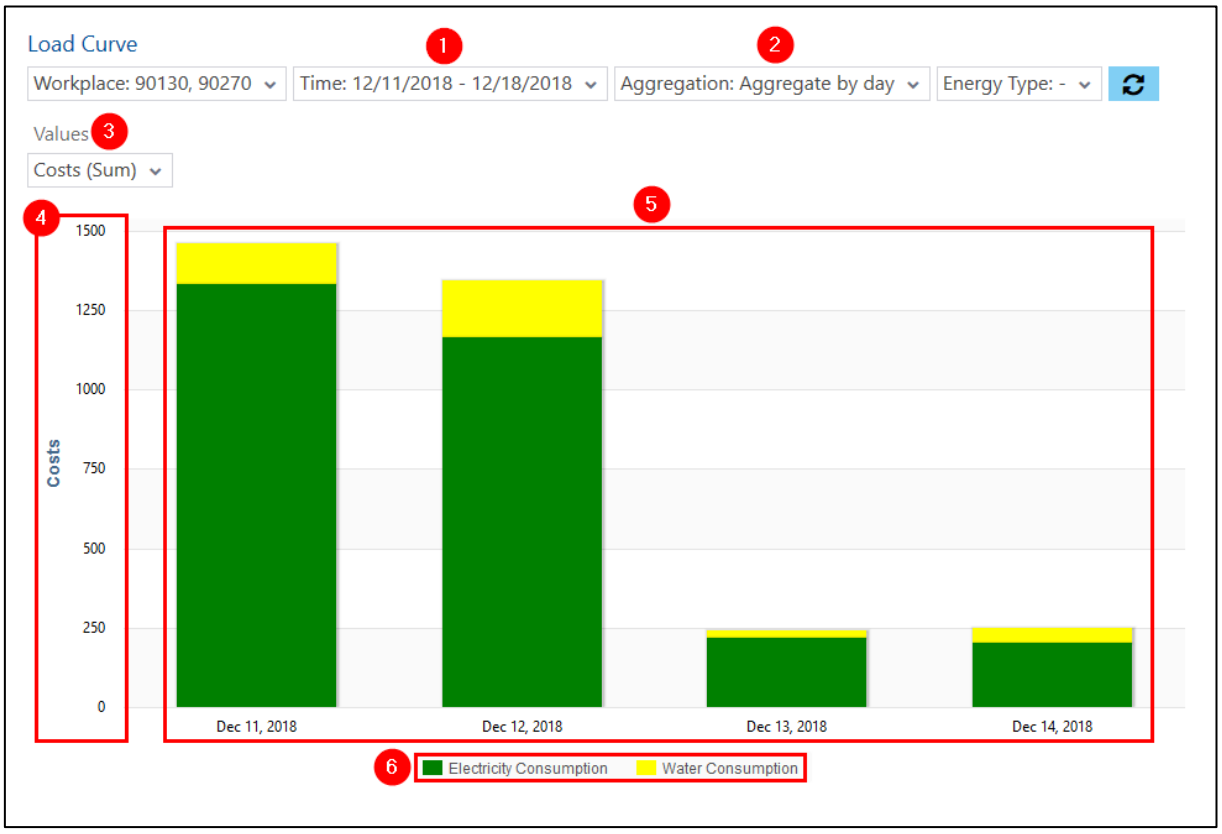

Fig. 11: Load curve

(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.

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 (Nm^3)
- Water consumption (m^3)
- Compressed air consumption (Nm^3)

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

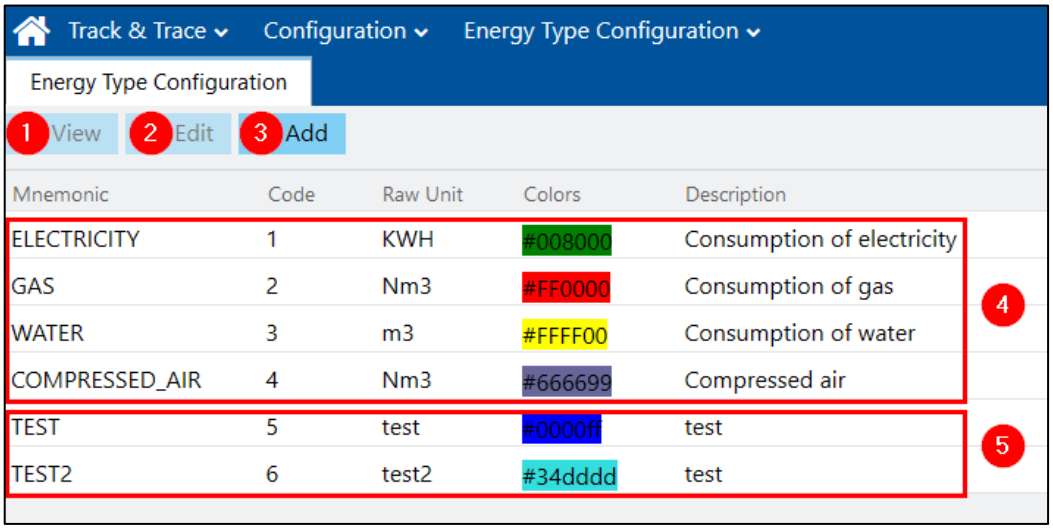

Fig. 12: Configuration page for energy types

(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 IIOT 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.

3.3 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**.

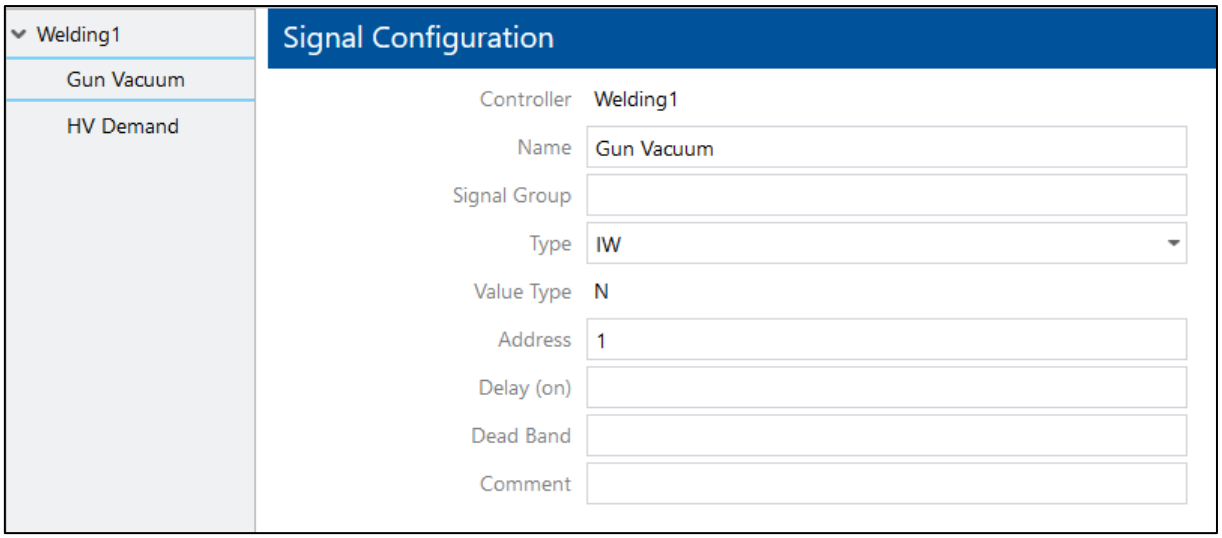

Fig. 13: Example of a configuration of signals

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.

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.

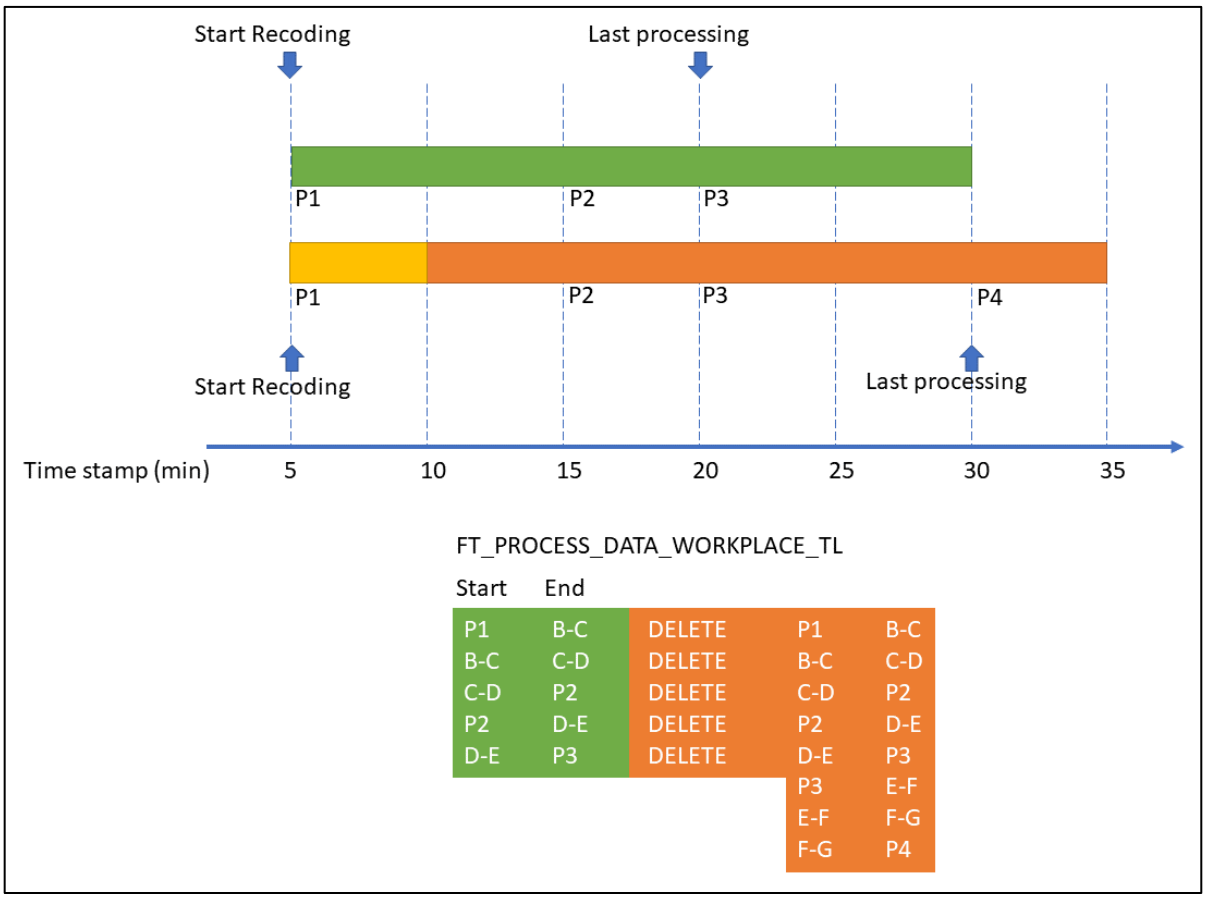

Fig. 14: EAS Recoding

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.

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.

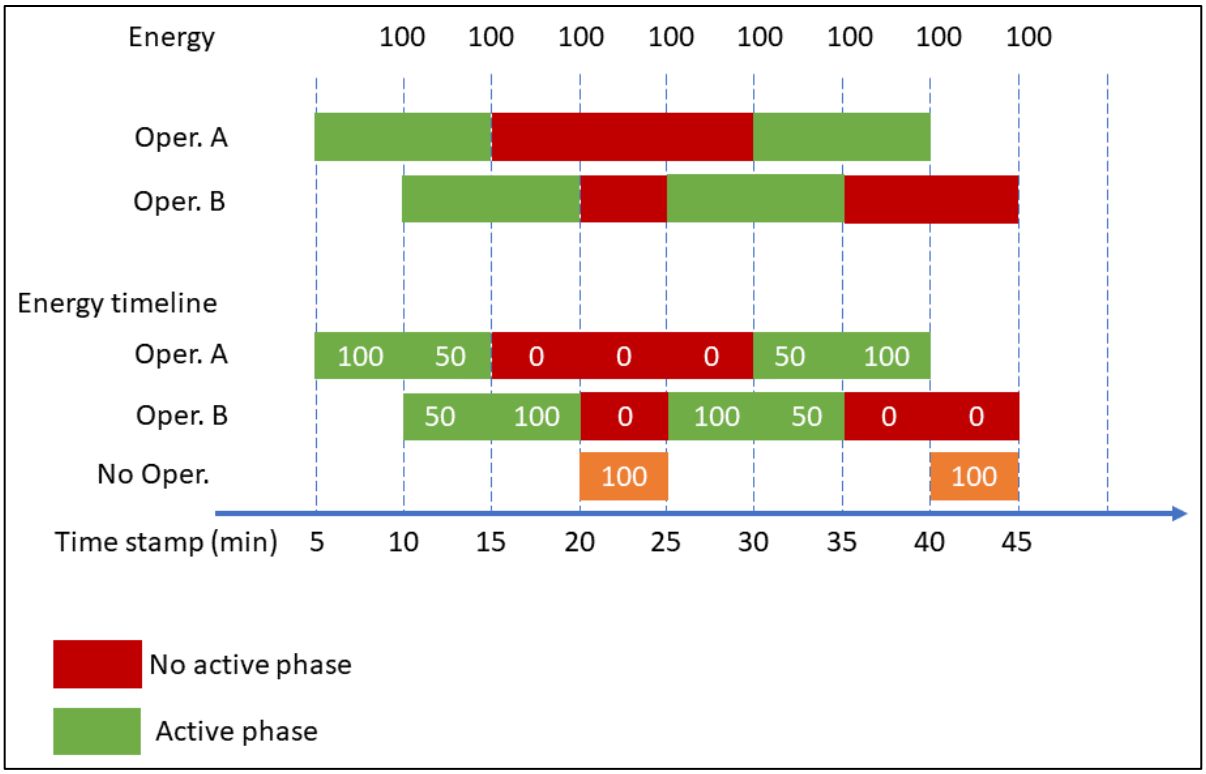

Fig. 15: Distributing the energy consumption values to several processes

4.3 Aggregating Energy Consumption Values of a Machine Line

In some production processes, components are manufactured on machine lines. FORCAM FORCE IIOT 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.

4.4 Deactivating / Activating EAS

Path (Workbench): Configurations > System > FORCAM FORCE IIOT > 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.

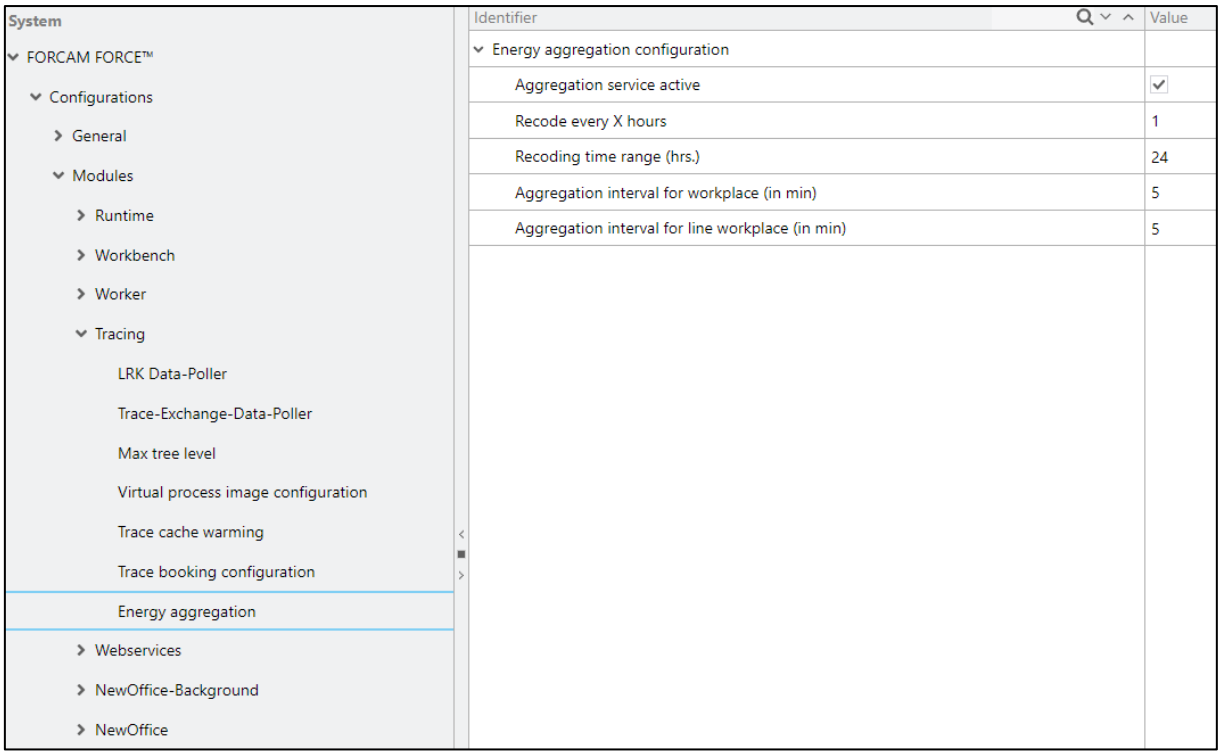

Fig. 16: Configuration of energy aggregation in the workbench

Table 1: 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.

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.

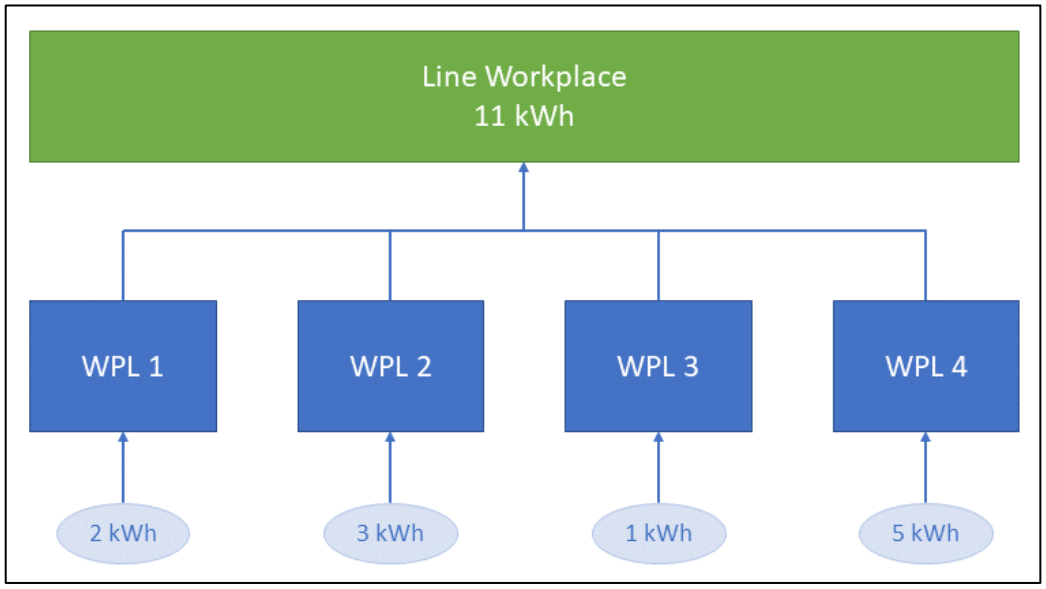

Fig. 17: Aggregation at a line workplace

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**.

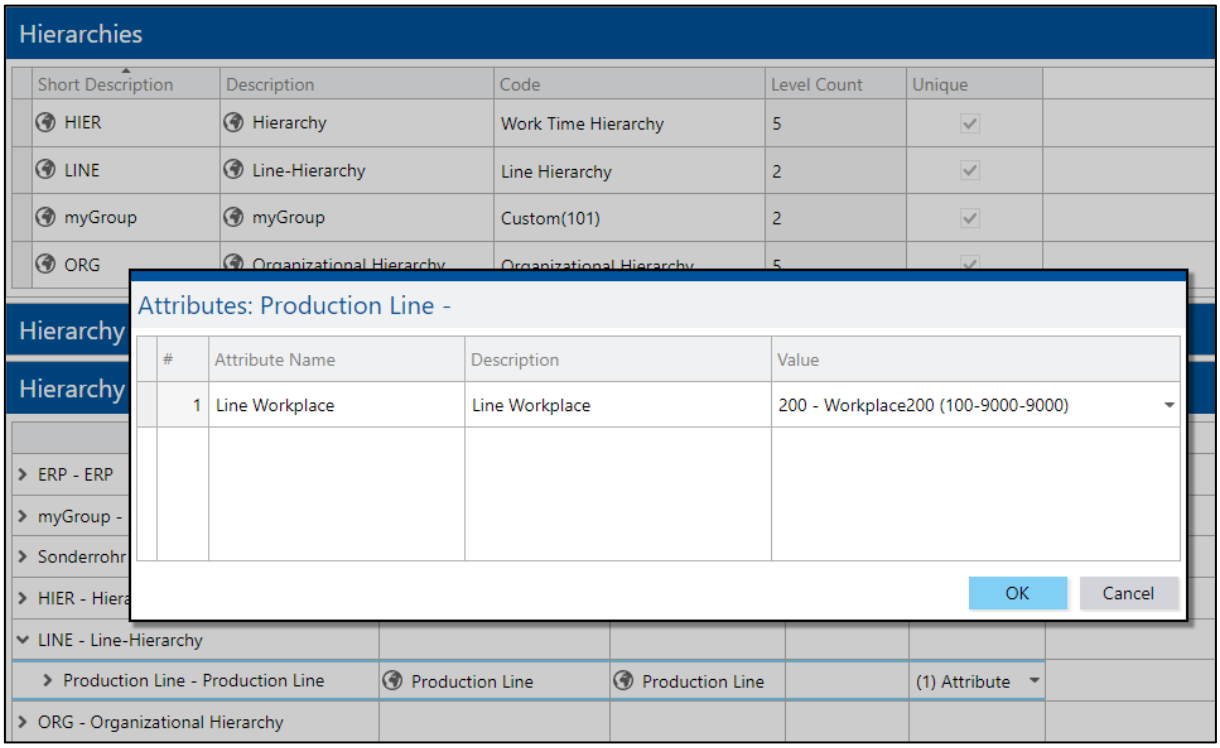

Fig. 18: Configuration of a line hierarchy

5 Appendix

5.1 Abbreviations

Table 2: 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

5.2 Table of Figures