FLEX 4 FACT

Industrial flexibility platform
for sustainable factories

# D4.3/ TECHNICAL REPORT:

## REQUIRED DATA DEFINITION FOR DEVELOPING AND EXECUTING THE ALGORITHMS FOR OPTIMIZING PLANNING AND SCHEDULING OF THE MANUFACTURING PROCESSES

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| 13/04/2023 | V0 | SENER | Draft. Information required has been defined only for SPS. Others use cases will be included in further stages. |
| 22/05/2023 | V1 | SENER | Comments from UPC included. Theben use case analysed. |
| 09/07/2023 | V2 | SENER | New comments. |
| 10/08/2023 | V3 | SENER | New version after Coral Review |
| 22/08/2023 | V4 | SENER, UPC | Final reviewed version |

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# DISSEMINATION LEVEL

| | |
|---|---|
| PU – public, fully open | X |
| SEN – sensitive, limited under the conditions of the Grant Agreement | |

# TABLE OF CONTENT

LIST OF TABLES ..... 4
LIST OF FIGURES ..... 5
LIST OF ABBREVATIONS ..... 6
SUMMARY ..... 7
1 INTRODUCTION ..... 8
2 PRODUCTION PLANNING ALGORITHM OVERVIEW ..... 10
2.1 MODEL OVERVIEW ..... 10
2.2 INPUTS REQUIRED ..... 11
3 SCHEDULING-RELATED DATA ..... 13
3.1 DAILY SCHEDULING-RELATED DATA ..... 13
3.2 FIXED SCHEDULING-RELATED DATA ..... 15
4 ENERGY-RELATED DATA ..... 16
4.1 ENERGY CONSUMPTION DATA ..... 17
4.2 ENERGY GENERATION AND PRICES DATA ..... 18
4.2.1 Electricity and gas prices ..... 18
4.2.2 CO2 emission factor ..... 18
4.2.3 On-site renewable generation ..... 18
4.2.4 Energy storage ..... 18
5 CONCLUSION AND RECCOMMENDATIONS ..... 19
6 BIBLIOGRAPHY ..... 20
ANNEX - INPUTS REQUIRED FOR THE PRODUCTION PLANNING ALGORITHM ..... 21

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101058657.

# LIST OF TABLES

*Table 1 Scheduling-related data types* ........ 13
*Table 2 Energy-related data types* ........ 16

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# LIST OF FIGURES

*Figure 1: WP4 Production planning algorithm data flow* ........................................................................... 9
*Figure 2: Proposed structure of the production planning algorithm* ................................................................ 10

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# LIST OF ABBREVATIONS

| ACRONYM | DESCRIPTION |
|---|---|
| F4F | Flex4Fact |
| WP | Work Package |
| DT | Digital Twin |
| UCF | Use Case Factory |

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# SUMMARY

The goal of Flex4Fact (F4F) is to develop an end-to-end ecosystem based on a modular and multi-level architecture to enable flexible manufacturing in industries and create the conditions for the necessary energy transition in energy intensive industrial sectors. Digital process twinning, machine learning techniques and data science analytics based on optimization tools will be used in this project to enhance manufacturing flexibility and overcome complex operational scenarios.

Work Package 4 will develop a flexible production planning and control system that combines the energy flexibility with manufacturing constraints, whose algorithms are under development by task 4.2. The aim of this report (deliverable D4.3) is to define the required data and its granularity needed for the optimization algorithms to be developed in task 4.2. The document is grouped into three parts: the first one introduces the planning algorithm, the relations with the other tasks, and the two main inputs categories (scheduling related and energy related data); the second and the third parts describe in more detail the scheduling related and energy related data respectively. Finally, the conclusions are presented.

The report D4.3 is due in month fifteen (i.e. August 2023) since the start of the F4F project.

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# 1 INTRODUCTION

As part of Work Package 4, the task 4.2 is developing the algorithms for a flexible production planning and scheduling of the manufacturing process combining the energy flexibility with manufacturing constraints (from now on referred to as the “production planning algorithms”). Those algorithms will be developed and implemented in the five industrial contexts (or “use cases”) of F4F consortium, i.e. CELSA, Inaventa, SEAC, SPS and Theben.

The production planning algorithms, designed to find the optimized use of the flexibility possibilities of industrial processes, require a huge amount of data. Data gathering process collection is the process of collecting, measuring, and analyzing data from various sources. The input required for the production planning algorithms can be grouped in the following 4 main categories:

- Direct data from the industry or the process itself (industry data): these will provide demand, customers’ production needs or process information. Additionally, this data also has usage restrictions and other types of conditions.
- Digital twin information (WP3): it will estimate the energy consumptions of the different processes and define the behavior of the process under different conditions. It has been considered that WP3 will let available libraries with key output variables that will be periodically updated based on combinations of simulation and sensor data for enhanced accuracy.
- On-site renewable energy generation (WP2): this will provide the forecast of solar generation (in case installed in the use case) for the planning horizon. In case storage is present, related data will also be provided.
- Third-party data from the electricity market (WP5): the aggregator platform should provide the energy price and associated CO2 emissions forecasts for the planning horizon.

An overview of the general scheme of inputs and outputs of the production planning algorithms and their relationship with the other work packages and the industry are shown in Figure 1.

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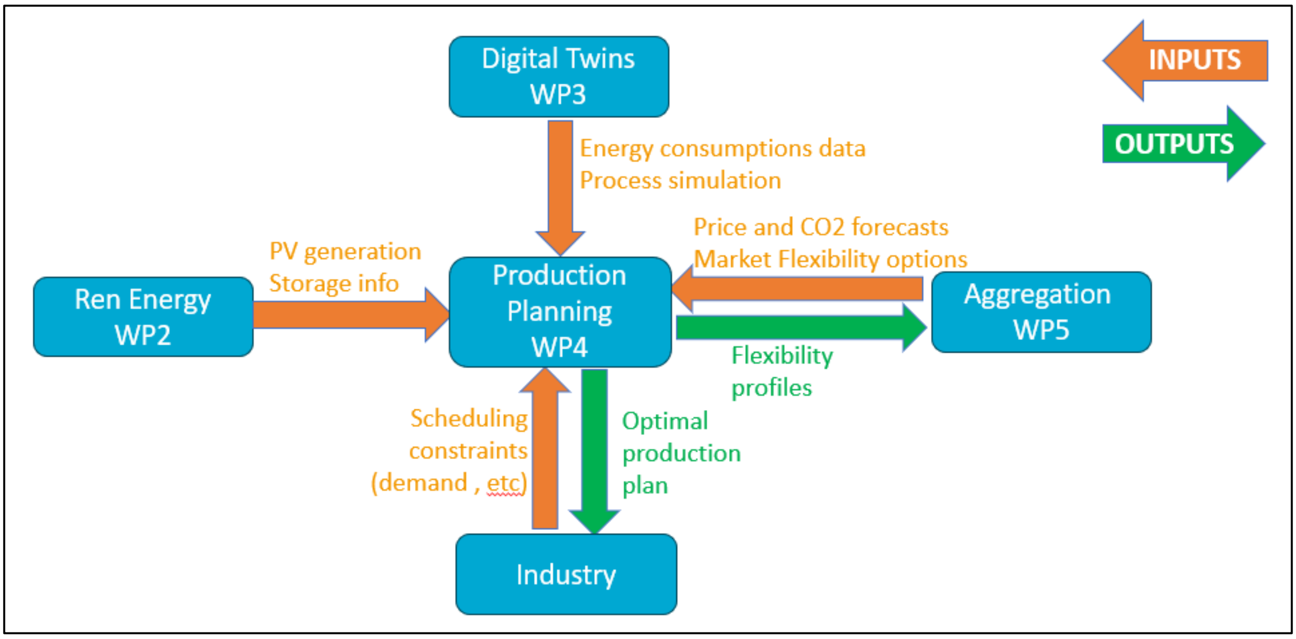


*Figure 1: WP4 Production planning algorithm data flow*

The aim of this report is to define the input data (and their granularity) required for developing and executing the algorithms for optimizing planning and scheduling of the manufacturing processes.

This report is organized as follows:

- Section 2 gives a general overview of the production planning algorithms, which are under development by task 4.2, and defining the two main categories of inputs needed: scheduling data and energy data;
- Section 3 details the scheduling data to be provided by the use case;
- Section 4 describes the energy data, which includes consumption characteristics of the industrial process, together with information about energy markets price, carbon emissions and renewable/energy storage systems available.

The detailed data needed for running the production planning algorithm in each use case, i.e. CELSA, Inaventa, SEAC, SPS and Theben, are reported in the Annex.

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# 2 PRODUCTION PLANNING ALGORITHM OVERVIEW

In this Section, it is provided an overview of the production planning algorithms (or models), i.e the optimization algorithms that support the production scheduling minimizing the production costs including the energy cost and the CO2 emissions cost explicitly. These algorithms are currently under development for each of the 5 use cases of the F4F project (task 4.2).

First, an overview of the model is provided in sub-Section 2.1. Afterwards, sub-Section 2.2 describes the required inputs.

## 2.1 MODEL OVERVIEW

This section describes a simplified model which designs the scheduling for the planning horizon (e.g. day-ahead), based on the defined energy prices, as well as the carbon emissions and renewable generation forecasts. The planning horizon will be generally day-ahead or week-ahead for most of the use cases, but the model can also be applied to other timeframes, such as monthly planning or even in the intraday market (i.e. defining the scheduling of the rest of the day considering the already completed production).

The proposed philosophy for the model is organised into two modules (ref. [1]): the first one is related to scheduling and the second to energy consumption (Figure 2). The first module aims to define the sequence in which every job must be performed, while the second module focusses on defining the consumption needed to accomplish the production plan. The two modules are logically related using a set of variables.

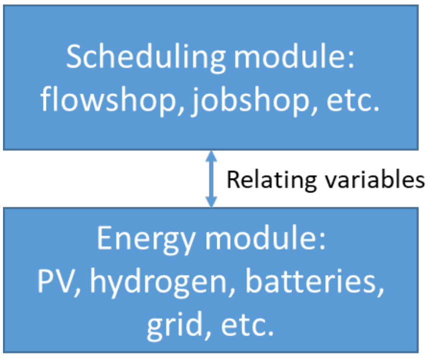


*Figure 2: Proposed structure of the production planning algorithm*

The model has been conceived in such a way that it can be easily adapted to the different case studies, even beyond F4F. Specifically, the scheduling module can be adapted depending on the characteristics of the productive system under study (i.e., jobshop, flowshop, etc.); and the energy module can also be adapted depending on the energy resources that are considered to cover the consumption (i.e., PV, hydrogen, batteries, etc.).

The scheduling problem (e.g. jobshop or flowshop) is a well-known optimization problem. However, the inclusion of energy-related considerations has only recently gained relevance, see for instance ref. [2] and [3].

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The objective function will be the minimization of the global cost of the production plan. This includes the purchase/sale of electricity from/to the grid, the cost of machines, the staff costs, the indirect costs, etc., depending on the characteristics of every case study.

The output of the model is expected to provide the production plan (i.e. the starting and ending periods of each job/product) as well as the energy consumption (i.e. the electricity demand at each period). Normally the time granularity of these outputs will be 15-min or hourly, depending on the use case.

## 2.2 INPUTS REQUIRED

Following the proposed model approach (Figure 2), the inputs required by the production planning algorithm can also be classified into the following 2 main groups:

- ***Scheduling-related data***: typical processes, constrains and decisions related to production planning consist of the following:
    - products demand forecast
    - number of products (and jobs)
    - number of machines
    - number of periods
    - processing times
    - processing costs
    - starting and stopping times of machines
    - shift time between batches
    - launching cost of batches
    - relationships between jobs and products
    - raw material costs
    - stock costs
    - person costs
    - process timings
    - other manufacturing inputs

- ***Energy-related data***: some of the inputs from the energy perspective are as follow:
    - energy needed for production
    - grid-electricity cost over time
    - renewable energy available over time (e.g. solar generation)
    - energy surplus price (if it is possible selling electricity back to the grid)
    - storage capacity
    - energy consumption of each machine
    - energy price day-ahead (and reward)
    - energy production (PV) forecast
    - $CO_2$ emission costs (forecast)
    - storage characteristics (e.g., hydrogen, lithium-ion battery, thermal borehole)

In general terms, energy-related data are mostly similar for all the use cases (besides the consumpt, while scheduling-related data are much more dependent on each specific industry.

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More details about those two main input groups are given in next Sections 3 and 4, and the complete list of required data is included in the Annex.

It should be noted that, in case some of those inputs cannot be obtained from the industry, simulated data will be used to test the production planning algorithms (synthetic data).

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# 3 SCHEDULING-RELATED DATA

Regarding scheduling-related data, each use case will have a different schedule philosophy and planning constrains, but some of the information required for the optimization algorithm will be similar.

In this Section the most relevant scheduling related inputs are described. Those inputs can be classified into two main categories:

- Daily scheduling-related data (sub-Section 3.1): data that should be updated each time the algorithm is run (normally with daily frequency)
- Fixed scheduling-related data (sub-Section 3.2): data that should be updated only when there has been a change in the production process, i.e. new products, machines updates, different working times, etc.

The summaries of the different types of daily and fixed scheduling-related data are shown in Table 1. The complete list of those data (and their granularity) for each use case is reported in the Annex.

*Table 1 Scheduling-related data types*

| DAILY SCHEDULING-RELATED DATA | FIXED SCHEDULING-RELATED DATA |
|---|---|
| Scheduling horizon | Number of operations for each product and available machines |
| Production orders | Production times |
| Workers available in each shift | Set-up times |
| Equipment Availability | Nominal production |
| Raw material availability (stock) | Stocking capacity |
| | Cost of stock |
| | Workers requirements |
| | Other resources needed |
| | Material loss |

## 3.1 DAILY SCHEDULING-RELATED DATA

This section gives an overview of the daily scheduling-related data gathered from the five use cases following the subcategories defined in Table 1. The inputs that are general for all use cases, such as worker availability, however, is not discussed further for the individual use cases.

### *CELSA*

The production planning algorithm needs information of the number and type of casting to be produced every day and which electric furnaces and rolling mills are available for the production that day. Also, the starting and ending time of critical orders should be reported, so the planning can ensure their fulfilment.

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Currently, CELSA participates in the Spanish electricity grid service specifically designed for demand side response (SRAD: Servicio de Respuesta Activa de la Demanda), being required to maintain a minimum power consumption (54 MW) at any time.

***INAVENTA***

In the case of Inaventa, it is likely that the daily data is actually not updated in a daily basis, but every time a planning is made for the extrusion. This planning should distinguish long-term (3 months) and short-term (next two-three days). However, every time a planning is carried out, the information required by the planning algorithm includes the demand in the studied period, including the due dates with clients, and the stocking capacity.

***SEAC***

The production planning algorithm needs information about the fins to be produced in the planning horizon (i.e. 5 days) and their deadline within it. Stock information about already produced fins will be also needed, together with planned unavailability (e.g. maintenance) of the machines.

***SPS***

The algorithm needs the set of profiles to be extruded during the following five days, specifying the number of units to be produced of each profile and its deadline. Also, in this case the human resources constitute a critical resource for the production scheduling. Thus, the number of available workers in each of the next five shifts should be reported, distinguishing the positions they can occupy.

***THEBEN***

Theben follows a production plan of 2-4 weeks ahead considering both the immediate orders from clients and also the annual forecast received at the beginning of the year. Updates of the manufacturing orders (quantity, product type etc.) can be obtained to change the production plan.

The production planning algorithm will consider products, and units, needed to be manufactured the following day. This input data is consistent with the capacity of the line and the raw materials available.

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## 3.2 FIXED SCHEDULING-RELATED DATA

This section gives an overview of the fixed data that should be available in libraries and are specific for each one of the five use cases following the subcategories defined in Table 1. These data only will change due to a modification in the production process, for this reason their granularity is not specified in the Annex.

***CELSA***

The production planning algorithm needs the average time to produce a casting in each electric furnace at each of three possible configurations (60MW, 70MW, 90MW). Also, it needs the set-up time both when the furnace has been stopped less than 2 hours and more than 2 hours. All constraints with next stages of the casting and rolling processes are required: for example, it is not possible to work at 60MW when using the continuous casting line 1, since the speed of the casting would be too low.

***INAVENTA***

The production planning algorithm requires the nominal production rate. This production rate can be unique or specific line configuration (in case, for example, the speed of the line can be changed). Also, it needs the time and cost for set-up the extrusion line and the cost associated to the stock of final products.

***SEAC***

The production planning algorithm requires the time needed to perform the different operations of the different fins in each moulding machine (both for heating the machine and for moulding the fins). The time for changing the mould is also needed.

***SPS***

In order to determine a feasible schedule, the critical resources (for example, laminating machines) that are needed for specific profiles (and forbid the overlap of some production orders) must be stated. Also, since the human resources are shared between the extrusion lines, the fraction of time that each worker is assigned to each line should be reported, as well as their polyvalence. Moreover, the time to change from the production of one profile to another is required. Finally, the need of workers for each profile and the material loss at the start of each production order of each profile is needed.

***THEBEN***

Production and process times are specified as to how long (hours) at a time production flow may not be interrupted or changed after production has started to process an order. These process times are also derived specifically for the flexibility options. In addition, frequencies for the use of the respective flexibility options are recorded, for example, how often the production process may be interrupted per day. In a future model scenario, the basic schedule of the battery energy storage (storage and withdrawal of electricity) is also planned in a fixed manner based on the dimensioning of the storage and the process and working times.

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# 4 ENERGY-RELATED DATA

Regarding energy-related data, the production planning algorithms require the information about on-site renewable energy generation and storage (WP2), gas and electricity consumptions (WP3), electricity, gas and CO2 hourly prices, and flexibility market information (WP5).

In this Section the most relevant energy-related inputs are described. Those inputs can be classified into two main categories:

- Energy consumption data (sub-Section 4.1): Data about the electrical consumption of the different processes
- Energy generation and prices data (sub-Section 4.2): CO2, electricity and gas prices, renewable generation forecast, storage information

The summaries of the different types of consumption data and external information are shown in Table 2. The complete list of those data (and their granularity) for each use case is reported in the Annex.

*Table 2 Energy-related data types*

| ENERGY CONSUMPTION DATA | ENERGY GENERATION AND PRICES DATA |
|---|---|
| Electric consumption continuous | Electricity buying price |
| Electric consumption transient | Electricity selling price |
| Continuous gas consumption during production of a profile | Gas buying price |
| Transient gas consumption during the set-up of a line | CO2 emission factor |
| | On-site renewable generation |
| | Energy storage |

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## 4.1 ENERGY CONSUMPTION DATA

This section gives an overview of the information that characterize the way that use case processes consume energy. These dynamic transients or average values should be available in libraries and are specific for each one of the five use cases following the subcategories defined in Table 2. These data will change due to modifications in the production process or updates/improvements in the real data gathering.

#### *CELSA*

The electric arc furnaces have strong variations on the energy consumption along the melting. The production planning algorithm should know the range of consumption between which the real consumption should be with high probability (for example, 95%). This information will be used not only for the determination of the planning cost, but also for the emission of flexibility bids for the Spanish electric market.

#### *INAVENTA*

The production planning needs the total average electric consumption during set-up and production. As discussed before with the production rate, this electric consumption can be unique or can depend on the line configuration adopted.

#### *SEAC*

The production planning algorithm needs the electrical consumption of the moulding machine for each of the different operations they perform (in both the heating and the moulding phases). The electrical consumption of the different moulding machines is currently monitored and the energy absorbed every hour is recorded and posted in a SQL Database. Crossing those data with the operations performed will permit obtaining the data required by the algorithms.

#### *SPS*

During production at steady-state, the consumption of electricity and gas can be considered constant, so it is required to know the average electric and gas consumption during the production of each profile. However, the energy consumption of some parts of the process can vary depending on the profile being manufactured. This affects the transitory gas consumption when changing from one profile to another. Thus, the algorithm needs as an input the gas consumption (for oven heat up or cool down) when changing from one profile to another one extruded in a specific line.

#### *THEBEN*

The energy consumption for heating the two welding machines may imply a much higher energy consumption than the production in steady state. The first welding machine (Rehm) must be heated from room temperature in stand-by mode, while the second welding machine (Seho) from the minimum temperature to keep the liquid under this condition. Usually at the start of a working week, the welding machines are started to heat up at 4 am to be ready at 6 am.

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In the current machine configuration, the power consumption of the production process is at a constant level, hardly changes its load profile and only shows minor load peaks. This is mainly due to the process temperature that the soldering machines must maintain during processing.

If historical consumption values of the machines for production are known, only the electricity prices and the batch sizes of orders to be produced are currently required as energy input data. In the future, feed-in forecasts from the company's own solar plants and the realised values will also be required, as well as input data from the storage units. This includes, for example, storage conditions or current charge/discharge.

## 4.2 ENERGY GENERATION AND PRICES DATA

Following the sub-categories defined in Table 2, this section gives an overview of the information of electricity and gas prices, the CO2 emission factors, and the forecasted on-site renewable generation (and storage).

### 4.2.1 ELECTRICITY AND GAS PRICES

Electrical market pricing options can range from fixed electricity price (SPS) to fully indexed price taking part of the daily energy market (CELSA). Depending on the granularity of the scheduling approach later, also price indicators of the intraday market may be needed.

In some use cases (such as SPS), gas prices will also be needed as it is an important cost of the manufacturing process.

### 4.2.2 CO2 EMISSION FACTOR

The production planning algorithms are going to consider the hourly CO2 emission factor based on the generation mix of each country.

### 4.2.3 ON-SITE RENEWABLE GENERATION

When solar panels are installed, the solar generation forecast during the planning horizon is needed by the algorithm. This is the case of SEAC, Inaventa, SPS (planned panels) and Theben. These forecasts will be provided by WP2.

### 4.2.4 ENERGY STORAGE

When there is a local energy storage system available (or foreseen), this information will be required by the planning algorithms. Local energy storage systems will be assessed in T2.3 and, depending on the use case, will consider thermal storage, lithium-ion batteries, or hydrogen.

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# 5 CONCLUSION AND RECCOMMENDATIONS

In this report, the input data needed by the production planning algorithms were defined classifying them into two main categories: scheduling-related and energy-related data. The specific data of each category were described and their details for each use case and granularity are reported in the Annex.

As far as production planning algorithms are still ongoing and currently under development for each of the 5 use cases of the F4F project in task 4.2, this document (D4.3) can be considered as a starting point for setting up the bases to unify the philosophy of the optimization process. Additionally, it can be useful to detect real data available and the one that must be artificially generated (synthetic data).

Additionally, this document and its annex shall be assessed in parallel with T3.2. (Data Gathering of industrial processes) and T6.1 (hardware and software set-up of pilot lines for data collection), each focusing respectively on i) the strategy to gather the required data for DT development, ii) the physical set-up of the pilot lines for collecting such data.

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101058657.

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# ANNEX - INPUTS REQUIRED FOR THE PRODUCTION PLANNING ALGORITHM

## *Daily Scheduling-related data*

| Data type | Specific data | Unit | Parameters | Use Case Factory | | | | | Data Origin | Granularity |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | SEAC | Theben | SPS | CELSA | Inaventa | | |
| DAILY SCHEDULING-RELATED DATA | | | | | | | | | | |
| Scheduling horizon | | days | 1 value | X | X | X | X | X | Use Case Factory (UCF) | Daily |
| Production orders | Units to be produced of each profile in each production line | units | Table to fill. 4 columns: Line, profile, demand, deadline. Indetermined number of raws | | | X | | | UCF | Daily |
| | Operations to be performed in each machine | units | Table to fill. 3 columns: product, demand, deadline. Indetermined number of raws | X | | | | | UCF | Daily |
| | Demand to be supplied in day t (macrolevel) | units | Timeseries of the demand (1 value for each day of the horizon) | | | | | X | UCF | Monthly |
| | Demand to be supplied before the end of the period (microlevel) | units | 1 value | | | | | X | UCF | To be defined |
| | Order and number of melting to produce | number | Table to fill. Product, number of melting, Yes/No they are critical or not. Time to start and end critical meltings. Indetermined number of raws. | | | | X | | UCF | Daily |
| | Number of changes of the production intensity of a production line | number | Table to fill. 2columns: line, number of changes | | X | | | | UCF | Daily |
| Workers available in each shift | | number | Table to fill. Number of workers for each position (4 positions) and shift (15 shifts) | | | X | | | UCF | Daily |
| Equipment Availability | Unavailable time slots of a machine/line | timeframes | Table to fill. 3 columns: Machine/line/Furnace, Day of scheduling, Timeframes of unavailability. Indetermined number of raws | X | X | X | X | X | UCF | Daily |
| | Number of interruptions of the production process (per shift, day, etc.) | number | 2 values (Min. & Max.) | | X | | | | UCF | Daily |
| Raw material availability | | units | | X | | | | | UCF | Daily |

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## *Fixed Scheduling-related data*

| Data type | Specific data | Unit | Parameters | Use Case Factory | | | | | Data Origin |
|---|---|---|---|---|---|---|---|---|---|
| | | | | SEAC | Theben | SPS | CELSA | Inaventa | |
| FIXED SCHEDULING-RELATED DATA | | | | | | | | | |
| Number of operations for each product and available machines | | number | Table to fill. 3 columns: product, number of operations, available machines for each operation. As many raws as products | X | | | | | UCF |
| Production times | Time to produce 1 unit of profile in the line | Time | Table to fill. 2 columns: profile, Time. As many raws as profiles | | | X | | | UCF / Digital Twin (DT) |
| | Time to perform an operation to 1 fin in a machine | Time | Table to fill. 3 columns: product, operation, machine, time. As many raws as products | X | | | | | UCF / DT |
| | Time to extrude 1 meter in the extrusion line with a line configuration | Time | Table to fill. 2 columns: line configuration, production time. As many raws as configurations | | | | | X | UCF / DT |
| | Time to produce 1 melting of each product in each speed | Time | Table to fill. 3 columns: product, speed, time. As many raws as products | | | | X | | UCF / DT |
| | Time to produce a batch(size) of products on a line | Time | Table to fill. 3 columns: line, batchsize, time | | X | | | | UCF |
| | Time to produce products on a line after start | Time | table to fill. 2 columns: line, time | | X | | | | UCF |
| Set-up times | Time to se-up a line for the start of a production order of a profile | Time | Table to fill. 2 columns: profile, Set-up Time. As many raws as profiles | | | X | | | UCF / DT |
| | Time to set-up a line to change from the production of one profile to another, without stopping the line | Time | Table to fill. Square matrix. As many raws and columns as the number of profiles | | | X | | | DT |
| | Time of changing the mould | Time | 1 value | X | | | | | UCF / DT |
| | Minimum time between start/end of any two operations | Time | 1 value | X | X | | | | UCF / DT |
| | Time to set-up the extrusion line with a configuration | Time | Table to fill. 2 columns: line configuration, set-up time. As many raws as configurations | | | | | X | UCF / DT |
| | Time to heat-up the furnace if it has been stopped more than 2 hours | Time | 1 value | | | | X | | UCF / DT |
| | Time to heat-up the furnace if it has been stopped less than 2 hours | Time | 1 value | | | | X | | UCF / DT |
| | Time to set-up a line to start production from off-mode | Time | 1 value | | X | | | | UCF |
| | Time to set-up a line to start production from stand-by | Time | 1 value | | X | | | | UCF |
| | Time to set-up a line to start with a new batchsize | Time | 1 value | | X | | | | UCF |
| | Time to set-up from production to standby-mode | Time | 2 values (Min. & Max.) | | X | | | | UCF |
| Nominal production | | m2/period | 1 value. Nominal production in any given period of time | | | | | X | UCF |
| Stocking capacity | | m2 | 1 value | | | | | X | UCF |
| Cost of stock | | €/m2*period | 1 value | | | | | X | UCF |
| Workers requirements | Workers requirements for each profile | | Number of workers needed for each profile. See data input file for SPS, tab SchedulingData_fixed | | | X | | | UCF |
| | Sharing rules of workers in the lines | | Fraction of need for each position in each line. See data input file for SPS, tab SchedulingData_fixed | | | X | | | UCF |
| | Workers polyvalence | | Capacity of the workers to perform in another position. See data input file for SPS, tab SchedulingData_fixed | | | X | | | UCF |
| Other resources needed | Tools needed for the set-up and production of profiles | | Table to fill. 3 columns: Resource, units available of the resource, profile/line that need that resource, time needed. As many raws as critical resources | | | X | | | UCF |
| Material loss | Kg of material loss at the start of a production order | kg | Table to fill. 3 columns: Profiles, kg of material loss, cost of the material. As many raws as profiles | | | X | | | UCF / DT |
| | Kg of material lost if a production order is stopped before ending | kg | Table to fill. 3 columns: Products, machine/line, kg of material loss. As many raws as products | X | | X | X | X | UCF / DT |

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## Energy consumption data

| Data type | Specific data | Unit | Parameters | Use Case Factory | | | | | Data Origin | Granularity |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | SEAC | Theben | SPS | CELSA | Inaventa | | |
| ENERGY CONSUMPTION DATA | | | | | | | | | | |
| Electric consumption continuous | Electric consumption during the production of a profile in a line | kWh | Table to fill. 3 columns. Line, Profile, Average consumption. As many raws as profiles | | | X | | | DT | 1 hour |
| | Electric consumption during the performance of an operaiton of 1 fin in a machine | kWh | Table to fill. 3 columns. product, operation, machine, average consumption. As many raws as products | X | | | | | DT | 1 hour |
| | Electric consumption of each melting when the furnace is operating at each speed | kWh | Table to fill. 3 columns. Product, speed, average consumption | | | | X | | UCF / DT | 1 hour |
| | Electric consumption during the extrusion with a line configuration | kWh | Table to fill. 2 columns: line configuration, average consumption. As many raws as configurations | | | | | X | UCF / DT | 1 hour |
| | Electric consumption for the production of an order/batch in a line | kWh | 1 value | | X | | | | UCF | 5 days |
| | Maximum Increase/Decrease of electric consumption on a line | | | | X | | | | UCF | |
| Electric consumption transient | Electric consumption during the set-up of a machine/line | kWh | Table to fill. Machine/line/Furnace. Product/Profile, Time-series of electric consumption | X | | X | X | X | DT | 15 minutes |
| | Electric consumption for specifically mould changing | kWh | 1 value | X | | | | | UCF / DT | 15 minutes |
| Continuous gas consumption during production of a profile | | kWh | Table to fill. 3 columns. Line, Profile, Average consumption. As many raws as profiles | | | X | | | DT | 1 hour |
| Transient gas consumption during the set-up of a line | | kWh | Table to fill. Line. Profile, Time-series of gas consumption | | | X | | | DT | 15 minutes |

## Energy generation and prices data

| Data type | Specific data | Unit | Parameters | Use Case Factory | | | | | Data Origin | Granularity |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | SEAC | Theben | SPS | CELSA | Inaventa | | |
| ENERGY GENERATION AND PRICES DATA | | | | | | | | | | |
| Electricity buying price | Electricity buying price for the day-ahead | €/kWh | Timeseries for the day-ahead | X | | | X | | National grid / UCF | 1 hour |
| | Forecast of the electricity buying price for the next 5 working days | €/kWh | Timeseries for the next 5 working days | | X | X | | X | WP5 / UCF | 1 hour |
| | Forecast of the electricity buying price for the next 3 months | €/kWh | Timeseries for the next 3 months | | | | | X | WP5 / UCF | 1 day |
| Electricity selling price | Electricity selling price for the day-ahead | €/kWh | Timeseries for the day-ahead | X | | | X | | National grid / UCF | 1 hour |
| | Forecast of the electricity selling price for the next 5 working days | €/kWh | Timeseries for the next 5 working days | | X | X | | X | WP5 / UCF | 1 hour |
| | Forecast of the electricity selling price for the next 3 months | €/kWh | Timeseries for the next 3 months | | | | | X | WP5 / UCF | 1 day |
| Gas buying price | | kWh | Timeseries for the next 5 working days | | | X | | | National gas network / UCF | 1 hour |
| CO2 emission factor | emission factor for the day-ahead | tCO2eq / MWh | Timeseries of factors of kWh consumed to CO2 emissions for the day ahead | X | X | | X | | National grid / UCF | 1 hour |
| | emission factor for the next 5 days | tCO2eq / MWh | Timeseries of factors of kWh consumed to CO2 emissions for the next 5 working days | | | X | | X | WP5 / UCF | 1 hour |
| | emissino factor for the next 3 months | tCO2eq / MWh | Timeseries of factors of kWh consumed to CO2 emissions for the next 3 months | | | | | X | WP5 / UCF | 1 hour |
| On-site renewable generation | Forecast of the PV production for the day-ahead | kWh | Timeseries for the day-ahead | X | | | X | | WP2 | 1 hour |
| | Forecast of the PV production for the next 5 working days | kWh | Timeseries for the next 5 working days | | | X | | X | WP2 | 1 hour |
| | Forecast of the PV production for the next 3 months | kWh | Timeseries for the next 3 months | | | | | X | WP2 | 1 day |
| Energy Storage | To Be Defined (TBD) | TBD | TBD | | | | | | WP2 | |

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