

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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# DISSEMINATION LEVEL

PU – public, fully open	Х
SEN – sensitive, limited under the conditions of the Grant Agreement	

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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 multilevel 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.





# **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 ٠ 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.







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.





# 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].





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:
  - o products demand forecast
  - number of products (and jobs)
  - o number of machines
  - number of periods
  - processing times
  - processing costs
  - o starting and stopping times of machines
  - $\circ$  shift time between batches
  - launching cost of batches
  - o relationships between jobs and products
  - o raw material costs
  - stock costs
  - o person costs
  - process timings
  - o other manufacturing inputs
- **Energy-related data**: some of the inputs from the energy perspective are as follow:
  - energy needed for production
  - o grid-electricity cost over time
  - o renewable energy available over time (e.g. solar generation)
  - o energy surplus price (if it is possible selling electricity back to the grid)
  - o storage capacity
  - o energy consumption of each machine
  - energy price day-ahead (and reward)
  - energy production (PV) forecast
  - CO2 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).





## **3 SCHEDULING-RELATED DATA**

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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.





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.





### 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.





## 4 ENERGY-RELATED DATA

Regarding energy-related data, the production planning algorithms require the information about onsite 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





### 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.





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.





## 6 **BIBLIOGRAPHY**

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# ANNEX - INPUTS REQUIRED FOR THE **PRODUCTION PLANNING ALGORITHM**

#### Daily Scheduling-related data

Data tura		11		Use Case Factory					Data Ostata	C
Data type	Specific data	Unit	Parameters	SEAC	Theben	SPS	CELSA	Inaventa	Data Origin	Granularity
DAILY SCHEDULING-R		DAILY SCHEDULING-RELATED	DATA							
	Scheduling horizon	days	1 value	х	х	х	х	х	Use Case Factory (UCF)	Daily
	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			х			UCF	Daily
	Operations to be performed in each machine	units	Table to fill. 3 columns: product, demand, deadline. Indetermined number of raws	х					UCF	Daily
	Demand to be supplied in day t (macrolevel)	units	Timeseries of the demand (1 value for each day of the horizon)					х	UCF	Monthly
Production orders	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
v	Vorkers available in each shift	number	Table to fill. Number of workers for each position (4 positions) and shift (15 shifts)			х			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	х	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		х					UCF	Daily





#### Fixed Scheduling-related data

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NUMBER OF LADARDED AND AND AND AND AND AND AND AND AND AN	Data type	Specific data	Unit	Parameters	SEAC	Theben	SPS	CELSA	Inaventa	Data Origin
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Interm The base of the second		Time to produce 1 unit of profile in the		Table to fill. 2 columns: profile, Time. As many raws as						1105 ( D: 11   T · (DT)
Interpretation of a final analysis of the software and product operation, maked in National Software and Softwar		line	Time	profiles			X			UCF / Digital Twin (DT)
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Time to produce a mething of each speed product in a speed product in a speed on a line to speed on a line to speed speed in a speed on a line to set speed speed in a speed speed in the speed on a line to set speed speed in the speed in the speed speed in the speed speed speed speed speed in the speed speed speed speed speed speed speed speed speed speed speed speed speed speed speed	Production	line with a line configuration	Time	time. As many raws as configurations					^	UCF/D1
product in each speedinfer raws as productsinfer raws as productsinfe	times	Time to produce 1 melting of each	Time	Table to fill. 3 columns: product, speed, time. As many				¥		LICE / DT
The to produce a batch (size) of products on a line after fills a columns: line, batch size, imme     N		product in each speed	Time	raws as products				~		001781
Image     Image <th< td=""><td></td><td>Time to produce a batch(size) of products</td><td>Time</td><td>Table to fill 3 columns: line batchsize time</td><td></td><td>x</td><td></td><td></td><td></td><td>LICE</td></th<>		Time to produce a batch(size) of products	Time	Table to fill 3 columns: line batchsize time		x				LICE
Imme to products on a line after statute     Time     pable to fill. 2 columns; line, time     N     X     V     Image     OUCF       Image     Time to serup a line for the start of production of one pointile another, without stopping the line     Time     Table to fill. 2 columns; profile, Setup Time, As many as porfiles     Image     X     X     X     V <t< td=""><td></td><td>on a line</td><td></td><td></td><td></td><td>~</td><td></td><td></td><td></td><td>00.</td></t<>		on a line				~				00.
time to set up line for the start of any form     Time     Table to fill. 2 columns: profile, Set up Time. As many raws and columns as the number of profiles     X     U     UCCF / DT       without stopping the line     Time     Table to fill. 2 columns: profile, Set up Time. As many raws and columns as the number of profiles     X     V     DT       Set up Time to set up a line to start up a fill to fill. 2 columns: line configuration, set up time.     X     X     V     UCCF / DT       Time to set up a line start/end of the start of a mode of the start up time in the start up a fill to fill. 2 columns: line configuration, set up time.     X     X     V     UCCF / DT       Set up Time to set up a file start up a line to start up of turnes (if thas bear time.     Time     1 value     X     X     V     UCCF / DT       Time to bear up the function (if the start of turnes (if thas bear time.     Time     1 value     X     X     UCCF / DT       Time to set up a line to start up of turnes of than start up a line.     Time     1 value     X     UCCF / DT     UCCF / DT       Time to set up a line to start up of turnes of trans up a up a line.     Time     1 value     X     UCCF / DT     UCCF / DT       Time to set up a line to start up of turnes of trans up a up a		Time to produce products on a line after	Time	table to fill. 2 columns: line. time		х				UCF
Interior to equal the form the start of a granite or metal star		start	-							
Image: set of a local scheme in the production order of a profile is a the number of profiles     N     N     N     D       Set up lines     Time to set up a line of shame from the production of one profile to another, without sognither line.     Time to set up a line of shame from the production of one profile to another, without sognither line.     X     X     X     UCF / DT       Set up lines     Time to set up a line without sognither line.     Time to set up a line without sognither line.     X     X     X     X     UCF / DT       Time to set up a line without sognither line.     Time to set up a line without sognither line.     X     X     X     X     UCF / DT       Time to set up a line without sognither line.     Time to set up a line.     Time to set up a line.     X     X     X     UCF / DT       Time to set up a line to start profiles     Time to set up a line to start profile.     Time to set up a line to start profile.     X     X     UCF / DT       Time to set up a line to start profile.     Time to set up a line to start profile.     Time to set up a line to start profile.     WCF     UCF     UCF       Time to set up a line to start profile.     Time to set up a line to start profile.     Time to set up a line to start profile.		Time to se-up a line for the start of a	Time	Table to fill. 2 columns: profile, Set-up Time. As many			х			UCF / DT
Image of the construction of the construction of profiles     Time of a base point is a base of profiles     Time of profile     Time of		production order of a profile		raws as profiles						
Production on the product on one product on		Time to set-up a line to change from the	Time	Table to fill. Square matrix. As many raws and columns			v			DT
Mindle Model Model Model Marked Market     Time     J value     X     Market     Marke		production of one profile to another,	Time	as the number of profiles			X			DI
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Netwo operationsTimeLvalueXXXCCUCF / DTInter to set-up inter extrusion line with a conjugation line with a conjugationTimeTable to fill. 2 columns: line configuration, set-up time As mary raw as configurationsCCXUCF / DTInter to heat-up the funces off thas been stopped more than 2 hoursTimeI valueCXVUCF / DTTime to heat-up the funces off thas been stopped more than 2 hoursTimeI valueCXVXUCF / DTTime to set-up a line to start production from standbyTimeI valueXXVVUCFUCFTime to set-up a line to start production from standby-modeTimeI valueXXVVUCFUCFTime to set-up a line to start production from standby-modeTimeI valueXXVVUCFUCFTime to set-up for production from standby-modeTimeI valueXXVVUCFUCFTime to set-up a line to start production from standby-modeTimeI valueXXVVUCFTime to set-up a line to start production from standby-modeTimeI valueXXVVUCFUCFTime to set-up a line to start production transTimeI valueXXVVVUCFUCFTime to set-up a line to start production transTimeI valueXXX		Minimum time between start/end of any	Time	1 Value	~					001701
Inter o set-up the extrusion line with a configuration, set-up time. Configuration, set-up time. As many raws as configurations, set-up time. As many raws as configurations. Set-up time. Set-up time to set up to therware if it has been stored to the set-up time to sate transform. Time a value for the set-up time to sate transform. Time a value for the set-up time to sate transform. Time a value for the set-up time to sate transform. Time a value for the set-up time to sate transform. Time a value for the set-up time to sate transform. Time a value for the set-up time to sate transform. Time a value for the set-up time to sate transform. Time a value for the set-up time to sate value the transform. Time a value for the set-up time to sate value the transform. Time a value for the set-up time to sate value the transform. The set-up time to sate value the transform. The value for the set-up time transform. The value form the set up time transform. The value for the set-up and production of profiles. The value for the set-up		two operations	Time	1 value	х	х				UCF / DT
Set-up time     Configuration     Time     As many raws as configurations     C     C     X     UCF / DT       Set-up time     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 more than 2 hours     Time     1 value     X     UCF / DT       Time to set-up aline to start production for more from off-mode     Time     1 value     X     X     UCF     UCF       Time to set-up aline to start production for from stand-by     Time     1 value     X     X     UCF     UCF       Time to set-up aline to start with a new batchsize     Time     1 value     X     X     UCF     UCF       Time to set-up aline to start with a new batchsize     Time     1 value     X     X     UCF     UCF       Time to set-up aline to start with a new batchsize     Time     1 value     X     X     UCF     UCF       Time to set-up aline to start with a new batchsize     Time     1 value     X     X     UCF     UCF       Time to set-up aline to start with a new batchsize		Time to set-up the extrusion line with a		Table to fill, 2 columns: line configuration, set-up time.						
Set-up times     Time the strup the furnace if it has been stopped nore than 2 hours     Time the stupped nore than 2 hours     Time the stupped nore thours     Time the stupped nore than 2 hours		configuration	Time	As many raws as configurations					X	UCF / DT
Setup time     stopped more than 2 hours     Time     Value     C     X     X     CUCF / DT       Time to heat-up the furnace if it has been stopped less than 2 hours     Time     1 value     X     X     VCCF / DT       Time to set-up a line to start production from off-mode     Time     1 value     X     X     VCCF / DT       Time to set-up a line to start production from stand-by     Time     1 value     X     X     VCCF     VCCF       Time to set-up a line to start production from stand-by     Time     1 value     X     X     VCCF     VCCF       Time to set-up a line to start production to standby-mode     Time     2 values (Min. & Max.)     X     X     VCCF     VCCF       Time to set-up a line to start production to standby-mode     Time     2 values (Min. & Max.)     X     X     VCCF     VCCF       Time to set-up from production to standby-mode     Time     2 values (Min. & Max.)     X     X     VCCF     VCCF       Vortice Standby-mode     Time     2 values (Min. & Max.)     X     X     VCCF     VCCF       Vortice Stand Standby-mode		Time to heat-up the furnace if it has been								1105 / DT
Imme to heat-up the function is any production of mode indoce is shard house if it has been indoce is shard house if it has been indoce is shard house indoce is	Set-up times	stopped more than 2 hours	Time 1	1 value				X		UCF / DI
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Image: stand by the set of		Time to set-up a line to start production	Time	1 value		x				LICE
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$\frac{1}{1 \text{ trom stand-by}}{1 \text{ time to set-up a line to start with a new batchsize}}{1 \text{ time to set-up from production to standby-mode}} \frac{1}{1 \text{ trade}} \frac{1}{1 \text{ value}} \frac{1}{1 \text{ valu}$		Time to set-up a line to start production	Time	1 value		x				UCF
Image: Nominal production to set-up from production to standby-mode Time 1 value X X X UCF   Time to set-up from production to standby-mode Time 2 values (Min. & Max.) X X V V V UCF   Nominal production m2/period 1 value. Nominal production in any given period of time X V X UCF   Cost of stock m2 1 value. V V X UCF   Workers Cost of stock C/m2*period 1 value X X UCF   Workers requirements for each profile V Number of workers needed for each profile. See data input file for SPS, tab SchedulingData_fixed X X UCF   Workers requirements for each profile Capacity of the workers to perform in another position. See data input file for SPS, tab SchedulingData fixed X X UCF   Workers polyvalence Capacity of the workers to perform in another position. See data input file for SPS, tab SchedulingData fixed X X UCF   Other resources needed for the set-up and production of profiles Table to fill. solumns: Resource, time needed for the set-up and production of profiles, the essure as critical resource in the diss, cot of the material. As many raws as products X X VCF   Material lost if a production order kg Table to fill. solumns		from stand-by								
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Nominal production     m2/period time     incertorinmal production many great particulation many great particulation     Image from the production many great particulation     Image from the production many great particulation     Image from the production     X     UCF       X tooking capacity     m2     1 value     Image from the production     X     UCF     X     UCF       Vorkers     Cost of stock     €/m2*period     1 value     Image from the production     X     UCF       Workers requirements for each profile     Mumber of workers needed for each position in each line. See data input file for SPS, tab SchedulingData_fixed     X     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     X     UCF       Workers polyvalence     Capacity of the workers to perform in another position. See data input file for SPS, tab     X     X     X     UCF       Other resources needed     Tools needed for the set-up and production of profiles     Table to fill. 3 columns: Profiles, kg of material loss, cost of the material. As many raws as profiles     X     X     X     UCF / DT       Material los if a production order is stoped before ending     kg		standby mode		1 value Nominal production in any given period of						
Stocking capacity   m2   1 value   X   UCF     X   UCF     Cost of stock   €/m2*period   1 value   X   UCF     Workers requirements for each profile   Number of workers needed for each position. See data input file for SPS, tab SchedulingData_fixed   X   UCF     Workers requirements     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/file that need that resources, time needed. As many raws as profiles, kg of material loss, cost of the material. As many raws as profiles   X   UCF / DT     Material loss   kg of material lost if a production order is skg out to fill. 3 columns: Products, machine/line, kg of material lost, so puped before ending   X   UCF / DT		Nominal production	m2/period	time					х	UCF
Cost of stock   €/m2*period   1 value   Mumber of workers needed for each profile. See data input file for SP5, tab SchedulingData_fixed   X   UCF     Workers requirements   Sharing rules of workers in the lines   Fraction of need for each position in each line. See data input file for SP5, tab SchedulingData_fixed   X   V/m2*period   UCF     Workers requirements   Sharing rules of workers in the lines   Fraction of need for each position in each line. See data input file for SP5, tab SchedulingData_fixed   X   V/m2*period   UCF     Workers polyvalence   Capacity of the workers to perform in another position. See data input file for SP5, tab   X   V/m2*period   UCF     Other resources needed   Tools needed for the set-up and production of profiles   Table to fill. 3 columns: Profiles, kg of material loss, cost of the material. As many raws as critical resource.   X   V/material loss, cost of the material. As many raws as profiles.   X   UCF / DT     Material loss   kg of material loss at the start of a production order is stored to fill. 3 columns: Profules, kg of material loss, cost of the material. As many raws as profiles.   X   X   X   UCF / DT		Stocking capacity	m2	1 value					х	UCF
Workers     Workers requirements for each profile     Number of workers needed for each profile. See data input file for SPS, tab SchedulingData_fixed     X     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     X     UCF       Workers polyvalence     Capacity of the workers to perform in another position. See data input file for SPS, tab SchedulingData_fixed     X     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 resources, profile/inter that need that resource, time needed. As many raws as profiles     X     X     UCF       Material loss is stopped before ending     kg     Table to fill. 3 columns: Products, machine/line, kg of material loss. As many raws as profiles     X     X     X     UCF / DT		Cost of stock	€/m2*period	1 value					Х	UCF
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requirements other set-up and production of profiles capacity of the workers to perform in another position. See data input file for SPS, tab SchedulingData fixed x x 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 resources, profile/line that need that resource, time X X UCF   Material loss Kg of material loss at the start of a production order kg material loss. Kg of material loss if a production order is stopped before ending kg material loss. Kg of material loss. As many raws as profiles X X X UCF / DT	Workers	Sharing rules of workers in the lines		Fraction of need for each position in each line. See			x			LICE
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Instruction of profiles production of profiles the resource, profile/initial resource, profile/initinitial resource, profile/initial resource, profile/initia	Other	Tools needed for the set-up and		table to fill. 3 columns: Resource, units available of			v			LICE
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Material loss     Production order     kg     Indicating to the material. As many raws as profiles     X     UCF / DT       Material loss     Kg of material lost if a production order is stopped before ending     kg     Table to fill. Scolums: Products, machine/line, kg of material loss. As many raws as products     X     X     X     X     UCF / DT	needed	Kg of material loss at the start of a		Table to fill 3 columns: Profiles ke of material loss						
Material loss     Kg of material loss if a production order is stopped before ending     Table to fill. 3 columns: Products, machine/line, kg of material loss. As many raws as products     X     X     X     UCF / DT		production order	kg	cost of the material. As many raws as profiles			х			UCF / DT
stopped before ending kg material loss. As many raws as products X X X X X UCF / DT	Material loss	Kg of material lost if a production order is		Table to fill. 3 columns: Products. machine/line. kg of						
		stopped before ending	kg	material loss. As many raws as products	х		х	x	×	UCF / DT





#### Energy consumption data

Data tura		11.44	D		U	se Case Facto	Data Octobe	Constanting		
Data type	Specific data	Unit	Parameters	SEAC	Theben	SPS	CELSA	Inaventa	Data Origin	Granularity
			ENERGY CONSUMPTION DA	TA						
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			х			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	Electric consumption during the set-up of a machine/line	kWh	Table to fill. Machine/line/Furnace. Product/Profile, Time-series of electric consumption	х		х	х	х	DT	15 minutes
consumption transient	Electric consumption for specifically mould changing	kWh	1 value	х					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			х			DT	1 hour
Transient gas	s consumption during the set-up of a line	kWh	Table to fill. Line. Profile, Time-series of gas consumption			х			DT	15 minutes

#### Energy generation and prices data

Data tuno	Specific data	Unit	Paramotors	Use Case Factory				Data Origin	Granularity	
Data type	Specific data	Unit	Falanieleis	SEAC	Theben	SPS	CELSA	Inaventa	Data Origin	Granularity
ENERGY GENERATION AND PRICES DATA										
Electricity buying price	Electricity buying price for the day-ahead	€/kWh	Timeseries for the day-ahead	х			х		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		х	х		х	WP5 / UCF	1 hour
	Forecast of the electricity buying price for the next 3 months	€/kWh	Timeseries for the next 3 months					х	WP5 / UCF	1 day
Electricity selling price	Electricity selling price for the day-ahead	€/kWh	Timeseries for the day-ahead	х			х		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		х	х		х	WP5 / UCF	1 hour
	Forecast of the electricity selling price for the next 3 months	€/kWh	Timeseries for the next 3 months					х	WP5 / UCF	1 day
	Gas buying price	kWh	Timeseries for the next 5 working days			х			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	х	х		х		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			х		х	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					х	WP5 / UCF	1 hour
On-site renewable generation	Forecast of the PV production for the day- ahead	kWh	Timeseries for the day-ahead	x			х		WP2	1 hour
	Forecast of the PV production for the next 5 working days	kWh	Timeseries for the next 5 working days			х		х	WP2	1 hour
	Forecast of the PV production for the next 3 months	kWh	Timeseries for the next 3 months					х	WP2	1 day
Energy Storage	To Be Defined (TBD)	TBD	TBD						WP2	

