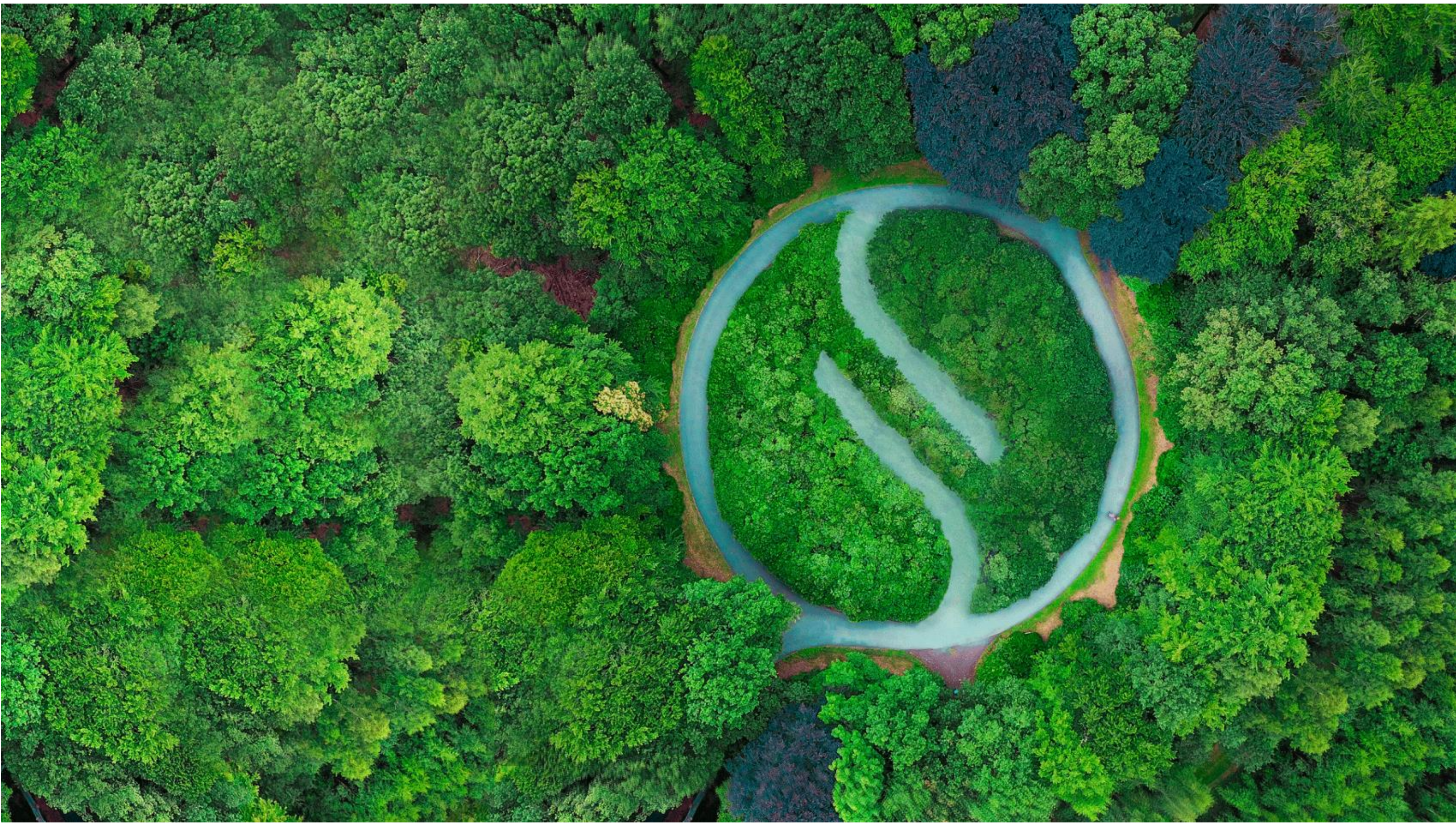

On behalf of Dell Technologies Inc.

Dell PCF & LCA Calculator

Background Report

Client:	Dell Technologies Inc.
Title:	Dell PCF and LCA Calculator Background Report
Report version:	V2.0
Report date:	13/12/2023

On behalf of Sphera Solutions, Inc. and its subsidiaries

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If you have any suggestions, complaints, or any other feedback, please contact us at *servicequality@sphera.com*.

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List of Acronyms

ADP	Abiotic Depletion Potential
AP	Acidification Potential
CML	Centre of Environmental Science at Leiden
CPU	Central Processing Unit
ELCD	European Life Cycle Database
EoL	End-of-Life
EP	Eutrophication Potential
GaBi	Ganzheitliche Bilanzierung (German for holistic balancing)
GHG	Greenhouse Gas
GPU	Graphics Processing Unit
GWP	Global Warming Potential
HDD	Hard Disk Drive
ILCD	International Cycle Data System
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
NMVOC	Non-Methane Volatile Organic Compound
ODD	Optical Disk Drive
ODP	Ozone Depletion Potential
POCP	Photochemical Ozone Creation Potential
PSU	Power Supply Unit
RAM	Random-Access Memory
SFP	Smog Formation Potential
SSD	Solid State Drive
TRACI	Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts
VOC	Volatile Organic Compound

Glossary

Life Cycle

A view of a product system as "consecutive and interlinked stages … from raw material acquisition or generation from natural resources to final disposal" (ISO 14040:2006, section 3.1). This includes all material and energy inputs as well as emissions to air, land and water.

Life Cycle Assessment (LCA)

"Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle" (ISO 14040:2006, section 3.2)

Life Cycle Inventory (LCI)

"Phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle" (ISO 14040:2006, section 3.3)

Life Cycle Impact Assessment (LCIA)

"Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product" (ISO 14040:2006, section 3.4)

Life Cycle Interpretation

"Phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations" (ISO 14040:2006, section 3.5)

Functional Unit

"Quantified performance of a product system for use as a reference unit" (ISO 14040:2006, section 3.20)

Allocation

"Partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems" (ISO 14040:2006, section 3.17)

Closed-loop and Open-loop Allocation of Recycled Material

"An open-loop allocation procedure applies to open-loop product systems where the material is recycled into other product systems and the material undergoes a change to its inherent properties."

"A closed-loop allocation procedure applies to closed-loop product systems. It also applies to open-loop product systems where no changes occur in the inherent properties of the recycled material. In such cases, the need for allocation is avoided since the use of secondary material displaces the use of virgin (primary) materials."

(ISO 14044:2006, section 4.3.4.3.3)

Foreground System

"Those processes of the system that are specific to it … and/or directly affected by decisions analyzed in the study." (JRC 2010, p. 97) This typically includes first-tier suppliers, the manufacturer itself and any downstream life cycle stages where the manufacturer can exert significant influence. As a general rule, specific (primary) data should be used for the foreground system.

Background System

"Those processes, where due to the averaging effect across the suppliers, a homogenous market with average (or equivalent, generic data) can be assumed to appropriately represent the respective process … and/or those processes that are operated as part of the system but that are not under direct control or decisive influence of the producer of the good…." (JRC 2010, pp. 97-98) As a general rule, secondary data are appropriate for the background system, particularly where primary data are difficult to collect.

Critical Review

"Process intended to ensure consistency between a life cycle assessment and the principles and requirements of the International Standards on life cycle assessment" (ISO 14044:2006, section 3.45).

Sphera LCA for Expert (LCA FE)

It was previously known as GaBi software.

Sphera LCA Calculator

It was previously known as Envision tool.

1. General information

1.1. Introduction

Dell Technologies is working to reduce their impacts on the planet throughout their business models and products. Reducing the carbon footprint of the products is a critical consideration in their product designs and it also enables their customers to achieve their own sustainability goals. For this reason, Dell Technologies has decided to develop 3 semi-automated LCA-tools for three different product categories (Notebooks, Desktops, Monitors) to calculate LCA results according to ISO 14040 and ISO 14044 and generate product carbon footprint reports (Environmental Product Declaration Type II) in accordance with ISO 14021. The tools enable Dell to quickly and reliably calculate the carbon footprint of their products, which contributes to their overall sustainability goals in several ways. First, the tools can be used to provide consistent product information to customers. Second, they can be used to track the impact of the product portfolio over time. Third, the tools give Dell the possibility to compare product configurations and promote products with lower environmental impacts internally and externally.

The following report describes the background, structure, functions, and outcomes of Dell's LCA-tools to enable a critical review according to ISO 14071.

In the following, chapter 1 describes the basic information about the LCA-Tools and the verification. Chapter 2 explains the scope of the LCAs generated with the tools regarding product systems, life cycle stages, assumptions, allocations, and data quality. In the following chapters 3, 4 and 5, the different tools are individually described in detail. Finally, the report contains guiding information for the data collection and use of the LCA-tools in chapter 5.

1.2. Owner & Approval of LCA Calculator

The owner of the LCA-tools is Dell Technologies Inc. The tools are realized with Sphera's LCA-Calculator and hosted by Sphera Solutions GmbH. The tools were reviewed in 2023 by:

Colin Fitzpatrick, University of Limerick, Castletroy, Co. Limerick, V94 T9PX, Ireland

The results are intended for disclosure to the public and are not intended for direct comparative assertions.

1.3. Overview LCA Calculators

The 3 LCA-Tools of Dell are used for 3 different product categories from Dell's product portfolio: Notebooks, Desktops, and Monitors. The respective LCA-Tools are called:

- LCA Calculator Notebook
- LCA Calculator Desktop
- LCA Calculator Monitor

The general structure of the tools is presented in the following figure.

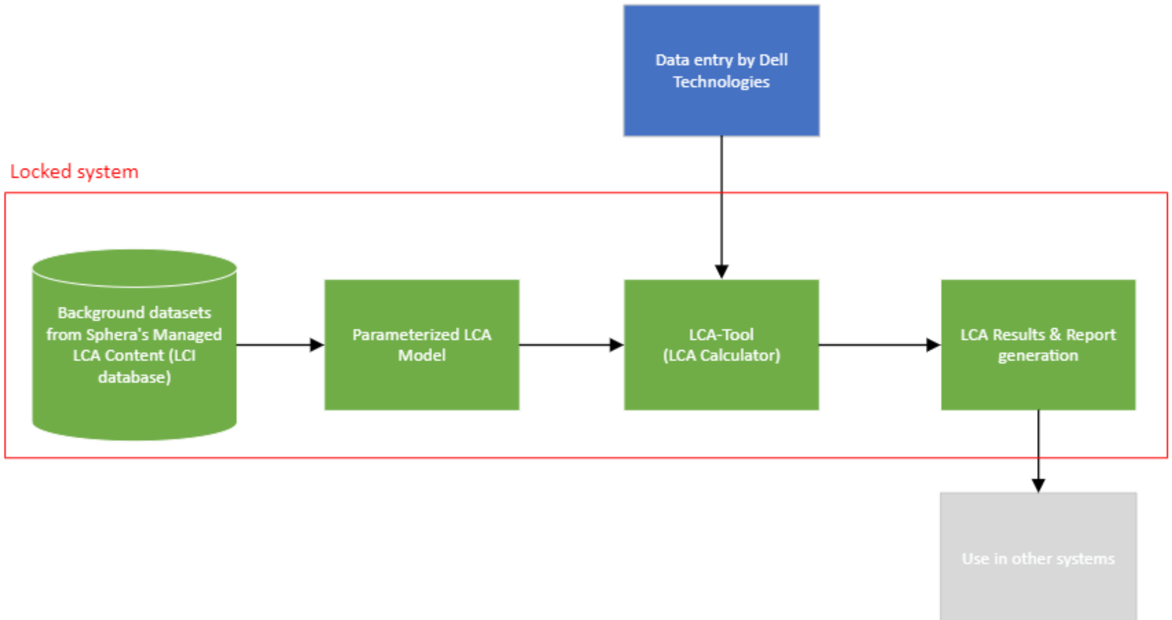


Figure 1-1: Schematic Structure LCA-Tools

As shown in the figure, the LCA-Tools are embedded in a locked system. The user access is limited to a predefined set of parameters and the functionality to generate and export new results and reports.

The LCA-Tool itself is hosted on Sphera's web-based tool "LCA Calculator" and enables the entry of primary data from Dell. The list of primary data/required input values will be described in the following chapters per LCA tool. Beyond each web-based tool, there is a parameterized LCA model, capable to reflect different product configurations and scenarios. The models have been created based on the disassembly and analysis of multiple products per group to offer a broad range of combinations. The Sphera Managed LCA Content (MLC - formerly GaBi) database is used to realize the models. Consequently, it functions as foundation of the models and the tools.

From the LCA Calculator, the user is not able to change or modify the underlying LCA-models or the calculation methodology. The user's main responsibility is to insert the primary data of the product, which should be analysed, by changing the predefined parameters. After the calculation, a new report can be download and exported to other system. Chapter 5 contains more details about these user interactions.

If updates to the tools and/or models are required, Dell must contact Sphera as they host the software and upload new tools. Either Sphera on behalf of Dell or Dell prepares such updates by extending the models. It is recommended to perform quality checks by Sphera if Dell prepares model extensions.

1.4. Content of the LCA Reports

All LCA-tools of Dell generate LCA reports with a similar structure. Figure 1-2 shows an exemplary report with its elements.

The results are intended for disclosure to the public and are not intended for direct comparative assertions.

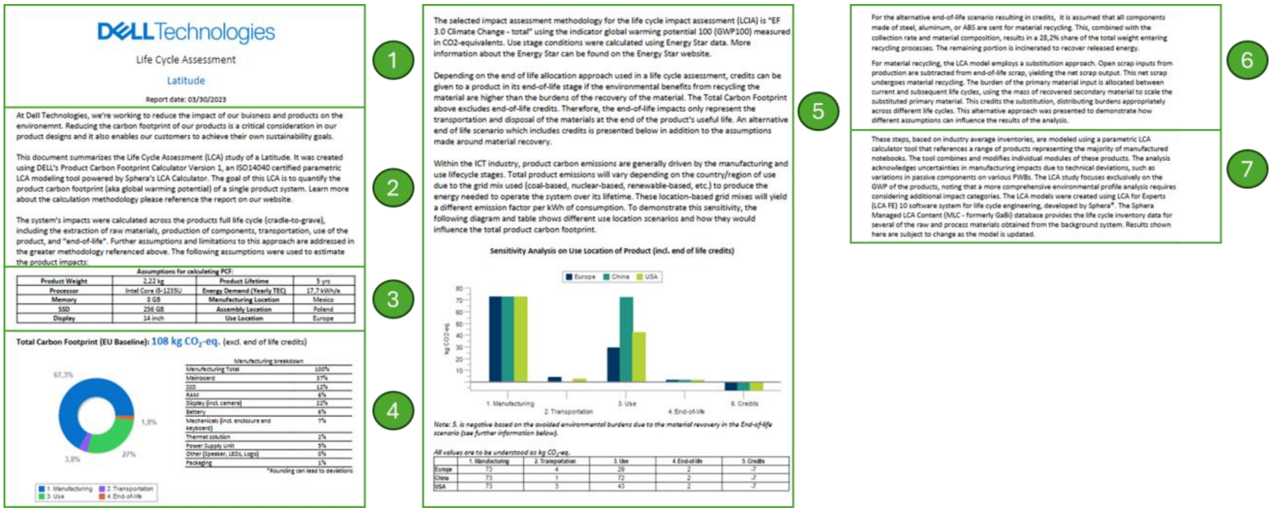


Figure 1-2: Structure LCA Report

The different elements are explained in the following table.

Table 1-1: Elements of the LCA Report

#	Element	Description
1	Heading & Report Data	• Automatic generated title based on the product name given by the input values of the user • Information about the author and date of the report to enable documentation management
2	Goal & Scope	• Goal and motivation of Dell's LCA studies • System boundaries regarding life cycle stages & activities considered
3	Product Specifications	• Summary of the technical specifications of the analyzed product based on the input values of the user
4	Product Carbon Footprint Results	• Single product carbon footprint result (total GWP excl. credits) based on European scenario • Breakdown of the total GWP excl. credits by life cycle stage based on European scenario • Breakdown of the manufacturing impacts
5	Interpretation	• Evaluation of the results • LCIA methodology • Sensitivity analysis based on the use location of the product (incl. end of life credits)
6	End-of-life Scenario	• Details on the end of life assumptions • Details on the end of life modelling approach
7	Limitations	• Background on the development of the LCA-tools • Limitations of the models

1.5. Verification

Sphera provides this report as main document for the verification. Other documents required and provided by Dell are:

- Data collection sheets (ENV0458 A03)
- LCA Calculator Tool User Guide
- Dell LCA-PCF Quality Assurance Process – Regulatory Quality Document

In order to verify the continued successful operation of the tools Sphera recommends implementing an annual sample test by an external party. Within these annual tests 1 to 2 environmental profiles per product category should be generated and checked for plausibility and consistency to the reports created by Dell's users.

As part of the initial verification, Sphera ran a successful trial with the LCA-tools and compared them with previous studies on Dell's products (Latitude 5430 , Chromebook 3110, Precision 7670, Alienware Horizon 15 MLK PLT C1, P2419H and U2720Q).

Dell tested the data collection process with their suppliers on previously analyzed products. Based on supplier feedback, enhancements were made to data collection guidance, templates, and internal quality assurance processes.

2. Scope of the LCA Models

The following sections describe the general scope of the LCA models. This includes, but is not limited to, the identification of specific product systems, that have been used to develop the LCA-tools, the product function(s), functional unit and reference flows, the system boundary, used datasets (including cut-off criteria and assumptions), and allocation procedures.

2.1. Product Systems

Table 2-1 provides an overview of the products and product categories examined (notebook, desktop and monitor). Four products have been analysed for the notebook category, five for the desktop category and four for the monitor category. Each product category is explained in more detail in the corresponding chapters. Table 2-1 shows an overview.

Table 2-1: Overview of Dell product categories and products

Product group	Dell products	Referred section
Notebook	Latitude 5430 Chromebook 3110 Precision 7670 Alienware MLK 15	3. Dell Notebook Calculator
Desktops	OptiPlex 3000 Micro Form Factor OptiPlex 7000 Tower Desktop OptiPlex 7090 Small Form Factor Precision 3260 Compact Form Factor Precision 5820 Desktop Workstation Precision 7820 Tower Workstation	4. Dell Desktop Calculator
Monitors	P2419H Monitor Ultrasharp 24 Monitor - U2723QE Ultrasharp 24 Monitor- U2422H Ultrasharp 27 Monitor- U2720Q	5. Dell Monitor Calculator

2.1.1. Notebook product system

Table 2-2 shows an overview of the examined notebooks. The table illustrates the differences between the products, e.g. in terms of display size, weight, product dimensions, battery capacity and other hardware configurations.

Table 2-2: Dell Notebook product information

	"Latitude 5430"	"Chromebook 3110"	"Precision 7670"	"Alienware Horizon 15 MLK PLT C1 "
Image				
Diagonal Viewing Size	14 inch	11.6 inch	16 inch	15.6 inch
Weight	1.54 kg (without packaging)	1.33 kg (without packaging)	2.97 kg (without packaging)	2.74 kg (without packaging)
Size	19mm (H) x 321mm (L) x Depth: 212mm (W)	21mm (H) x 304mm (W) x 208mm (D)	25mm (H) x 356mm (W) x 258mm (D)	24mm (H) x 356mm (W) x 272mm (D)
Battery capacity	58Wh	42Wh	83Wh	87Wh
Main hardware components:	Intel Core i5-1235U 16GB RAM 256GB SSD 2 speakers Touchpad WiFi + Bluetooth Multiple ports, incl. HDMI	Intel Celeron N4500 4GB RAM 32GB SSD 2 speakers Touchpad WiFi + Bluetooth Multiple ports, incl. HDMI	Intel Core i7-12850HX 16GB RAM 512GB M.2 SSD 2 speakers Touchpad WiFi + Bluetooth Multiple ports, incl. HDMI	Intel Core i7-12700H 16GB RAM 2TB M.2 SSD 2 speakers Touchpad WiFi + Bluetooth Multiple ports, incl. HDMI
Lifetime	5 years	5 years	5 years	5 years

2.1.2. Desktop product system

Table 2-3 gives an overview of the analyzed desktops. The table shows the differences between the products, e.g. in terms of weight, dimensions, or power supply.

Table 2-3: Dell Desktop product information

	"OptiPlex 3000"	"OptiPlex 7000"	"OptiPlex 7090"
Image			
Weight	1,10 kg (without packaging)	5,54 kg (without packaging)	6,83 kg (without packaging)
Size	36 mm (H) x 178 mm (W) x 180 mm (D)	169 mm (H) x 300.8 mm (W) x 367 mm (D)	92.6 mm (H) x 290 mm (W) x 292.8 mm (D)
PSU	65W AC Adapter	500W	300W
Main hard-ware compo-nents:	Intel Core i5-12500T 16GB DDR4 RAM 256GB SSD Multiple ports, incl. HDMI	Intel Core i5-12500 32GB DDR5 RAM 256GB SSD Multiple ports, incl. HDMI	Intel Core i7-11700 16GB DDR4 RAM 1TB HDD 512GB SSD AMD Radeon RX640 4GB Multiple ports, incl. HDMI
Lifetime	5 years	5 years	5 years

	"Precision 3260"	"Precision 5280 "	„Precision 7280“
Image			
Weight	1,60 kg (without packaging)	14,10 kg (without packaging)	14,71 kg (without packaging)
Size	190 mm (H) x 71.8 mm (W) x 178 mm (D)	417.9 mm (H) x 176.5 mm (W) x 518.3 (D)	417.9 mm (H) x 176.5 mm (W) x 518.3 mm (D)
PSU	240W AC Adapter	950W	950W
Main hard-ware compo-nents:	Intel Core i9-12900 32GB DDR5 RAM 1TB SSD Nvidia T400 4GB Multiple ports, incl. HDMI	Intel Xeon W 32GB DDR4 RAM 1TB SSD Nvidia RTX A2000 6GB 1TB HDD Multiple ports, incl. HDMI	Intel Xeon Silver 64GB DDR4 1TB SSD Nvidia RTX A4500 20GB 2TB HDD Multiple ports, incl. HDMI
Lifetime	5 years	5 years	5 years

2.1.3. Monitor product system

Table 2-4 shows an overview of the examined monitors. The table highlights the differences between the products, e.g. in terms of display size, weight, dimensions, battery capacity and other hardware configurations.

Table 2-4: Dell Monitor product information

	"P2419H"	"U2422H"	"U2720Q"	"U2723QE"
Image				
Diagonal Viewing Size	24 inch	24 inch	27 inch	27 inch
Weight	5.25 kg (without packaging)	5.17 kg (without packaging)	4,40 kg (without packaging)	6.64 kg (without packaging)
Size	486.2 mm (H) x 540.3 mm (W) x 166.1 mm (D)	364 mm (H) x 537.6 mm (W) x 179.6 (D)	385.1 mm (H) x 611.3 mm (W) x 184 mm (D)	385.2 mm (H) x 611.4 mm (W) x 185 mm (D)
Screen Type	IPS	IPS	IPS	IPS
Resolution	1920 x 1080	1920 x 1080	2560 x 1440	3840 x 2160
Frequency	60 hertz	60 hertz	60 hertz	60 hertz
Ports	USB 2.0 HDMI VGA	2 x USB 3.2 2 x USB-C 2 x Display Port HDMI	5 x USB 3.2 2 x USB-C 2 x Display Port HDMI	5 x USB 3.2 3 x USB-C 2 x Display Port HDMI
Lifetime	6 years	6 years	6 years	6 years

2.2. Manufacturing stage

The manufacturing stage of the product systems consists of the raw material extraction, processing, and assembly of the individual product modules. The manufacturing and assembly of Dell products mainly takes place in China. However, the energy & materials required for the final assembly as well as upstream transportation from tier I suppliers is neglected.

Data on the individual modules and materials have been collected based on teardowns of sample products provided by Dell. The following table describes the modules considered in each product category.

Table 2-5: Components description in each product group

Product	Component group defined in each product
Notebook	Battery, RAM, SSD, Keyboard, Mainboard, Touchpad, Display, Camera, PSU, Other Electronics, Thermal Solution, Speaker, Mechanicals, Packaging
Monitor	Electromechanicals, Keyboard (Button keys), Mainboard, Display, Power Supply Unit, USB board, Extension board, Mechanicals, Packaging
Desktop	Mainboard, CPU, RAM, SSD, Power Supply board, Graphic Card, Network Card, USB Board, LED Board, HDD, ODD, Other Electronic Boards, Electromechanicals, Mechanicals, Packaging

2.3. Distribution stage

Dell's products get distributed from China to distribution hubs in Europe, US and China. Then, distributors transport the products within the country of use. Both distribution processes may occur by ship, truck, or plane. Transportation by rail is not considered. Information on the transport distances, hubs and ports has been delivered by Dell. However, the LCA-tool allows the modification of the distances. The default assumptions are listed below and in Dell's LCA Calculator Tool User Guide.

Table 2-6: Default assumptions transportation to country of use

Use Location	Distance (km)	Ship (km)	Plane (km)	Truck (km)
EU	21100	17550	1950	1600
China	1600	0	0	1600
US	12100	9450	1050	1600
France	21100	17550	1950	1600
Germany	21100	17550	1950	1600
Great Britain	22000	19800	1600	1600

Assumptions based on the following:

1,600 km is appx. distance between coastal China and rough center of country. This is to represent distance for manufacturing to assembly.

19,500 km is appx. distance from Port of Shanghai to Port of Rotterdam (90% by ship, 10% by plane)

10,500 km is appx. distance from Port of Shanghai to Port of LA distributed (90% by ship, 10% by plane)

22,000 km is appx. distance from Port of Shanghai to Port of Felixstowe distributed (90% by ship, 10% by plane)

Table 2-7: Default assumptions transportation within country of use

Use Location	Distance (km)	Ship (km)	Plane (km)	Truck (km)
EU	1060	0	0	1060
China	1600	0	0	1600
US	2600	0	0	2600
France	475	0	0	475
Germany	725	0	0	725
Great Britain	380	0	0	380

Assumptions based on the following:

1,060km is appx. Distance from port of Rotterdam to Austria

2,600 km is appx distance from port of LA to Kansas

1,600 km Is appx distance from port of Shanghai to Chongqing

475 km Is appx distance from port of Rotterdam to Paris

725 km Is appx distance from port of Rotterdam to Berlin

380 km Is appx distance from port of Felixstowe to Center of Great Britain

2.4. Use stage

Following the distribution of the products to different regions (US, Europe and China), use stage takes place in the respective region. The required data entries are based on the US EPA's Energy Star Typical Energy Consumption (TEC) methodology for notebooks and desktops (ENERGY STAR, 2022), and on the Energy related Product (ErP) directive for monitors (European Parlament, 2009). Consequently, the data sources are Energy Star Certification and Environmental Data Sheets.

For the TEC methodology, the user can either insert the annual TEC or insert detailed information on the different operation modes as exemplary shown in the following table.

Table 2-8: Example of use scenario for Notebooks

Mode	Latitude 5430	Chromebook 3110	Precision 7670	Alienware

Hours of Long Idle mode per day (0-24) [hrs]	1.2	1.2	1.2	1.2
Power Long Idle mode [kW]	0.0012	0.0004	0.0017	0.00119
Hours of off mode per day (0-24) [hrs]	6	6	6	6
Power off mode [kW]	0.0005	0.0003	0.0007	0.00048
Hours of Short Idle mode per day (0-24) [hrs]	6	6	6	6
Power Short Idle mode [kW]	0.0052	0.0033	0.0124	0.024
Hours of sleep mode per day (0-24) [hrs]	10.8	10.8	10.8	10.8
Power sleep mode [kW]	0.0012	0.0004	0.0017	0.00119

The ErP calculation requires information on two operation modes. The LCA model for monitor uses these data to calculate the annual electricity consumption as follows:

TEC (kWh) = [("Standby mode" watts +"On mode" watts)*8 hrs/day * 365 days per year]/1000

Both methods combine the result with the inserted lifespan to calculate the electricity consumption for the entire life span. In addition, the user can select the location of use to select the national average grid mix. The available regions are:

- USA
- Europe
- China
- Great Britain
- France
- Germany

2.5. End-of-Life Stage

The user can modify the collection rates for the products to adapt regional differences. The models assume that products that are not collected will be disposed of in landfills. For the collection and transport to recycling / incineration centers, a truck transport (diesel) of 500 km is assumed.

The end-of-life scenario for the collected products is a mix of different processes based on information by Dell and Sphera's experience. All processes refer to default scenarios for all regions, which cannot be changed, only the collection rate is flexibly adjustable. Business-to-business (B2B) equipment has a very high collection and treatment rate due to high data protection measures. From the collected products, the materials with higher economic value (metals and electronics) enter the recycling processes. The recovered materials replace virgin materials on the market, what prevents the impacts and gives credits to the product system. Materials with lower economic value (plastic & paper) are incinerated and the produced energy is recovered, what also gives credits to the product system. Materials, which can either be recycled or incinerated (e.g. Magnesium) ends in landfilling. In addition to these assumptions, Dell provided the information that parts made of PC, PC-ABS, and ABS can be recovered from their products. Therefore, the scenario considers recycling and credits for this material group.

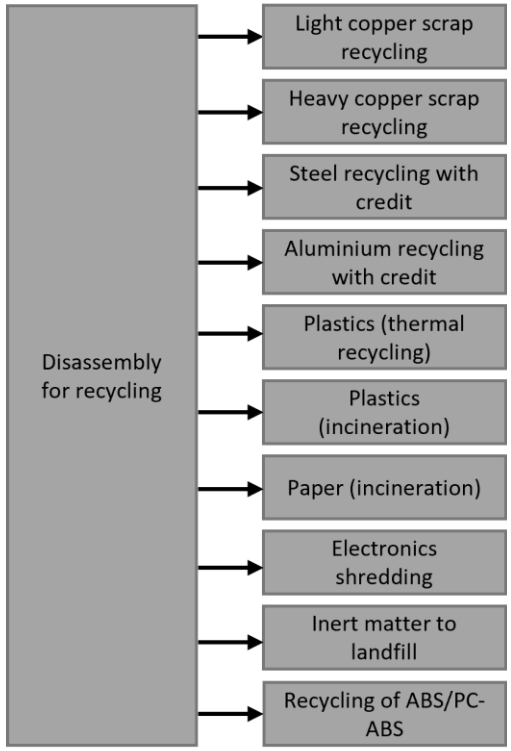


Figure 2-1: EoL Scenario for collected products

The data on the product composition have been generated based on the teardown of the products and typical material declarations of the electronic components. The user has the flexibility to select a reference product in end of life, what integrates the material composition of this reference into the model. Beside this function, other user input parameters such as total weight or weight of stainless steel parts in the product are automatically taken from the data entry and considered in the end-of-life model.

In summary, the end-of-life model can be described as semi-flexible approach. The following parameters of the LCA-tools influence the end-of-life and can be changed by the user:

- Total weight of the product
- Weight of selected materials (e.g. steel) in the module “mechanicals”
- Reference model for EoL
- Product collection rate

In contrast, the following data are fixed or implemented as dependent variables in the LCA models:

- Transport distance & vehicle in End-Of-life (fixed assumption for collected products)
- Material composition in all modules expected for “mechanicals” (values based on the teardown data)
- Weight of electronics (values based on the teardown data)

2.6. Software and database

The LCA models were created using LCA FE 10 Software system for life cycle engineering, developed by Sphera Solutions, Inc. The Sphera Managed LCA Content (MLC - formerly GaBi) database provides the life cycle inventory data for several of the raw and process materials obtained from the background system.

2.7. Overview of the LCA for Experts Software model

The LCA models of all products are parameterized to enable data entry via the LCA Calculator for the user of the LCA tool.

2.7.1. LCA model – Primary Plan: Life Cycle Plan

The primary life cycle plan shows the four main stages of the life cycle - Manufacturing, Distribution, Use and End-of-Life. This layout is the same for all three product types - notebook, desktop and monitor. In the Manufacturing plan, the content differs from product to product. The plan for Distribution, Use and End-of-Life is the same for all three product types. The differences in the Manufacturing Plan are shown in 2.7.2.

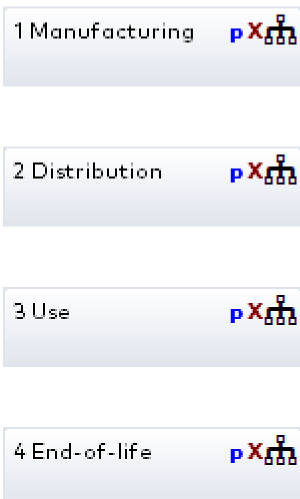


Figure 2-2: Primary Life Cycle Plan for all models – Manufacturing, Distribution, Use and End-of-Life

2.7.2. LCA model – Sub Plan: Manufacturing

The Manufacturing Plan includes different plans for the respective product. The contents of the Manufacturing Plans are therefore shown product by product for all three product types.

Notebook Manufacturing

The Notebook Manufacturing plan includes all components used to manufacture the different types of notebooks - Packaging, Housing, Battery, RAM, SSD, Thermal Solution, Speaker, Keyboard, Mainboard, Touchpad, Display Camera, Camera, Display, PSU and Other Electronics. The contents of the listed components are shown in Figure 2-3.

The model is designed so that a basic model can initially be selected. A distinction is made between low performance, standard performance, high performance and gaming. The components of the products can be combined with each other in the tool.

Figures showing the subplans of the model of Notebook manufacturing can be found in Annex C1: Notebook LCA for Experts Model.

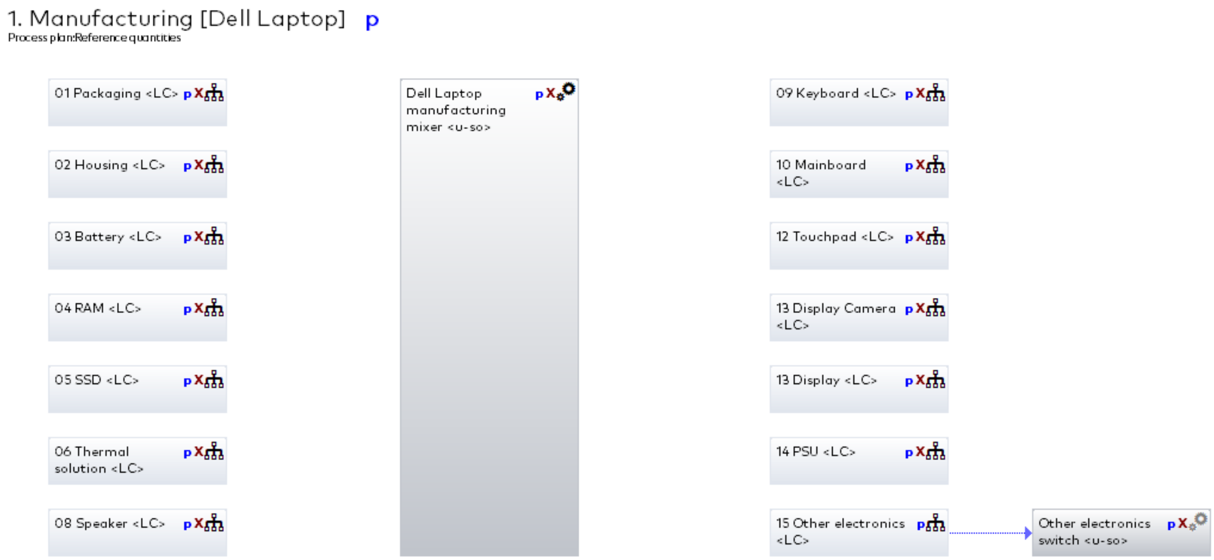


Figure 2-3: Notebook manufacturing plan incl. all sub plans for the components of the notebook

Desktop Manufacturing

The Desktop Manufacturing plan includes all components used to manufacture the different types of desktops - Packaging, Mechanicals, Electromechanicals, RAM, SSD, HDD, Mainboard, Power Supply Unit, Graphic Card, ODD, Connectivity components and peripherals. The content of the listed components is shown in Figure 2-4.

Figures showing the subplans of the model of Desktop manufacturing can be found in Annex C2: Desktop LCA for Experts Model.

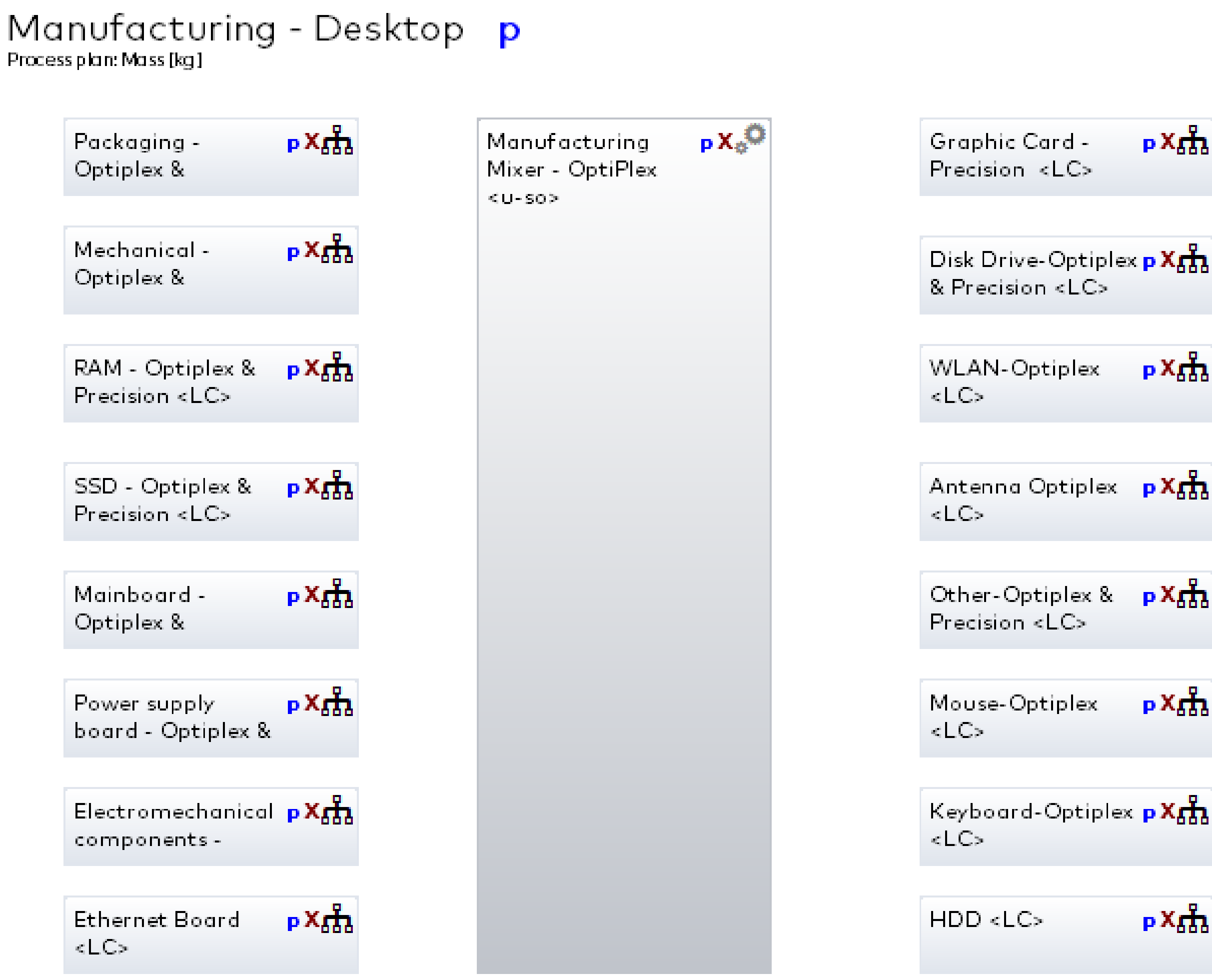


Figure 2-4: Desktop manufacturing plan incl. all sub plans for the components of the notebook

Monitor Manufacturing

The Monitor Manufacturing plan includes all components used to manufacture the different types of monitors - Packaging, Keyboard, Power Supply Unit, Electromechanical components, PWB boards, Mainboard, Panel and Mechanical components. The contents of the listed components are shown in Figure 2-5.

Figures showing the subplans of the model of Monitor manufacturing can be found in Annex C3: Monitor LCA for Experts Model.

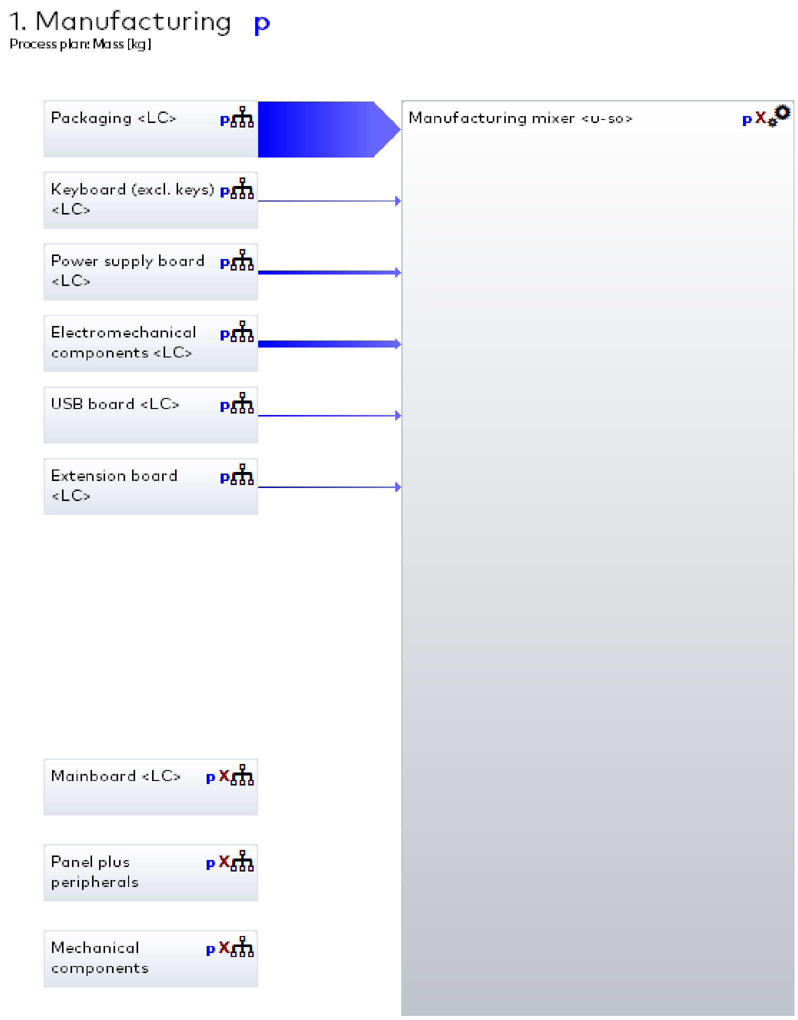


Figure 2-5: Monitor manufacturing plan incl. all sub plans for the components of the notebook

Custom ICs

ICs with special characteristics were identified and sent to an external laboratory for a more precise determination of their properties. Important characteristics are the die size, the chip technology, and the information whether gold bond wire was used. Figure 2-6, Figure 2-7 and Figure 2-8 show an example IC and how the data from the laboratory looks like. Figure 2-9 shows the parametric IC model.

The ICs that are considered for submission and examination in the laboratory must meet certain criteria. The criteria are as follows:

- Size of the ICs (min. 10 x 10 mm)
- Type of technology (DIMM, Memory, CMOS)
- Function (CPU, GPU, RAM, SSD)

A total of 24 custom ICs were analyzed for the notebooks. Duplicates were also taken into account. The exact number of analyzed custom ICs per notebook type can be seen in Table 2-9. For the desktops, a total of 32 custom ICs were identified. The breakdown by desktop type can be seen in Table 2-10. For the monitor models, 5 custom ICs were analyzed. It should be noted that only the U2422H and U2723QE models were examined for possible custom ICs. The P2419H and U2720Q models were taken from earlier LCA studies, whereby no custom ICs were examined. A breakdown of the custom ICs for the two monitor models can be found in Table 2-11.

Table 2-9: Number of Custom ICs analysed for Notebooks

Notebook	Number of Custom ICs
Latitude 5430	5
Chromebook 3110	5
Precision 7670	6
Alienware MLK 15	8

Table 2-10: Number of Custom ICs analysed for Desktops

Desktop	Number of Custom ICs
OptiPlex 3000	2
OptiPlex 7000	6
Precision 3260	9
Precision 5820	13
Precision 7820	12

Table 2-11: Number of Custom ICs analysed for Monitors

Monitor	Number of Custom ICs
P2419H	0
U2422H	2
U2720Q	0
U2723QE	3

Figure 2-6 shows a close-up picture of the IC. This picture helps to identify the IC in question, after decapping the die. We analyzed multiple ICs for each product. An example of the detailed analysis is described in the following:

Figure 2-6: Close-up picture of SSD IC

Figure 2-7 shows the die, after the decapping process. Important information gained from this is the area, a possible stacking of multiple dies, as seen for example in Figure 2-7 (2-stack die). Also, the length of gold or copper bond wire can be determined, if used.

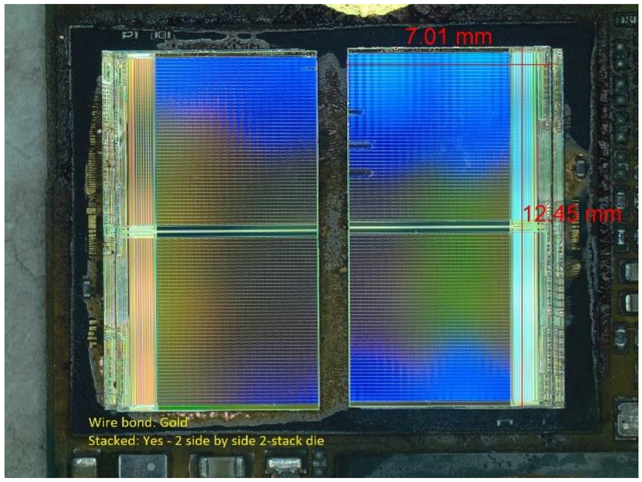


Figure 2-7: Decapped IC incl. die dimensions, gold bond wires and die stack count

Figure 2-8 shows an x-ray of the IC. This picture helps to identify the amount of solder bumps, but sometimes also reveals additional information like die area or bond wire.

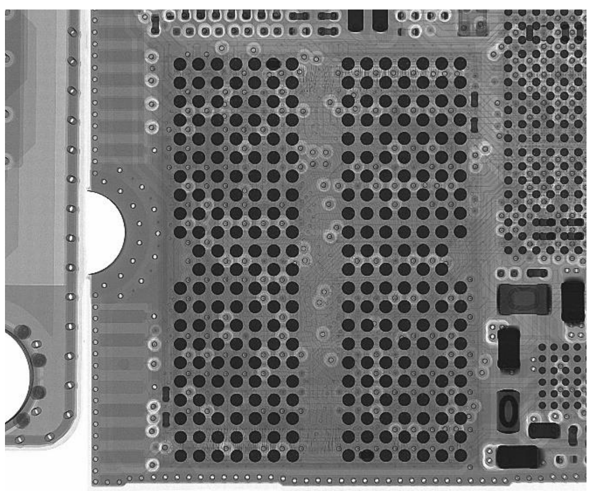


Figure 2-8: X-Ray of IC, incl. solder bumps count and additional information like gold bond wires

The information from the laboratory is then used in our Open IC model. The Open IC model uses parameters to customize each IC. The modeling of the Open IC plan is shown in Figure 2-9.

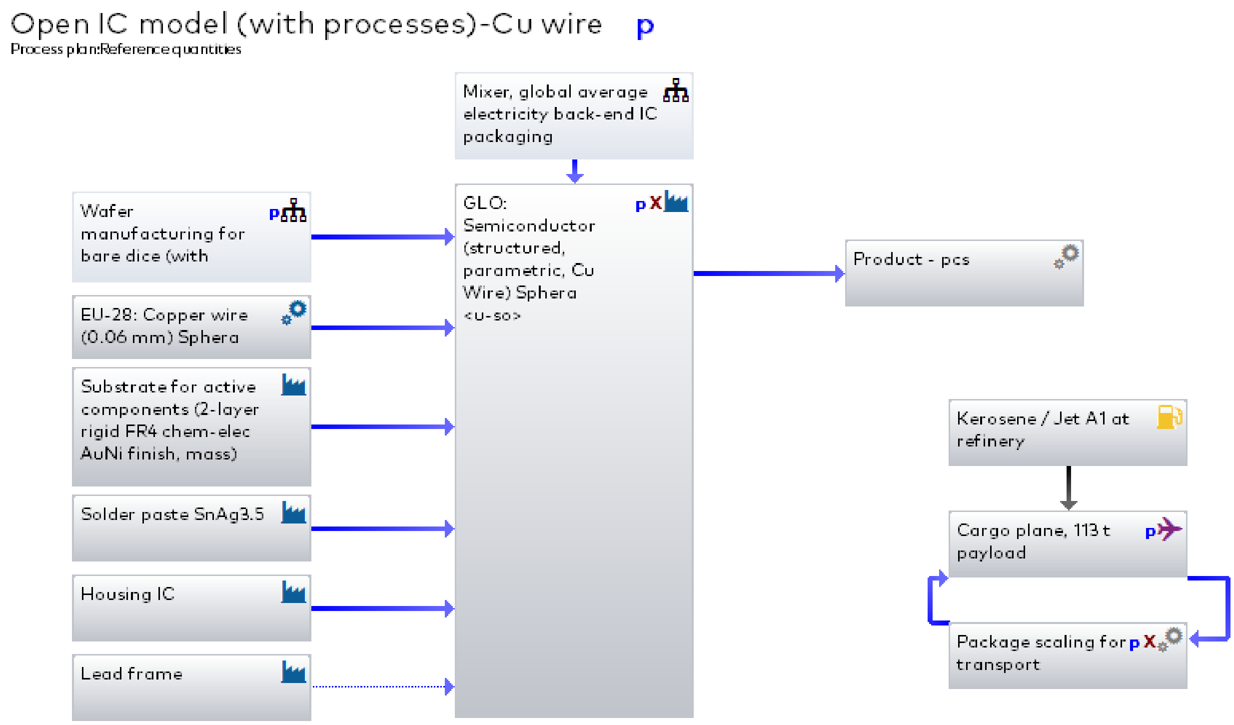
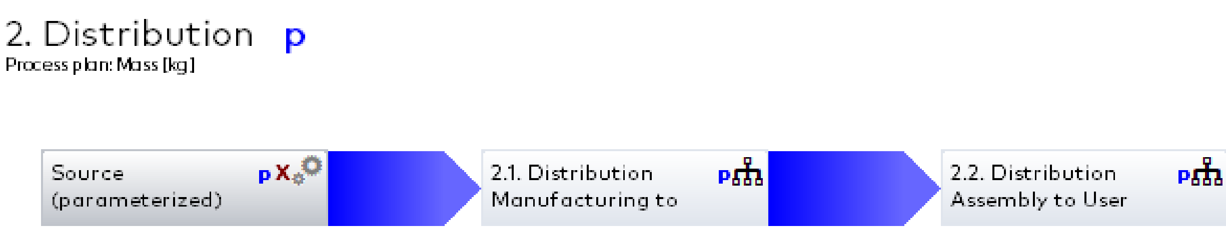


Figure 2-9: Open IC model (optional with gold or copper wire)

2.7.3. LCA model – Sub Plan: Distribution

The distribution stage is modelled based on different transport modes: airplane, ship and truck. The variable transport distances depend on the country of use.



2.7.4. LCA model – Sub Plan: Use

Five sub-plans are shown in Figure 2-10, where the top four plans represent different user modes and the last one indicates the total power consumption. The model is modeled in such a way that either the total power consumption or the power consumption. User will need to specified either mode.

Figure 2-10: Use scenario selection – Scenario Type 1: Use modes (Plan 1 to 4), Scenario Type 2: Energy Star (Plan 5)

Figure 2-11 shows the used energy processes for the included use phase locations – United States, Europe, China, France, Great Britain, and Germany.

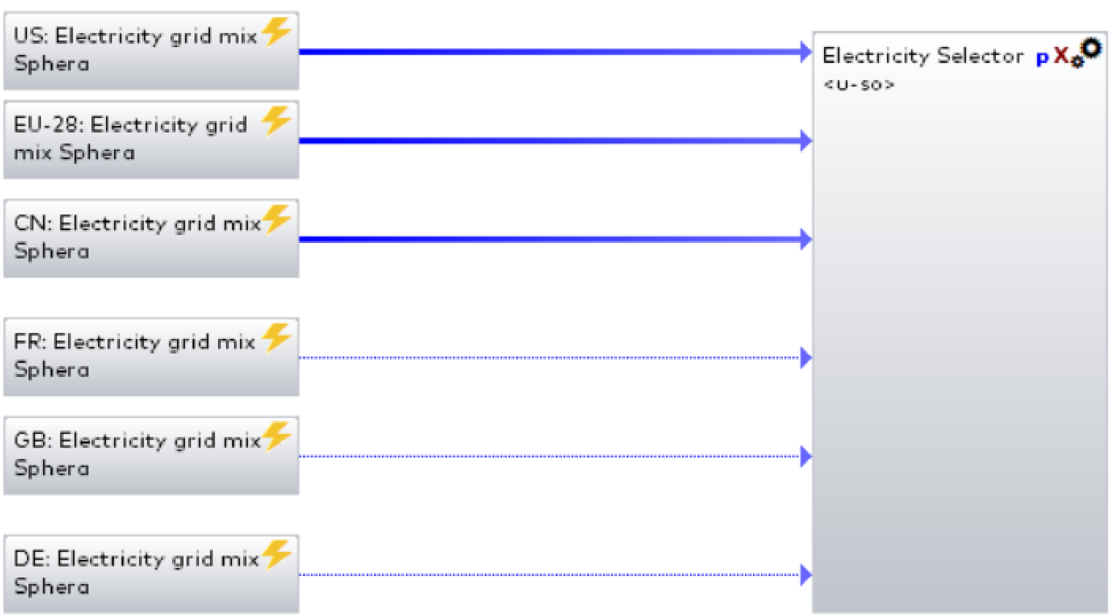


Figure 2-11: Use phase electricity selection by location (same for all the plans and notebook types, is controlled by parameter settings)

2.7.5. LCA model – Sub Plan: End-of-Life

The end-of-life plan is modeled the same way for all product categories. The modeling can be seen in Figure 2-12. The end-of-life stage plan contains sub-plans for the recycling of different metals, the incineration of plastic types and the landfill of materials, which can neither be recycled nor incinerated.

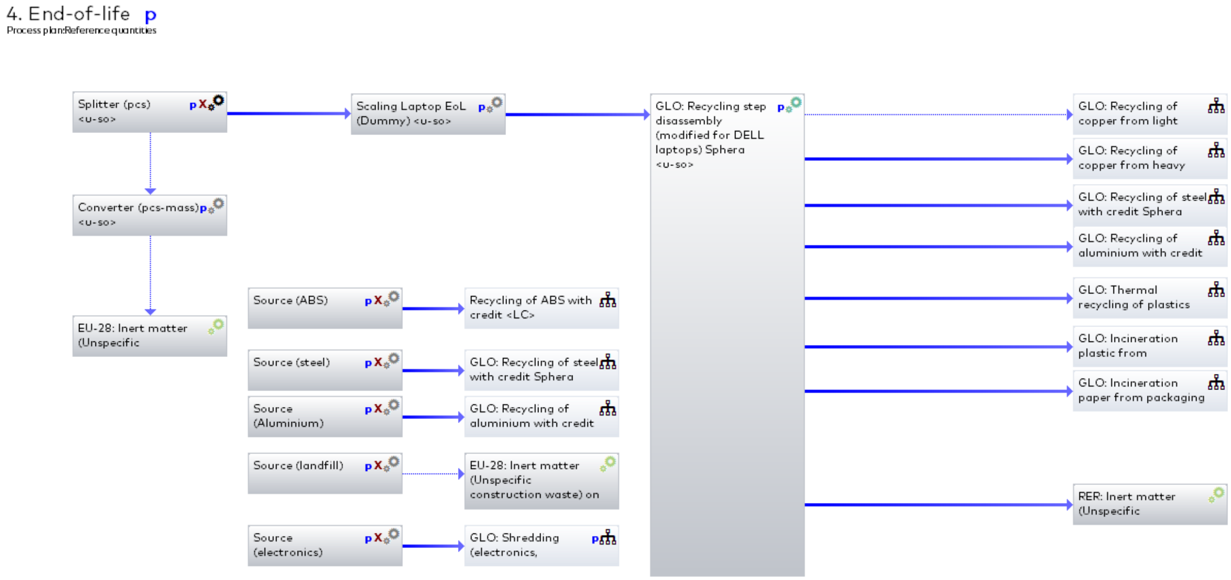


Figure 2-12: End-of-Life plan model structure (same for all product types)

2.8. List of Datasets, Cut-off criteria, Assumptions and Data Quality

A list of used datasets can be found in Annex B1: List of datasets used in models. The list also contains an evaluation of the datasets quality for technology, time and geographical representativeness.

Production of capital equipment, facilities and infrastructure required for manufacture are outside the scope of this assessment. Raw material extraction, processing and assembly of the individual products modules are included in the manufacturing stage. The manufacturing and assembly of Dell products mainly takes place in China. However, the energy & materials required for the final assembly as well as upstream transportation from tier I suppliers is neglected.

2.9. Allocation Principles and Procedures

Allocation principles and procedures, including documentation and justification of allocation procedures and uniform application of allocation procedures.

2.9.1. Allocation of background data

Information about allocation procedure of single datasets is documented in https://sphera.com/product-sustainability-gabi-data-search/.

2.9.2. Allocation in the foreground data

The production process does not deliver any co-products. The applied software model does not contain any allocation.

2.9.3. Allocation for waste materials

Production waste (metals and plastics) is recycled - first sent to a granulation, then to a palletizing and compounding process.

The product waste at end-of-life is modelled according to the described scenario. Within the incineration processes with energy recovery, the environmental burden of the incineration of packaging and the product in the end of life scenario are assigned to the system. All applied incineration processes are displayed via a partial stream consideration for the combustion process, according to the specific composition of the incinerated material. For the waste incineration plant an R1-value > 0.6 is assumed.

The credits for thermal and electrical energy are calculated via inversion of the life cycle inventory of European average data.

2.10. Data Quality Assessment

2.10.1. Representativeness

Technological: All primary and secondary data are modelled to be specific to the technologies or technology mixes under study. Where technology-specific data are unavailable, proxy data are used (see chapter 2.8). The overall technological representativeness is considered to be good.

Geographical: All primary and secondary data are collected specific to the countries / regions under study. Where country / region specific data are unavailable, proxy data are used (country / region specific data are displayed in 2.8). The overall geographical representativeness is considered to be good.

Temporal: All primary data are collected for the year 2021. All secondary data come from the Sphera Managed LCA Content (MLC - formerly GaBi) database and are representative of the years 2019-2022. As the study intended to compare the product systems for the reference year 2021 temporal representativeness is very good.

2.10.2. Reliability

Primary data are collected by the client using a specifically adapted spreadsheet. Sphera supported the data collection by preparing a specific questionnaire and virtual or onsite support.

Cross-checks concerning the plausibility of mass and energy flows are carried out on the data received. Similar checks are made on the software model developed during the study.

Overall, the data quality can be described as good and is guaranteed with the data collection sheet ENV0458 A03 (see

Annex D1: ENV0458 A03). The primary data collection has been done thoroughly; all relevant flows are considered.

Dell Global Product Compliance Engineering (GPCE) group conducts sampling audits throughout the year for quality assurance of product carbon footprint reports. Every quarter a representative sample of products are picked for the audit. GPCE audit lead is responsible for verifying input variables with the actual data source. Results of the sampling audit are communicated with the LCA-PCF SME and any deviation is addressed using the GPCE corrective action process.

2.10.3. Consistency

To ensure consistency, all primary data are collected with the same level of detail, while all background data are sourced from the Sphera Managed LCA Content (MLC - formerly GaBi) database. Allocation and other methodological choices are made consistently throughout the model.

2.10.4. Treatment of missing data

All relevant process steps are considered and modelled to represent the specific situations. The process chain is considered sufficiently complete regarding the goal and scope of this study. Omitted material and energy flows are described in chapter 2.

The data quality of the inventory is assessed on the basis of its precision (measured, calculated, literature values or estimated), completeness (e.g. unreported emissions), consistency (degree of uniformity of the methods used) and representativeness (geographical, temporal, technological).

In order to do justice to these aspects and thus ensure reliable results, first-hand industrial data were used together with consistent background data from the Sphera Managed LCA Content database. The inventory data from the Sphera Managed LCA Content database is widely used in the Sphera LCA FE 10 software. The data sets are used worldwide in LCA models both internally and in many critically reviewed and published studies for industrial and scientific purposes. As part of the data provision, the data sets are compared with those of other databases as well as data from industry and science.

Precision and Completeness

Precision: Since the majority of the relevant foreground data was measured or calculated on the basis of the process operator's primary data sources, the precision is considered to be high. All background data come from the Sphera Managed LCA Content (MLC - formerly GaBi) database with the respective documented precision.

Completeness: Each foreground process was checked for its mass balance and the completeness of the emissions inventory. No data was knowingly excluded. The completeness of the foreground processes is considered high. All background data come from the Sphera Managed LCA Content (MLC - formerly GaBi) database with the respective documented completeness.

Consistency and reproducibility

Consistency: To ensure the consistency of the data, all primary data were collected with the same level of detail, while all background data was taken from the Sphera Managed LCA Content (MLC - formerly GaBi) database.

Reproducibility: Reproducibility is guaranteed as far as possible by disclosing the input-output data, data set selection and model assumptions in this report. With this information, any third party should be able to approximate the results of this study using the same data sets and modelling approaches.

Representativeness

Temporal: All primary data were collected for 2021. All background data come from the Sphera Sphera Managed LCA Content (MLC - formerly GaBi) database and are representative for the years 2018-2022 (Annex B1: List of datasets used in models).

Geographical: All primary and background data were modelled on a country- or region-specific basis. Where country or region-specific data were not available, proxy data was used. The geographical representation is considered to be high.

3. Dell Notebook Calculator

3.1. General information

3.1.1. LCA Calculator Tool

The LCA calculator tool was developed to calculate the LCA results in accordance with ISO 14040/44 for the Dell Notebook product group.

3.1.2. Goal and scope of the study

The goal of the study is to quantify the carbon footprint of a single Notebook system across the product life cycle (cradle-to-grave), including the extraction of raw materials, production of components, transportation, use of the product and end-of-life.

3.1.3. Product group description

The product group in the Dell Notebook calculator includes Latitude 5430, Chromebook 3110, Precision 7670, and Alienware MLK 15. The LCA model can be combined and modified per individual configuration of the products. Figures of the LCA for Experts model structure can be found in 2.7 Overview of the LCA for Experts Software model.

3.1.4. Application area of product group

Dell Notebooks can be found in a wide range of applications, from simple low-power office tasks to performance applications, to very demanding computing and graphics tasks.

3.1.5. Declared unit

The declared unit is one piece of product with a lifetime of 5 years.

3.1.6. Data collection for LCA-tool set-up

Primary data for the material content of the products were collected using a physical teardown provided by Dell. During the product teardown, parts and materials were identified, weighed, and measured. The teardown was conducted on a mass-production-ready version of the product provided by Dell. Data on distribution, product use and end of life were collected and discussed through online communication in regular project meetings. Upon receipt, each questionnaire was cross-checked for completeness and plausibility using mass balance as well as internal and external benchmarking. The data were discussed via online communication and in regular project meetings.

The decision of ICs to be sent for laboratory analysis are based on dimensions (any ICs above 10 x 10 mm) and the functionality with focus on CMOS, Flash and RAM technology. The larger ICs are sent to a laboratory for decapsulation ("decapping") to reveal the actual die size, die stacking, identify whether gold is being used as bond wire material and to take x-rays to identify pin count of electrical interconnects (e.g., solder bumps). Decision basis for the collection of these additional data points was the understanding, that these ICs potentially bear a high environmental footprint, resulting in a need to improve the certainty of the results by using a higher level of granularity in data collection and modelling.

3.1.7. Life Cycle Inventory Analysis

The weight of each main modules of the Dell Laptop is summarized in the following table:

Table 3-1: Weight by product module for laptops under investigation

Material/Part	Latitude 5430 (kg)	Chromebook 3110 (kg)	Precision 7670 (kg)	Alienware MLK 15 (kg)
Packaging	0.68	0.40	0.80	2.20
Housing	0.52	0.51	1.07	0.70
Mainboard	0.15	0.14	0.26	0.19
RAM	0.008	-	0.01	-
SSD	0.01	-	0.02	0.03
Battery	0.21	0.18	0.38	0.33
Display	0.29	0.21	0.4	0.31
Camera	0.003	0.003	0.003	0.01
Thermal Solution	0.08	-	0.33	0.49
Keyboard	0.11	0.11	0.19	0.17
Touch Pad	0.06	0.06	0.10	0.04
Speaker	0.01	0.02	0.02	0.02
Power Supply Unit	0.08	0.08	0.18	0.37
Other Electronics	-	-	-	0.09
Total weight	**2.22**	**1.72**	**3.77**	**4.94**

3.1.8. System boundary

Dell's Notebooks are manufactured and assembled in China. Afterwards, they get distributed to different hubs in the world (e.g. Europe, US, China) (see Figure 3-1). The selection of the country of use needs to be aligned accordingly (see chapter 3.2). All collected products end-up in a mixed end-of-life scenario (see chapter 2.5).

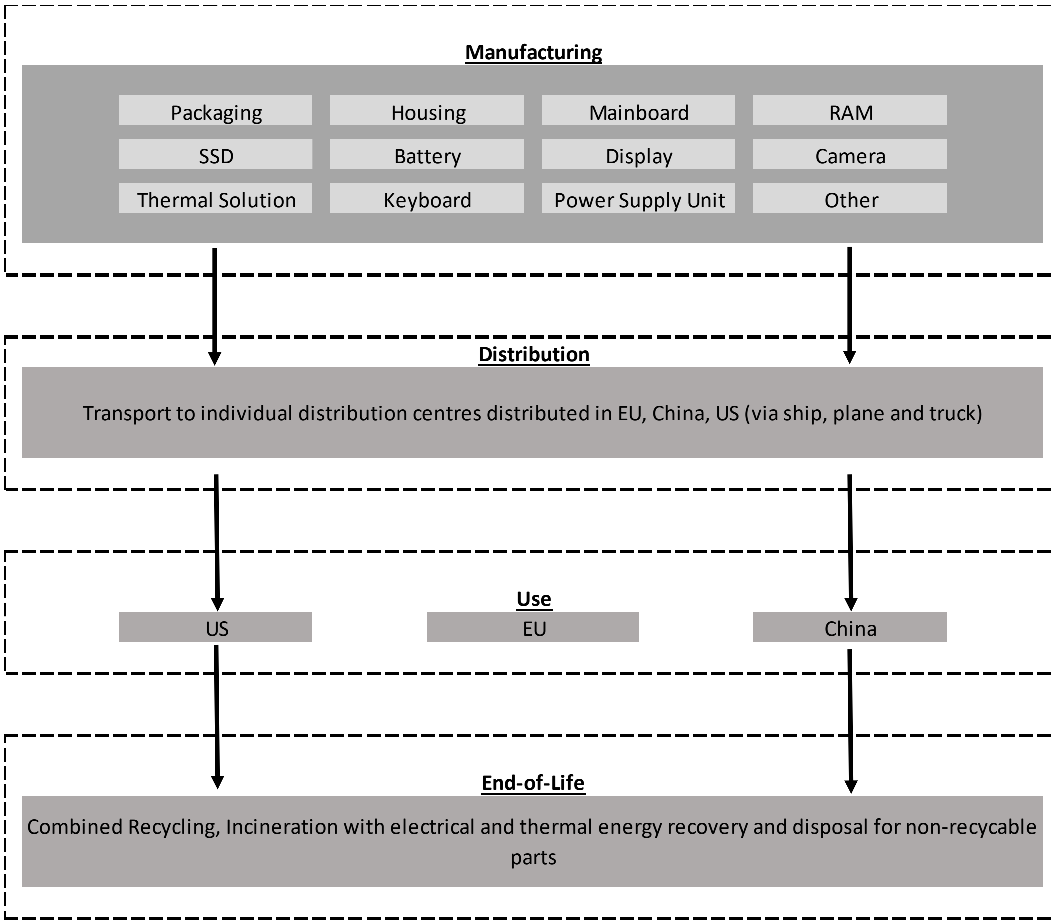


Figure 3-1: Dell Notebook system boundaries

3.2. Notebook LCA Calculator Web Tool

Figure 3-2 shows the general structure of the Notebook LCA Calculator. The user can select one item of the structure to get the specified input field with different options related to each item. The structure of the tool, according to LCA norms, consists of manufacturing, distribution, use phase and end-of-life. In the manufacturing phase, each component can be adapted individually, depending on the parameterization. The individual customization options can be found in 3.2.1. The customization options for distribution are divided between transportation to the country of use and transportation in the country of use. The input possibilities can be found in 3.2.2. In 3.2.3 the user first enters general information for the use phase and then has the choice of using the TEC as the value for the use phase or using a detailed description of the use of the product. For the EoL the collection rate and the base product can be selected as described in 3.2.4.

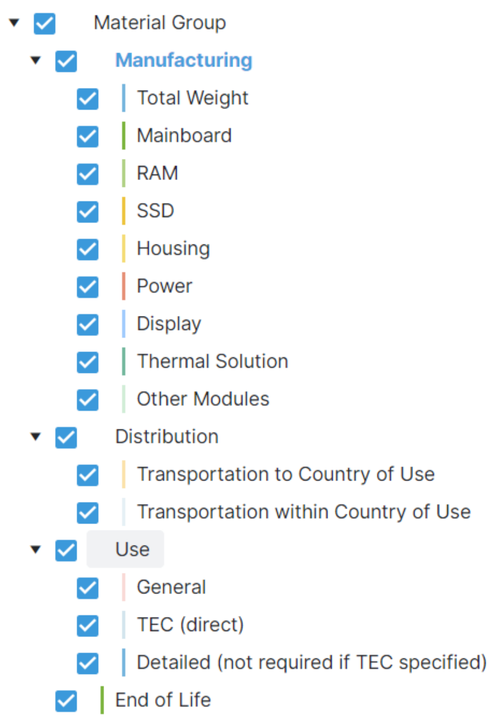


Figure 3-2: Overview of Notebook LCA Calculator in the web tool

3.2.1. Manufacturing

The customization options of the manufacturing are based on the components of the Notebooks. The depth of customization depends on the components. The different customization options for the components are shown below.

Total Weight

Total weight is an open parameter that can be adjusted by changing the mass. Please note that the response of the model will be changed when the parameters are adjusted. This relates to if the total weight changes without adjusting the housing, the model assumes that more electronic components are included in the scenario. If the housing is adjusted but not the total weight, the model assumes that fewer electronic components are included in the model. In an ideal case, the changes of mass of housing should correspond to the total weight, so that no automatic scaling of electronic components and housing. An image of the web tool is shown in Figure 3-3.

	Name	Europe	China	USA	Comment
👁	Total weight	2.22	2.22	2.22	[kg] Total weight (incl. packaging)

Figure 3-3: Input for Total Weight for the Notebook LCA Calculator Web Tool

Mainboard

The drop-down menu of the reference product consists of Latitude 5430, Chromebook 3110, Precision 7670 and Alienware MLK 15. The reference product parameter dictates the changes in the following parameter: PWB layer count, PWB area and IC area. Figure 3-4 shows the open input parameters for the Mainboard.

	Name	Europe	China	USA	Comment
👁	Reference	Latitude	Latitude	Latitude	Select the reference product
👁	PWB layer	8	8	8	[1,2,4,6,8,10,12,16] Layer count of PWB
👁	PWB area	0.0272	0.0272	0.0272	[m^2] Area of Mainboard
👁	IC area	164	164	164	[cm^2] Total package area of Integrated Circuits on Mainboard

Figure 3-4: Input for Mainboard for the Notebook LCA Calculator Web Tool

RAM

The drop-down menu of the reference product consists of 8GB DDR4 and 16GB DDR5. The reference product parameter dictates the changes in the following parameter: RAM Number of pieces, PWB layer count, PWB area and IC area. Figure 3-5 shows the open input parameters for RAM.

	Name	Europe	China	USA	Comment
👁	RAM type	8GB DDR4	8GB DDR4	8GB DDR4	Select the reference product
👁	RAM Number of pieces	1	1	1	
👁	RAM PWB	8	8	8	[1,2,4,6,8,10,12,16] Layer count of PWB
👁	PWB area	0.0021	0.0021	0.0021	[m^2] Area of RAM board
👁	IC area	7.56	7.56	7.56	[cm^2] Total package area of Integrated Circuits on RAM

Figure 3-5: Input for RAM for the Notebook LCA Calculator Web Tool

SSD

The drop-down menu of the reference product consists of 256GB, 512GB and 2TB. The reference product parameter dictates the changes in the following parameter: Number of pieces, PWB layer count, PWB area and IC area. Figure 3-6 shows the open input parameters for SSD.

	Name	Europe	China	USA	Comment
👁	SSD type	256 GB	256 GB	256 GB	Select the reference product
👁	SSD Number of pieces	1 piece	1 piece	1 piece	Number of SSDs used
👁	SSD PWB	6	6	6	[1,2,4,6,8,10,12,16] Layer count of PWB
👁	PWB area	0.00066	0.00066	0.00066	[m^2] Area of SSD board
👁	IC area	10.9	10.9	10.9	[cm^2] Total package area of Integrated Circuits on SSD

Figure 3-6: Input for SSD for the Notebook LCA Calculator Web Tool

Housing

The drop-down menu of the reference product consists of Latitude 5430, Chrome-book 3110, Precision 7670 and Alienware MLK 15. The reference product parameter dictates the changes in the following parameter: User can determine the composition of the material what will be use in the product. The material options consist of aluminum, magnesium, PC-ABS and steel. Figure 3-7 shows the open input parameters Housing.

	Name	Europe	China	USA	Comment
	Housing type	Latitude ▾	Latitude ▾	Latitude ▾	Select the reference product
	Alu	0.01347	0.01347	0.01347	[kg] Mass of Aluminium parts
	Magnesium	0	0	0	[kg] Mass of Magnesium parts
	PC-ABS	0.124	0.124	0.124	[kg] Mass of PC-ABS parts
	Steel	0.00502	0.00502	0.00502	[kg] Mass of Steel sheet

Figure 3-7: Input for Housing for the Notebook LCA Calculator Web Tool

Battery

A basic capacity can be selected for the battery. This can then be scaled by changing the weight. Figure 3-8 shows the open input parameters for batteries.

	Name	Europe	China	USA	Comment
	Battery capacity	58 Wh ▾	58 Wh ▾	58 Wh ▾	Select the battery capacity
	Battery weight	0.213	0.213	0.213	[kg] Mass of Battery (Lat: 0,213; Chr: 0,182; Pre: 0,375; Ali: 0,328)

Figure 3-8: Input for Battery for the Notebook LCA Calculator Web Tool

Display

The drop-down menu of the reference product consists of Latitude 5430, Chrome-book 3110, Precision 7670 and Alienware MLK 15. Each reference product refers to a different screen size. Additionally, the display diagonal and the display ratio can be adjusted. Figure 3-9 shows the open input parameters for Display.

	Name	Europe	China	USA	Comment
	Reference	Latitude ▾	Latitude ▾	Latitude ▾	Select the reference product
	Display diagonale	13.98	13.98	13.98	[in] Lat: 13,98; Chr: 11,81; Pre: 15,94; Ali: 15,59
	Display ratio	17:10 ▾	17:10 ▾	17:10 ▾	Select aspect ratio

Figure 3-9: Input for Display for the Notebook LCA Calculator Web Tool

Thermal Solution

The drop-down menu of the reference product consists of Latitude 5430, Chrome-book 3110, Precision 7670 and Alienware MLK 15. The materials options available to choose from are copper and aluminum. Also, the number of fans can be customized. Users can choose between 0 to 4 fans. An overview of the web tool is shown in Figure 3-10.

	Name	Europe	China	USA	Comment
	Thermal solution type	Latitude ▾	Latitude ▾	Latitude ▾	Select the reference product
	Al sheet	0.00487	0.00487	0.00487	[kg] Mass of Aluminium parts (Lat: 0,00487; Pre: 0,081; Ali: 0;)
	Cu sheet	0.0361	0.0361	0.0361	[kg] Mass of Copper parts (Lat: 0,0361; Pre: 0,128; Ali: 0,341;)
	Fans	1 fan ▾	1 fan ▾	1 fan ▾	Select the number of fans

Figure 3-10: Input for Thermal Solution for the Notebook LCA Calculator Web Tool

Packaging

The drop-down menu of the reference product consists of Latitude 5430, Chrome-book 3110, Precision 7670 and Alienware MLK 15. Figure 3-11 shows the open input parameters for the Other Modules. The Power Supply Unit is an external charger. The selection refers to the power rating of the device. There is a choice of 65W, 180W and 240W charger. For the packaging, keyboard, touchpad and camera the reference model can be determined. The reference models are Latitude 5430, Chrome-book 3110, Precision 7670 and Alienware MLK 15. The drop-down menu of the reference product consists of Latitude 5430, Chrome-book 3110, Precision 7670 and Alienware MLK 15. For Other Electronics, user can select between "no extras" and LED stripes & Logo.

Name	Europe	China	USA	Comment
Packaging	Latitude ▾	Latitude ▾	Latitude ▾	Select the reference product
PSU	65 W ▾	65 W ▾	65 W ▾	Select the power rating
Keyboard	Latitude ▾	Latitude ▾	Latitude ▾	Select the reference product
Touchpad	Latitude ▾	Latitude ▾	Latitude ▾	Select the reference product
Display Camera	Latitude ▾	Latitude ▾	Latitude ▾	Select the reference product
Other Electronics	No extras ▾	No extras ▾	No extras ▾	Select additional electronics

Figure 3-11: Input for Other Modules for the Notebook LCA Calculator Web Tool

3.2.2. Distribution

The distribution stage is split into distribution to country of use and to distribution within country of use. The user can select the transportation mode by plane, ship, and truck.

Transportation to country of use

The transportation options for distribution to the country of use are by plane, train and truck. The unit by default is in kilometers. Figure 3-12 shows the open input parameters for Distribution to Country of use.

Name	Europe	China	USA	Comment
Distance_plane	1950	0	1050	[km] Transportation distance plane
Distance_ship	17550	0	9450	[km] Transportation distance ship
Distance_truck	1600	1600	1600	[km] Transportation distance truck

Figure 3-12: Input for Distribution to country of use for the Notebook LCA Calculator Web Tool

Transportation within country of use

The transportation options for distribution to the country of use are by plane, train and truck. The unit by default is in kilometers. Figure 3-13 shows the open input parameters for Distribution within Country of use.

Name	Europe	China	USA	Comment
Distance_plane	0	0	0	[km] Transportation distance plane
Distance_ship	0	0	0	[km] Transportation distance ship
Distance_truck	1060	1600	2600	[km] Transportation distance truck

Figure 3-13: Input for Distribution within country of use for the Notebook LCA Calculator Web Tool

3.2.3. Use

For the use phase, user will first determine the lifespan and the use location of the product (Figure 3-14). The user can then decide whether to enter use information as a TEC input (Figure 3-15) or to enter detailed information on usage scenarios of the product (Figure 3-16). The user needs to enter one of the options but not both.

General

The user can define the lifespan of the product and set the use location for the product. Use locations are, Europe, China, USA, France, Great Britan, and Germany.

Name	Europe	China	USA	Comment
Lifespan	5	5	5	[years] Life span of the product
Use Location	Europe ▼	China ▼	USA ▼	Select Use Location

Figure 3-14: Input for General use information for the Notebook LCA Calculator Web Tool

TEC

Typical Energy Consumption (TEC) is a method for evaluating and comparing computer energy performance that focuses on the average amount of electricity used by an item while it is operating normally over an extended period of time. The TEC is used as an Energy Star Program requirement. The TEC is given in the typical annual energy consumption (kWh/a) of the product.

Name	Europe	China	USA	Comment
P_TEC	0	0	0	[kWh/a] Annual Typical Energy Consumption (TEC)

Figure 3-15: Input for TEC use information for the Notebook LCA Calculator Web Tool

Detailed

Detailed information is not required if TEC is specified. The detailed information is split up into different usage modes (long idle, short idle, sleep and off mode). The input for the usage modes is in Kilowatt. User can enter the time for each usage mode in hours of use.

	Name	Europe	China	USA	Comment
	Long_idle_hr	1.2	1.2	1.2	[hrs] Hours of Long Idle mode per day (0-24)
	Long_idle_mode	0.0012	0.0012	0.0012	[kW] Power Long Idle mode
	Off_hr	6	6	6	[hrs] Hours of off mode per day (0-24)
	Off_mode	0.0005	0.0005	0.0005	[kW] Power off mode
	Short_idle_hr	6	6	6	[hrs] Hours of Short Idle mode per day (0-24)
	Short_idle_mode	0.0052	0.0052	0.0052	[kW] Power Short Idle mode
	Sleep_hr	10.8	10.8	10.8	[hrs] Hours of sleep mode per day (0-24)
	Sleep_mode	0.0012	0.0012	0.0012	[kW] Power sleep mode

Figure 3-16: Input for detailed use information for the Notebook LCA Calculator Web Tool

3.2.4. End-of-Life

As shown in Figure 3-17 , user can select a reference product (Latitude 5430, Chromebook 3110, Precision 7670 and Alienware MLK 15) to set a base for the inputs for the End-of-Life. Additionally, the collection rate can be adjusted. The collection rate specifies how much percent of the product is collected for end-of-life.

	Name	Europe	China	USA	Comment
	Reference	Latitude ▾	Latitude ▾	Latitude ▾	Select the reference product
	Collection Rate	100	100	100	[%] Collection rate products at End-of-Life

Figure 3-17: Input for End-of-Life information for the Notebook LCA Calculator Web Tool

3.2.5. Results Generation

The Notebook LCA Calculator Web Tool generates Total Carbon Footprint by Life Cycle Stages (excluding end-of-life credits) in Pie chart (Figure 3-18), Bar chart (Figure 3-19) and results table (Figure 3-20). The following scenario is assumed for the purpose of demonstrating how the results are presented:

	Scenario Settings	Europe	China	USA	Comment
S3	ScenarioSettings\Manufacturing\Total Weight\Total weight	2.22	2.22	2.22	[kg] Total weight (incl. packaging)
S5	ScenarioSettings\Manufacturing\Mainboard\Reference	Latitude	Latitude	Latitude	Select the reference product
S6	ScenarioSettings\Manufacturing\Mainboard\PWB layer	8	8	8	[1,2,4,6,8,10,12,16] Layer count of PWB
S7	ScenarioSettings\Manufacturing\Mainboard\PWB area	0.0272	0.0272	0.0272	[m^2] Area of Mainboard
S8	ScenarioSettings\Manufacturing\Mainboard\IC area	164	164	164	[cm^2] Total package area of Integrated Circuits on Mainboard
S10	ScenarioSettings\Manufacturing\RAM\RAM type	Latitude	Latitude	Latitude	Select the reference product
S11	ScenarioSettings\Manufacturing\RAM\RAM Number of pieces	1	1	1	Number of RAM bars
S12	ScenarioSettings\Manufacturing\RAM\RAM PWB	8	8	8	[1,2,4,6,8,10,12,16] Layer count of PWB
S13	ScenarioSettings\Manufacturing\RAM\PWB area	0.0021	0.0021	0.0021	[m^2] Area of RAM board
S14	ScenarioSettings\Manufacturing\RAM\IC area	7.56	7.56	7.56	[cm^2] Total package area of Integrated Circuits on RAM
S16	ScenarioSettings\Manufacturing\SSD\SSD type	Latitude	Latitude	Latitude	Select the reference product
S17	ScenarioSettings\Manufacturing\SSD\SSD Number of pieces	1 piece	1 piece	1 piece	Number of SSDs used
S18	ScenarioSettings\Manufacturing\SSD\SSD PWB	6	6	6	[1,2,4,6,8,10,12,16] Layer count of PWB
S19	ScenarioSettings\Manufacturing\SSD\PWB area	0.00066	0.00066	0.00066	[m^2] Area of SSD board
S20	ScenarioSettings\Manufacturing\SSD\IC area	10.9	10.9	10.9	[cm^2] Total package area of Integrated Circuits on SSD
S22	ScenarioSettings\Manufacturing\Housing\Housing type	Latitude	Latitude	Latitude	Select the reference product
S23	ScenarioSettings\Manufacturing\Housing\Alu	0.01347	0.01347	0.01347	[kg] Mass of Aluminium parts
S24	ScenarioSettings\Manufacturing\Housing\Magnesium	0	0	0	[kg] Mass of Magnesium parts
S25	ScenarioSettings\Manufacturing\Housing\PC-ABS	0.124	0.124	0.124	[kg] Mass of PC-ABS parts

S26	ScenarioSettings\Manufacturing\Housing\Steel	0.00502	0.00502	0.00502	[kg] Mass of Steel sheet
S28	ScenarioSettings\Manufacturing\Power\Battery capacity	58 Wh	58 Wh	58 Wh	Select the battery capacity
S29	ScenarioSettings\Manufacturing\Power\Battery weight	0.213	0.213	0.213	[kg] Mass of Battery (Lat: 0,213; Chr: 0,182; Pre: 0,375; Ali: 0,328)
S31	ScenarioSettings\Manufacturing\Display\Reference	Latitude	Latitude	Latitude	Select the reference product
S32	ScenarioSettings\Manufacturing\Display\Display diagonale	13.98	13.98	13.98	[in] Lat: 13,98; Chr: 11,81; Pre: 15,94; Ali: 15,59
S33	ScenarioSettings\Manufacturing\Display\Display ratio	17:10	17:10	17:10	Select aspect ratio
S35	ScenarioSettings\Manufacturing\Thermal Solution\Thermal solution type	Latitude	Latitude	Latitude	Select the reference product
S36	ScenarioSettings\Manufacturing\Thermal Solution\Al sheet	0.00487	0.00487	0.00487	[kg] Mass of Aluminium parts (Lat: 0,00487; Pre: 0,081; Ali: 0;)
S37	ScenarioSettings\Manufacturing\Thermal Solution\Cu sheet	0.0361	0.0361	0.0361	[kg] Mass of Copper parts (Lat: 0,0361; Pre: 0,128; Ali: 0,341;)
S38	ScenarioSettings\Manufacturing\Thermal Solution\Fans	1 fan	1 fan	1 fan	Select the number of fans
S40	ScenarioSettings\Manufacturing\Other Modules\Packaging	Latitude	Latitude	Latitude	Select the reference product
S41	ScenarioSettings\Manufacturing\Other Modules\PSU	65 W	65 W	65 W	Select the power rating
S42	ScenarioSettings\Manufacturing\Other Modules\Keyboard	Latitude	Latitude	Latitude	Select the reference product
S43	ScenarioSettings\Manufacturing\Other Modules\Touchpad	Latitude	Latitude	Latitude	Select the reference product
S44	ScenarioSettings\Manufacturing\Other Modules\Display Camera	Latitude	Latitude	Latitude	Select the reference product
S45	ScenarioSettings\Manufacturing\Other Modules\Other Electronics	No extras	No extras	No extras	Select additional electronics
S48	ScenarioSettings\Distribution\Transportation to Country of Use\Distance_plane	1950	0	1050	[km] Transportation distance plane
S49	ScenarioSettings\Distribution\Transportation to Country of Use\Distance_ship	17550	0	9450	[km] Transportation distance ship
S50	ScenarioSettings\Distribution\Transportation to Country of Use\Distance_truck	1600	1600	1600	[km] Transportation distance truck
S51	ScenarioSettings\Distribution\Transportation within Country of Use\Distance_plane	0	0	0	[km] Transportation distance plane

S52	ScenarioSettings\Distribution\Transportation within Country of Use\Distance_ship	0	0	0	[km] Transportation distance ship
S53	ScenarioSettings\Distribution\Transportation within Country of Use\Distance_truck	1060	1600	2600	[km] Transportation distance truck
S57	ScenarioSettings\Use\General\Lifespan	5	5	5	[years] Life span of the product
S58	ScenarioSettings\Use\General\Use Location	Europe	China	USA	Select Use Location
S60	ScenarioSettings\Use\TEC (direct)\P_TEC	0	0	0	[kWh/a] Annual Typical Energy Consumption (TEC)
S62	ScenarioSettings\Use\Detailed (not required if TEC specified)\Long_idle_hr	1.2	1.2	1.2	[hrs] Hours of Long Idle mode per day (0-24)
S63	ScenarioSettings\Use\Detailed (not required if TEC specified)\Long_idle_mode	0.0012	0.0012	0.0012	[kW] Power Long Idle mode
S64	ScenarioSettings\Use\Detailed (not required if TEC specified)\Off_hr	6	6	6	[hrs] Hours of off mode per day (0-24)
S65	ScenarioSettings\Use\Detailed (not required if TEC specified)\Off_mode	0.0005	0.0005	0.0005	[kW] Power off mode
S66	ScenarioSettings\Use\Detailed (not required if TEC specified)\Short_idle_hr	6	6	6	[hrs] Hours of Short Idle mode per day (0-24)
S67	ScenarioSettings\Use\Detailed (not required if TEC specified)\Short_idle_mode	0.0052	0.0052	0.0052	[kW] Power Short Idle mode
S68	ScenarioSettings\Use\Detailed (not required if TEC specified)\Sleep_hr	10.8	10.8	10.8	[hrs] Hours of sleep mode per day (0-24)
S69	ScenarioSettings\Use\Detailed (not required if TEC specified)\Sleep_mode	0.0012	0.0012	0.0012	[kW] Power sleep mode
S71	ScenarioSettings\End of Life\Reference	Latitude	Latitude	Latitude	Select the reference product
S72	ScenarioSettings\End of Life\Collection Rate	100	100	100	[%] Collection rate products at End-of-Life

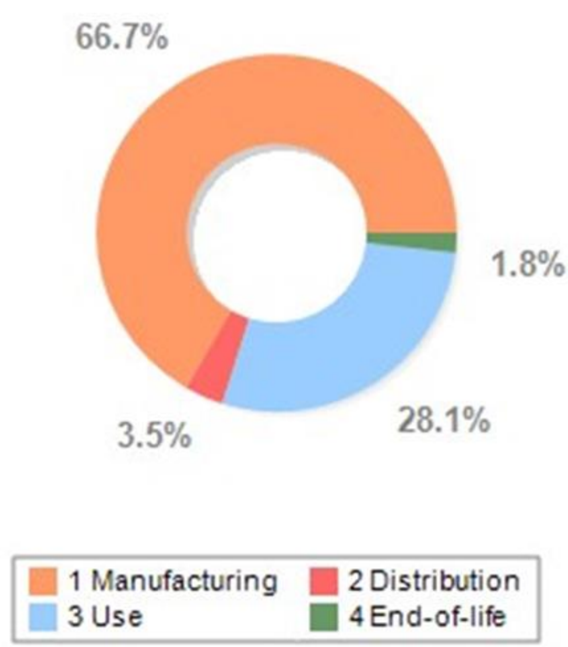


Figure 3-18: LCA Calculator Web Tool results generation (pie chart)

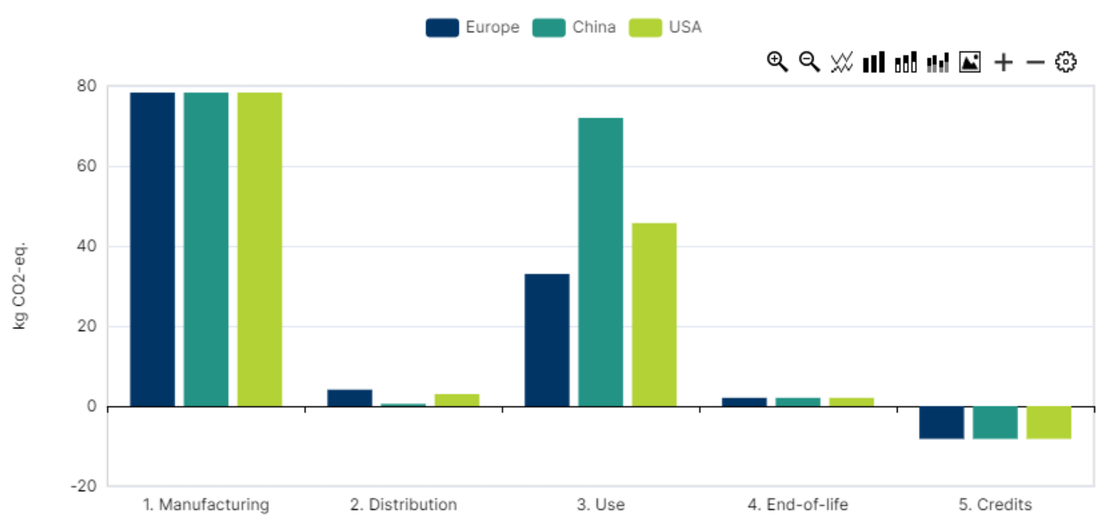


Figure 3-19: LCA Calculator Web Tool results generation (bar chart)

	1. Manufacturing	2. Distribution	3. Use	4. End-of-life	5. Credits
Europe	78.323	4.101	33.014	2.060	-8.188
China	78.323	0.549	72.003	2.060	-8.188
USA	78.323	3.001	45.726	2.060	-8.188

Figure 3-20: LCA Calculator Web Tool results generation (table)[1]

In a detailed view of the carbon footprint of the three scenarios, it shows that the major fraction of the impact is from the manufacturing stage, followed by the use stage. Depending on the country of use and EoL, the carbon footprint results will be different due to the power grid mix used in different countries/regions. It is important to note that results will differ, based on different parameter settings.

3.2.6. Report Generation

The LCA Calculator offers the possibility to create a predefined report for a product. An example and detailed description of the report can be found in chapter 1.

[1] All results in the figure refer to kg CO_2-eq..

4. Dell Desktop Calculator

4.1. General information

4.1.1. LCA Calculator Tool

The LCA calculator tool was developed to calculate the LCA results in accordance with ISO 14040/44 for the Dell Desktop PC product group.

4.1.2. Goal and scope of the study

The goal of the study is to quantify the carbon footprint of a single Desktop PC system across the product life cycle (cradle-to-grave), including the extraction of raw materials, production of components, transportation, use of the product and end-of-life.

4.1.3. Product group description

The product group in the Dell Desktop calculator includes OptiPlex 3000, OptiPlex 7000, OptiPlex 7090, Precision 3260, Precision 5820 and Precision 7820. The LCA model can combine and modify individual modules of the products.

4.1.4. Application area of product group

Dell Desktop Calculator is designed for internal and external communication.

4.1.5. Declared unit

The declared unit is one piece of product with a lifetime of 5 years.

4.1.6. Data collection for LCA-tool set-up

Primary data for the material content of the product were collected using a physical teardown provided by Dell. During the product teardown, parts and materials were identified, weighed, and measured. The teardown was conducted on a mass-production-ready version of the product provided by Dell. Data on distribution, product use and end of life were collected and discussed through online communication in regular project meetings. Upon receipt, each questionnaire was cross-checked for completeness and plausibility using mass balance as well as internal and external benchmarking. The data were discussed via online communication and in regular project meetings.

The decision for ICs to be sent for laboratory analysis are based on dimensions (any ICs above 10 x 10 mm) and the functionality with focus on CMOS, Flash and RAM technology. The larger ICs are sent to a laboratory for decapsulation ("decapping") to reveal the actual die size, die stacking, identify whether gold is being used as bond wire material and to take x-rays to identify pin count of electrical interconnects (e.g., solder bumps). Decision basis for the collection of these additional data points was the understanding, that these ICs potentially bear a high environmental footprint, resulting in a need to improve the certainty of the results by using a higher level of granularity in data collection and modelling.

4.1.7. Life Cycle Inventory Analysis

The weight of each main modules of the Dell Desktops are summarized in the following table:

Table 4-1: Weight by product module for desktops under investigation

Material/Part	OptiPlex 3000 (kg)	OptiPlex 7000 (kg)	OptiPlex 7090 (kg)	Precision 3269 (kg)	Precision 5820 (kg)	Precision 7820 (kg)
Packaging	0.62	2.31	1.74	1.05	2.38	2.80
Mechanicals	0.75	3.72	2.99	1.12	10.9	9.55
Electromechanicals	0.05	0.31	0.4	0.08	1.61	1.15
Mainboard	0.16	0.34	0.31	0.19	0.74	0.95
CPU	0.04	0.04	0.03	0.04	0.05	0.11
RAM	0.01	0.02	0.03	0.02	0.04	0.02
SSD	0.003	0.003	0.02	0.01	0.37	0.39
Graphic Card	0	0	0.07	0.13	0.63	1.08
Power Supply Unit	0.21	0.50	0.22	0	0.97	0.96
ODD	0	0	0	0	0	0
Connectivity	0	0.14	0.14	0	0	0
Mouse	0	0.09	0.08	0	0	0
Keyboard	0	0.43	0.61	0	0	0
Total weight	**1.84**	**7.90**	**8.57**	**2.64**	**17.04**	**17.01**

4.1.8. System boundary

Dell's Notebooks are manufactured and assembled in China. Afterwards, they get distributed to different hubs in the world (e.g. Europe, US, China) (see following figure). The selection of the country of use needs to be aligned accordingly (see chapter 3.2). All collected products end-up in a mixed end-of-life scenario (see chapter 2.5).

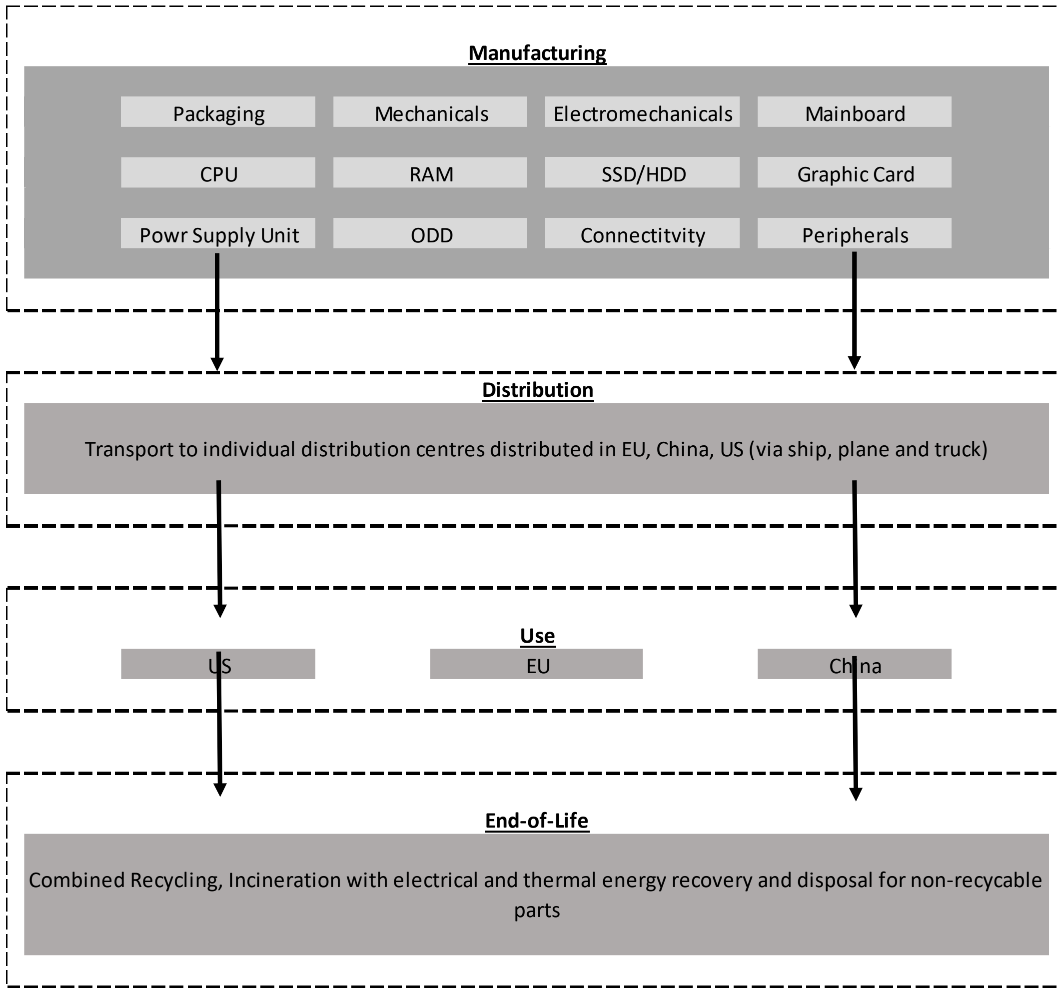


Figure 4-1: Dell Desktop system boundaries

4.2. Desktop LCA Calculator Web Tool

Figure 4-2 shows the general structure of the Desktop LCA Calculator. The user can select one item of the structure to get the specified input field with different options related to each item. The structure of the tool, according to an LCA, consists of manufacturing, distribution, use phase and end-of-life. In manufacturing, each component can be adapted individually, depending on the parameterization. The individual customization options can be found in 4.2.1. The customization options for distribution are divided between transportation to the country of use and transportation in the country of use. The input possibilities can be found in 4.2.2. In 4.2.3 the user first enters general information for the use phase and then has the choice of using the TEC as the value for the use phase or using a detailed description of the use of the product. For the EoL the collection rate and the base product can be selected as described in 4.2.4.

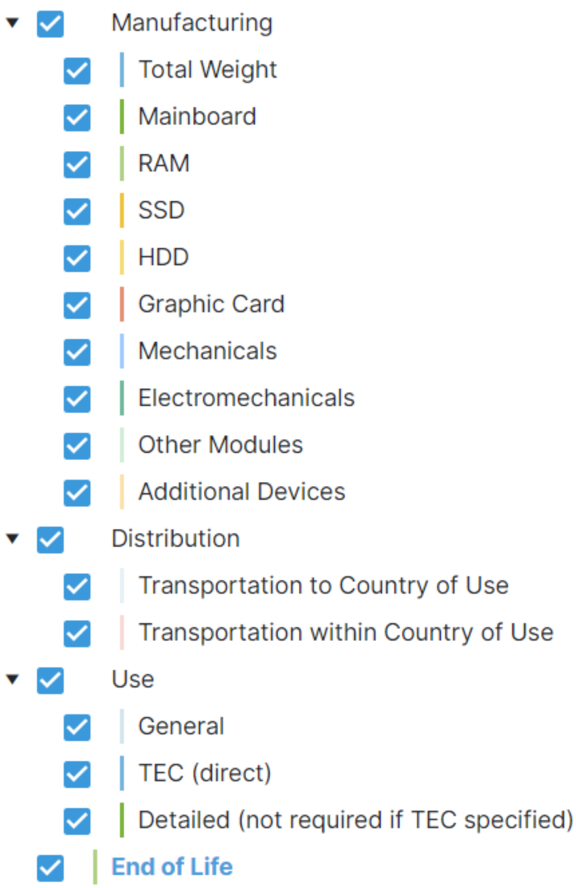


Figure 4-2: Overview of Desktop LCA Calculator in the web tool

4.2.1. Manufacturing

The customization options of the manufacturing are based on the components of the desktops. The depth of customization depends on the components. The different customization options for the components are shown below.

Total Weight

Total weight is an open parameter that can be adjusted by changing the mass. Please note that the response of the model will be changed when the parameters are adjusted. This relates to if the total weight changes without adjusting the housing, the model assumes that more electronic components are included in the scenario. If the housing is adjusted but not the total weight, the model assumes that fewer electronic components are included in the model. In an ideal case, the changes of mass of housing should correspond to the total weight, so that no automatic scaling of electronic components and housing. An image of the web tool is shown in Figure 4-3.

Figure 4-3: Input for Total Weight for the Desktop LCA Calculator Web Tool

Mainboard

The drop-down menu of the reference product consists of MFF (Micro Form Factor), Mini Tower, SFF (Small Form Factor), CFF (Compact Form Factor), Standard Tower (Precision 5820) and Standard Tower (Precision 7820). The reference product parameter dictates the changes in the following parameter: PWB layer count, PWB area and IC area. Figure 4-4 shows the open input parameters for the Mainboard.

	Name	Europe	China	USA	Comment
👁	Mainboard Selection	MFF ▾	MFF ▾	MFF ▾	Select the reference
👁	PWB_layer	4 ▾	4 ▾	4 ▾	[1,2,4,8,10,12,16] Layer count of ...
👁	IC_area	25.6	25.6	25.6	[cm^2] Total package area of In...
👁	PWB_area	274	274	274	[cm^2] Area of Mainboard

Figure 4-4: Input for Mainboard for the Desktop LCA Calculator Web Tool

RAM

The drop-down menu of the reference product consists of 8GB DDR4, 16GB DDR4, 32GB DDR5, 32GB DDR4 and 64GB. The reference selection parameter dictates the changes in the following parameter: RAM Number of pieces, PWB layer count, PWB area and IC area. Figure 4-5 shows the open input parameters for RAM.

	Name	Europe	China	USA	Comment
👁	RAM Selection	16GB - DDR4 - MFF ▾	16GB - DDR4 - MFF ▾	16GB - DDR4 - MFF ▾	Select the reference
👁	RAM Number of pieces	1 piece ▾	1 piece ▾	1 piece ▾	Number of RAM bars used
👁	PWB_layer	8 ▾	8 ▾	8 ▾	[1,2,4,8,10,12,16] Layer count of ...
👁	IC_area	8.86	8.86	8.86	[cm^2] Total IC package area
👁	PWB_area	40.1	40.1	40.1	[cm^2] Area of RAM board

Figure 4-5: Input for RAM for the Desktop LCA Calculator Web Tool

SSD

The drop-down menu of the reference product consists of MFF (Micro Form Factor), Mini Tower, SFF (Small Form Factor), CFF (Compact Form Factor), Standard Tower (Precision 5820) and Standard Tower (Precision 7820). The reference product parameter dictates the changes in the following parameter: SSD Number of pieces, PWB layer count, PWB area and IC area. Figure 4-6 shows the open input parameters for SSD.

	Name	Europe	China	USA	Comment
👁	SSD Selection	256GB SSD ▾	256GB SSD ▾	256GB SSD ▾	Select the reference
👁	SSD Number of pieces	1 piece ▾	1 piece ▾	1 piece ▾	Number of SSDs used
👁	PWB_layer	8 ▾	8 ▾	8 ▾	[1,2,4,8,10,12,16] Layer count of ...
👁	IC_area	3.28	3.28	3.28	[cm^2] Total package area of In...
👁	PWB_area	6.6	6.6	6.6	[cm^2] Area of SSD board

Figure 4-6: Input for SSD for the Desktop LCA Calculator Web Tool

Graphic Card

The drop-down menu of the reference product consists of MFF (Micro Form Factor), Mini Tower, SFF (Small Form Factor), CFF (Compact Form Factor), Standard Tower (Precision 5820) and Standard Tower (Precision 7820). The reference product parameter dictates the changes in the following parameter: PWB layer count, PWB area and IC area. Figure 4-7 shows the open input parameters for Graphic Card.

Name	Europe	China	USA	Comment
GPU selection	none ▾	none ▾	none ▾	Select the Graphic Card
PWB_Layer	10 ▾	10 ▾	10 ▾	[1,2,4,8,10,12,16] Layer count of PWB
IC_area	7.45	7.45	7.45	[cm^2] Total IC package area
PWB_area	92.95	92.95	92.95	[cm^2] Area of Graphic Card

Figure 4-7: Input for Graphic Card for the Desktop LCA Calculator Web Tool

Mechanicals

The drop-down menu of the reference product consists of MFF (Micro Form Factor), Mini Tower, SFF (Small Form Factor), CFF (Compact Form Factor), Standard Tower (Precision 5820) and Standard Tower (Precision 7820). Users can determine the composition of the material that will be used to produce the chassis, thermal solution, fans, speaker and cables. The material options consist of aluminum, magnesium, (ABS & PC-ABS) and steel. Figure 4-8 shows the open input parameters for Mechanicals.

Name	Europe	China	USA	Comment
Mechanical Selection	MFF ▾	MFF ▾	MFF ▾	Select the reference
Plastic	0.023	0.023	0.023	[kg] Mass of ABS and PC-ABS ...
Steel_Sheet	0.577	0.577	0.577	[kg] Mass of Steel parts
Al_Sheet	0	0	0	[kg] Mass of Aluminium parts

Figure 4-8: Input for Mechanical components for the Desktop LCA Calculator Web Tool

The drop-down menu of the reference product consists of MFF (Micro Form Factor), Mini Tower, SFF (Small Form Factor), CFF (Compact Form Factor), Standard Tower (Precision 5820) and Standard Tower (Precision 7820). The number of electromechanical components used within the products differ. Figure 4-9 shows the open input parameters for Mechanicals.

Name	Europe	China	USA	Comment
EM Selection	MFF ▾	MFF ▾	MFF ▾	Select the reference
ODD	none ▾	none ▾	none ▾	[pcs] Number of Optical Disk Dr...

Figure 4-9: Input for Electromechanicals components for the Desktop LCA Calculator Web Tool

Other Modules

The Power Supply Unit can be external charger (MFF and CFF) and internal (Mini Tower, SFF and Standard Tower). The selection refers to the power rating of the device. There is a choice of 65W and 240W for external PSU and 300W, 500W, and 950W for the external PSU´s.

Name	Europe	China	USA	Comment
WLAN	External WLAN - MFF ▼	External WLAN - MFF ▼	External WLAN - MFF ▼	Select if WLAN board is included
Antenna Selection	Antenna ▼	Antenna ▼	Antenna ▼	Select if Anteanna is included
PSU Selection	65W AC Adapter ▼	65W AC Adapter ▼	65W AC Adapter ▼	Select the reference
Other Electronics	none ▼	none ▼	none ▼	Select the reference
Packaging	MFF ▼	MFF ▼	MFF ▼	Select the reference

Figure 4-10: Input for Other Modules for the Desktop LCA Calculator Web Tool

Additional devices

As shown in Figure 4-11 additional input devices can be selected. It is possible to select a keyboard and a mouse.

Name	Europe	China	USA	Comment
Keyboard	Keyboard ▼	Keyboard ▼	Keyboard ▼	Select if Keyboard is included
Mouse	Mouse ▼	Mouse ▼	Mouse ▼	Select if Mouse is included

Figure 4-11: Input for Input devices for the Desktop LCA Calculator Web Tool

Packaging

The drop-down menu of the reference product consists of MFF (Micro Form Factor), Mini Tower, SFF (Small Form Factor), CFF (Compact Form Factor), Standard Tower (Precision 5820) and Standard Tower (Precision 7820). Figure 4-12 shows the open input parameters for Packaging.

Name	Europe	China	USA	Comment
Packaging	Optiplex 3000 ▼	Optiplex 3000 ▼	Optiplex 3000 ▼	Select the reference

Figure 4-12: Input for Packaging for the Desktop LCA Calculator Web Tool

4.2.2. Distribution

The distribution stage is split into distribution to country of use and to distribution within country of use. The user can select the transportation mode by plane, ship, and truck.

Transportation to country of use

The transportation options for distribution to the country of use are by plane, train and truck. The unit by default is in kilometers. Figure 4-13 shows the open input parameters for Distribution to Country of use.

	Name	Europe	China	USA	Comment
👁	Distance_plane	1950	0	1050	[km] Transportation distance plane
👁	Distance_ship	17550	0	9450	[km] Transportation distance ship
👁	Distance_truck	1600	1600	1600	[km] Transportation distance truck

Figure 4-13: Input for Distribution to country of use for the Desktop LCA Calculator Web Tool

Transportation within country of use

The transportation options for distribution to the country of use are by plane, train and truck. The unit by default is in kilometers. Figure 4-14 shows the open input parameters for Distribution within Country of use.

	Name	Europe	China	USA	Comment
👁	Distance_plane	0	0	0	[km] Transportation distance plane
👁	Distance_ship	0	0	0	[km] Transportation distance ship
👁	Distance_truck	1060	1600	2600	[km] Transportation distance truck

Figure 4-14: Input for Distribution within country of use for the Desktop LCA Calculator Web Tool

4.2.3. Use

For the use phase the user first enters the lifespan and the use location of the product (Figure 4-15). The user can then decide whether to enter use information as a TEC input (Figure 4-16) or to enter detailed information about usage scenarios of the product (Figure 4-17). The user needs to enter one of the options but not both.

General

The user can define the lifespan of the product and set the use location for the product. Use locations are, Europe, China, USA, France, Great Britan and Germany.

	Name	Europe	China	USA	Comment
👁	Lifespan	5	5	5	[years] Life span of the product
👁	Use Location	Europe ▼	China ▼	USA ▼	Select Use Location

Figure 4-15: Input for General use information for the Desktop LCA Calculator Web Tool

TEC

Typical Energy Consumption (TEC) is a technique for evaluating and comparing computer energy performance that focuses on the average amount of electricity used by an item while it is operating normally over an extended period of time. The TEC is used as an Energy Star Program requirement. The TEC is given in the typical annual energy consumption (kWh/a) of the product.

	Name	Europe	China	USA	Comment
👁	P_TEC	0	0	0	[kWh/a] Annual Typical Energy Consumption (TEC)

Figure 4-16: Input for TEC use information for the Desktop LCA Calculator Web Tool

Detailed

Detailed information is not required if TEC is specified. The detailed information is split up into different usage modes (long idle, short idle, sleep and off mode). The input for the usage modes is in Kilowatt. User can enter the time for each usage mode in hours of use.

Name	Europe	China	USA	Comment
Long_idle_hr	2.4	2.4	2.4	[hrs] Hours of Long Idle mode per day (0-24)
Long_idle_mode	0.01263	0.01263	0.01263	[kW] Power Long Idle mode
Off_hr	3.6	3.6	3.6	[hrs] Hours of off mode per day (0-24)
Off_mode	0.0004	0.0004	0.0004	[kW] Power off mode
Short_idle_hr	7.2	7.2	7.2	[hrs] Hours of Short Idle mode per day (0-24)
Short_idle_mode	0.01469	0.01469	0.01469	[kW] Power Short Idle mode
Sleep_hr	10.8	10.8	10.8	[hrs] Hours of sleep mode per day (0-24)
Sleep_mode	0.00176	0.00176	0.00176	[kW] Power sleep mode

Figure 4-17: Input for detailed use information for the Desktop LCA Calculator Web Tool

4.2.4. End-of-Life

As shown in Figure 4-18 the user can select a reference product (MFF (Micro Form Factor), Mini Tower, SFF (Small Form Factor), CFF (Compact Form Factor), Standard Tower (Precision 5820) and Standard Tower (Precision 7820)) to set a base for the inputs for the End-of-Life. Additionally, the collection rate can be adjusted. The collection rate specifies how much percent of the product is collected for end-of-life.

Name	Europe	China	USA	Comment
EoL Selection	MFF	MFF	MFF	Select the reference
Collection Rate	100	100	100	[%] Collection rate products at ...

Figure 4-18: Input for End-of-Life information for the Desktop LCA Calculator Web Tool

4.2.5. Results Generation

The Notebook LCA Calculator Web Tool generates Total Carbon Footprint by Life Cycle Stages (excluding end-of-life credits) in Pie chart (Figure 4-19), Bar chart (Figure 4-20Figure 3-19) and results table (Figure 4-21). The following scenario is assumed for the purpose of demonstrating how the results are presented:

	Scenario Settings	Europe	China	USA	Comment
S3	ScenarioSettings\Manufacturing\Total Weight\Total_weight	1.71842	1.71842	1.71842	[kg] Total weight of the product (incl. packaging)
S5	ScenarioSettings\Manufacturing\Main-board\Mainboard Selection	MFF	MFF	MFF	Select the reference
S6	ScenarioSettings\Manufacturing\Main-board\PWB_layer	4	4	4	[1,2,4,8,10,12,16] Layer count of PWB
S7	ScenarioSettings\Manufacturing\Main-board\IC_area	25.6045	25.6045	25.6045	[cm^2] Total package area of Inte-grated Circuits on Mainboard
S8	ScenarioSettings\Manufacturing\Main-board\PWB_area	273.8925	273.8925	273.8925	[cm^2] Area of Mainboard
S10	ScenarioSettings\Manufacturing\RAM\RAM Selection	16GB - DDR4	16GB - DDR4	16GB - DDR4	Select the reference
S11	ScenarioSettings\Manufacturing\RAM\RAM Number of pieces	1 piece	1 piece	1 piece	Number of RAM bars
S12	ScenarioSettings\Manufactur-ing\RAM\PWB_layer	8	8	8	[1,2,4,8,10,12,16] Layer count of PWB
S13	ScenarioSettings\Manufactur-ing\RAM\IC_area	8.86	8.86	8.86	[cm^2] Total IC package area
S14	ScenarioSettings\Manufactur-ing\RAM\PWB_area	40.1	40.1	40.1	[cm^2] Area of RAM board
S16	ScenarioSettings\Manufacturing\SSD\SSD Selection	MFF	MFF	MFF	Select the reference
S17	ScenarioSettings\Manufacturing\SSD\SSD Number of pieces	1 piece	1 piece	1 piece	Number of SSD´s
S18	ScenarioSettings\Manufactur-ing\SSD\PWB_layer	8	8	8	[1,2,4,8,10,12,16] Layer count of PWB
S19	ScenarioSettings\Manufactur-ing\SSD\IC_area	3.2825	3.2825	3.2825	[cm^2] Total package area of Inte-grated Circuits on SSD
S20	ScenarioSettings\Manufactur-ing\SSD\PWB_area	6.6	6.6	6.6	[cm^2] Area of SSD board
S25	ScenarioSettings\Manufacturing\Graphic Card\GPU selection	none	none	none	Select the Graphic Card
S26	ScenarioSettings\Manufacturing\Graphic Card\PWB_Layer	10	10	10	[1,2,4,8,10,12,16] Layer count of PWB
S27	ScenarioSettings\Manufacturing\Graphic Card\IC_area	7.45	7.45	7.45	[cm^2] Total IC package area

S28	ScenarioSettings\Manufacturing\Graphic Card\PWB_area	92.95	92.95	92.95	[cm^2] Area of Graphic Card
S30	ScenarioSettings\Manufacturing\Mechanicals\Mechanical Selection	MFF	MFF	MFF	Select the reference
S31	ScenarioSettings\Manufacturing\Mechanicals\Plastic	0.023	0.023	0.023	[kg] Mass of ABS and PC-ABS parts
S32	ScenarioSettings\Manufacturing\Mechanicals\Steel_Sheet	0.577	0.577	0.577	[kg] Mass of Steel parts
S33	ScenarioSettings\Manufacturing\Mechanicals\Al_Sheet	0	0	0	[kg] Mass of Aluminium parts
S35	ScenarioSettings\Manufacturing\Electromechanicals\EM Selection	MFF	MFF	MFF	Select the reference
S36	ScenarioSettings\Manufacturing\Electromechanicals\ODD	none	none	none	[pcs] Number of Optical Disk Drives
S38	ScenarioSettings\Manufacturing\Other Modules\WLAN	WLAN	WLAN	WLAN	Select the reference
S39	ScenarioSettings\Manufacturing\Other Modules\Antenna Selection	Antenna	Antenna	Antenna	Select if WLAN board is included
S40	ScenarioSettings\Manufacturing\Other Modules\PSU Selection	65W AC Adapter	65W AC Adapter	65W AC Adapter	Select if Anteanna is included
S41	ScenarioSettings\Manufacturing\Other Modules\Other Electronics	none	none	none	Select the reference
S42	ScenarioSettings\Manufacturing\Other Modules\Packaging	MFF	MFF	MFF	Select if Keyboard is included
S44	ScenarioSettings\Manufacturing\Additional Devices\Keyboard	none	none	none	Select if Mouse is included
S45	ScenarioSettings\Manufacturing\Additional Devices\Mouse	none	none	none	Select the reference
S46	ScenarioSettings\Distribution\Transportation to Country of Use\Distance_plane	1950	0	1050	[km] Distance travelled
S47	ScenarioSettings\Distribution\Transportation to Country of Use\Distance_ship	17550	0	9450	[km] Distance travelled
S48	ScenarioSettings\Distribution\Transportation to Country of Use\Distance_truck	1600	1600	1600	[km] Distance travelled
S50	ScenarioSettings\Distribution\Transportation within Country of Use\Distance_plane	0	0	0	[km] Distance travelled
S51	ScenarioSettings\Distribution\Transportation within Country of Use\Distance_ship	0	0	0	[km] Distance travelled
S52	ScenarioSettings\Distribution\Transportation within Country of Use\Distance_truck	1060	1600	2600	[km] Distance travelled

S55	ScenarioSettings\Use\General\Lifespan	5	5	5	[years] Life span of the product
S56	ScenarioSettings\Use\General\Use Location	Europe	China	USA	Select Use Location
S58	ScenarioSettings\Use\TEC (direct)\P_TEC	0	0	0	[kWh] Annual Total Energy Consumption (TEC)
S60	ScenarioSettings\Use\Detailed (not required if TEC specified)\Long_idle_hr	2.4	2.4	2.4	[hrs] Hours of Long Idle mode per day (0-24)
S61	ScenarioSettings\Use\Detailed (not required if TEC specified)\Long_idle_mode	0.01263	0.01263	0.01263	[kW] Power Long Idle mode
S62	ScenarioSettings\Use\Detailed (not required if TEC specified)\Off_hr	3.6	3.6	3.6	[hrs] Hours of off mode per day (0-24)
S63	ScenarioSettings\Use\Detailed (not required if TEC specified)\Off_mode	0.0004	0.0004	0.0004	[kW] Power off mode
S64	ScenarioSettings\Use\Detailed (not required if TEC specified)\Short_idle_hr	7.2	7.2	7.2	[hrs] Hours of Short Idle mode per day (0-24)
S65	ScenarioSettings\Use\Detailed (not required if TEC specified)\Short_idle_mode	0.01469	0.01469	0.01469	[kW] Power Short Idle mode
S66	ScenarioSettings\Use\Detailed (not required if TEC specified)\Sleep_hr	10.8	10.8	10.8	[hrs] Hours of sleep mode per day (0-24)
S67	ScenarioSettings\Use\Detailed (not required if TEC specified)\Sleep_mode	0.00176	0.00176	0.00176	[kW] Power sleep mode
S69	ScenarioSettings\End of Life\EoL Selection	MFF	MFF	MFF	Select the reference
S70	ScenarioSettings\End of Life\Collection Rate	100	100	100	[%] Collection rate products at End-of-Life

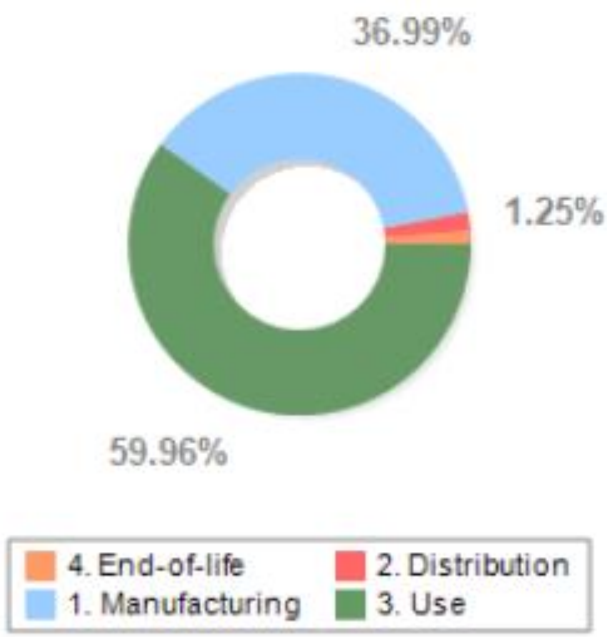


Figure 4-19: LCA Calculator Web Tool results generation (pie chart)

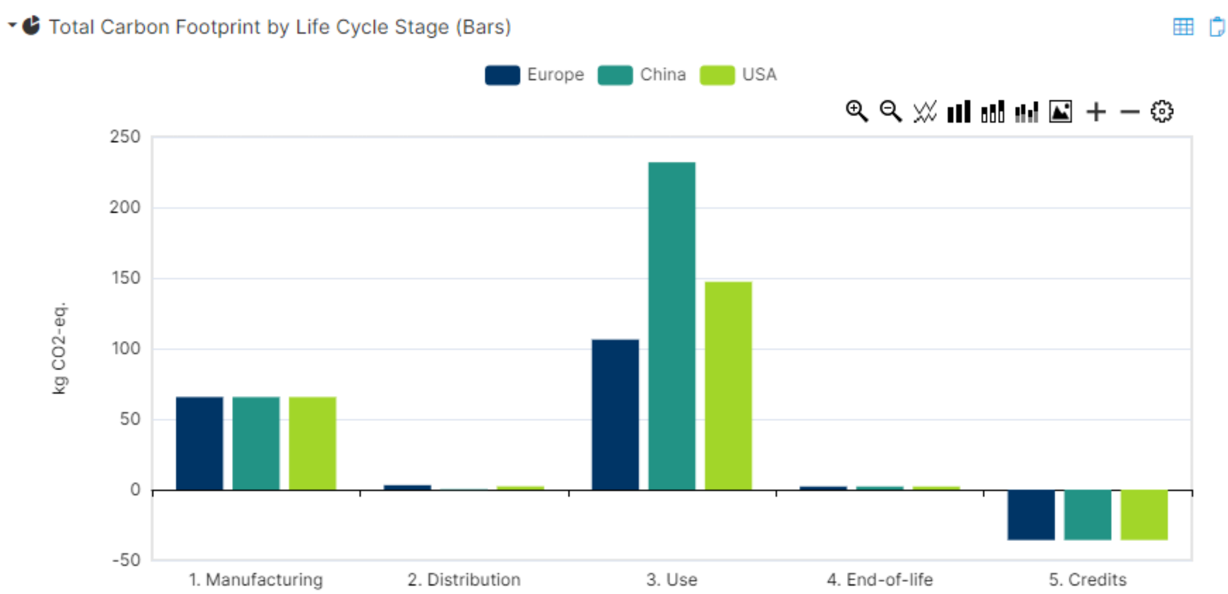


Figure 4-20: LCA Calculator Web Tool results generation (bar chart)

	1. Manufacturing	2. Distribution	3. Use	4. End-of-life	5. Credits
Europe	65.595	3.174	106.330	2.222	-35.682
China	65.595	0.425	231.900	2.222	-35.682
USA	65.595	2.323	147.270	2.222	-35.682

Figure 4-21: LCA Calculator Web Tool results generation (table)[2]

In a detailed view of the carbon footprint of the three scenarios, it shows that the major fraction of the impact is from the use stage, followed by the manufacturing stage. The main reason why use stage has higher impact is due to the electricity consumption. Desktops consume more electricity compared to notebooks.

Depending on the country of use and EoL, the carbon footprint results will be different due to the power grid mix used in different countries/regions. It is important to note that results will differ, based on different parameter settings.

4.2.6. Report Generation

The LCA Calculator offers the possibility to create a predefined report for a product. An example and detailed description of the report can be found in chapter 1.

[2] All results in the figure refer to kg CO_2-eq..

5. Dell Monitor Calculator

5.1. General information

5.1.1. LCA Calculator Tool

The LCA calculator tool was developed to calculate the LCA results in accordance with ISO 14040/44 for the Dell Monitors product group.

5.1.2. Goal and scope of the study

The goal of the study is to quality the carbon footprint of a single monitor system across the product life cycle (cradle-to-grave), including the extraction of raw materials, production of components, transportation, use of the product and end-of-life.

5.1.3. Product group description

The product group in the Dell Monitor calculator includes P2419H Monitor, Ultrasharp 24 Monitor - U2720Q, Ultrasharp 24 Monitor- U2422H and Ultrasharp 27 Monitor- U2720D. The parametric LCA calculator tool leveraged the two monitor models (U2720Q & P2419H) as a reference model. U2422H and U2720D are then built based upon U2720Q and P2419H. The LCA model can combine and modify individual modules of the products.

5.1.4. Application area of product group

Dell Monitor Calculator is designed for internal and external communication.

5.1.5. Declared unit

The declared unit is one piece of product with a lifetime of 6 years.

5.1.6. Data collection for LCA-tool set-up

Primary data for the material content of the product were collected using a combination of photographs, physical teardown and BOM, that were provided by Dell. During the product teardown, parts and materials were identified, weighed, and measured. During photograph mapping the same procedure was applied to high-resolution photos with a dimension reference, together with components datasheets and supporting information. The teardown was conducted on a mass-production-ready version of the product provided by Dell. Data on distribution, product use and end of life were collected and discussed through online communication in regular project meetings. Upon receipt, each questionnaire was cross-checked for completeness and plausibility using mass balance, as well as internal and external benchmarking. The data were discussed via online communication and in regular project meetings.

The decision of ICs to be sent for laboratory analysis are based on dimensions (any ICs above 10 x 10 mm) and the functionality with focus on CMOS, Flash and RAM technology. The larger ICs are sent to a laboratory for decapsulation (“decapping”) to reveal the actual die size, die stacking, identify whether gold is being used as bond wire material and to take x-rays to identify pin count of electrical interconnects (e.g., solder bumps). Decision basis for the collection of these additional data points was the understanding, that these ICs potentially bear a high environmental footprint, resulting in a need to improve the certainty of the results by using a higher level of granularity in data collection and modelling.

5.1.7. Life Cycle Inventory Analysis

The weight of each main modules of the Dell monitors are summarized in the following table:

Table 5-1: Weight by product module for monitors under investigation

Material/Part	P2419H (kg)	U2720Q (kg)	U2422H (kg)	U2723QE (kg)
Electromechanicals	0.27	0.46	0.83	0.83
Keyboard	0.0017	0.0014	0.0088	0.0046
Mainboard	0.031	0.143	0.14	0.21
Display	0.98	1.23	0.68	0.69
Power supply board	0.123	0.33	0.20	0.31
USB board	0.007	0.0098	0.021	0.047
Extension board	-	0.033	-	0.023
Mechanicals	3.63	4.44	2.06	3.28
Packaging	1.94	2.72	2.15	2.79
Display (Panel and board)	0.98	1.23	1.09	1.44
Total weight	**7.96**	**10.60**	**7.18**	**9.62**

5.1.8. System boundary

Dell's Notebooks are manufactured and assembled in China. Afterwards, they get distributed to different hubs in the world (e.g. Europe, US, China) (see following figure). The selection of the country of use needs to be aligned accordingly (see chapter 3.2). All collected products end-up in a mixed end-of-life scenario (see chapter 2.5).

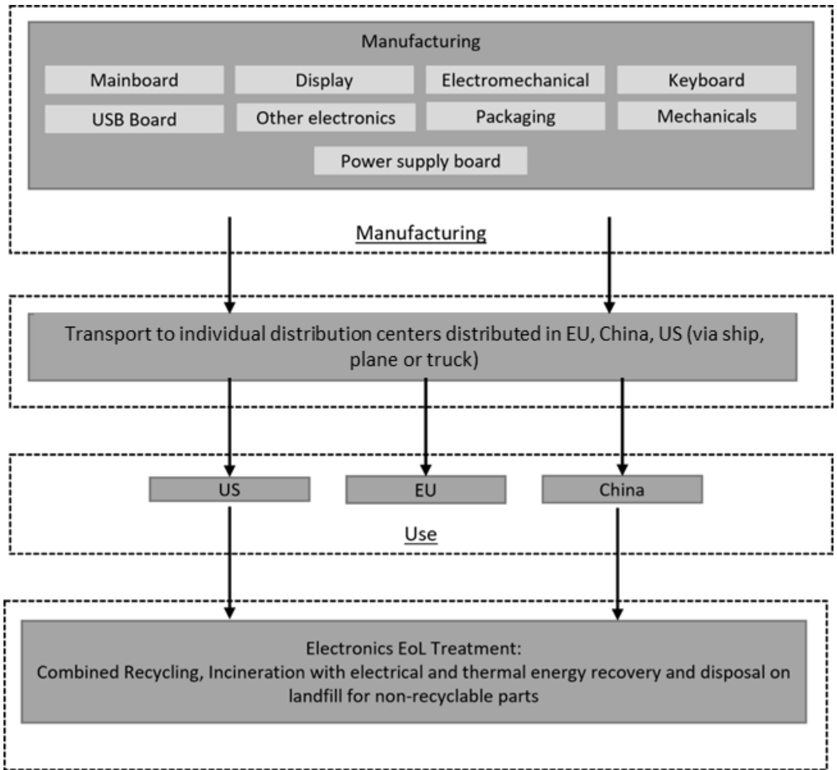


Figure 5-1: Dell Monitor system boundaries

5.2. Monitor LCA Calculator Web Tool

The following sections show the structure of the Monitor LCA Calculator Web Tool. User can select one item of the structure to get the specified input field with different options related to each item. The structure of the tool, according to an LCA, consists of manufacturing, distribution, use phase and end-of-life. In manufacturing, each component can be adapted individually, depending on the parameterization. The individual customization options can be found in 5.2.1. The customization options for distribution are divided between transportation to the country of use and transportation in the country of use. The input possibilities can be found in 5.2.2. In 5.2.3 the user first enters general information for the use phase and then has the choice of using the TEC as the value for the use phase or using a detailed description of the use of the product. For the EoL the collection rate and the base product can be selected as described in 5.2.4.

- Material Group
  - Manufacturing
    - Total Weight
    - Mainboard
    - Mechanicals (Housing, Stand & Foot)
    - LCD Panel
    - Other Modules
  - Distribution
    - Transportation to Country of Use
    - Transportation within Country of Use
  - Use
    - General
    - TEC (direct)
    - Detailed (not required if TEC specified)
  - End of Life

5.2.1. Manufacturing

The customization options of the manufacturing are based on the components found in monitors. The depth of customization depends on the components. The different customization options for the components are shown below.

Total weight

Total weight is an open parameter that can be adjusted by changing the mass. Please note that the response of the model will be changed when the parameters are adjusted. This relates to if the total weight changes without adjusting the housing, the model assumes that more electronic components are included in the scenario. If the housing is adjusted but not the total weight, the model assumes that fewer electronic components are included in the model. In an ideal case, the changes of mass of housing should correspond to the total weight, so that no automatic scaling of electronic components and housing. An image of the web tool is shown in Figure 5-2.

Name	Europe	China	USA	Comment
Tot_weight	9.36667	9.36667	9.36667	[kg] Total product weight (incl. packaging)

Figure 5-2: Input for Total weight for the Monitor LCA Calculator Web tool

Mainboard

The drop-down menu of the reference product consists of P2419H Monitor, Ultrasharp 24 Monitor - U2720Q, Ultrasharp 24 Monitor- U2422H and Ultrasharp 27 Monitor- U2720D. The reference product parameter dictates the changes in the following parameter: PWB layer count, PWB area and IC area. Figure 5-3 shows the open input parameters for the Mainboard.

	Name	Europe	China	USA	Comment
	Reference	U2720Q ▾	U2720Q ▾	U2720Q ▾	Select the reference product
	PWB_layer	8 ▾	8 ▾	8 ▾	[1,2,4,8,10,12,16] Layer count of PWB
	PWB_area	0.0278	0.0278	0.0278	[m^2] Area of Mainboard
	IC_area	7.0625	7.0625	7.0625	[cm^2] Total package area of Integrated Circuits on Mainboard

Figure 5-3: Input for Motherboard for the Monitor LCA Calculator Web Tool

Mechanicals (Housing, Stand and Foot)

This section includes all large mechanicals of the monitor, which includes housing, stand and foot. Users can determine the weight of the plastics and the type of plastics (ABS or PC/ABS 50:50) as well as weight of aluminum and steel parts. Figure 5-4 shows the list of parameters for mechanicals.

	Name	Europe	China	USA	Comment
	Plastics	1.24745	1.24745	1.24745	[kg] Mass of plastic parts
	Plastic Type	ABS ▾	ABS ▾	ABS ▾	Select plastic type
	Al_sheet	1.371	1.371	1.371	[kg] Mass of Aluminium parts
	St_steel	0.9049	0.9049	0.9049	[kg] Mass of Steel sheet

Figure 5-4: Input for Mechanicals for the Monitor LCA Calculator Web Tool

LCD Panel

The drop-down menu of the reference product consists of P2419H Monitor, Ultrasharp 24 Monitor - U2720Q, Ultrasharp 24 Monitor- U2422H and Ultrasharp 27 Monitor- U2720D. Each reference product refers to a different screen size. Additionally, the display diagonal and the display ratio can be adjusted. Figure 5-5 shows the list of parameters.

	Name	Europe	China	USA	Comment
	Reference	U2720Q ▾	U2720Q ▾	U2720Q ▾	Select the reference product
	Display_dia	27	27	27	[in] Display diameter (diagonal)
	Display Ratio	16:9 ▾	16:9 ▾	16:9 ▾	

Figure 5-5: Input for Display for the Monitor LCA Calculator Web Tool

Other Modules

Other modules in the tool include Electromechanical components, Keyboard, Power Supply Board, USB-Board, Other electronics, and Packaging, where user can select between P2419H Monitor, Ultrasharp 24 Monitor - U2720Q, Ultrasharp 24 Monitor- U2422H and Ultrasharp 27 Monitor- U2720D. Figure 5-6 shows the list of parameters.

	Name	Europe	China	USA	Comment
👁	Electromechanical Com...	U2720Q ▾	U2720Q ▾	U2720Q ▾	Select the reference product
👁	Keyboard	U2720Q ▾	U2720Q ▾	U2720Q ▾	Select the reference product
👁	Power Supply Board	U2720Q ▾	U2720Q ▾	U2720Q ▾	Select the reference product
👁	USB-Board	U2720Q ▾	U2720Q ▾	U2720Q ▾	Select the reference product
👁	Other Electronics	U2720Q ▾	U2720Q ▾	U2720Q ▾	Select the reference product
👁	Packaging	U2720Q ▾	U2720Q ▾	U2720Q ▾	Select the reference product

Figure 5-6: Input for Other Modules for the Monitor LCA Calculator Web Tool

5.2.2. Distribution

The distribution stage is split into distribution to country of use and to distribution within country of use. The user can select the transportation mode by plane, ship, and truck.

Transportation to Country of Use

The transportation options for distribution to the country of use are by plane, train and truck. The unit by default is in kilometers. Figure 5-7 shows the open input parameters for Distribution to Country of use.

	Name	Europe	China	USA	Comment
👁	Distance_plane	1950	0	1050	[km] Transportation distance plane
👁	Distance_ship	17550	0	9450	[km] Transportation distance ship
👁	Distance_truck	1600	1600	1600	[km] Transportation distance truck

Figure 5-7: Input for Distribution to country of use for the Monitor LCA Calculator Web Tool

Transportation within Country of Use

The transportation options for distribution to the country of use are by plane, train and truck. The unit by default is in kilometers. Figure 5-8 shows the open input parameters for Distribution within Country of use.

	Name	Europe	China	USA	Comment
👁	Distance_plane	0	0	0	[km] Transportation distance plane
👁	Distance_ship	0	0	0	[km] Transportation distance ship
👁	Distance_truck	1060	1600	2600	[km] Transportation distance truck

Figure 5-8: Input for Distribution within of use for the Monitor LCA Calculator Web Tool

5.2.3. Use

For the use phase, user will first determine the lifespan and the use location of the product (Figure 5-9 Figure 3-14). The user can then decide whether to enter use information as a TEC input (Figure 5-10) or to enter detailed information on usage scenarios of the product (Figure 5-11). The user needs to enter one of the options but not both.

General

The user can define the lifespan of the product and set the use location for the product. Use locations are, Europe, China, USA, France, Great Britan, and Germany.

Name	Europe	China	USA	Comment
Lifespan	6	6	6	[years] Lifespan of the product
Use Location	Europe	China	USA	Select Use Location

Figure 5-9: Input for General for the Monitor LCA Calculator Web Tool

TEC (direct)

Typical Energy Consumption (TEC) is a technique for evaluating and comparing computer energy performance that focuses on the average amount of electricity used by an item while it is operating normally over an extended period of time. The TEC is used as an Energy Star Program requirement. The TEC is given in the typical annual energy consumption (kWh/a) of the product.

Name	Europe	China	USA	Comment
P_TEC	63.815	63.815	63.815	[kWh/a] Annual Typical Energy Consumption (TEC)

Figure 5-10: Input for TEC for the Monitor LCA Calculator Web Tool

Detailed

Detailed information is not required if TEC is specified. The detailed information is split up into different usage modes (on and standby mode). The input for the usage modes is in Kilowatt. For each mode the user can enter the time for each usage mode in hours of use.

Name	Europe	China	USA	Comment
On_hr	1	1	1	[hrs] Hours of Long Idle mode per day (0-24)
On_mode	1	1	1	[kW] Power Long Idle mode
Standby_hr	1	1	1	[hrs] Hours of sleep mode per day (0-24)
Standby_mode	1	1	1	[kW] Power sleep mode

Figure 5-11: Input for Detailed settings for the Monitor LCA Calculator Web Tool

5.2.4. End-of-Life

As shown in Figure 5-12 the user can select a reference product (P2419H Monitor, Ultrasharp 24 Monitor - U2720Q, Ultrasharp 24 Monitor- U2422H and Ultrasharp 27 Monitor- U2720D) to set a base for the inputs for the End-of-Life. Additionally, the collection rate can be adjusted. The collection rate specifies how much percent of the product is collected for end-of-life.

	Name	Europe	China	USA	Comment
	Reference	U2720Q	U2720Q	U2720Q	Select the reference product
	Collection Rate	100	100	100	[%] Collection rate products at End-of-Life

Figure 5-12: Input for End-of-Life information for the Monitor LCA Calculator Web Tool

5.2.5. Results Generation

The Monitor LCA Calculator Web Tool generates Total Carbon Footprint by Life Cycle Stages (excluding end-of-life credits) in Pie chart (Figure 5-13), Bar chart (Figure 5-14) and results table (

Figure 5-15). The following scenario is assumed for the purpose of demonstrating how the results are presented:

	Scenario Settings	Europe	China	USA	Comment
S1	Manufacturing				
S2	Manufacturing\Total Weight				
S3	Manufacturing\Total Weight\Tot_weight	9.36667	9.36667	9.36667	[kg] Total product weight (incl. packaging)
S4	Manufacturing\Mainboard				
S5	Manufacturing\Mainboard\Reference	U2720Q	U2720Q	U2720Q	Select the reference product
S6	Manufacturing\Mainboard\PWB_layer	8	8	8	[1,2,4,8,10,12,16] Layer count of PWB
S7	Manufacturing\Mainboard\PWB_area	0.0278	0.0278	0.0278	[m^2] Area of Mainboard
S8	Manufacturing\Mainboard\IC_area	7.0625	7.0625	7.0625	[cm^2] Total package area of Integrated Circuits on Mainboard
S9	Manufacturing\Mechanicals (Housing, Stand & Foot)				
S10	Manufacturing\Mechanicals (Housing, Stand & Foot)\Plastics	1.24745	1.24745	1.24745	[kg] Mass of plastic parts
S11	Manufacturing\Mechanicals (Housing, Stand & Foot)\Plastic Type	ABS	ABS	ABS	Select plastic type
S12	Manufacturing\Mechanicals (Housing, Stand & Foot)\Al_sheet	1.371	1.371	1.371	[kg] Mass of Aluminium parts
S13	Manufacturing\Mechanicals (Housing, Stand & Foot)\St_steel	0.9049	0.9049	0.9049	[kg] Mass of Steel sheet
S14	Manufacturing\LCD Panel				
S15	Manufacturing\LCD Panel\Reference	U2720Q	U2720Q	U2720Q	Select the reference product
S16	Manufacturing\LCD Panel\Display_dia	27	27	27	[in] Display diameter (diagonal)
S17	Manufacturing\LCD Panel\Display Ratio	16:9	16:9	16:9	
S18	Manufacturing\Other Modules				
S19	Manufacturing\Other Modules\Electromechanical Components	U2720Q	U2720Q	U2720Q	Select the reference product
S20	Manufacturing\Other Modules\Keyboard	U2720Q	U2720Q	U2720Q	Select the reference product
S21	Manufacturing\Other Modules\Power Supply Board	U2720Q	U2720Q	U2720Q	Select the reference product
S22	Manufacturing\Other Modules\USB-Board	U2720Q	U2720Q	U2720Q	Select the reference product
S23	Manufacturing\Other Modules\Other Electronics	U2720Q	U2720Q	U2720Q	Select the reference product
S24	Manufacturing\Other Modules\Packaging	U2720Q	U2720Q	U2720Q	Select the reference product
S25	Distribution				
S26	Distribution\Transportation to Country of Use				

S27	Distribution\Transportation to Country of Use\Distance_plane	1950	0	1050	[km] Transportation distance plane
S28	Distribution\Transportation to Country of Use\Distance_ship	17550	0	9450	[km] Transportation distance ship
S29	Distribution\Transportation to Country of Use\Distance_truck	1600	1600	1600	[km] Transportation distance truck
S30	Distribution\Transportation within Country of Use				
S31	Distribution\Transportation within Country of Use\Distance_plane	0	0	0	[km] Transportation distance plane
S32	Distribution\Transportation within Country of Use\Distance_ship	0	0	0	[km] Transportation distance ship
S33	Distribution\Transportation within Country of Use\Distance_truck	1060	1600	2600	[km] Transportation distance truck
S34	Use				
S35	Use\General				
S36	Use\General\Lifespan	6	6	6	[years] Lifespan of the product
S37	Use\General\Use Location	Europe	China	USA	Select Use Location
S38	Use\TEC (direct)				
S39	Use\TEC (direct)\P_TEC	63.815	63.815	63.815	[kWh/a] Annual Typical Energy Consumption (TEC)
S40	Use\Detailed (not required if TEC specified)				
S41	Use\Detailed (not required if TEC specified)\On_hr	0	0	0	[hrs] Hours of Long Idle mode per day (0-24)
S42	Use\Detailed (not required if TEC specified)\On_mode	0	0	0	[kW] Power Long Idle mode
S43	Use\Detailed (not required if TEC specified)\Standby_hr	0	0	0	[hrs] Hours of sleep mode per day (0-24)
S44	Use\Detailed (not required if TEC specified)\Standby_mode	0	0	0	[kW] Power sleep mode
S45	End of Life				
S46	End of Life\Reference	U2720Q	U2720Q	U2720Q	Select the reference product
S47	End of Life\Collection Rate	100	100	100	[%] Collection rate products at End-of-Life

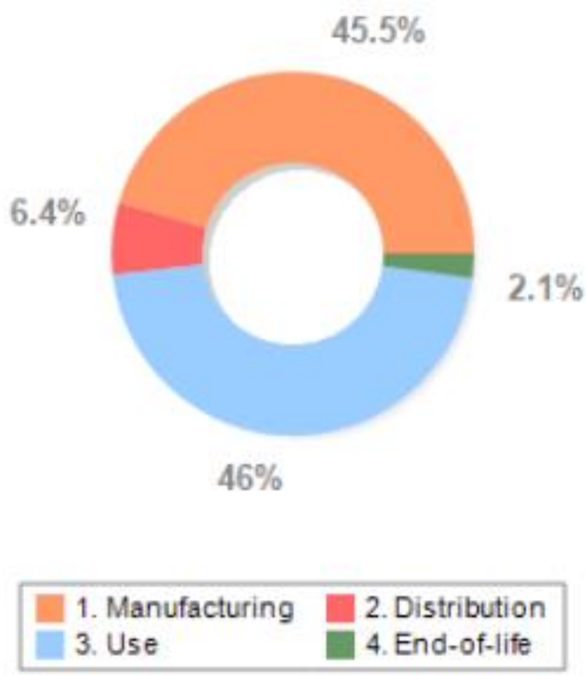


Figure 5-13: Pie chart showing Total Carbon Footprint by Life Cycle Stage in the Monitor LCA Calculator

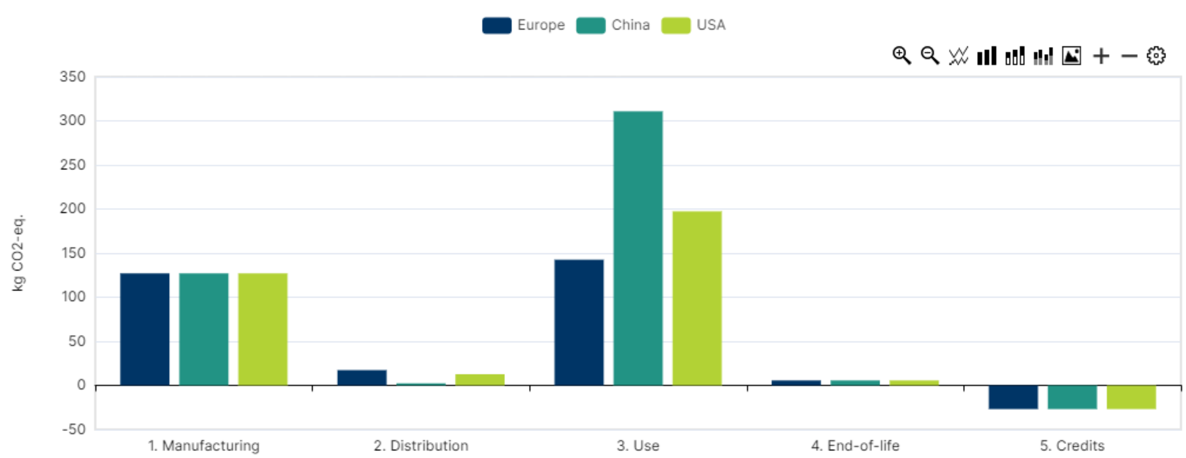


Figure 5-14: Bar graph showing Carbon Footprint by Life Cycle Stage in the Monitor LCA Calculator

	1. Manufacturing	2. Distribution	3. Use	4. End-of-life	5. Credits
Europe	127.030	17.302	142.520	5.612	-26.851
China	127.030	2.318	310.830	5.612	-26.851
USA	127.030	12.661	197.400	5.612	-26.851

Figure 5-15: LCA Calculator Web Tool results generation (table)3

In a detailed view of the carbon footprint of the three scenarios, it shows that the major fraction of the impact is from the manufacturing stage, followed by the use stage. Depending on the country of use and EoL, the carbon footprint results will be different due to the power grid mix used in different countries/regions. It is important to note that results will differ, based on different parameter settings.

5.2.6. Report Generation

The LCA Calculator offers the possibility to create a predefined report for a product. An example and detailed description of the report can be found in chapter 1.

[3] All results in the figure refer to kg CO_2-eq..

6. Workflow LCA-Tools & Data Collection / Upload

The following section describes the process flow for the usage of the LCA-tools. In addition, this section contains guidance on the data collection and upload.

6.1. Workflow LCA-Tools

Dell created a holistic standard process flow for product carbon footprint calculations based on the LCA Calculators. The document includes all necessary steps and guidance for the calculation procedure from the data collection to the external publication of the LCA reports. The most recent version and a detailed description can be found in Dell's Data collection sheets (ENV0458 A03). The following chapter focuses on the workflow in Sphera's software LCA Calculator.

An overview is shown in the following figure.

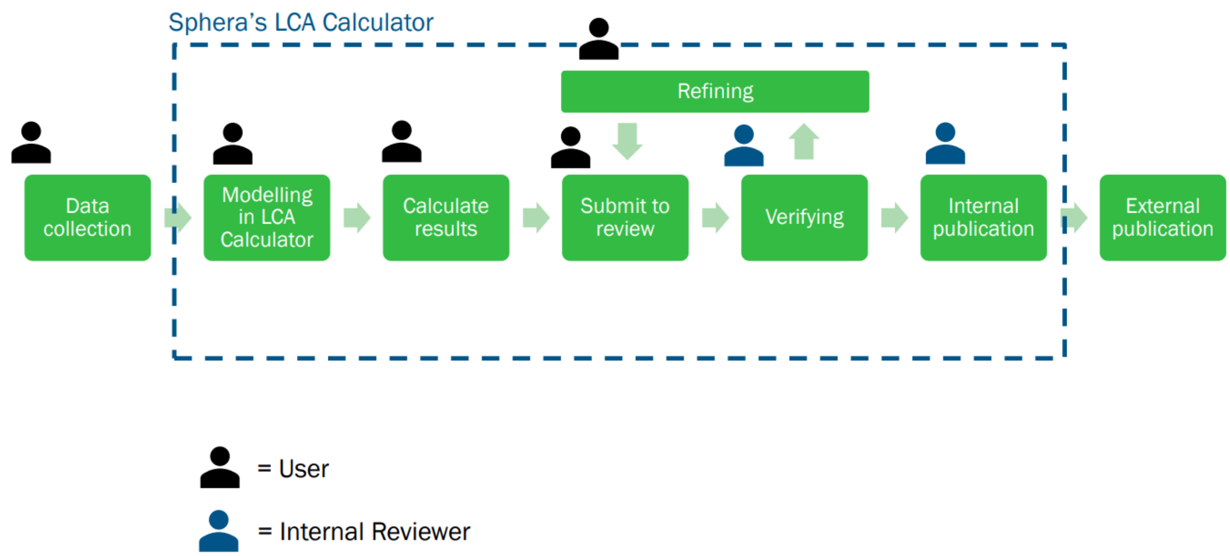


Figure 6-1: Workflow LCA Calculator

Dell has multiple accounts for the web-based LCA-tools, with two different roles: User and Internal reviewer. Both have different user rights and different responsibilities. Once the compliance team of Dell receives the populated data collection sheets (ENV0458 template) from the ODMs/Suppliers, they will save a copy of the populated data collection sheet. Then, the compliance personnel (user) will upload the populated data collection template into the LCA Calculator tool and save it in a predefined format (see LCA Calculator Tool User Guide for more information). Afterwards, the user calculates the results and submits them for an internal review. The internal reviewer of Dell receives it in his/her account. The internal review will check the plausibility of the calculated results and consistency to previous reports. Depending on the outcomes of the review, the internal reviewer can either send the report back to the user to refine the data or publish the report within the software. After successful internal publication, the report can be downloaded and used in other systems.

6.2. Data Collection & Upload

Dell provides an excel-based data collection template to their ODM/suppliers to collect most of the required information. Dell assigned a role (Dell PCF SME) to check the incoming data, finish the data collection and uploads the excel workbook to the LCA-Tools. A full overview of the process is provided in Dell LCA-PCF Quality Assurance Document. The upload enables a fast integration of the information into the software, since excel files can be directly uploaded. The previous sections showed and explained the required parameters for each LCA tool individually. In addition, Dell's LCA Calculator Tool User Guide and Data collection sheets (ENV0458 A03) contain default values and defines responsibilities for the individual data points. There are 3 different parameter types with different requirements to the format in the data collection sheet.

1. **Text variables (text input fields)** are used to add specific information to the report such as product name, author, or report date. These parameters have no impact on the LCA calculation and have no restriction to the format. They are automatically inserted into the LCA report.
2. **Text variables (scenario settings)** refer to specific product design options, that are non-continuous variables. An example is the layer count of the printed wiring board of the mainboard. This parameter has to be either "1", "2", "4", "6", "8", "10", "12", or "16". The variables of this type have impacts on the LCA results as they change settings in the model. The input values in the excel template have to be identical to one of the design options. Otherwise, it cannot be uploaded to LCA Calculator (see Figure 6-2). To help the user, the excel files contain information on the range of the values, listing the options for each text variable individually.
3. **Numeric variable (scenario settings)** are continuous variables. They are used to specify properties of the product that cannot be grouped in design options, An example is the total weight of the product (incl. packaging. There are no restrictions regarding the range of the value, but it has be a number. These parameters have impacts on the LCA results as they change settings in the model.

Once the data collection template is completely filled out, the file can be uploaded. If the values does not match the required format, the import stops and the user receives an error message. Figure 6-2 shows an example.

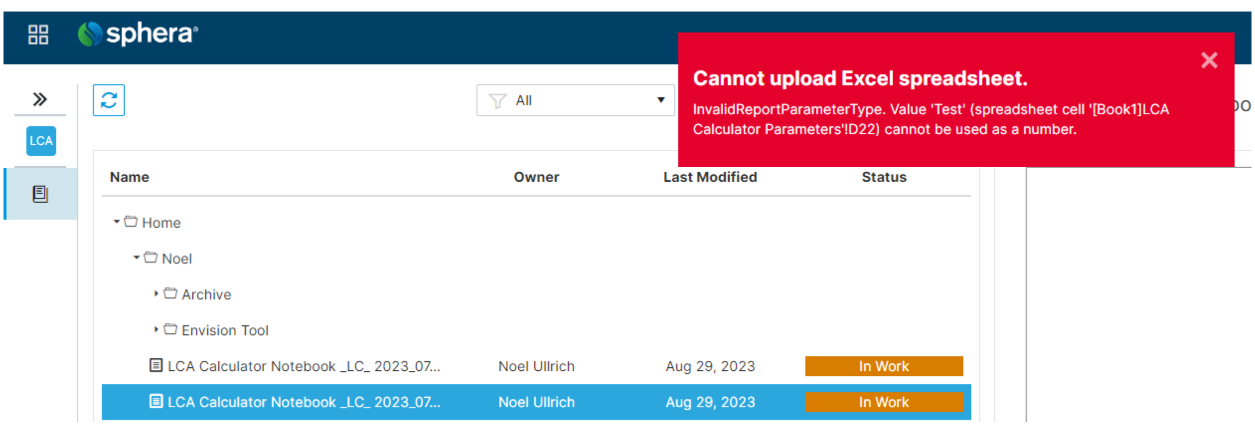


Figure 6-2: Example of Import error message

The described feature of the software ensures that all parameters of the models are specified. Furthermore, it helps to identify gaps and mistakes in the data collection. The message includes information, which value can not be imported and indicates the reason why it was not possible to import it. (In the shown example, "Test" as text variable has been entered for a numeric parameter.) Additionally, the error message points out where the wrong value is located in the excel file (here: spreadsheet "LCA Calculator Parameters" – cell D22), what helps to made correction.

Further guidance on the data collection can be found in:

- Data collection sheets (

- Annex D1: ENV0458 A03)

Dell's LCA Calculator Tool User Guide (

- Annex D2: LCA Calculator Tool User Guide)
- Dell LCA-PCF Quality Assurance Document (Annex D3: Dell LCA-PCF Quality Assurance Process)

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Annex A: Critical Review Statement

Critical Review Statement

Dell LCA Calculator

Commissioned by: Dell Technologies Inc.

Conducted by: Sphera

Reviewed by: Prof. Colin Fitzpatrick, University of Limerick, Ireland

Reference: ISO 14040 (2006): Environmental Management – Life Cycle Assessment- Principles and Framework

ISO 14044 (2006): Environmental Management – Life Cycle Assessment – Requirements and Guidelines

ISO/TS 14071 (2014): Environmental Management – Life Cycle Assessment- Critical Review Processes and reviewer competencies: Additional requirements and guidelines to ISO 14044:2006

Scope of the critical review

The reviewer had the task to assess whether

- The methods used to generate the LCA reports in the Dell LCA Calculator are consistent with the international standards ISO 14040, ISO 14044 and ISO 14021
- The methods used to carry out the LCA are scientifically and technically valid
- The data used are appropriate and reasonable in relation to the goal of the study
- The interpretations reflect the limitations identified and the goal of the study
- The study report is transparent and consistent
- The results generated by the Dell LCA Calculator are reproducible
- The internal quality assurance procedures and verification is consistent.

The critical review was performed concurrently with the study. The results are intended for disclosure to the public and are not intended for direct comparative assertions.

The calculator scope is for notebooks, desktops and monitors.

The analysis and verification of individual datasets is outside the scope of this review.

The review process

The review process was co-ordinated by Sphera and it included a series of trilateral calls between Sphera, Dell and the Critical Reviewer commencing on 3rd August 2023 and continuing bi-weekly until December 2023. A series of tasks was identified to be completed to satisfy the critical review and these were worked through systematically. The entire process by which the LCA reports are generated was demonstrated in a highly systematic, detailed and professional manner. The team was very willing to discuss all aspects of the data collection, checking and all models in a comprehensive manner.

General Evaluation

The goal and scope of the assessments created by the tool are defined unambiguously. The functional unit is clearly defined and measurable. The system boundary appropriately includes all major life cycle stages from production, distribution, use through to end of life.

The input data is collected by Dell from their suppliers using purposely developed templates and Energy Star certifications. The method and process by which data is collected and inputted to the Calculator was explained in detail. The individuals and teams responsible for compiling each of these reports are clearly identified. The process of quality assurance and verification of the data collected was also presented and deemed to be satisfactory. Any major assumptions which had a significant bearing on the results including electricity mixes, transport routes and end of life outcomes are well justified.

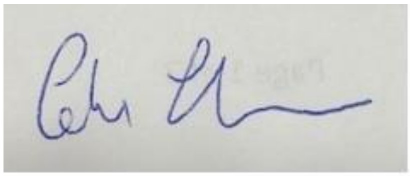
The model which is the engine behind the Calculator was explained in detail. The life cycle impact assessment is performed to a high standard and includes all mandatory elements and all aspects of this are judged to be scientifically and technically valid. The life cycle interpretation is adequate.

The products chosen to demonstrate the system were amongst a wide variety of the best-selling products in different product categories and checks.

The calculator was calibrated against detailed teardowns and showed a very high level of agreement in the results.

Conclusion

The study has been carried out in full conformity with ISO 14040 and ISO 14044 and has undergone third party review. The critical reviewer found the overall quality and rigour of the methodology and its execution to be very adequate for the purposes of this study.



Colin Fitzpatrick

1st December 2023

Reviewer Credentials

Colin Fitzpatrick is a Professor in the Department of Electronic & Computer Engineering at the University of Limerick, Ireland. He has been active in research in the area of electronics and the environment for almost 20 years and has published widely in this field. His most prominent work in LCA has been in the area of evaluation of environmental impacts of repurposing of IT equipment and in the reuse of large household appliances. He has taught LCA as part of courses at the University of Limerick since 2004.

For further information see: https://www.linkedin.com/in/colin-fitzpatrick-b522222a/

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Annex B: LCA Managed Content and Data Quality

Annex B1: List of datasets used in models

Object name	Reference year	Technological representativeness	Time representativeness	Geographical representativeness
CH: Electricity grid mix Sphera	2019	Good	Very Good	Good
CN: Aluminium sheet Sphera	2022	Good	Very Good	Good
CN: BF Steel billet / slab/ bloom Sphera <p-agg>	2022	Good	Very Good	Good
CN: Copper sheet Sphera	2022	Fair	Very Good	Fair
CN: Copper wire (0.06 mm) Sphera	2022	Good	Very Good	Very Good
CN: Diesel mix at refinery Sphera	2019	Good	Very Good	Good
CN: Electricity grid mix Sphera	2019	Good	Very Good	Good
CN: Electricity grid mix Sphera	2019	Good	Very Good	Good
CN: Lithium-ion LCO (LiCoO2) battery cell, 100g Sphera	2022	Good	Very Good	Good
CN: Lubricants at refinery Sphera	2019	Good	Very Good	Good
CN: Magnesium Sphera	2022	Very Good	Very Good	Very Good
CN: Magnet Nd-Fe-Dy-B Sphera	2022	Good	Very Good	Good
CN: Polycarbonate granulate (PC) Sphera	2022	Good	Very Good	Good
CN: Polyethylene high density granulate (HDPE/PE-HD) Sphera	2021	Good	Very Good	Very Good
CN: Polyethylene low density granulate (LDPE/PE-LD) (approximation) Sphera	2022	Good	Very Good	Good
CN: Polystyrene Granulate (PS) (approximation) Sphera	2021	Very Good	Very Good	Very Good
CN: Polyvinyl chloride granulate (S-PVC) mix Sphera	2022	Good	Very Good	Good
CN: Tap water from groundwater Sphera	2022	Good	Very Good	Very Good
CN: Thermal energy from LPG Sphera	2019	Good	Very Good	Good
CN: Thermal energy from natural gas Sphera	2019	Good	Very Good	Good

DE: Acrylonitrile-butadiene-styrene granulate (ABS) mix Sphera	2022	Very Good	Very Good	Very Good
DE: Aluminium cast part machining (standard) Sphera <u-so>	2022	Good	Very Good	Very Good
DE: Aluminium die-cast part Sphera <u-so>	2022	Good	Very Good	Very Good
DE: Aluminium fluoride Sphera	2022	Good	Very Good	Good
DE: Aluminium ingot mix Sphera	2022	Good	Very Good	Good
DE: Ammonium chloride (Salmiac, Solvay-process) Sphera	2022	Fair	Very Good	Very Good
DE: BF Steel billet / slab / bloom Sphera <p-agg>	2022	Very Good	Very Good	Very Good
DE: Calcium hydroxide (Ca(OH)2; dry; slaked lime) (EN15804 A1-A3) Sphera	2022	Good	Very Good	Good
DE: Copper sheet Sphera	2022	Good	Very Good	Good
DE: Copper wire (0.06 mm) Sphera	2022	Good	Very Good	Very Good
DE: Copper wire (0.06 mm) Sphera <u-so>	2022	Good	Very Good	Very Good
DE: EAF Steel billet / slab / bloom Sphera <p-agg>	2022	Very Good	Very Good	Very Good
DE: Elastomer joint tape, silicone rubber (EN15804 A1-A3) Sphera	2022	Good	Very Good	Good
DE: Electricity grid mix Sphera	2019	Good	Very Good	Good
DE: Epoxy Resin (EP) Sphera	2022	Very Good	Very Good	Very Good
DE: Fan HDD (120X25mm, PWM) Sphera	2022	Good	Very Good	Good
DE: Fan PSU (78X25mm, not PWM) Sphera	2022	Good	Very Good	Good
DE: Fixing material screws stainless steel (EN15804 A1-A3) Sphera <p-agg>	2022	Good	Very Good	Good
DE: Glass fibres Sphera	2022	Good	Very Good	Good
DE: Hydrochloric acid (32%) Sphera	2022	Very Good	Very Good	Very Good
DE: Isopropanol Sphera	2022	Good	Very Good	Very Good
DE: Lead frame Sphera	2022	Fair	Very Good	Good
DE: Liquid Crystalline Polymer with 30% glass fiber (LCP) Sphera	2022	Very Good	Very Good	Very Good
DE: Magnesium die-cast part Sphera <u-so>	2022	Good	Very Good	Very Good
DE: Magnet Nd-Fe-Dy-B Sphera	2022	Good	Very Good	Good
DE: Natural rubber (NR) (excl. LUC emissions) Sphera	2022	Fair	Fair	Fair
DE: Natural rubber (NR) (incl. LUC emissions) Sphera	2022	Fair	Fair	Fair
DE: Nitric acid (60%) Sphera	2022	Good	Very Good	Very Good
DE: Polyamide 6 granulate (PA 6) Sphera	2022	Very Good	Very Good	Very Good

DE: Polyamide 6.6 granulate (PA 6.6) mix Sphera	2022	Very Good	Very Good	Very Good
DE: Polybutylene terephthalate granulate (PBT) mix Sphera	2022	Very Good	Very Good	Very Good
DE: Polycarbonate granulate (PC) Sphera	2022	Good	Very Good	Very Good
DE: Polyether polyol Sphera	2022	Good	Very Good	Very Good
DE: Polyethylene Film (PE-HD) without additives Sphera	2022	Good	Very Good	Very Good
DE: Polyethylene Film (PE-LD) without additives Sphera	2022	Good	Very Good	Very Good
DE: Polyethylene linear low density granulate (LLDPE/PE-LLD) Sphera	2022	Very Good	Very Good	Very Good
DE: Polyethylene terephthalate granulate (PET via DMT) Sphera	2022	Good	Very Good	Very Good
DE: Polymethyl methacrylate granulate (PMMA) Sphera	2022	Good	Very Good	Very Good
DE: Polypropylene / ethylene propylene diene elastomer granulate (PP/EPDM, TPO, TPE-O) mix Sphera	2022	Good	Very Good	Very Good
DE: Polypropylene Film (PP) without additives Sphera	2022	Good	Very Good	Very Good
DE: Polypropylene granulate (PP) mix Sphera	2022	Very Good	Very Good	Very Good
DE: Polypropylene granulate (PP) Sphera	2022	Very Good	Very Good	Very Good
DE: Polystyrene granulate (PS) mix Sphera	2022	Very Good	Very Good	Very Good
DE: Polystyrene high impact granulate (HI-PS) mix Sphera	2022	Very Good	Very Good	Very Good
DE: Polytetrafluoroethylene granulate (PTFE) Sphera	2022	Very Good	Very Good	Very Good
DE: Polyurethane flexible foam (PU) Sphera <u-so>	2022	Good	Very Good	Very Good
DE: Polyvinyl chloride foam (PVC) Sphera	2021	Very Good	Very Good	Very Good
DE: Polyvinyl chloride granulate (S-PVC) mix Sphera	2022	Very Good	Very Good	Very Good
DE: Populated printed wiring board (after RoHS) in waste incineration plant Sphera <p-agg>	2022	Good	Very Good	Very Good
DE: PVC adhesive (approximation) Sphera	2022	Good	Very Good	Good
DE: PVC part (injection moulding) Sphera	2022	Good	Very Good	Very Good
DE: Silicone fluids (highly viscous) / polydimethylsiloxanes (from organosilanes) Sphera	2022	Good	Very Good	Very Good
DE: Silicone rubber (RTV-2, condensation) Sphera	2022	Good	Very Good	Very Good
DE: Sodium hydroxide (from chlorine-alkali electrolysis, diaphragm) Sphera	2022	Good	Very Good	Good
DE: Steel cold rolled coil <1,5mm Sphera <p-agg>	2022	Very Good	Very Good	Very Good
DE: Steel cold rolled coil 1,5 mm Sphera <p-agg>	2022	Very Good	Very Good	Very Good
DE: Steel screw (hardened and galvanized) Sphera <p-agg>	2022	Good	Very Good	Good

DE: Steel wire rod Sphera <p-agg>	2022	Very Good	Very Good	Very Good
DE: Thermal energy from natural gas Sphera	2019	Good	Very Good	Good
DE: Toluene diisocyanate (TDI) by-product toluene diamine (TDA), hydro-chloric acid (phosgenation) Sphera	2022	Very Good	Very Good	Very Good
DE: Value of Scrap Sphera	2022	Good	Very Good	Good
DE: Waste incineration (plastics) Sphera <p-agg>	2022	Good	Very Good	Very Good
DE: Water (desalinated; deionised) Sphera	2022	Good	Very Good	Very Good
DE: White raw phosphorus (incl. sinter) Sphera	2022	Very Good	Very Good	Very Good
DE: Zinc (remelting) Sphera <p-agg>	2022	Good	Very Good	Good
EU28+EFTA: Aluminium refining: casting alloy ingot from scrap (2010) European Aluminium <p-agg>	2011	Very Good	Very Good	Very Good
EU28+EFTA: Primary aluminium production ingot mix Europe (2015 only produced in Europe) European Aluminium	2015	Very Good	Very Good	Very Good
FR: Electricity grid mix Sphera	2019	Good	Very Good	Good
GB: Electricity grid mix Sphera	2019	Good	Very Good	Good
GLO: Alkaline cell - LR series (AA) Sphera	2022	Good	Very Good	Good
GLO: Assembly line SMD (1SP, 2CS, 1CP, 1R, 1Rf) throughput 300/h - open input printed circuit board Sphera <p-agg>	2022	Good	Very Good	Good
GLO: Assembly line THT/SMD (1TP,1SP,1CS,1WO,1Rf) throughput 300/h - open input printed circuit board Sphera <p-agg>	2022	Good	Very Good	Good
GLO: Backlight Assembly (without LEDs) (Mass per Framelength) Sphera	2022	Good	Very Good	Very Good
GLO: Backlight Assembly Sheets (Mass per Cell Area) Sphera	2022	Fair	Very Good	Very Good
GLO: Bare die pixel control chip(s) 3X20X0.1 Sphera	2022	Good	Very Good	Good
GLO: Bulk commodity carrier, 1.000 to 250.000 dwt payload capacity, deep sea Sphera <u-so>	2022	Very Good	Very Good	Very Good
GLO: Cable 10-core data ribbon 28AWG PE (25 g/m) 12.7x0.9 Sphera	2022	Very Good	Very Good	Very Good
GLO: Cable 10-core data ribbon 28AWG PVC (25 g/m) 12.7x0.9 Sphera	2022	Very Good	Very Good	Very Good
GLO: Cable 1-core power 18AWG PVC (16 g/m) D2.9 Sphera	2022	Good	Very Good	Good
GLO: Cable 1-core signal 24AWG PVC (4.5 g/m) D1.4 Sphera	2022	Good	Very Good	Good
GLO: Cable 3-core mains power 10A/13A 16AWG mPPE (60 g/m) D6.3 Sphera	2022	Good	Very Good	Good
GLO: Cable 3-core mains power 10A/13A 16AWG PVC (100 g/m) D8 Sphera	2022	Good	Very Good	Good
GLO: Cable USB2.0 28AWG PE/PVC (18 g/m) D4.2 Sphera	2022	Good	Very Good	Good

GLO: Capacitor Al-capacitor axial THT (21g) D21x40 Sphera	2022	Very Good	Very Good	Good
GLO: Capacitor Al-capacitor axial THT (300mg) D3.3x11 Sphera	2022	Very Good	Very Good	Good
GLO: Capacitor Al-capacitor axial THT (6g) D14x25 Sphera	2022	Very Good	Very Good	Good
GLO: Capacitor Al-capacitor radial THT (110mg) D3x5 Sphera	2022	Very Good	Very Good	Good
GLO: Capacitor Al-capacitor radial THT (15.41g) D18x41 Sphera	2022	Very Good	Very Good	Good
GLO: Capacitor Al-capacitor radial THT (5.65g) D12.5x30 Sphera	2022	Very Good	Very Good	Good
GLO: Capacitor Al-capacitor SMD (1.29g) D10x10.2 Sphera	2022	Good	Very Good	Good
GLO: Capacitor Al-capacitor SMD (2.54g) D12.5x13.5 Sphera	2022	Good	Very Good	Good
GLO: Capacitor Al-capacitor SMD (300mg) D6.3x5.4 Sphera	2022	Good	Very Good	Good
GLO: Capacitor Al-capacitor SMD (5.01g) D16x16.5 Sphera	2022	Good	Very Good	Good
GLO: Capacitor Al-capacitor SMD (7.89g) D18x21.5 Sphera	2022	Good	Very Good	Good
GLO: Capacitor Al-capacitor SMD (80mg) D3x5.4 Sphera	2022	Good	Very Good	Good
GLO: Capacitor Aluminium screw terminal (220g) D 51.6 x 75 mm Sphera	2022	Good	Very Good	Good
GLO: Capacitor Aluminium screw terminal (400g) D 64.3 x 96 mm Sphera	2022	Good	Very Good	Good
GLO: Capacitor Ceramic MLCC 01005 (0.054mg) 0.4x0.2x0.22 (Base Metals) Sphera	2022	Good	Very Good	Good
GLO: Capacitor ceramic MLCC 01005 (0.054mg) 0.4x0.2x0.22 (Precious Metals) Sphera	2022	Good	Very Good	Good
GLO: Capacitor ceramic MLCC 0201 (0.17mg) 0.6x0.3x0.3 (Base Metals) Sphera	2022	Good	Very Good	Good
GLO: Capacitor ceramic MLCC 0201 (0.17mg) 0.6x0.3x0.3 (Precious Metals) Sphera	2022	Good	Very Good	Good
GLO: Capacitor ceramic MLCC 0603 (6mg) 1.6x0.8x0.8 (Base Metals) Sphera	2022	Good	Very Good	Good
GLO: Capacitor ceramic MLCC 0603 (6mg) 1.6x0.8x0.8 (Precious Metals) Sphera	2022	Good	Very Good	Good
GLO: Capacitor ceramic MLCC 1210 (50mg) 3.2x2.5x1.6 (Base metals) Sphera	2022	Good	Very Good	Good
GLO: Capacitor ceramic MLCC 1210 (50mg) 3.2x2.5x1.6 (Precious Metals) Sphera	2022	Good	Very Good	Good
GLO: Capacitor ceramic MLCC 2220 (450mg) 5.7x5x2.5 (Base Metals) Sphera	2022	Good	Very Good	Good
GLO: Capacitor ceramic MLCC 2220 (450mg) 5.7x5x2.5 (Precious Metals) Sphera	2022	Good	Very Good	Good

GLO: Capacitor film-capacitor boxed RM15 (3.2g) 17.7x10x16.5 Sphera	2022	Good	Very Good	Good
GLO: Capacitor film-capacitor boxed RM27.5 (20.4g) 31x21x31 Sphera	2022	Good	Very Good	Good
GLO: Capacitor film-capacitor boxed RM5 (600mg) 7.2x6x11 Sphera	2022	Good	Very Good	Good
GLO: Capacitor film-capacitor unboxed RM15 (2.6g) 15x7x12 Sphera	2022	Good	Very Good	Good
GLO: Capacitor film-capacitor unboxed RM27.5 (11g) 27.5x11x17.5 Sphera	2022	Good	Very Good	Good
GLO: Capacitor film-capacitor unboxed RM7.5 (150mg) 7.5x1.5x6.0 Sphera	2022	Good	Very Good	Good
GLO: Capacitor tantal SMD E (500mg) 7.3x4.3x4.1 Sphera	2022	Good	Very Good	Good
GLO: Capacitor tantal SMD Y (25mg) 3.2x1.6x1.6 Sphera	2022	Good	Very Good	Good
GLO: Capacitor tantal SMD Z (8mg) 2x1.25x1.2 Sphera	2022	Good	Very Good	Good
GLO: Cargo plane, 113 t payload Sphera <u-so>	2022	Very Good	Very Good	Very Good
GLO: Cargo plane, 22 t payload Sphera <u-so>	2022	Very Good	Very Good	Very Good
GLO: Coil miniature wound SDR0302 (81mg) D3x2.5 Sphera	2022	Good	Very Good	Good
GLO: Coil miniature wound SDR1006 (1.16g) D9.8x5.8 Sphera	2022	Good	Very Good	Good
GLO: Coil miniature wound SRP1040 (2.652g) D11.8x4.2 Sphera	2022	Good	Very Good	Good
GLO: Coil miniature wound SRR0804 (580mg) D10.5x3.8 Sphera	2022	Good	Very Good	Good
GLO: Coil miniature wound SRR1806 (3.12g) D18.3x6.8 Sphera	2022	Good	Very Good	Good
GLO: Coil multilayer chip 0402 (1mg) 1x0.5x0.5 Sphera	2022	Good	Very Good	Good
GLO: Coil multilayer chip 1812 (108mg) 4.5x3.2x1.5 Sphera	2022	Good	Very Good	Good
GLO: Coil quad-chokes (2.5g) 14.5x13.3x8.0 Sphera	2022	Good	Very Good	Good
GLO: Coin cell (Li/Poly-carbonmonofluoride - RB0.8; RS0.65) Sphera	2022	Good	Very Good	Good
GLO: Components mixer (modified) Sphera <u-so>	2020	Good	Very Good	Good
GLO: Components mixer Sphera <u-so>	2022	Good	Very Good	Good
GLO: Compounding (plastics) Sphera <u-so>	2022	Good	Very Good	Very Good
GLO: Compressed air 7 bar (low power consumption) Sphera <u-so>	2019	Good	Very Good	Good
GLO: Compressed air 7 bar (medium power consumption) Sphera <u-so>	2019	Good	Very Good	Good
GLO: Connector audio TRS 3.5mm socket (800mg) (gold-plated) Sphera	2022	Good	Very Good	Good
GLO: Connector audio TRS 3.5mm socket (800mg) (silver-plated) Sphera	2021	Good	Very Good	Good
GLO: Connector board-to-board 0.4mm-pitch SMD 60-pin plug (25mg) 15x2.6x1.0mm Sphera	2022	Good	Very Good	Good

GLO: Connector board-to-board 0.4mm-pitch SMD 60-pin socket (56mg) 15x2.6x1.0mm Sphera	2022	Good	Very Good	Good
GLO: Connector Cinch female (15 g, 1 pin, gold plated) - based on parametric plan model Sphera	2022	Good	Very Good	Good
GLO: Connector coaxial micro-miniature W.FL SMD plug (18.6mg) 2.0x3.7x1.15mm Sphera	2022	Good	Very Good	Good
GLO: Connector coaxial micro-miniature W.FL SMD socket (5.6mg) 1.7x1.7x0.85mm Sphera	2022	Good	Very Good	Good
GLO: Connector DC power female (2 g, 1 pin) - based on parametric plan model Sphera	2022	Good	Very Good	Good
GLO: Connector D-sub DE-15 (VGA) 15-pin socket (8.4g) (gold-plated) Sphera	2022	Good	Very Good	Good
GLO: Connector D-sub DE-9 (RS-232/serial) 9-pin socket (7.2g) (gold-plated) Sphera	2022	Good	Very Good	Good
GLO: Connector HDMI Type-A 19-pin plug (7.8g) (gold-plated) Sphera	2022	Good	Very Good	Good
GLO: Connector HDMI Type-A 19-pin socket (2.0g) (gold-plated) Sphera	2022	Good	Very Good	Good
GLO: Connector IC single-row (2 g, 10 pins) - based on parametric plan model Sphera	2022	Good	Very Good	Good
GLO: Connector IC single-row (2 g, 10 pins, gold plated) - based on parametric plan model Sphera	2022	Good	Very Good	Good
GLO: Connector IDC socket (5 g, 40 pins, gold plated) - based on parametric plan model Sphera	2021	Good	Very Good	Good
GLO: Connector IEC-60320-C13 female (28,5 g, 3 pins) - based on parametric plan model Sphera	2021	Good	Very Good	Good
GLO: Connector IEC-60320-C14 male (9,1 g, 3 pins) - based on parametric plan model Sphera	2022	Good	Very Good	Good
GLO: Connector IEC-60320-C5 female (16,8 g, 3 pins) - based on parametric plan model Sphera	2022	Good	Very Good	Good
GLO: Connector IEC-60320-C6 male (5,5 g, 3 pins) - based on parametric plan model Sphera	2022	Good	Very Good	Good
GLO: Connector NEMA type B (27,7 g, 3 pins) - based on parametric plan model Sphera	2022	Good	Very Good	Good
GLO: Connector PATA - based on parametric plan model Sphera	2022	Good	Very Good	Good
GLO: Connector PCI (2,6 g, 72 pins, gold plated) - based on parametric plan model Sphera	2022	Good	Very Good	Good
GLO: Connector power AC mains Euro/Schuko Type-C CEE 7/16 2-pin plug (15g) Sphera	2021	Good	Very Good	Good
GLO: Connector power AC mains Euro/Schuko Type-C CEE 7/7 3-pin plug (39.9g) Sphera	2021	Good	Very Good	Good

GLO: Connector power AC mains NEMA Type-A 2-pin plug (19.2g) Sphera	2022	Good	Very Good	Good
GLO: Connector power AC mains NEMA Type-B 3-pin plug (27.7g) Sphera	2022	Good	Very Good	Good
GLO: Connector power DC circular plug (2.9g) Sphera	2022	Good	Very Good	Good
GLO: Connector power DC circular socket (2g) Sphera	2022	Good	Very Good	Good
GLO: Connector power IEC-60320-C13 3-pin plug (28.5g) Sphera	2022	Good	Very Good	Good
GLO: Connector power IEC-60320-C14 3-pin socket (10g) Sphera	2022	Good	Very Good	Good
GLO: Connector power IEC-60320-C5 3-pin plug (17.2g) Sphera	2022	Good	Very Good	Good
GLO: Connector power IEC-60320-C6 3-pin socket (5.5g) Sphera	2022	Good	Very Good	Good
GLO: Connector RJ45/8P8C ethernet 8-pin socket (2.5g) (gold-plated) Sphera	2022	Good	Very Good	Good
GLO: Connector RJ45/8P8C ethernet EMI/RFI shielded 8-pin socket (3.6g) (gold-plated) Sphera	2022	Good	Very Good	Good
GLO: Connector S-ATA (2 g, 7 pins, gold plated) - based on parametric plan model Sphera	2022	Good	Very Good	Good
GLO: Connector SATA 7 + 15 (22-pin) plug (1.4g) (gold-plated) Sphera	2022	Good	Very Good	Good
GLO: Connector SATA/SAS - based on parametric plan model Sphera	2022	Good	Very Good	Good
GLO: Connector SD card micro THT/SMD socket (600mg) 14x16x1.7mm Sphera	2022	Good	Very Good	Good
GLO: Connector SIM card mini THT/SMD socket (1.1g) 26x18x1.8mm Sphera	2022	Good	Very Good	Good
GLO: Connector Steck Klemme Leiste (3 g, 2 pins) - based on parametric plan model Sphera	2022	Good	Very Good	Good
GLO: Connector Steck Rck Einpress Male (4,2 g, 55 pins, gold plated) - based on parametric plan model Sphera	2022	Good	Very Good	Good
GLO: Connector TRS 2,5 female (10 g, 1 pin) - based on parametric plan model Sphera	2022	Good	Very Good	Good
GLO: Connector TRS 3,5 female (15 g, 1 pin) - based on parametric plan model Sphera	2022	Good	Very Good	Good
GLO: Connector TRS 3,5 female (15 g, 1 pin, gold plated) - based on parametric plan model Sphera	2021	Good	Very Good	Good
GLO: Connector USB micro (2,5 g, 4 pins, gold plated) - based on parametric plan model Sphera	2022	Good	Very Good	Good
GLO: Connector USB micro-AB THT/SMD 5-pin socket (260mg) 7.5x5.0x2.5mm Sphera	2022	Good	Very Good	Good
GLO: Connector USB mini 5-pin socket (760mg) (gold-plated) Sphera	2022	Good	Very Good	Good

GLO: Connector USB type A (1,6 g, 4 pins, gold plated) - based on parametric plan model Sphera	2022	Good	Very Good	Good
GLO: Connector USB Type-A 4-pin plug (9.2g) (gold-plated) 36x12x4.5mm Sphera	2022	Good	Very Good	Good
GLO: Connector USB Type-A 4-pin socket (2.1g) (gold-plated) Sphera	2022	Good	Very Good	Good
GLO: Connector USB Type-B 4-pin plug (10.2g) (gold-plated) Sphera	2021	Good	Very Good	Good
GLO: Connector USB Type-B 4-pin socket (2.8g) (gold-plated) Sphera	2022	Good	Very Good	Good
GLO: Connector wire-to-board IDC 2.54mm-pitch 2x10 (20-pin) cable-mounted socket (3.3g) (gold-plated) Sphera	2022	Good	Very Good	Good
GLO: Connector wire-to-board IDC 2.54mm-pitch 2x10 (20-pin) cable-mounted socket (3.3g) (tin-plated) Sphera	2022	Good	Very Good	Good
GLO: Connector wire-to-board pin-header 2.54mm-pitch 2x10 (20-pin) (1.3g) (gold-plated) Sphera	2022	Good	Very Good	Good
GLO: Connector wire-to-board pin-header 2.54mm-pitch 2x10 (20-pin) (1.3g) (tin-plated) Sphera	2022	Good	Very Good	Good
GLO: Container ship, 5.000 to 200.000 dwt payload capacity, deep sea Sphera <u-so>	2022	Very Good	Very Good	Very Good
GLO: Copper mix (99,999% from electrolysis) Sphera	2022	Good	Very Good	Good
GLO: Detergent (fatty acid sulphonate derivate) Sphera	2022	Poor	Fair	Poor
GLO: Diode MELF (130mg) D2.6x5.2 Sphera	2022	Very Good	Very Good	Very Good
GLO: Diode mMELF (40mg) D1.6x3.8 Sphera	2022	Very Good	Very Good	Very Good
GLO: Diode power DO214/219 (93mg) 4.3x3.6x2.3 Sphera	2022	Very Good	Very Good	Very Good
GLO: Diode power THT DO201 (1.12g) D5.3x9.5 Sphera	2022	Very Good	Very Good	Very Good
GLO: Diode power THT DO35 (150mg) D1.76x3.77 Sphera	2022	Very Good	Very Good	Very Good
GLO: Diode signal DO214/219 (14.8mg) 3.9x1.9x1 Sphera	2022	Very Good	Very Good	Very Good
GLO: Diode signal SOD123/323/523 (1.59mg) 0.8x0.75x1.6 with Au-Bondwire Sphera	2022	Very Good	Very Good	Very Good
GLO: Diode signal SOD123/323/523 (9.26mg) 2.4x1.6x1 with Au-Bondwire Sphera	2022	Very Good	Very Good	Very Good
GLO: Electricity credit Sphera <u-so>	2022	Good	Very Good	Good
GLO: Electrolytic galvanisation (1 m² steel sheet part; electrolytic) Sphera <u-so>	2022	Good	Very Good	Very Good
GLO: EMS Shielding Sphera	2022	Good	Very Good	Good
GLO: Energy credit Sphera <u-so>	2022	Good	Very Good	Good
GLO: Filter SAW (25mg) 3x7x1 Sphera	2022	Good	Very Good	Good

GLO: Flexible printed wiring board, 1 layer, single sided, with FR4, chem-elec AuNi finish Sphera	2022	Good	Very Good	Very Good
GLO: Flexible printed wiring board,1 layer, single sided, without FR4, chem-elec AuNi finish Sphera	2021	Good	Very Good	Very Good
GLO: Gold (primary) Sphera	2022	Fair	Very Good	Fair
GLO: Gold, primary (in Electronics) Sphera	2022	Good	Very Good	Very Good
GLO: Hard disk drive (HDD), 2.5", 1 platter, 2 sides, 7 mm high Sphera	2022	Good	Very Good	Good
GLO: Hard disk drive (HDD), 2.5", 2 platters, 4 sides, 9.5 mm high Sphera	2022	Good	Very Good	Good
GLO: Hard disk drive (HDD), 2.5", 3 platters, 6 sides, 12.5 mm high Sphera	2022	Good	Very Good	Good
GLO: Hard disk drive (HDD), 2.5", 4 platters, 8 sides, 15 mm high Sphera	2022	Good	Very Good	Good
GLO: Hard disk drive (HDD), 3.5", 1 platter, 1 side, 26 mm high Sphera	2022	Good	Very Good	Good
GLO: Hard disk drive (HDD), 3.5", 1 platter, 2 sides, 26 mm high Sphera	2022	Good	Very Good	Good
GLO: Hard disk drive (HDD), 3.5", 2 platters, 4 sides, 26 mm high Sphera	2022	Good	Very Good	Good
GLO: Hard disk drive (HDD), 3.5", 3 platters, 6 sides, 26 mm high Sphera	2022	Good	Very Good	Good
GLO: Hard disk drive (HDD), 3.5", 4 platters, 8 sides, 26 mm high Sphera	2022	Good	Very Good	Good
GLO: Hard disk drive (HDD), 3.5", 5 platters, 10 sides, 26 mm high Sphera	2022	Good	Very Good	Good
GLO: Housing IC Sphera	2022	Fair	Very Good	Very Good
GLO: IC BGA 144 (1.32g) 14x12 mm MCM WiFi/Bluetooth Sphera	2022	Very Good	Very Good	Very Good
GLO: IC BGA 144 (181mg) 10x10mm MPU generic (130 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC BGA 144 (360mg) 13X13mm MPU generic (130 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC BGA 1515 (14.6 g) 40x40 mm CMOS logic (14 nm) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC BGA 256 (4g) 27x27 mm CMOS logic (45 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC BGA 300 (1.90g) 18x13mm 1GB NAND flash (45 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC BGA 48 (72mg) 8x6 mm CMOS logic (14 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC BGA 672 (4.92g) 35x35x2.36 CMOS logic (65 nm node) [based on models 2004-2014] Sphera	2022	Very Good	Very Good	Very Good
GLO: IC BGA 672 (6.6g) 27x27 mm CMOS (14 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC BGA 78 (446 mg) 8x10 mm 1GB DDR4 RAM (57 nm node) Sphera	2022	Very Good	Very Good	Very Good

GLO: IC DFN 10 (22.3 mg) 3x3 mm CMOS logic (14 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC DIP 24 (1.7g) 35.5x8.2 mm CMOS logic (250 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC DIP 42 (6.30g) 54.6x14.1x3.9 [based on models 2004-2014] Sphera	2022	Very Good	Very Good	Very Good
GLO: IC DIP 8 (538mg) 10.9x6.6 mm CMOS logic (250 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC LGA 1366 (ca. 5g) 45x42.5x ca. 2.5 CMOS logic (32 nm node) [based on models 2004-2014] Sphera	2022	Very Good	Very Good	Very Good
GLO: IC PLCC 20 (751mg) 9x9 mm CMOS logic (250 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC PLCC 44 (2.6g) 16.6x16.6 mm CMOS logic (250 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC PLCC 68 (5g) 24.2x24.2 mm CMOS logic (250 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC QFN 24 (61.6 mg) 4x6 mm CMOS logic (14 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC QFN 76 (578.8 mg) 10x11 mm CMOS logic (14 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC QFP 240 (6.20g) 32x32x3.5 [based on models 2004-2014] Sphera	2022	Very Good	Very Good	Very Good
GLO: IC QFP 32 (184mg) 7x7 mm CMOS logic (90 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC QFP 80 (1.60g) 14x20x2.7 [based on models 2004-2014] Sphera	2022	Very Good	Very Good	Very Good
GLO: IC SO 20 (530mg) 12.8x7.5 mm CMOS logic (90 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC SO 44 (910mg) 28.3x13.3x2.3 [based on models 2004-2014] Sphera	2022	Very Good	Very Good	Very Good
GLO: IC SO 8 (76mg) 4.9x3.9 mm CMOS logic (90 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC SSOP 14 (120mg) 6.0x5.3x1.75 [based on models 2004-2014] Sphera	2022	Very Good	Very Good	Very Good
GLO: IC SSOP 24 (123mg) 8.2x5.3 mm CMOS logic (65 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC SSOP 64 (340mg) 26x10.2x1.75 [based on models 2004-2014] Sphera	2022	Very Good	Very Good	Very Good
GLO: IC TQFP 100 (513mg) 14x14 mm MPU generic (130 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC TQFP 32 (146mg) 5x5 mm MPU generic (130 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC TQFP 44 (272mg) 10x10 mm MPU generic (130 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC TSOP 28 (232mg) 8x13.4 mm DRAM (57 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC TSOP 28 (232mg) 8x13.4 mm flash (45 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC TSOP 32 (373mg) 8x20 nm DRAM (57 nm node) Sphera	2022	Very Good	Very Good	Very Good

GLO: IC TSOP 32 (373mg) 8x20 nm flash (45 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC TSOP 56 (590mg) 14x20x1.2 DRAM [based on models 2004-2014] Sphera	2022	Very Good	Very Good	Very Good
GLO: IC TSOP 56 (590mg) 14x20x1.2 flash [based on models 2004-2014] Sphera	2022	Very Good	Very Good	Very Good
GLO: IC TSSOP 16 (59mg) 4.4x5.0 mm DRAM (57 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC TSSOP 16 (59mg) 4.4x5.0 mm flash (45 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC TSSOP 48 (187mg) 6.1x12.5 mm DRAM (57 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC TSSOP 48 (187mg) 6.1x12.5 mm flash (45 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC TSSOP 8 (23mg) 3x3 mm DRAM (57 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC TSSOP 8 (23mg) 3x3 mm flash (45 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC WLP CSP 196 (209mg) 12x12x1.41mm CMOS logic (14 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC WLP CSP 196 (209mg) 12x12x1.41mm CMOS logic (22 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC WLP CSP 196 (209mg) 12x12x1.41mm DRAM (57 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC WLP CSP 196 (209mg) 12x12x1.41mm flash (45 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC WLP CSP 196 (209mg) 12x12x1.41mm MPU generic (130 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC WLP CSP 425 (4.78g) 19x19x1.5mm CMOS logic (14 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC WLP CSP 425 (4.78g) 19x19x1.5mm CMOS logic (22 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC WLP CSP 425 (4.78g) 19x19x1.5mm DRAM (57 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC WLP CSP 425 (4.78g) 19x19x1.5mm flash (45 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC WLP CSP 425 (4.78g) 19x19x1.5mm MPU generic (130 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC WLP CSP 49 (10.2mg) 3.17x3.17x0.55mm CMOS logic (14 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC WLP CSP 49 (10.2mg) 3.17x3.17x0.55mm CMOS logic (22 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC WLP CSP 49 (10.2mg) 3.17x3.17x0.55mm DRAM (57 nm node) Sphera	2022	Very Good	Very Good	Very Good

GLO: IC WLP CSP 49 (10.2mg) 3.17x3.17x0.55mm flash (45 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: IC WLP CSP 49 (10.2mg) 3.17x3.17x0.55mm MPU generic (130 nm node) Sphera	2022	Very Good	Very Good	Very Good
GLO: Key switch Dip (79mg) 11.39x4.5x1.5 Sphera	2022	Good	Very Good	Good
GLO: Key switch tact (242mg) 6.2x6.3x1.8 Sphera	2022	Good	Very Good	Good
GLO: LCD Cell (Panel) (cm2) Sphera	2022	Good	Very Good	Very Good
GLO: LED SMD high-efficiency with lens max 0.5A (235mg) Au bondwire 9.0x7.0x4.4 Sphera	2022	Very Good	Very Good	Very Good
GLO: LED SMD high-efficiency with lens max 0.5A (235mg) Flip Chip 9.0x7.0x4.4 Sphera	2022	Very Good	Very Good	Very Good
GLO: LED SMD high-efficiency with lens max 0.5A (59mg) Au bondwire 3.5x3.5x2.0 Sphera	2022	Very Good	Very Good	Very Good
GLO: LED SMD high-efficiency with lens max 0.5A (59mg) Flip Chip 3.5x3.5x2.0 Sphera	2022	Very Good	Very Good	Very Good
GLO: LED SMD high-efficiency with lens max 1.5A (61mg) Au bondwire 3.5x3.5x2.0 Sphera	2022	Very Good	Very Good	Very Good
GLO: LED SMD high-efficiency with lens max 1.5A (61mg) Flip Chip 3.5x3.5x2.0 Sphera	2022	Very Good	Very Good	Very Good
GLO: LED SMD high-efficiency with lens max 1A (235mg) Au bondwire 9.0x7.0x4.4 Sphera	2022	Very Good	Very Good	Very Good
GLO: LED SMD high-efficiency with lens max 1A (235mg) Flip Chip 9.0x7.0x4.4 Sphera	2022	Very Good	Very Good	Very Good
GLO: LED SMD high-efficiency with lens max 1A (60mg) Au bondwire 3.5x3.5x2.0 Sphera	2022	Very Good	Very Good	Very Good
GLO: LED SMD high-efficiency with lens max 1A (60mg) Flip Chip 3.5x3.5x2.0 Sphera	2022	Very Good	Very Good	Very Good
GLO: LED SMD low-efficiency max 50mA (35mg) without Au 3.2x2.8x1.9 Sphera	2022	Very Good	Very Good	Very Good
GLO: LED THT 5mm (350mg) D5x7 Sphera	2022	Very Good	Very Good	Very Good
GLO: Lubricant (aqueous emulsion of fatty substances) Sphera	2022	Poor	Fair	Poor
GLO: Micro Speaker (2g, dynamic, Nd magnet, SMD) Sphera	2022	Good	Very Good	Good
GLO: Nickel mix Sphera	2022	Good	Very Good	Good
GLO: ODD PC Sphera	2022	Good	Very Good	Good
GLO: Oscillator crystal (500mg) 11.05x4.65x2.5 Sphera	2022	Good	Very Good	Good
GLO: Oscillator crystal (750mg) 11.35x4.65x3.6 Sphera	2022	Good	Very Good	Good

GLO: Package scaling for transport (dummy) Sphera <u-so>	2022	Fair	Fair	Fair
GLO: Palladium mix Sphera	2022	Good	Very Good	Good
GLO: Panel Electronics (pixel control board) Sphera	2022	Good	Very Good	Very Good
GLO: Plastic Film (PE, PP, PVC) Sphera <u-so>	2022	Good	Very Good	Very Good
GLO: Plastic injection moulding (parameterized) Sphera <u-so>	2022	Good	Very Good	Very Good
GLO: Platinum mix Sphera	2022	Good	Very Good	Good
GLO: Printed Wiring Board 10-layer rigid FR4 with chem-elec AuNi finish (Subtractive method) Sphera	2022	Good	Very Good	Very Good
GLO: Printed Wiring Board 10-layer rigid FR4 with chemSn elecAuNi finish (Subtractive method) Sphera	2022	Good	Very Good	Very Good
GLO: Printed Wiring Board 10-layer rigid FR4 with HASL finish (Subtractive method) Sphera	2022	Good	Very Good	Very Good
GLO: Printed Wiring Board 12-layer rigid FR4 with chem-elec AuNi finish (Subtractive method) Sphera	2022	Good	Very Good	Very Good
GLO: Printed Wiring Board 12-layer rigid FR4 with chemSn elecAuNi finish (Subtractive method) Sphera	2022	Good	Very Good	Very Good
GLO: Printed Wiring Board 12-layer rigid FR4 with HASL finish (Subtractive method) Sphera	2022	Good	Very Good	Very Good
GLO: Printed Wiring Board 16-layer rigid FR4 with chem-elec AuNi finish (Subtractive method) Sphera	2022	Good	Very Good	Very Good
GLO: Printed Wiring Board 16-layer rigid FR4 with chemSn elecAuNi finish (Subtractive method) Sphera	2022	Good	Very Good	Very Good
GLO: Printed Wiring Board 16-layer rigid FR4 with HASL finish (Subtractive method) Sphera	2022	Good	Very Good	Very Good
GLO: Printed Wiring Board 1-layer rigid FR4 with chem-elec AuNi finish (Subtractive method) Sphera	2022	Good	Very Good	Very Good
GLO: Printed Wiring Board 1-layer rigid FR4 with chemSn elecAuNi finish (Subtractive method) Sphera	2022	Good	Very Good	Very Good
GLO: Printed Wiring Board 1-layer rigid FR4 with HASL finish (Subtractive method) Sphera	2022	Good	Very Good	Very Good
GLO: Printed Wiring Board 2-layer rigid FR4 with chem-elec AuNi finish (Subtractive method) Sphera	2022	Good	Very Good	Very Good
GLO: Printed Wiring Board 2-layer rigid FR4 with chemSn elecAuNi finish (Subtractive method) Sphera	2022	Good	Very Good	Very Good
GLO: Printed Wiring Board 2-layer rigid FR4 with HASL finish (Subtractive method) Sphera	2022	Good	Very Good	Very Good
GLO: Printed Wiring Board 4-layer rigid FR4 with chem-elec AuNi finish (Subtractive method) Sphera	2022	Good	Very Good	Very Good

GLO: Printed Wiring Board 4-layer rigid FR4 with chemSn elecAuNi finish (Subtractive method) Sphera	2022	Good	Very Good	Very Good
GLO: Printed Wiring Board 4-layer rigid FR4 with HASL finish (Subtractive method) Sphera	2022	Good	Very Good	Very Good
GLO: Printed Wiring Board 8-layer rigid FR4 with chem-elec AuNi finish (Subtractive method) Sphera	2022	Good	Very Good	Very Good
GLO: Printed Wiring Board 8-layer rigid FR4 with chemSn elecAuNi finish (Subtractive method) Sphera	2022	Good	Very Good	Very Good
GLO: Printed Wiring Board 8-layer rigid FR4 with HASL finish (Subtractive method) Sphera	2022	Good	Very Good	Very Good
GLO: Product - area Sphera <u-so>	2022	Good	Very Good	Good
GLO: Product - kgkm Sphera <u-so>	2022	Good	Very Good	Good
GLO: Product - pcs Sphera <u-so>	2022	Good	Very Good	Good
GLO: Product - volume Sphera <u-so>	2022	Good	Very Good	Good
GLO: Product Sphera <u-so>	2022	Good	Very Good	Good
GLO: Punching steel sheet small part Sphera <u-so>	2022	Good	Very Good	Very Good
GLO: Resistor flat chip 0402 (0.6mg) Sphera	2022	Good	Very Good	Good
GLO: Resistor flat chip 0603 (1.9mg) Sphera	2022	Good	Very Good	Good
GLO: Resistor flat chip 1206 (9.2mg) Sphera	2022	Good	Very Good	Good
GLO: Resistor MELF MMA 0204 (19mg) D1.4x3.6 Sphera	2022	Very Good	Very Good	Good
GLO: Resistor MELF MMB 0207 (79mg) D2.2x5.8 Sphera	2022	Very Good	Very Good	Good
GLO: Resistor MELF MMU 0102 (7mg) D1.1x2.2 Sphera	2022	Very Good	Very Good	Good
GLO: Resistor thick film flat chip 01005 (0.04mg) Sphera	2022	Good	Very Good	Good
GLO: Resistor thick film flat chip 0201 (0.15mg) Sphera	2022	Good	Very Good	Good
GLO: Resistor thick film flat chip 0402 (0.75mg) Sphera	2022	Good	Very Good	Good
GLO: Resistor thick film flat chip 0603 (2.1mg) Sphera	2022	Good	Very Good	Good
GLO: Resistor thick film flat chip 1206 (8.9mg) Sphera	2022	Good	Very Good	Good
GLO: Resistor THT MBA 0204 (125mg) D1.6x3.6 Sphera	2022	Very Good	Very Good	Good
GLO: Resistor THT MBB 0207 (220mg) D2.5x6.3 Sphera	2022	Very Good	Very Good	Good
GLO: Resistor THT MBE 0414 (700mg) D4.0x11.9 Sphera	2022	Very Good	Very Good	Good
GLO: Ring Core Coil 30g (With housing) Sphera	2022	Good	Very Good	Good
GLO: Ring Core Coil 30g (Without housing) Sphera	2022	Good	Very Good	Good

GLO: Ring Core Coil 8 g (With housing) Sphera	2022	Good	Very Good	Good
GLO: Ring Core Coil 8 g (Without housing) Sphera	2022	Good	Very Good	Good
GLO: Ring Core Coil 80 g (With housing) Sphera	2022	Good	Very Good	Good
GLO: Ring Core Coil 80 g (Without housing) Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing CMOS logic 130 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing CMOS logic 14 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing CMOS logic 180 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing CMOS logic 22 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing CMOS logic 250 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing CMOS logic 32 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing CMOS logic 350 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing CMOS logic 45 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing CMOS logic 65 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing CMOS logic 90 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing CMOS logic with on-chip flash memory 130 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing DRAM 130 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing DRAM 180 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing DRAM 250 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing DRAM 57 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing DRAM 70 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing DRAM 90 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing flash memory 150 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing flash memory 45 nm tech node Sphera	2022	Good	Very Good	Good

GLO: Semiconductor manufacturing flash memory 65 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing flash memory 90 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing for transistors, diodes & LEDs Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing WLP CSP CMOS logic 14 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing WLP CSP CMOS logic 22 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing WLP CSP CMOS logic with on-chip flash memory 130 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing WLP CSP DRAM 57 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Semiconductor manufacturing WLP CSP flash memory 45 nm tech node Sphera	2022	Good	Very Good	Good
GLO: Silver mix Sphera	2022	Fair	Very Good	Fair
GLO: Small mechanics and electromechanics Sphera	2022	Good	Very Good	Good
GLO: Solder paste AuIn18 Sphera	2022	Good	Very Good	Good
GLO: Solder paste AuSn20 Sphera	2022	Good	Very Good	Good
GLO: Solder paste InPb40 Sphera	2022	Good	Very Good	Good
GLO: Solder paste InSn48 Sphera	2022	Good	Very Good	Good
GLO: Solder paste SnAg2.6Cu0.3 Sphera	2022	Good	Very Good	Good
GLO: Solder paste SnAg3.5 Sphera	2022	Good	Very Good	Good
GLO: Solder paste SnAg3.5Cu0.7 (SAC-Lot) Sphera	2022	Good	Very Good	Good
GLO: Solder paste SnAg3Cu0.5 (SAC-Lot) Sphera	2022	Good	Very Good	Good
GLO: Solder paste SnAg4Cu0.6 Sphera	2022	Good	Very Good	Good
GLO: Solder paste SnCu0.7 Sphera	2022	Good	Very Good	Good
GLO: Solder paste SnCu0.7Ag0.3 Sphera	2022	Good	Very Good	Good
GLO: Solder paste SnCu0.7Ni0.05 Sphera	2022	Good	Very Good	Good
GLO: Solder paste SnIn10Ag3.1 Sphera	2022	Good	Very Good	Good
GLO: Solder paste SnPb34Ag2 Sphera	2022	Good	Very Good	Good
GLO: Solder paste SnPb36 Sphera	2022	Good	Very Good	Good
GLO: Solder paste SnZn9 Sphera	2022	Good	Very Good	Good

GLO: Special high grade zinc only from Zn concentrate IZA	2022	Very Good	Very Good	Good
GLO: Steel sheet stamping and bending (5% loss) Sphera <u-so>	2022	Good	Very Good	Very Good
GLO: Steel wire rod worldsteel	2022	Very Good	Very Good	Good
GLO: Substrate for active components (2-layer rigid FR4 chem-elec AuNi finish, mass) Sphera	2022	Good	Very Good	Very Good
GLO: Thermistor SMD NTC 0402 (4mg) Sphera	2022	Very Good	Very Good	Good
GLO: Thermistor SMD NTC 0603 (6mg) Sphera	2022	Very Good	Very Good	Good
GLO: Thermistor SMD NTC 0805 (13mg) Sphera	2022	Very Good	Very Good	Good
GLO: Thermistor SMD NTC 1206 (18mg) Sphera	2022	Very Good	Very Good	Good
GLO: Thermistor SMD PTC (400mg) 6.3x8x3.3 Sphera	2022	Very Good	Very Good	Good
GLO: Thermistor THT NTC, Leaded Disk (120mg) 2.5xD43 Sphera	2022	Very Good	Very Good	Good
GLO: Thermistor THT NTC, Leaded Disk (250mg) 4.5xD41 Sphera	2022	Very Good	Very Good	Good
GLO: Thermistor THT PTC Overcurrent Protection, Leaded Disk (980mg) 12xD35 Sphera	2022	Very Good	Very Good	Good
GLO: Thermistor THT PTC Switch, Leaded Disk (420mg) 6xD13 Sphera	2022	Very Good	Very Good	Good
GLO: Thermistor THT PTC Temp Sensor, Leaded Disk (250mg) 4xD42 Sphera	2022	Very Good	Very Good	Good
GLO: Tin Sphera	2022	Fair	Very Good	Fair
GLO: Transistor D2PAK TO263 (1.38g) 10.3x9.6x4.5 Sphera	2022	Very Good	Very Good	Very Good
GLO: Transistor DPAK TO252 (290mg) 6.6x6.2x2.2 Sphera	2022	Very Good	Very Good	Very Good
GLO: Transistor power THT/SMD SOT93/TO218 3 leads (4.70g) 15.5x12.9x4.7 Sphera	2022	Very Good	Very Good	Very Good
GLO: Transistor power THT/SMD SOT93/TO218 7 leads (4.80g) 15.5x12.9x4.7 Sphera	2022	Very Good	Very Good	Very Good
GLO: Transistor signal SOT223 3 leads (110mg) 3.8x7.65x2.3 Sphera	2022	Very Good	Very Good	Very Good
GLO: Transistor signal SOT223 8 leads (180mg) 3.8x7.65x3 Sphera	2022	Very Good	Very Good	Very Good
GLO: Transistor signal SOT23 3 leads (10mg) 1.4x3x1 Sphera	2022	Very Good	Very Good	Very Good
GLO: Transistor signal SOT23 8 leads (18mg) 1.4x3x2 Sphera	2022	Very Good	Very Good	Very Good
GLO: Transistor THT SOT82 (720mg) 10.6x7.6x2.5 Sphera	2022	Very Good	Very Good	Very Good
GLO: Transistor THT TO92 (250mg) D4.8x5.3 Sphera	2022	Very Good	Very Good	Very Good
GLO: Truck, Euro 0 - 6 mix, 20 - 26t gross weight / 17,3t payload capacity Sphera <u-so>	2022	Very Good	Very Good	Very Good

GLO: Truck, Euro 3, more than 32t gross weight / 24.7t payload capacity Sphera <u-so>	2022	Very Good	Very Good	Very Good
GLO: Truck, Euro 6 A-C, 28 - 32t gross weight / 22t payload capacity Sphera <u-so>	2022	Very Good	Very Good	Very Good
GLO: Value of stainless steel scrap (304) Sphera	2022	Fair	Fair	Fair
GLO: Varistor THT VDR, Leaded Disk (2g) D12x25 Sphera	2022	Very Good	Very Good	Good
GLO: Waste water treatment (metal processing) Sphera <u-so>	2022	Fair	Very Good	Very Good
GLO: Zinc mix Sphera	2022	Very Good	Very Good	Very Good
GLO: Zinc oxide (technology mix: American and French process) Sphera	2022	Very Good	Very Good	Very Good
IL: Electricity grid mix Sphera	2019	Good	Very Good	Good
JP: Electricity grid mix Sphera	2019	Good	Very Good	Good
KR: Electricity grid mix Sphera	2019	Good	Very Good	Good
MX: Electricity grid mix Sphera	2019	Good	Very Good	Good
MY: Electricity grid mix Sphera	2019	Good	Very Good	Good
RER: Acrylonitrile-butadiene-styrene (ABS) in waste incineration plant Sphera <p-agg>	2022	Good	Very Good	Good
RER: Aluminium extrusion profile - open input aluminium ingot Sphera <p-agg>	2022	Good	Very Good	Good
RER: Aluminium foil Sphera	2022	Good	Very Good	Good
RER: Aluminium ingot mix Sphera	2022	Good	Very Good	Good
RER: Aluminium oxide mix (alumina, Al2O3) Sphera	2022	Good	Very Good	Good
RER: Aluminium recycling (95% efficiency) Sphera <p-agg>	2022	Good	Very Good	Good
RER: Aluminium sheet - open input aluminium rolling ingot Sphera <p-agg>	2022	Good	Very Good	Good
RER: Aluminium sheet (AlCu4Mg1) Sphera	2022	Good	Very Good	Good
RER: Aluminium sheet (AlMg1(C)) Sphera	2022	Good	Very Good	Good
RER: Aluminium sheet (AlMg2.5) Sphera	2022	Good	Very Good	Good
RER: Aluminium sheet (AlMg2Mn0.8) Sphera	2022	Good	Very Good	Good
RER: Aluminium sheet (AlMg3) Sphera	2022	Good	Very Good	Good
RER: Aluminium sheet (AlMg3Mn) Sphera	2022	Good	Very Good	Good
RER: Aluminium sheet (AlMg4.5) Sphera	2022	Good	Very Good	Good
RER: Aluminium sheet (AlMg4.5Mn0.7) Sphera	2022	Good	Very Good	Good

RER: Aluminium sheet (AlSi1MgMn) Sphera	2022	Good	Very Good	Good
RER: Aluminium sheet mix Sphera	2022	Good	Very Good	Good
RER: Borosilicate glass production Sphera	2022	Good	Very Good	Good
RER: Brass (CuZn20) Sphera <p-agg>	2022	Good	Very Good	Good
RER: Cast iron part Sphera <p-agg>	2022	Very Good	Very Good	Very Good
RER: Copper wire (0.06 mm) Sphera	2022	Good	Very Good	Very Good
RER: Copper wire (0.6 mm) Sphera	2022	Good	Very Good	Very Good
RER: Corrugated board 2018; excl. paper production; input: paper Sphera/FEFCO <p-agg>	2022	Very Good	Very Good	Good
RER: Diesel at refinery Sphera	2019	Good	Very Good	Good
RER: Diesel mix at filling station Sphera	2019	Good	Very Good	Good
RER: Diesel mix at refinery Sphera	2019	Good;Very Good	Very Good	Good;Very Good
RER: Electricity grid mix Sphera	2019	Good	Very Good	Good
RER: Electrolytic copper secondary (input heavy copper scrap 95-98% Cu) Sphera <p-agg>	2022	Fair	Very Good	Good
RER: Electrolytic copper secondary (input light copper scrap 90% Cu) Sphera <p-agg>	2022	Fair	Very Good	Good
RER: Ferro metals on landfill Sphera	2022	Good	Very Good	Very Good
RER: Heavy fuel oil at refinery (1.0wt.% S) Sphera	2019	Good;Very Good	Very Good	Good;Very Good
RER: Inert matter (Aluminium) on landfill Sphera	2022	Good	Very Good	Very Good
RER: Inert matter (Steel) on landfill Sphera	2022	Good	Very Good	Very Good
RER: Inert matter (Unspecific construction waste) on landfill Sphera	2022	Good	Very Good	Very Good
RER: Kerosene / Jet A1 at refinery Sphera	2019	Good;Very Good	Very Good	Good;Very Good
RER: Kraft paper (EN15804 A1-A3) Sphera	2022	Good	Very Good	Fair
RER: Kraftliner 2018; by-products: tall oil, turpentine; cut-off EoL; [mass allocation] Sphera/FEFCO <p-agg>	2022	Very Good	Very Good	Good
RER: Lubricants at refinery Sphera	2019	Good	Very Good	Good
RER: Municipal waste water treatment (mix) Sphera	2022	Good	Very Good	Good
RER: Natural Rubber, vulcanised Sphera	2022	Good	Very Good	Good
RER: Paper and board (water 0%) in waste incineration plant Sphera <p-agg>	2022	Good	Very Good	Good
RER: Plastic granulate secondary (low metal contamination) Sphera <p-agg>	2022	Fair	Very Good	Good

RER: Plastic packaging in municipal waste incineration plant Sphera <p-agg>	2022	Good	Very Good	Good
RER: Plastic waste on landfill Sphera	2022	Good	Very Good	Very Good
RER: Polyamide (PA) 6.6 GF30 (4.5% H2O) in waste incineration plant Sphera <p-agg>	2022	Good	Very Good	Good
RER: Polycarbonate (PC) in waste incineration plant Sphera <p-agg>	2022	Good	Very Good	Good
RER: Polyethylene (PE) in waste incineration plant Sphera <p-agg>	2022	Good	Very Good	Good
RER: Polyethylene Film (PE-LD) without additives Sphera	2022	Good;Very Good	Very Good	Very Good
RER: Polyethylene low density granulate (LDPE/PE-LD) Sphera	2022	Good	Very Good	Good
RER: Polyethylene terephthalate (PET) in waste incineration plant Sphera <p-agg>	2022	Good;Very Good	Very Good	Good
RER: Polyethylene terephthalate granulate (PET) via DMT Sphera	2022	Good	Very Good	Very Good
RER: Polypropylene (PP) in waste incineration plant Sphera <p-agg>	2022	Good	Very Good	Good
RER: Polystyrene (PS) in waste incineration plant Sphera <p-agg>	2022	Good	Very Good	Good
RER: Polystyrene granulate (PS) Sphera	2022	Very Good	Very Good	Very Good
RER: Polyurethane (PU) in waste incineration plant Sphera <p-agg>	2022	Good	Very Good	Good
RER: Polyurethane rigid foam (PU) PlasticsEurope	2005	Fair	Fair	Fair
RER: Polyvinyl chloride (PVC) in waste incineration plant Sphera <p-agg>	2022	Good	Very Good	Good
RER: Process water from groundwater Sphera	2022	Good	Very Good	Very Good
RER: PVC adhesive (approximation) Sphera	2022	Good	Very Good	Good
RER: Recycling of copper from electronic scrap (allocation with precious metals) Sphera <p-agg>	2022	Fair	Very Good	Good
RER: Recycling of gold from electronic scrap Sphera <p-agg>	2022	Fair	Very Good	Good
RER: Recycling of palladium from electronic scrap Sphera <p-agg>	2022	Fair	Very Good	Good
RER: Recycling of platinum from electronic scrap Sphera <p-agg>	2022	Fair	Very Good	Good
RER: Recycling of silver from electronic scrap Sphera <p-agg>	2022	Fair	Very Good	Good
RER: Semichemical Fluting 2018; cut-off EoL Sphera/FEFCO <p-agg>	2022	Very Good	Very Good	Good
RER: Stainless steel screw Sphera <p-agg>	2022	Good	Very Good	Good
RER: Stainless steel sheet (EN15804 A1-A3) Sphera <p-agg>	2022	Very Good	Very Good	Very Good
RER: Talcum powder (filler) Sphera	2022	Good	Very Good	Fair
RER: Tap water from groundwater Sphera	2022	Good	Very Good	Very Good
RER: Testliner 2018; cut-off EoL Sphera/FEFCO <p-agg>	2022	Very Good	Very Good	Good

RER: Thermal energy from natural gas Sphera	2019	Good	Very Good	Good
RER: Wellenstoff / Fluting 2018; cut-off EoL Sphera/FEFCO <p-agg>	2022	Very Good	Very Good	Good
SG: Electricity grid mix Sphera	2019	Good	Very Good	Good
TW: Electricity grid mix Sphera	2019	Good	Very Good	Good
US: Acrylonitrile-butadiene-styrene granulate (ABS) Sphera	2022	Very Good	Very Good	Very Good
US: Diesel mix at refinery Sphera	2019	Good	Very Good	Good
US: Electricity grid mix Sphera	2019	Good	Very Good	Good
US: Glass fibres Sphera	2022	Good	Very Good	Fair
US: Industry average uncoated glass (NGA) (A1-A3) Sphera-EPD	2015	Very Good	Very Good	Very Good
US: Lubricants at refinery Sphera	2019	Good	Very Good	Good
US: Polycarbonate granulate (PC) Sphera	2022	Good	Very Good	Very Good
US: Polycarbonate-acrylonitrile-butadiene-styrene compound (80% PC, 20% ABS) Sphera	2022	Good	Very Good	Very Good
US: Polyethylene Film (LDPE/PE-LD) Sphera	2022	Good	Very Good	Very Good
US: Polystyrene granulate (PS) (approximation) Sphera	2022	Very Good	Very Good	Very Good
US: Polyvinyl chloride granulate (S-PVC) Sphera	2022	Very Good	Very Good	Very Good
US: Sulphur (elemental) at refinery Sphera	2019	Good	Very Good	Good

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Annex C: LCA for Experts Model

Annex C1: Notebook LCA for Experts Model

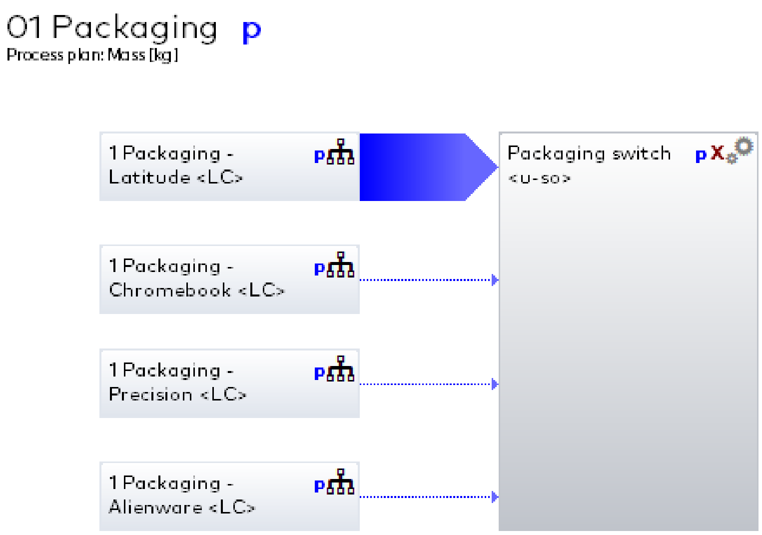

Figure 6-3: Packaging selection for different notebook types – Latitude 5430, Chromebook 3110, Precision 7670 and Alienware MLK 15

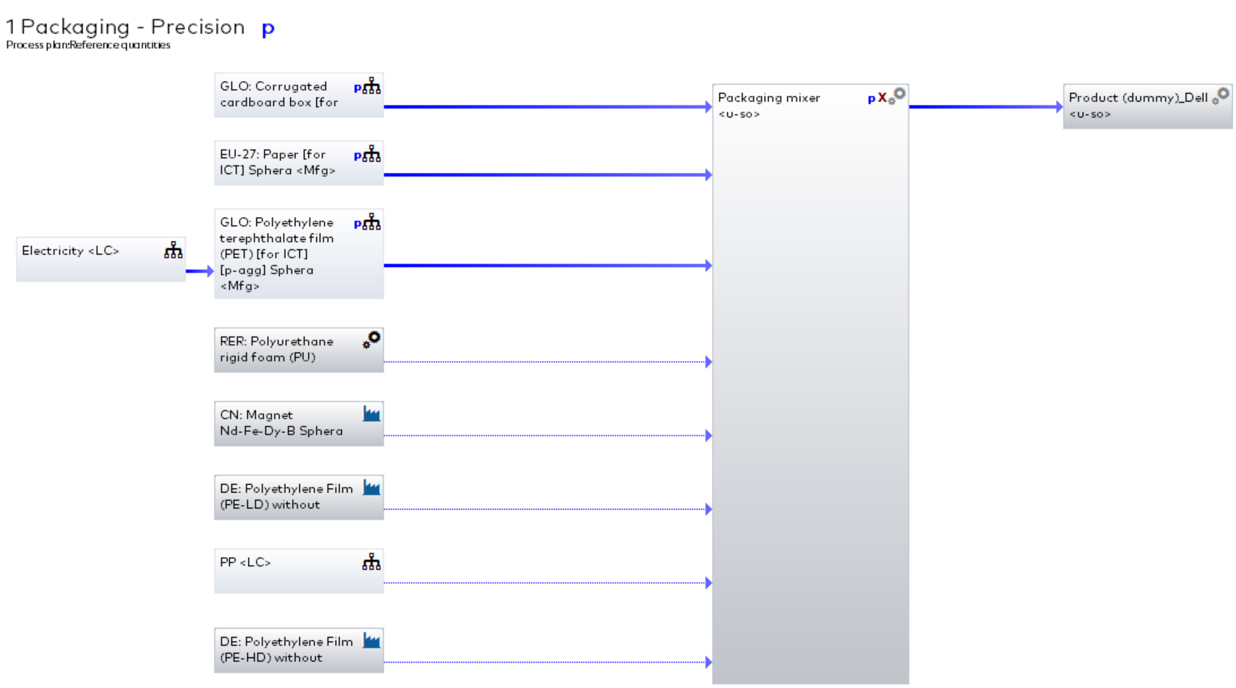

Figure 6-4: Packaging plan model structure (same for all four notebook types)

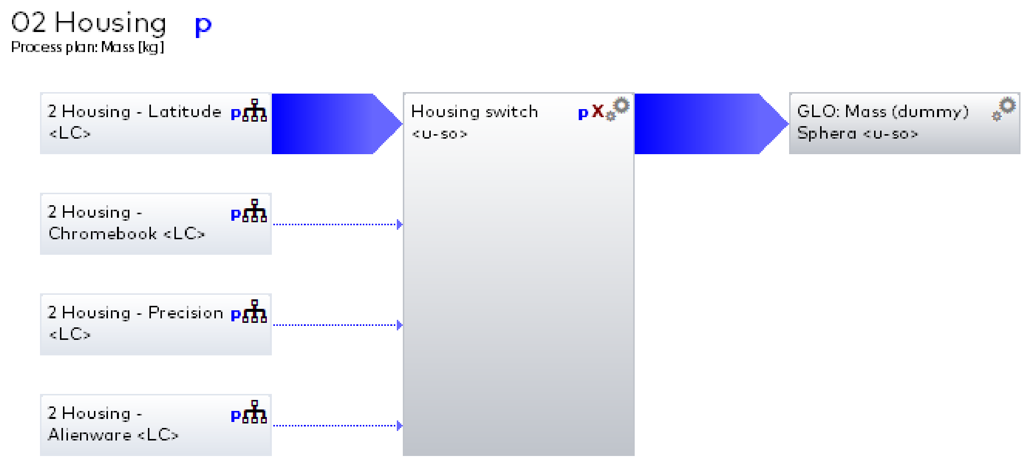

Figure 6-5: Housing selection for different notebook types – Latitude 5430, Chromebook 3110, Precision 7670 and Alienware MLK 15

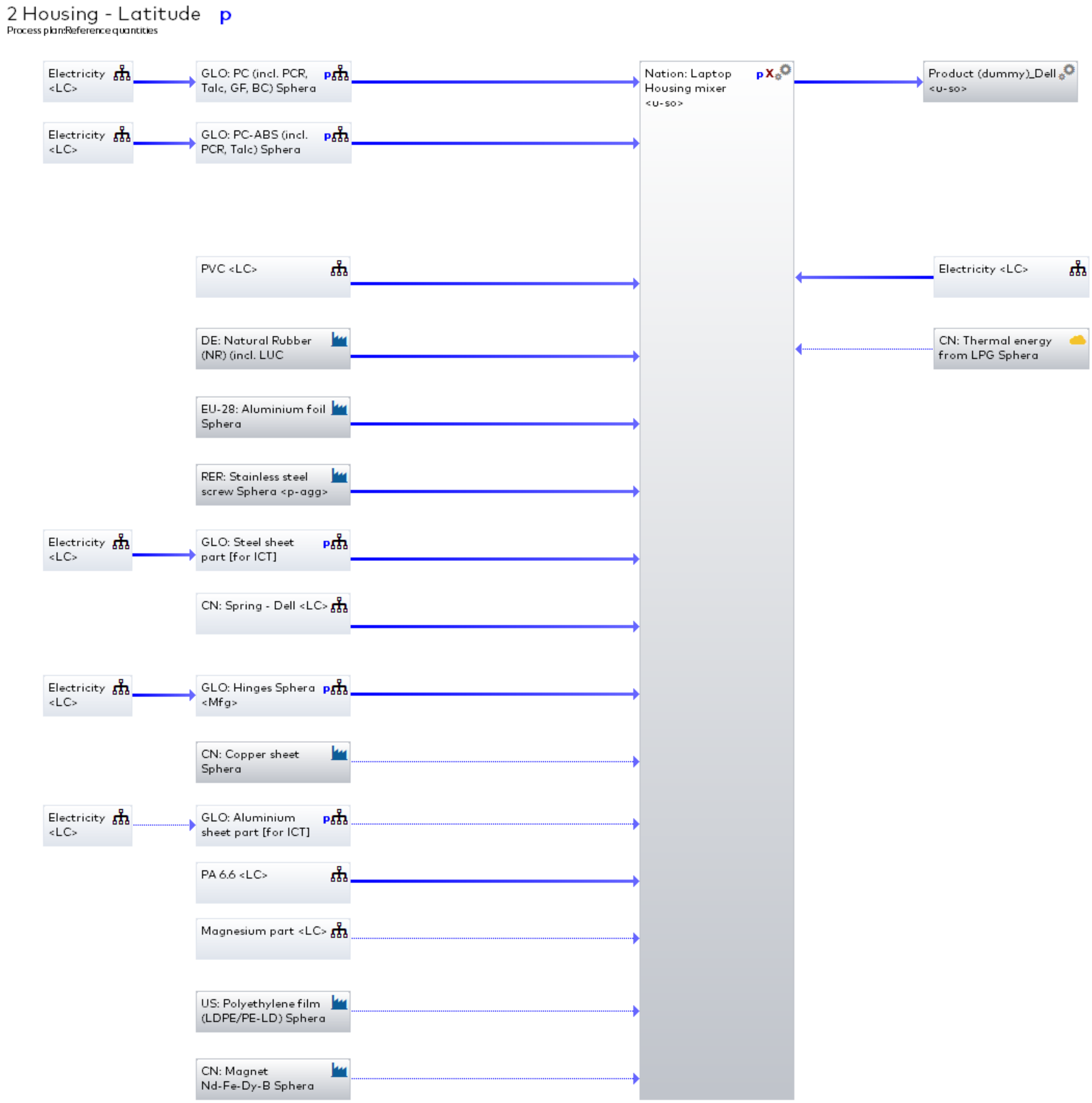

Figure 6-6: Housing plan model structure (same for all four notebook types)

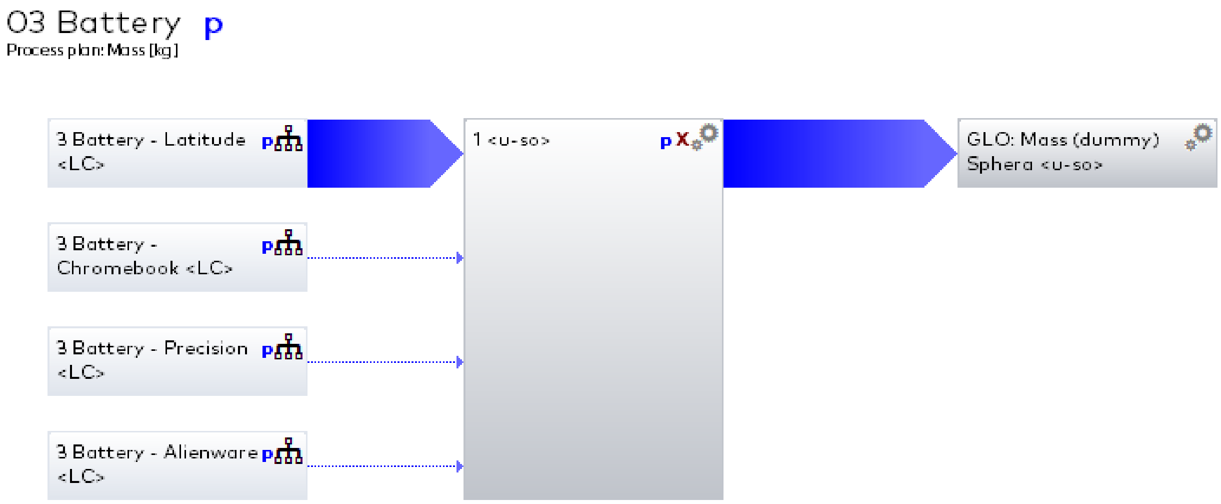

Figure 6-7: Battery selection for different notebook types – Latitude 5430, Chromebook 3110, Precision 7670 and Alienware MLK 15

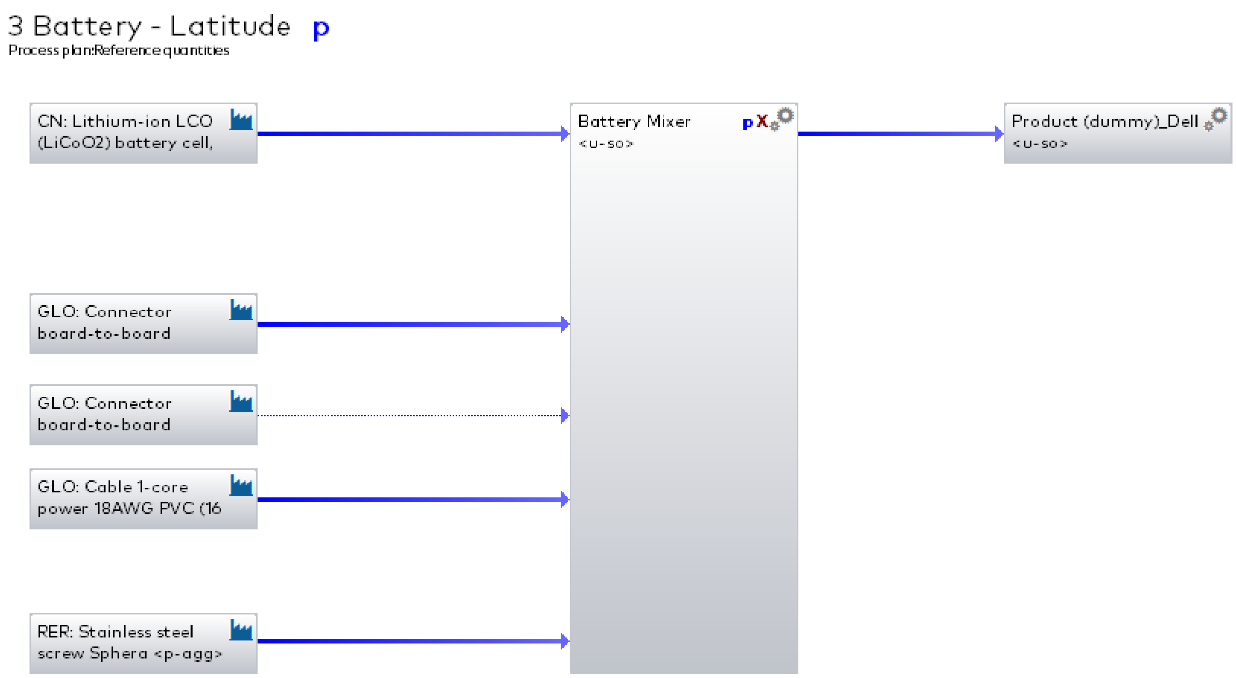

Figure 6-8: Battery plan model structure (same for all four notebook types)

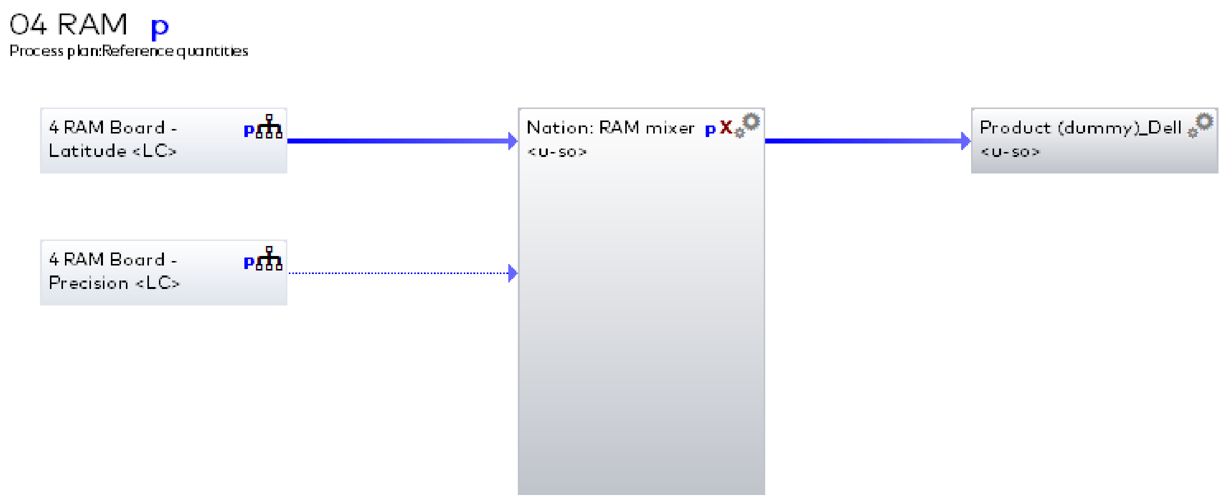

Figure 6-9: RAM selection for different notebook types – Latitude 5430, Chromebook 3110, Precision 7670 and Alienware MLK 15

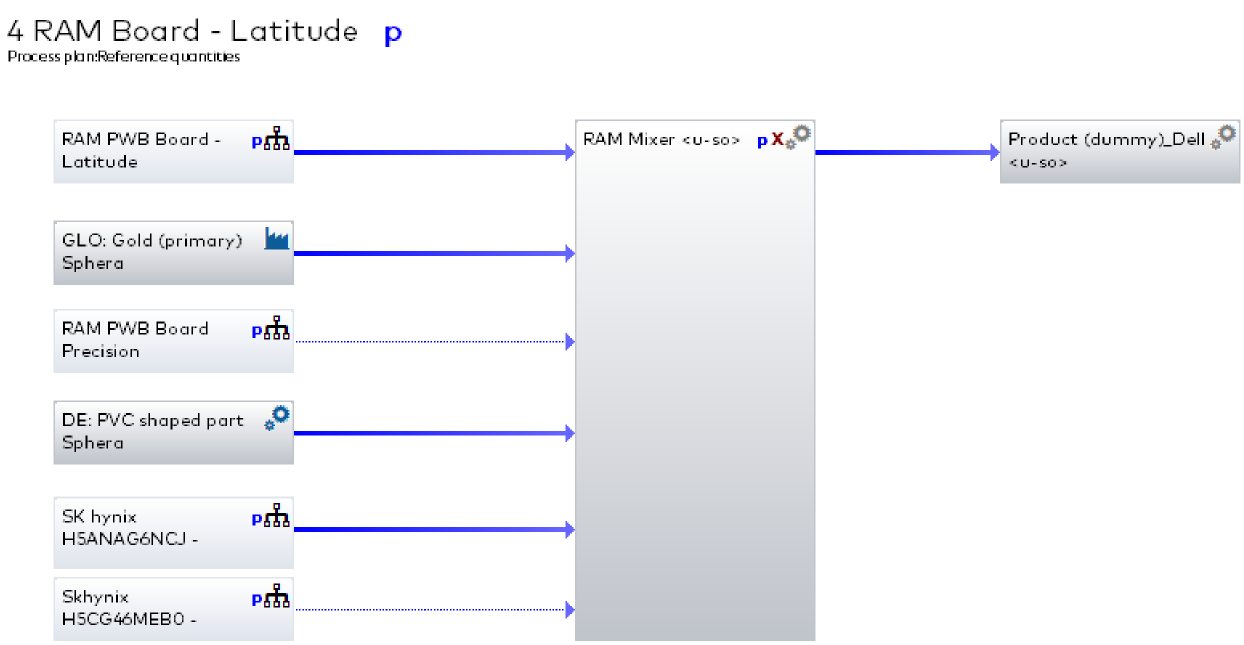

Figure 6-10: RAM plan model structure (same for all four notebook types)

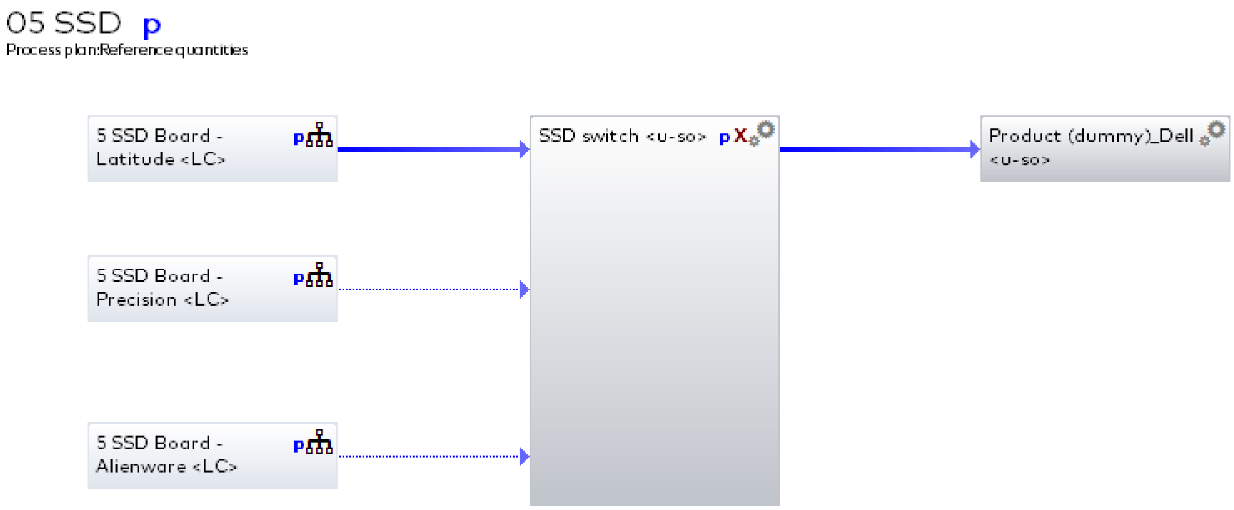

Figure 6-11: SSD selection for different notebook types – Latitude 5430, Chromebook 3110, Precision 7670 and Alienware MLK 15

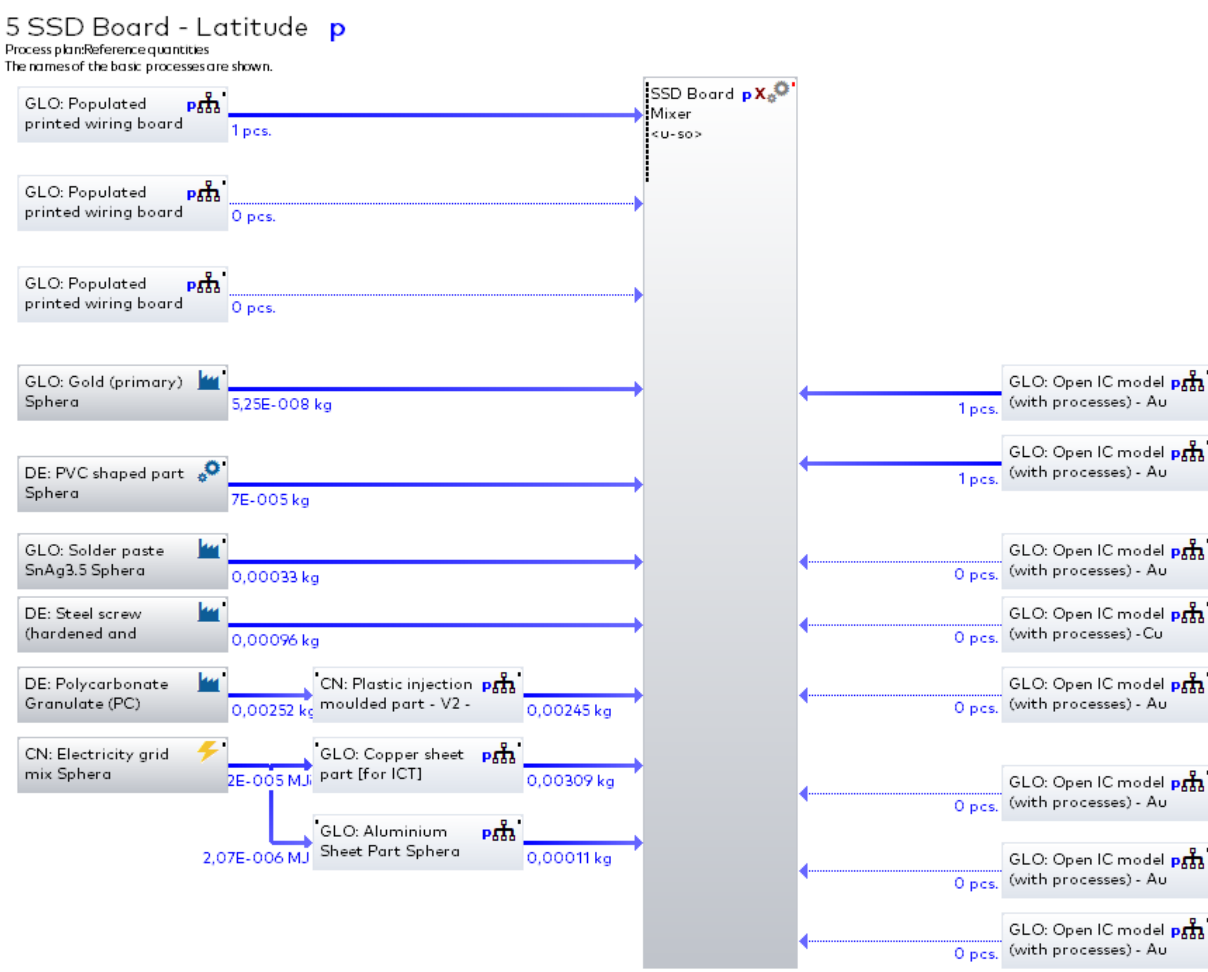

Figure 6-12: SSD plan model structure (same for all four notebook types)

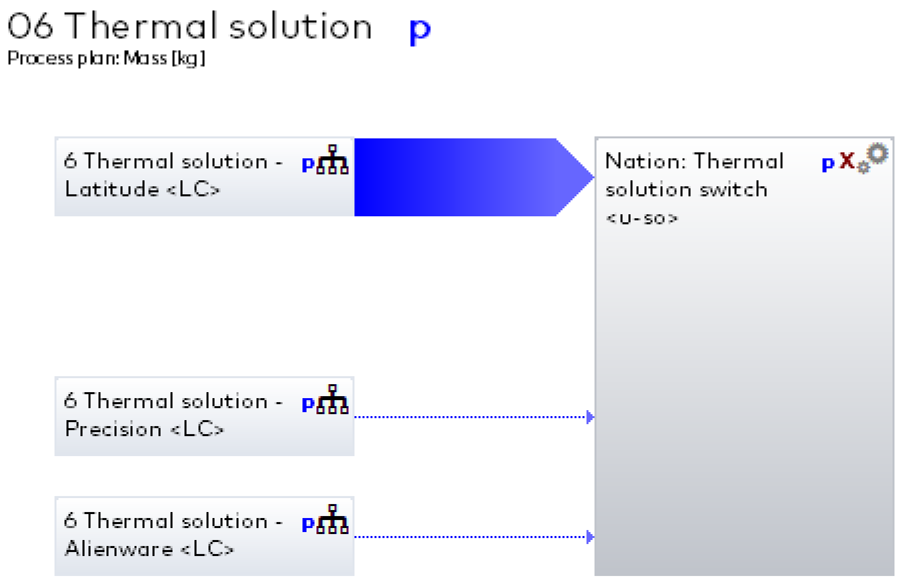

Figure 6-13: Thermal Solution selection for different notebook types – Latitude 5430, Chromebook 3110, Precision 7670 and Alienware MLK 15

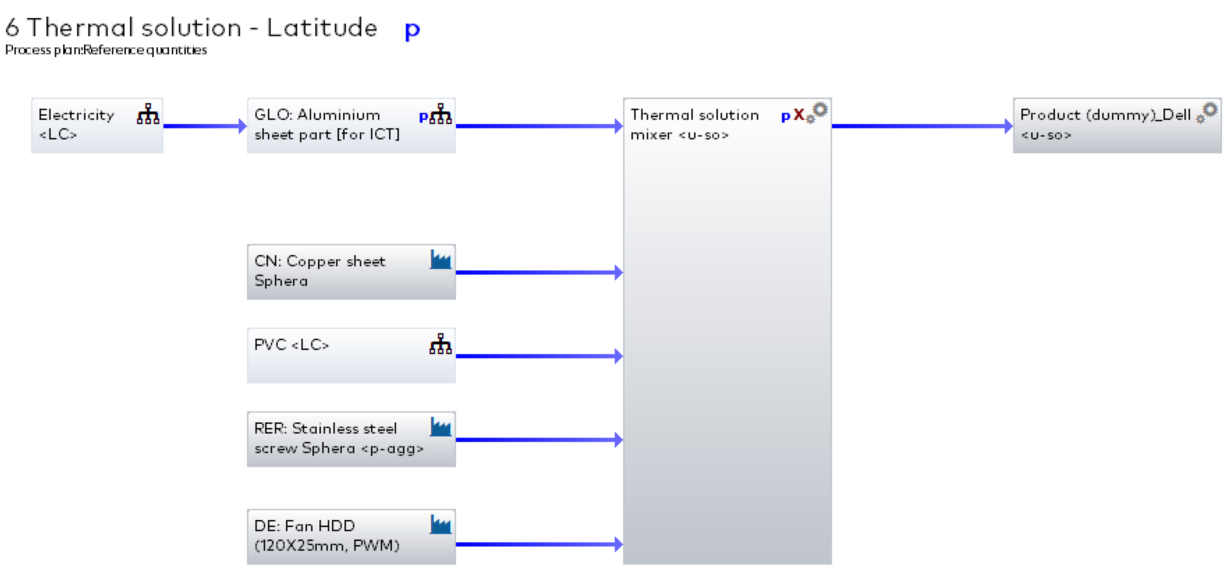

Figure 6-14: Thermal Solution plan model structure (same for all four notebook types)

08 Speaker p

Process plan:Reference quantities

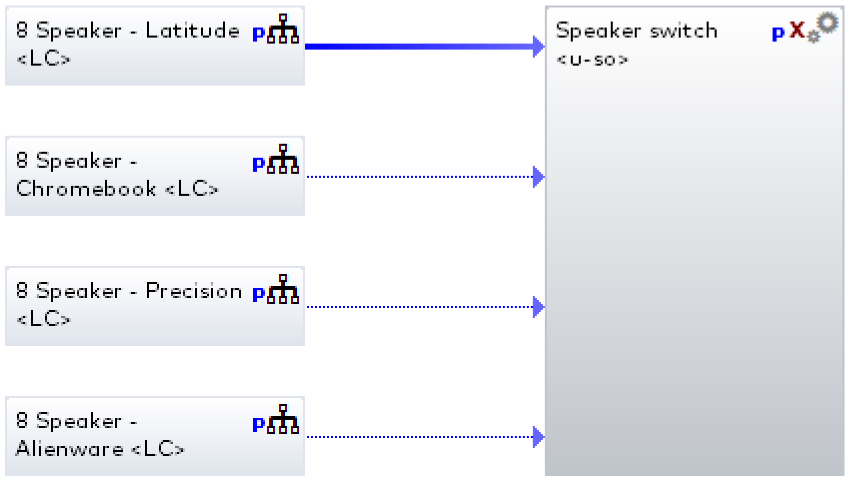

Figure 6-15: Speaker selection for different notebook types – Latitude 5430, Chromebook 3110, Precision 7670 and Alienware MLK 15

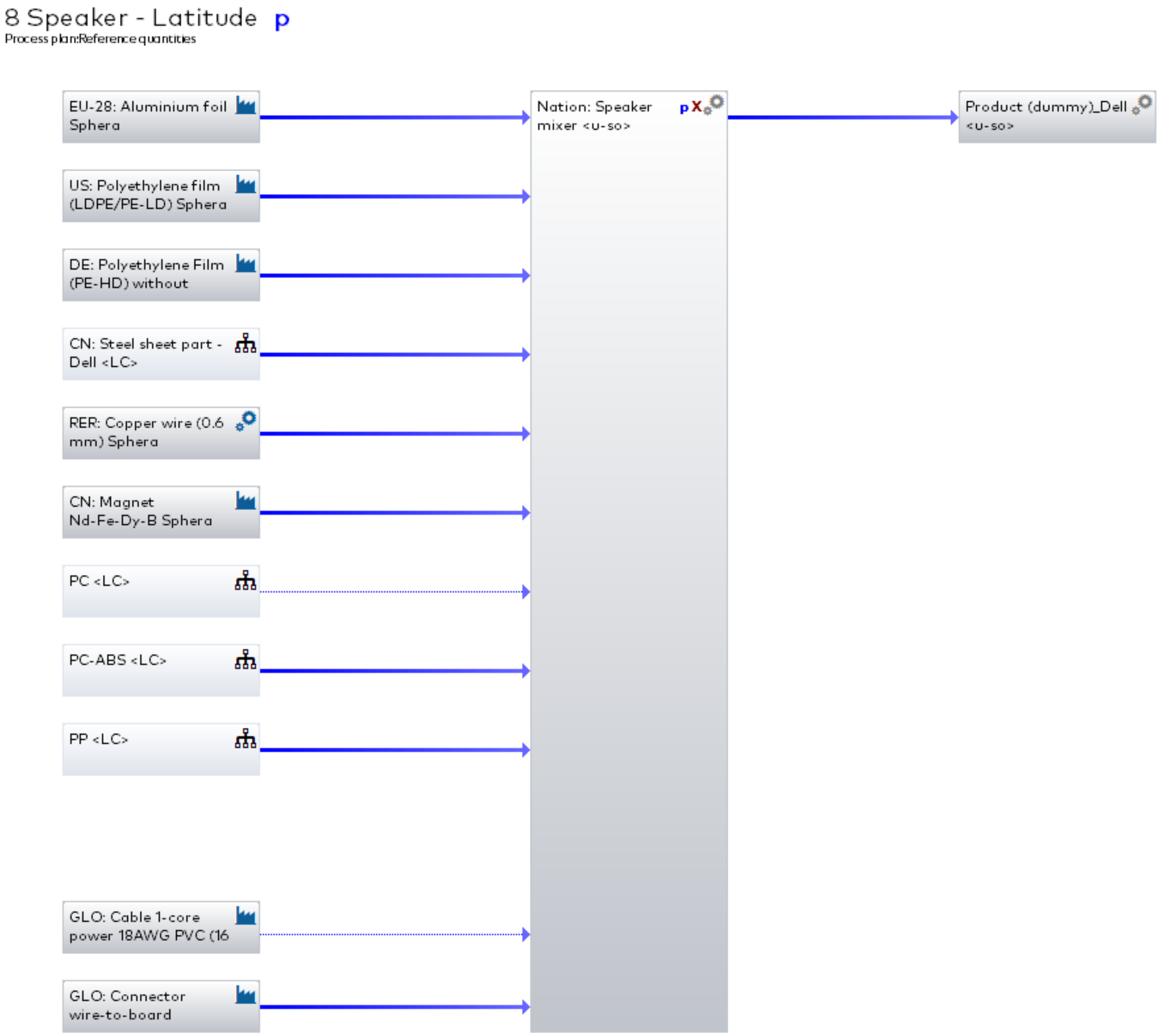

Figure 6-16: Speaker plan model structure (same for all four notebook types)

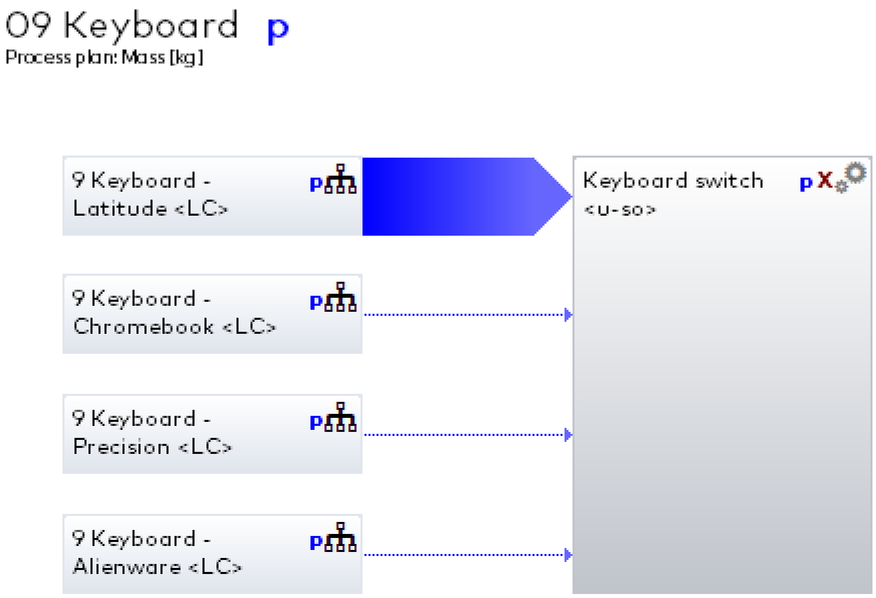

Figure 6-17: Keyboard selection for different notebook types – Latitude 5430, Chromebook 3110, Precision 7670 and Alienware MLK 15

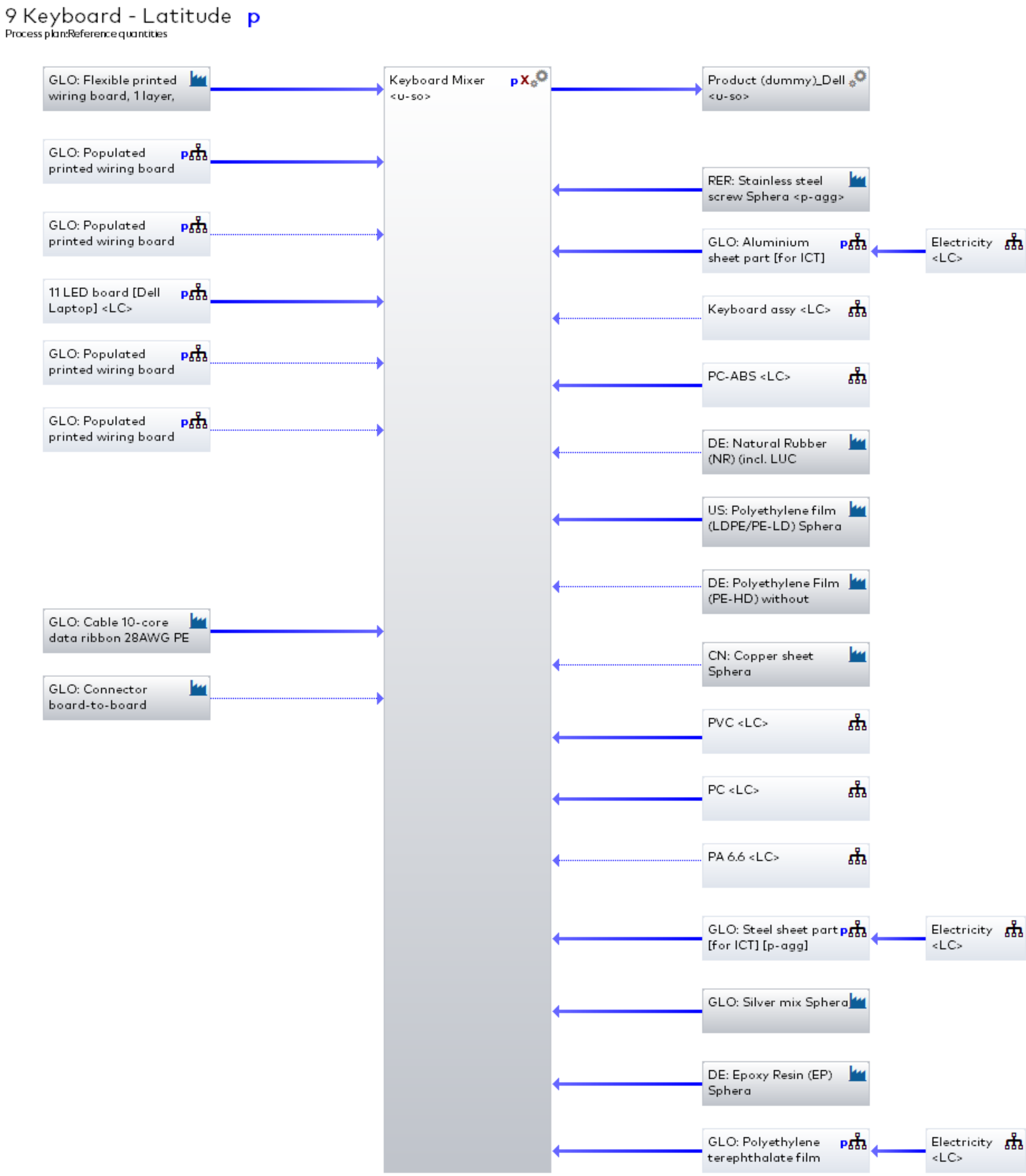

Figure 6-18: Keyboard plan model structure (same for all four notebook types)

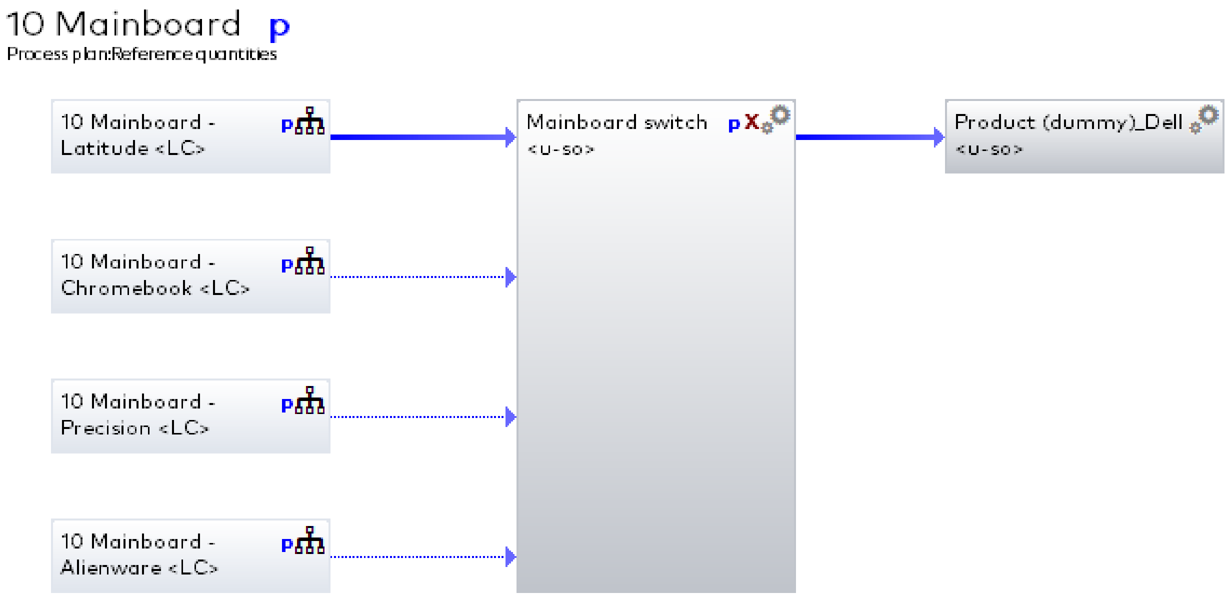

Figure 6-19: Mainboard selection for different notebook types – Latitude 5430, Chromebook 3110, Precision 7670 and Alienware MLK 15

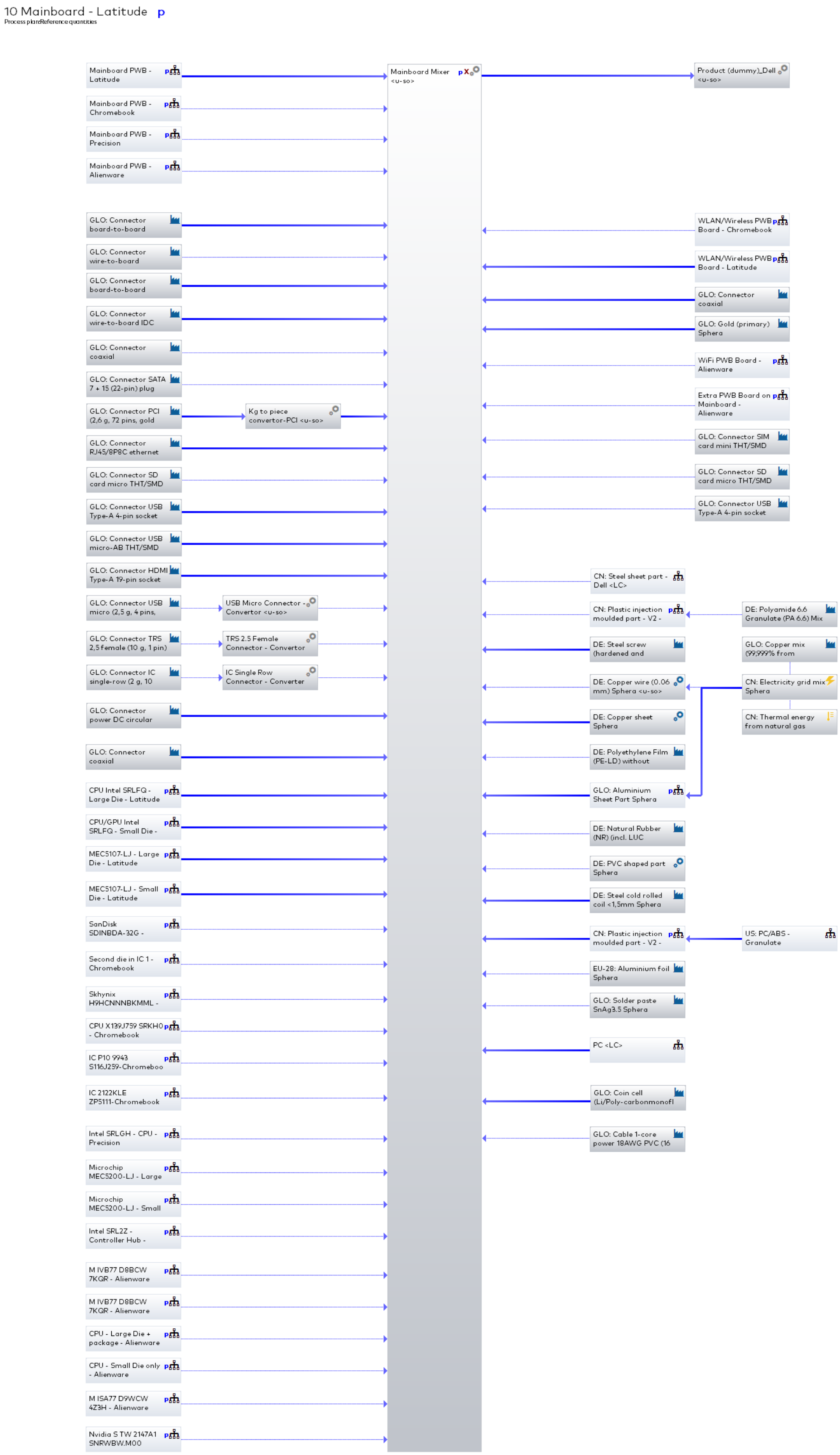

Figure 6-20: Mainboard plan model structure (same for all four notebook types)

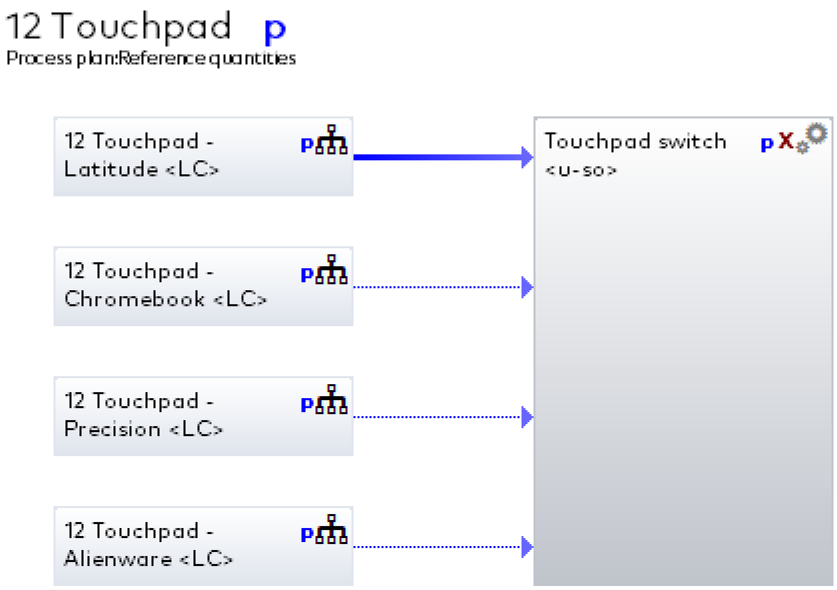

Figure 6-21: Touchpad selection for different notebook types – Latitude 5430, Chromebook 3110, Precision 7670 and Alienware MLK 15

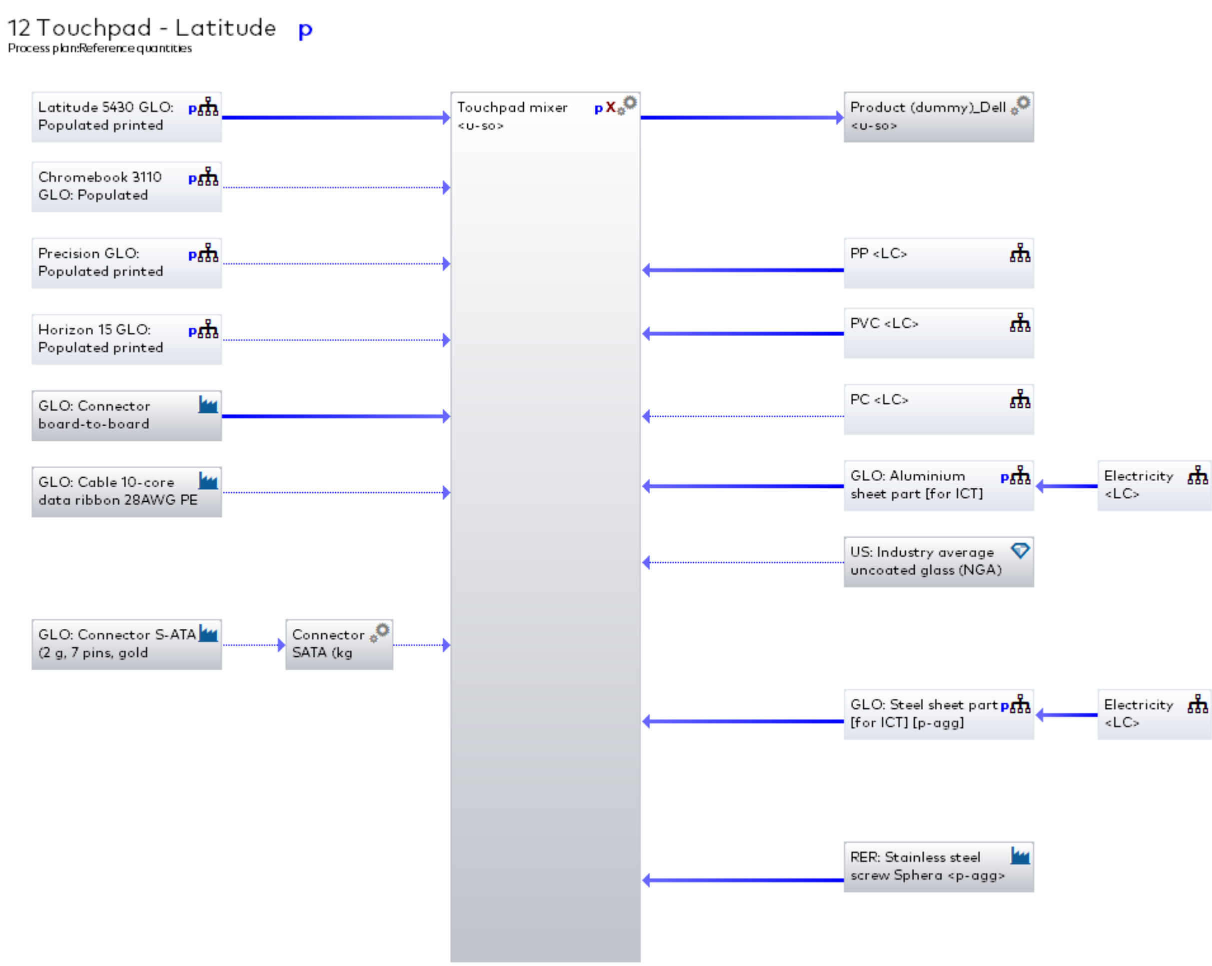

Figure 6-22: Touchpad plan model structure (same for all four notebook types)

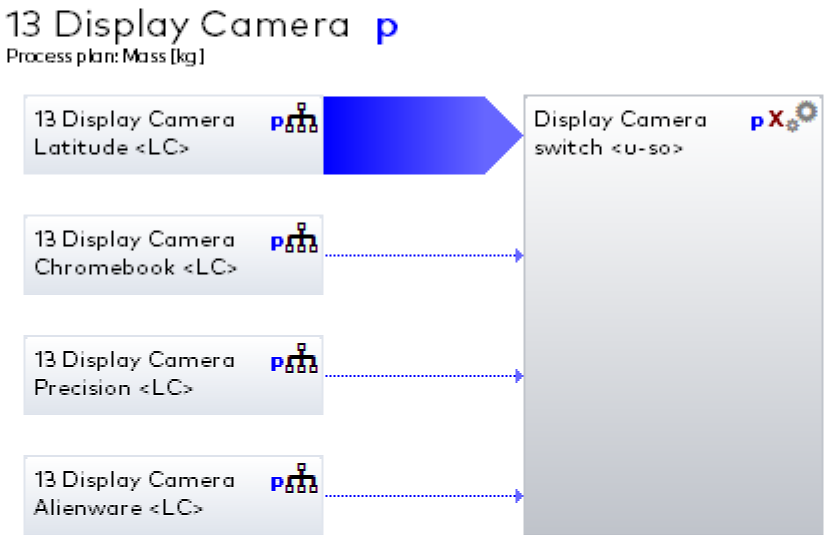

Figure 6-23: Display Camera selection for different notebook types – Latitude 5430, Chromebook 3110, Precision 7670 and Alienware MLK 15

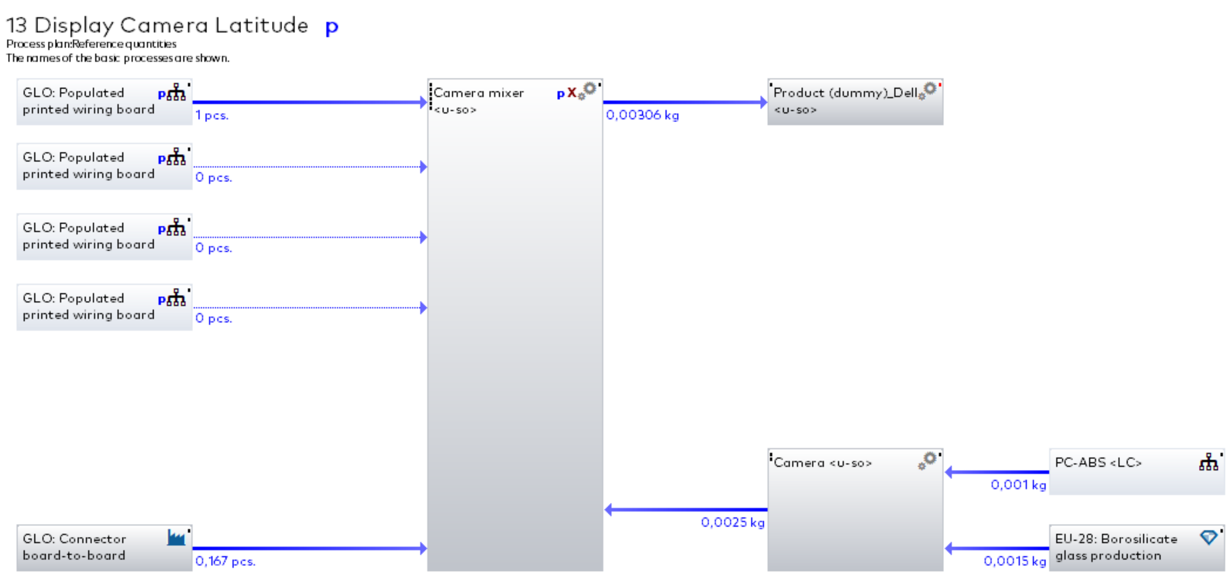

Figure 6-24: Display Camera selection for different notebook types – Latitude 5430, Chromebook 3110, Precision 7670 and Alienware MLK 15

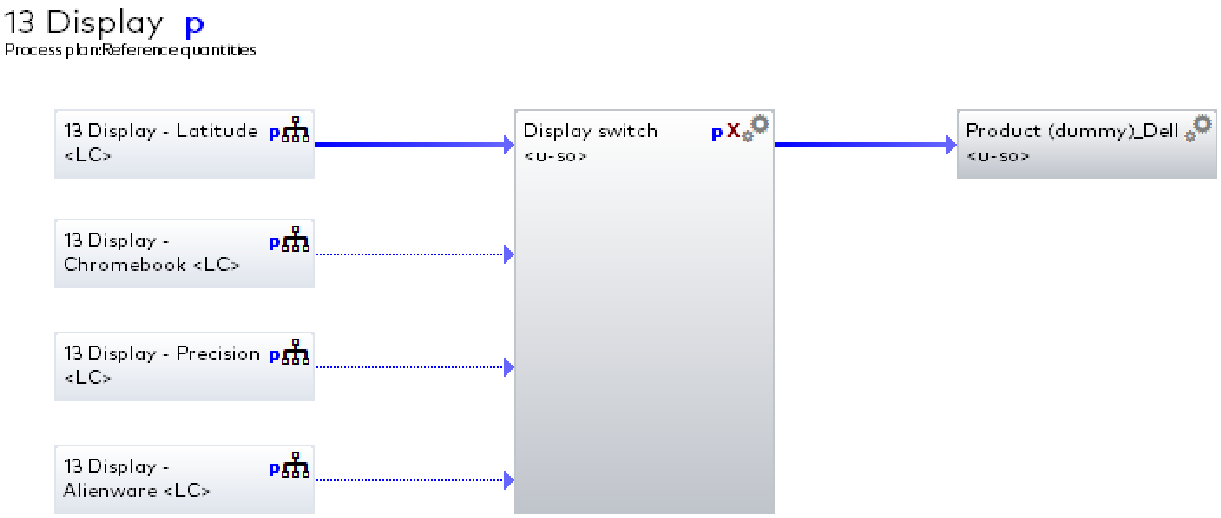

Figure 6-25: Display selection for different notebook types – Latitude 5430, Chromebook 3110, Precision 7670 and Alienware MLK 15

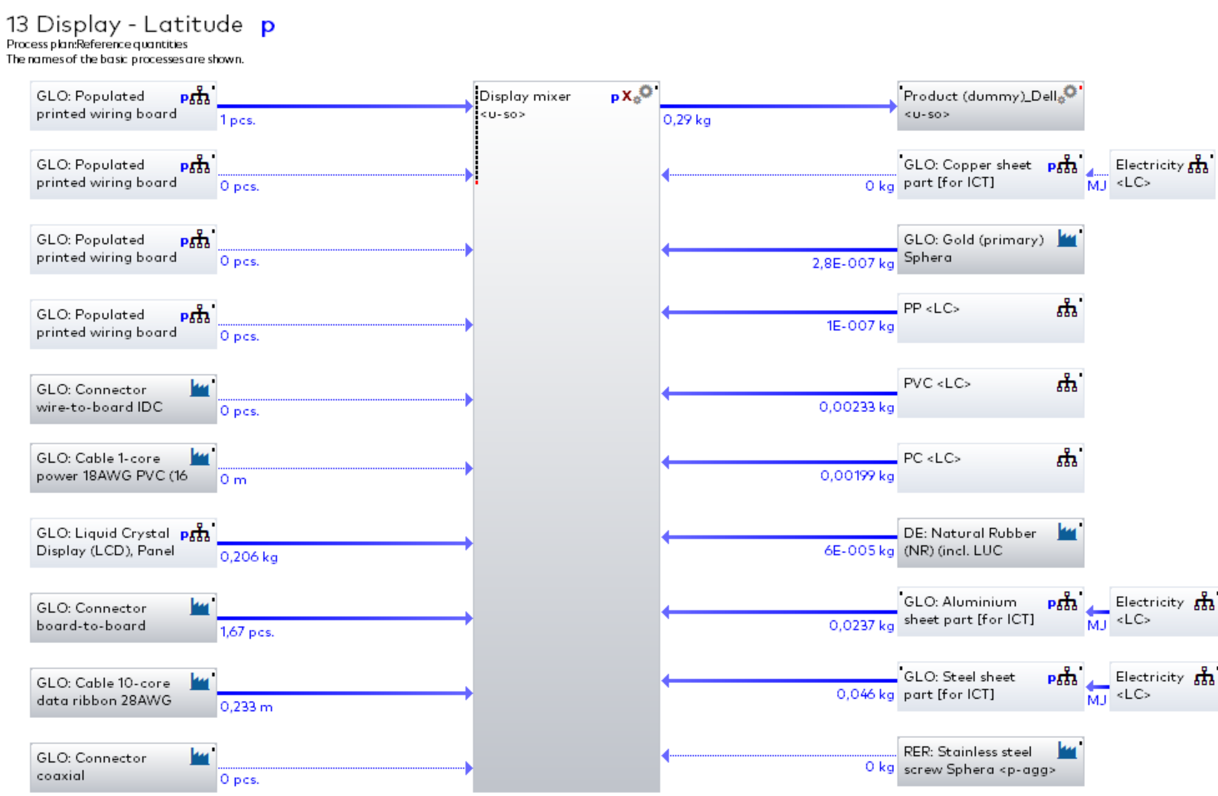

Figure 6-26: Display plan model structure (same for all four notebook types)

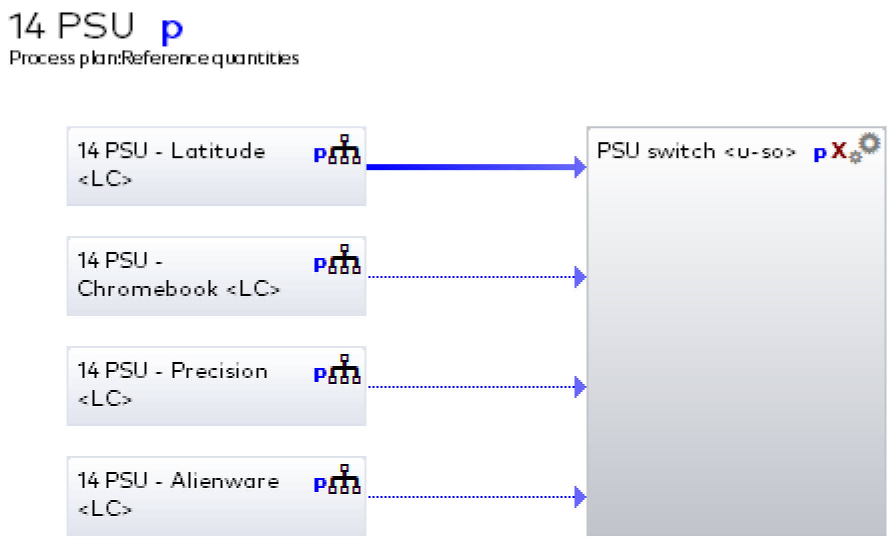

Figure 6-27: Power Supply Unit (PSU) selection for different notebook types – Latitude 5430, Chromebook 3110, Precision 7670 and Alienware MLK 15

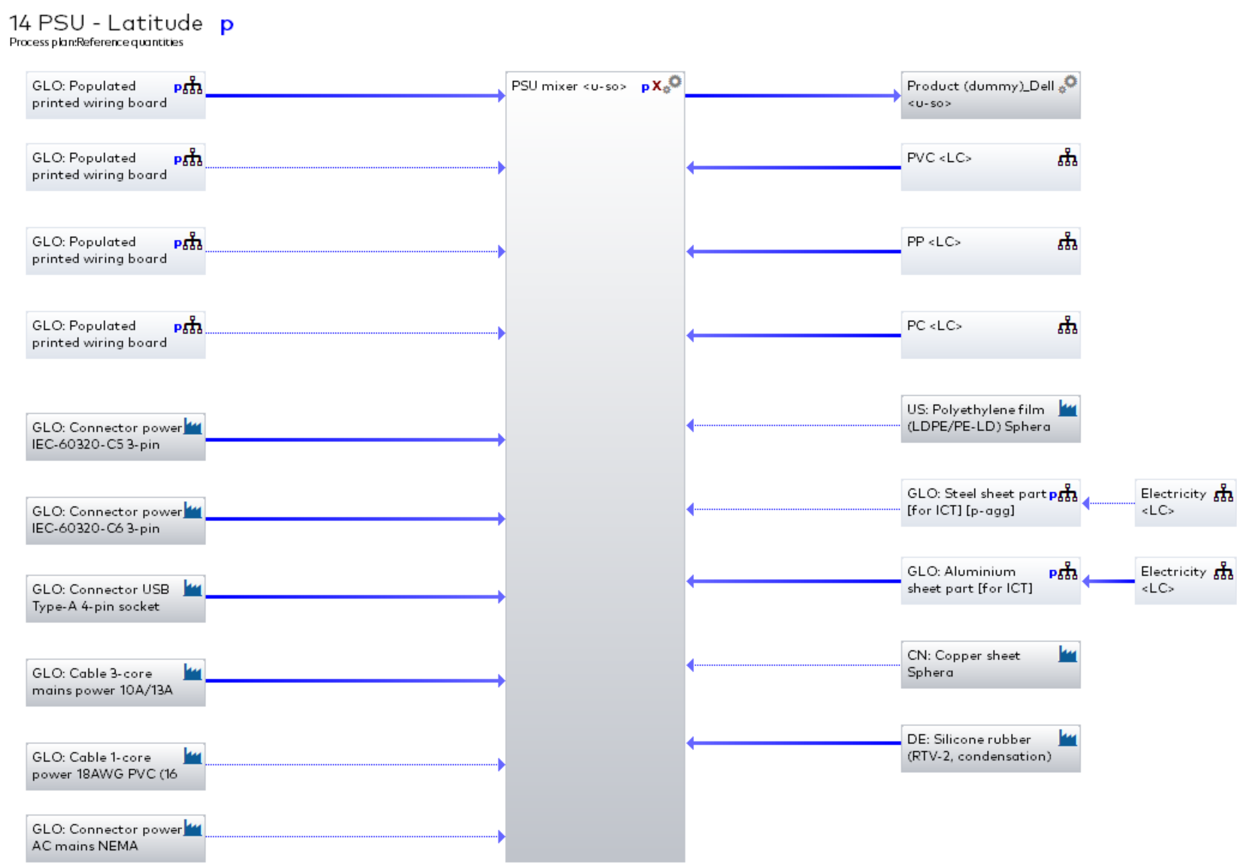

Figure 6-28: Power Supply Unit (PSU) plan model structure (same for all four notebook types)

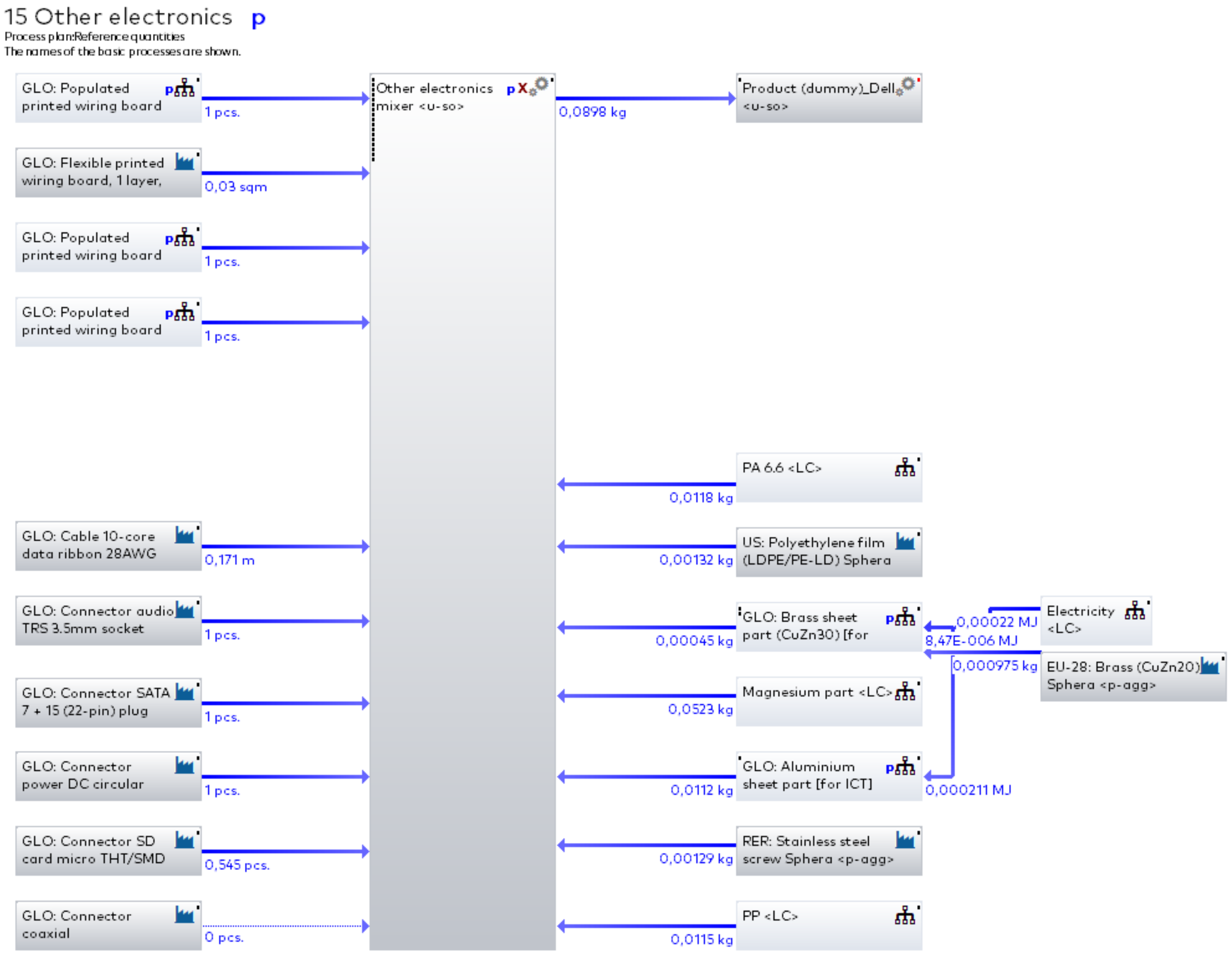

Figure 6-29: Other electronics plan model structure (only used for Alienware MLK 15)

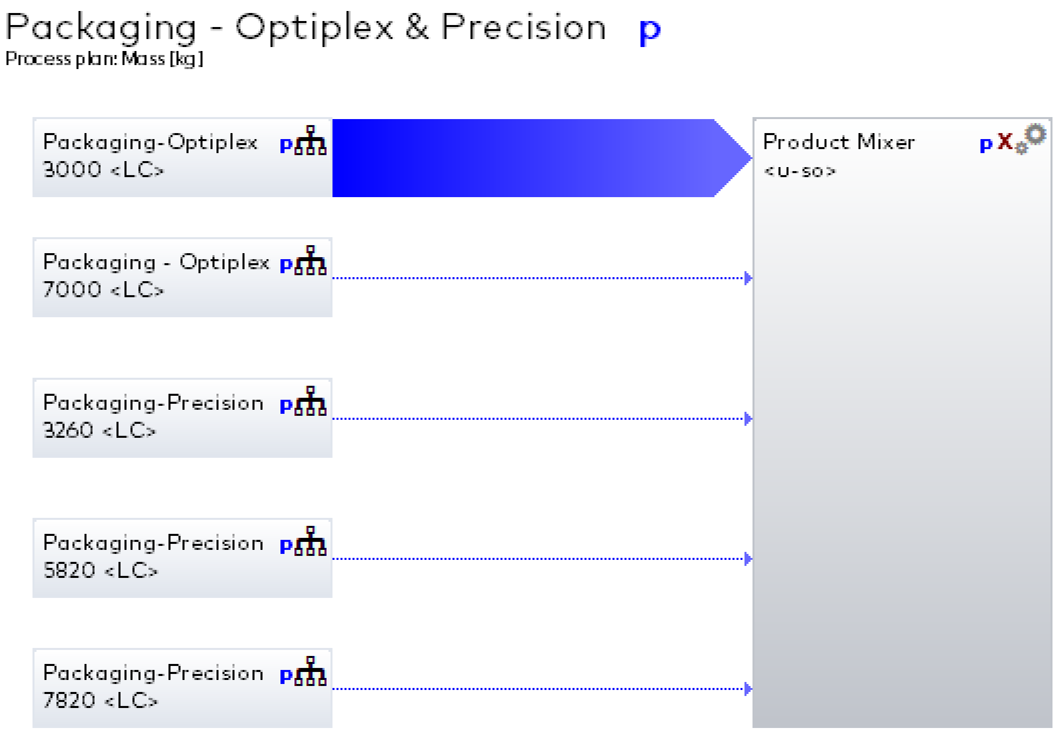

Figure 6-30: Packaging selection for different desktop types – OptiPlex 3000, OptiPlex 7000, Precision 3260, Precision 5820 and Precision 7820

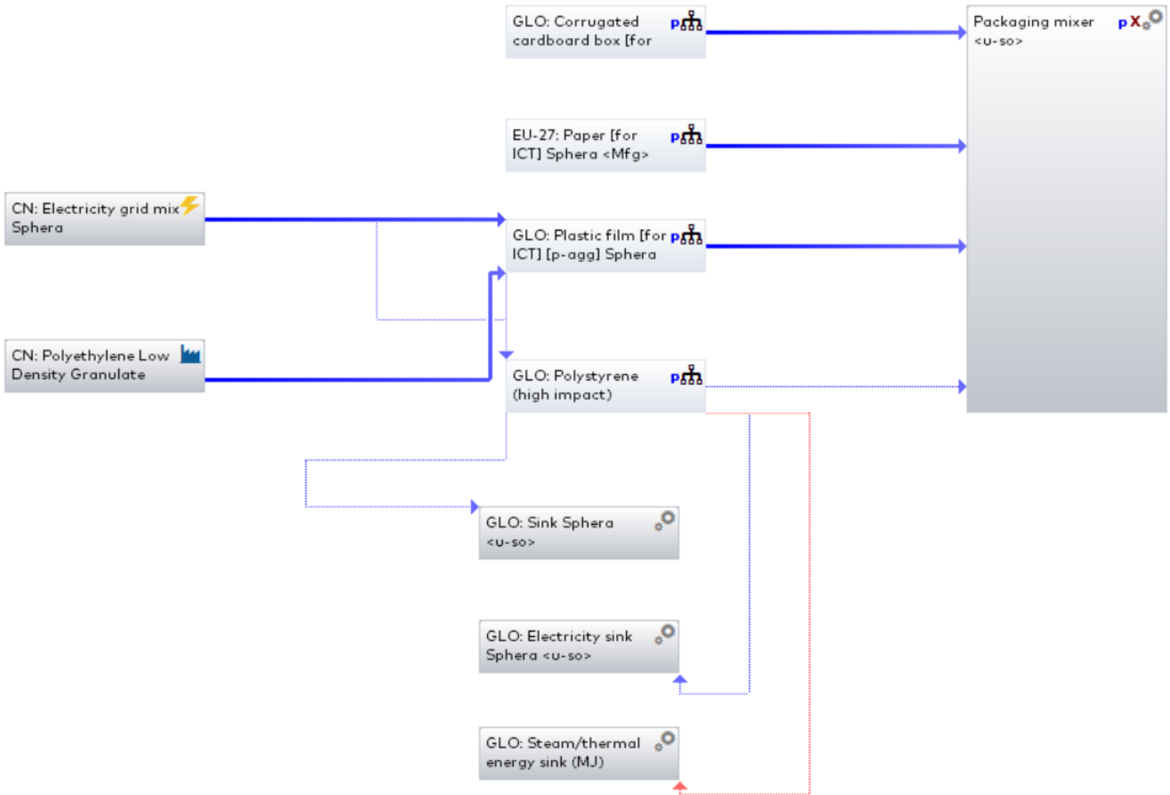

Figure 6-31: Packaging plan model structure (same for all Desktops)

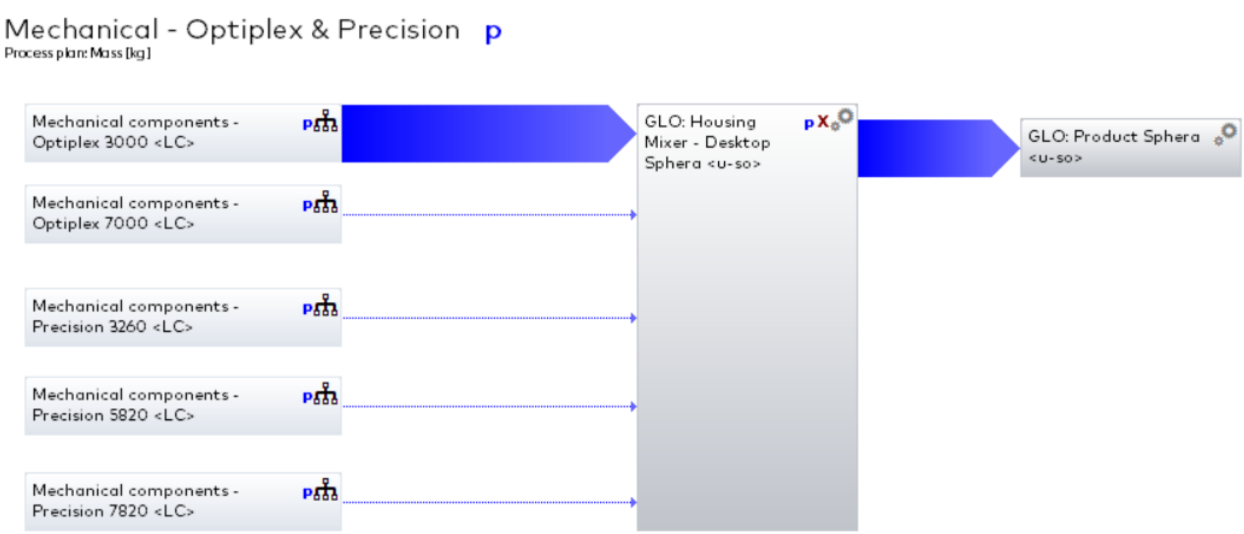

Figure 6-32: Mechanical selection for different desktop types – OptiPlex 3000, OptiPlex 7000, Precision 3260, Precision 5820 and Precision 7820

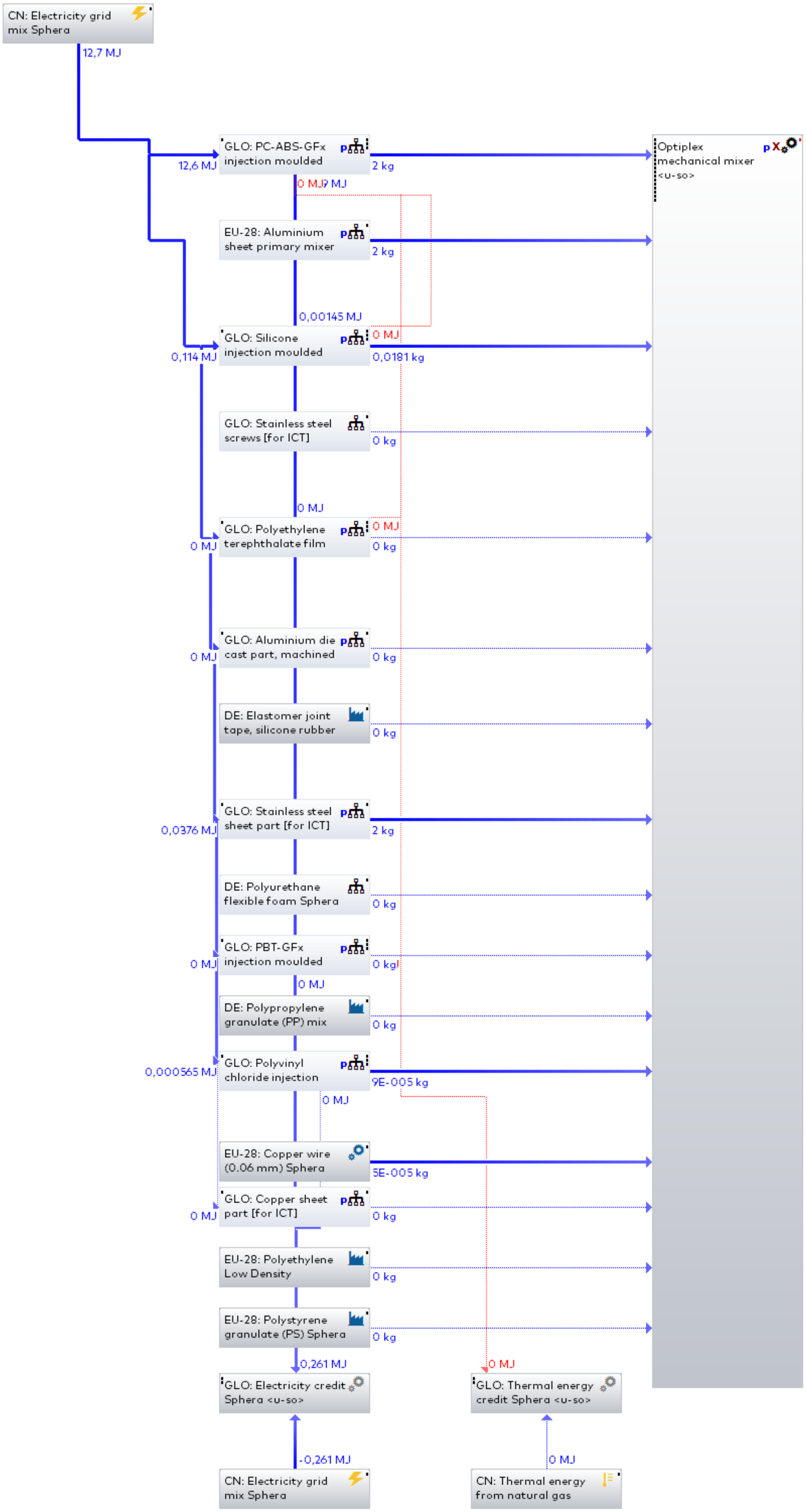

Figure 6-33: Mechanical plan model structure (same for all Desktops)

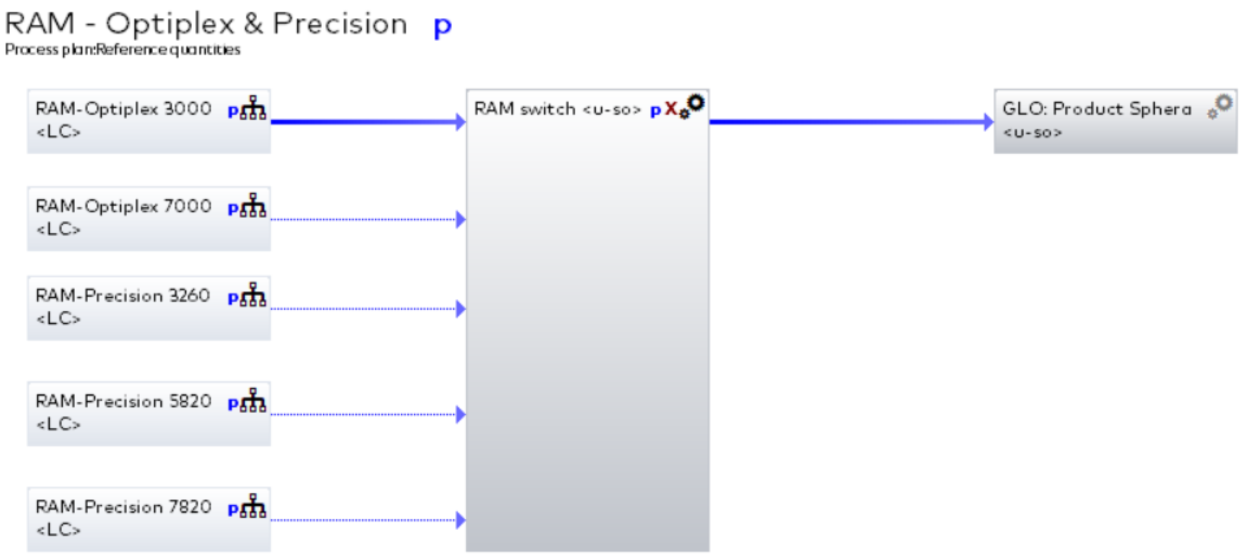

Figure 6-34: RAM selection for different desktop types – OptiPlex 3000, OptiPlex 7000, Precision 3260, Precision 5820 and Precision 7820

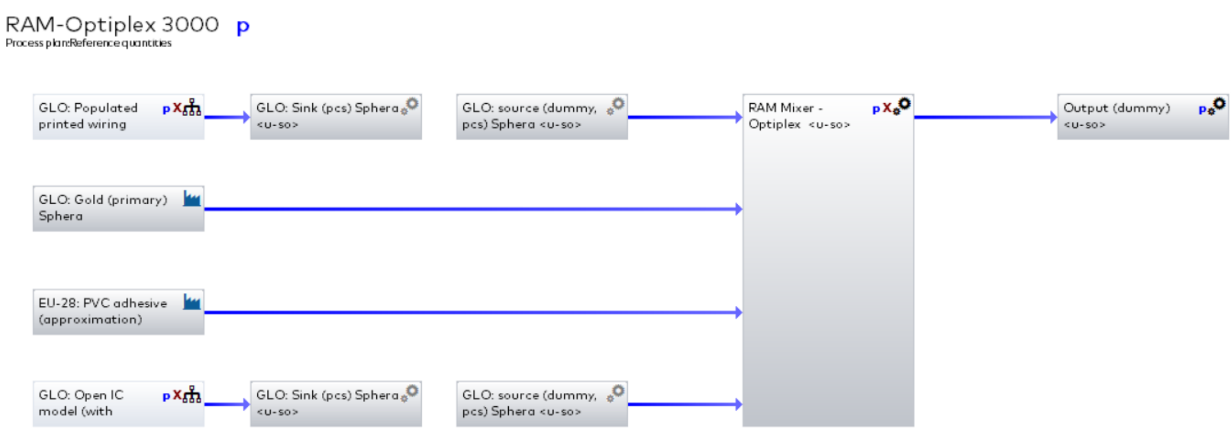

Figure 6-35: RAM plan model structure (same for all Desktops)

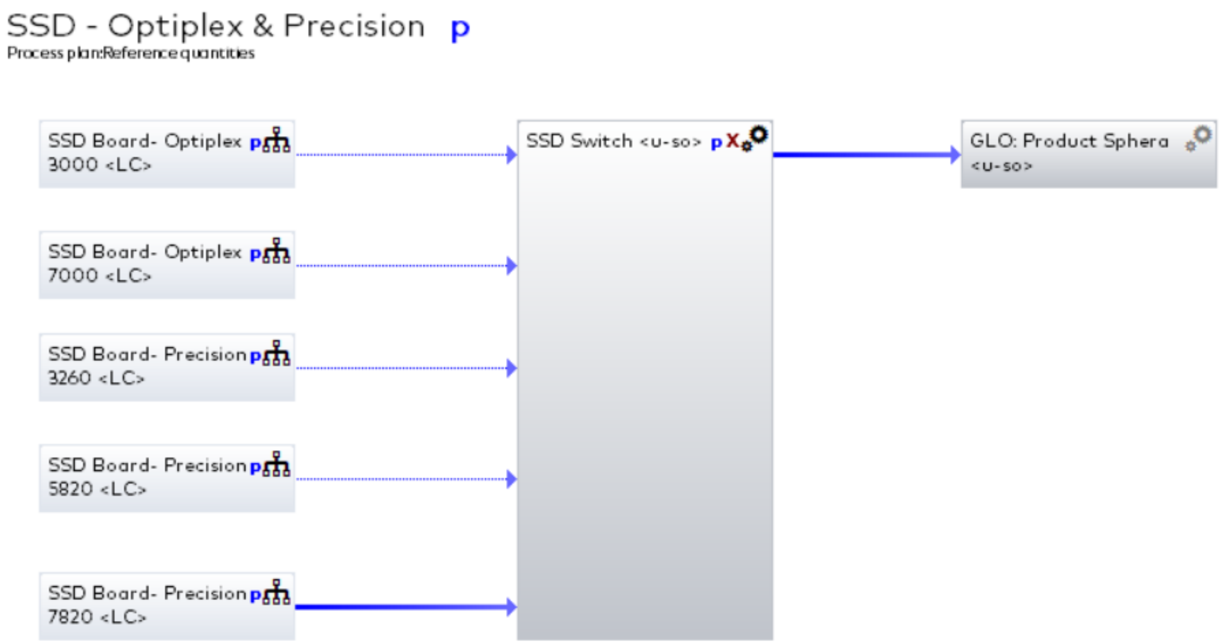

Figure 6-36: SSD selection for different desktop types – OptiPlex 3000, OptiPlex 7000, Precision 3260, Precision 5820 and Precision 7820

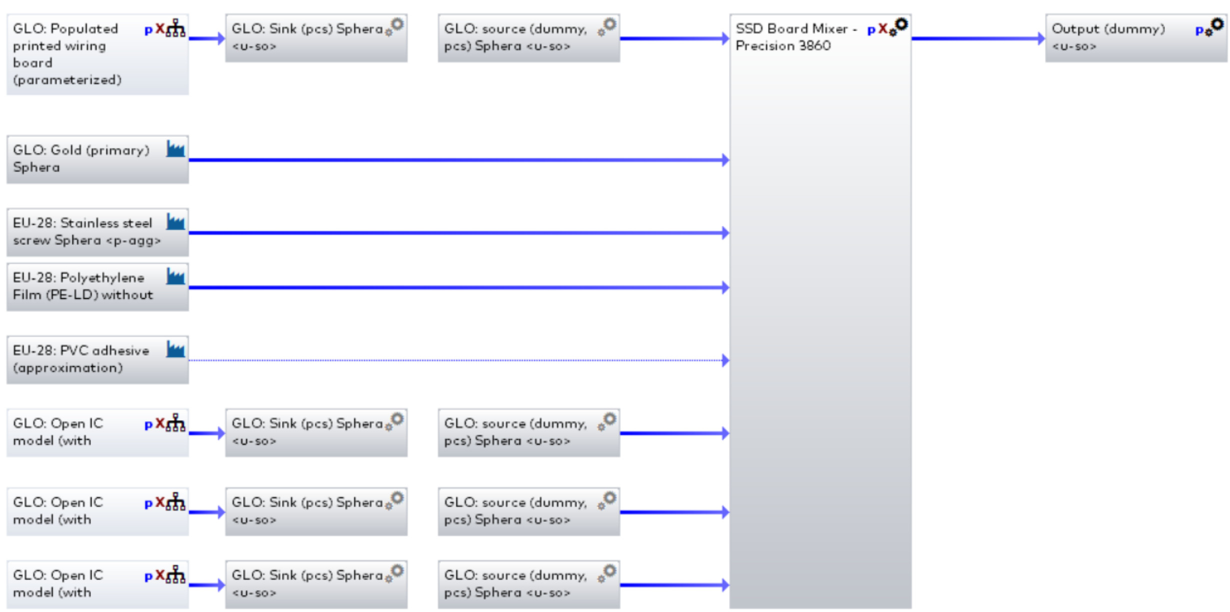

Figure 6-37: SSD plan model structure (same for all Desktops)

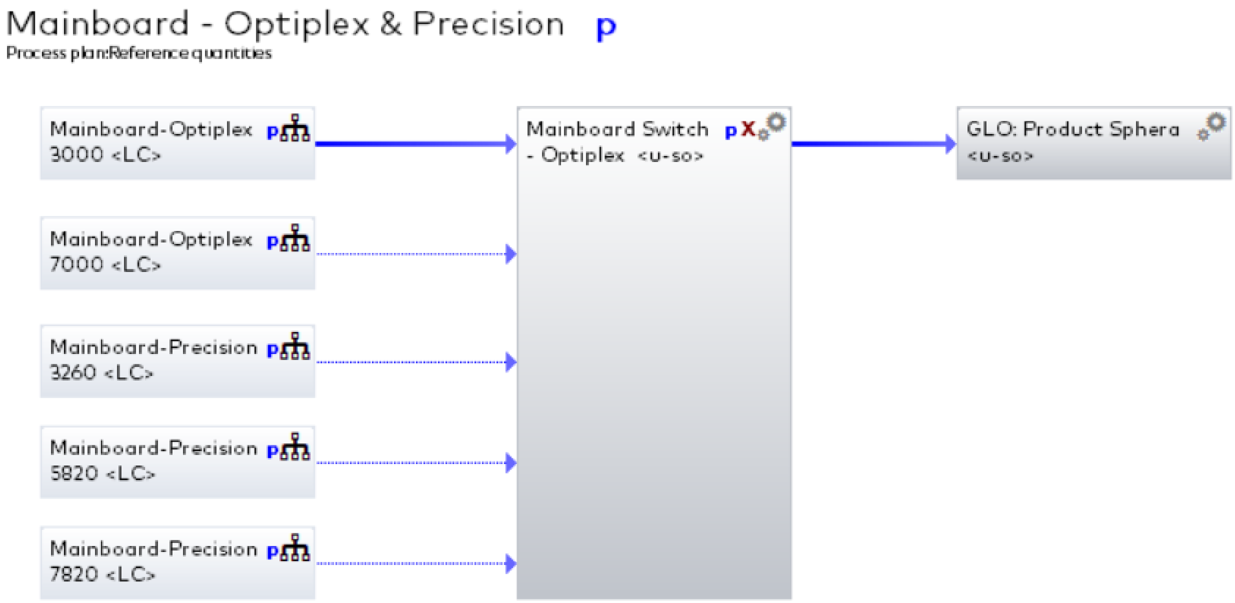

Figure 6-38: Mainboard selection for different desktop types – OptiPlex 3000, OptiPlex 7000, Precision 3260, Precision 5820 and Precision 7820

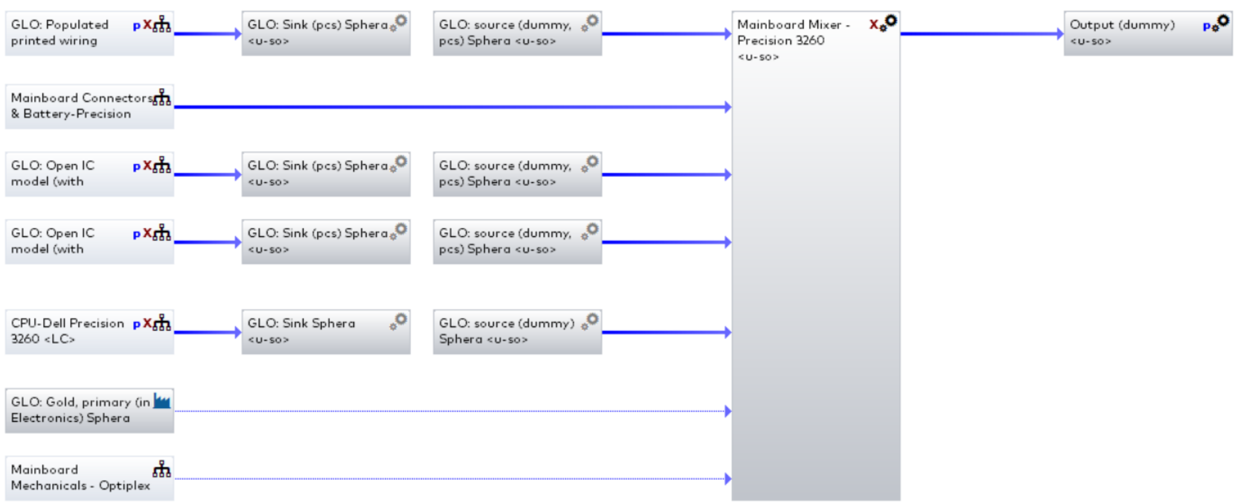

Figure 6-39: Mainboard plan model structure (same for all Desktops)

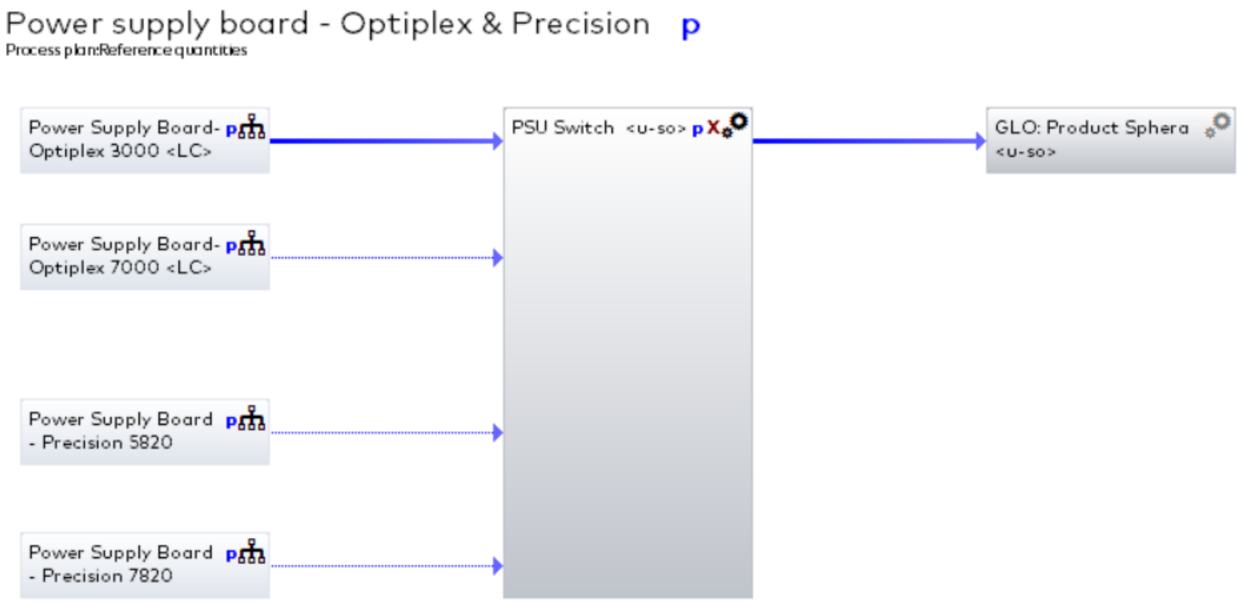

Figure 6-40: Power Supply Unit selection for different desktop types – OptiPlex 3000, OptiPlex 7000, Precision 3260, Precision 5820 and Precision 7820

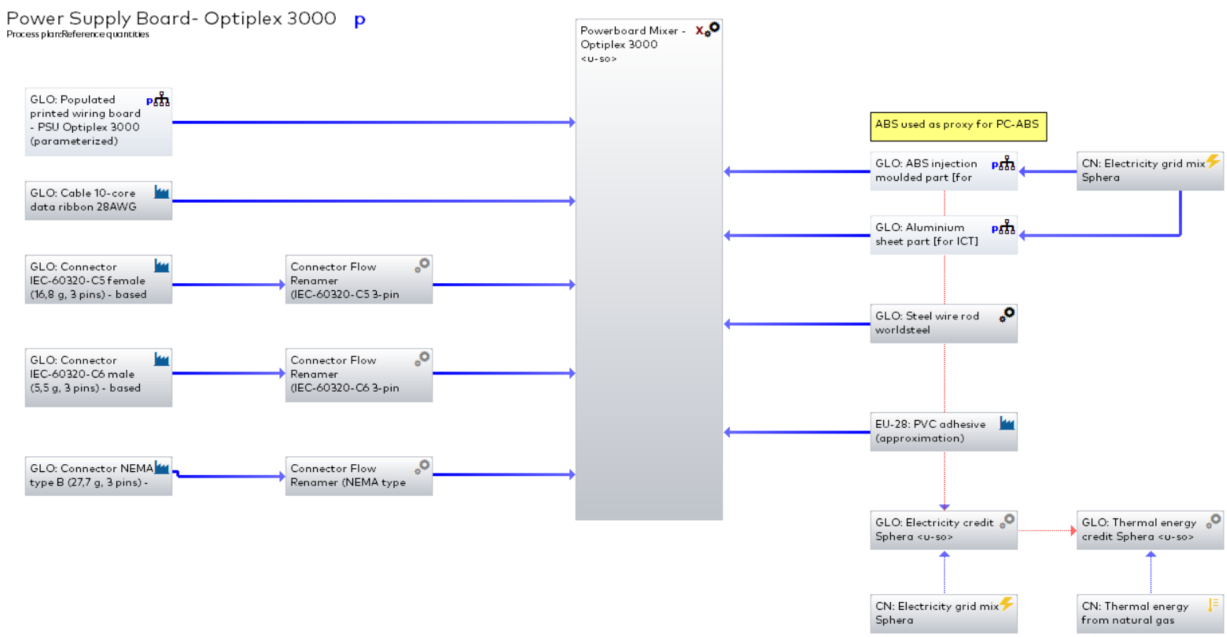

Figure 6-41: OptiPlex 3000 Power Supply Unit plan model structure (same for all OptiPlex Desktops)

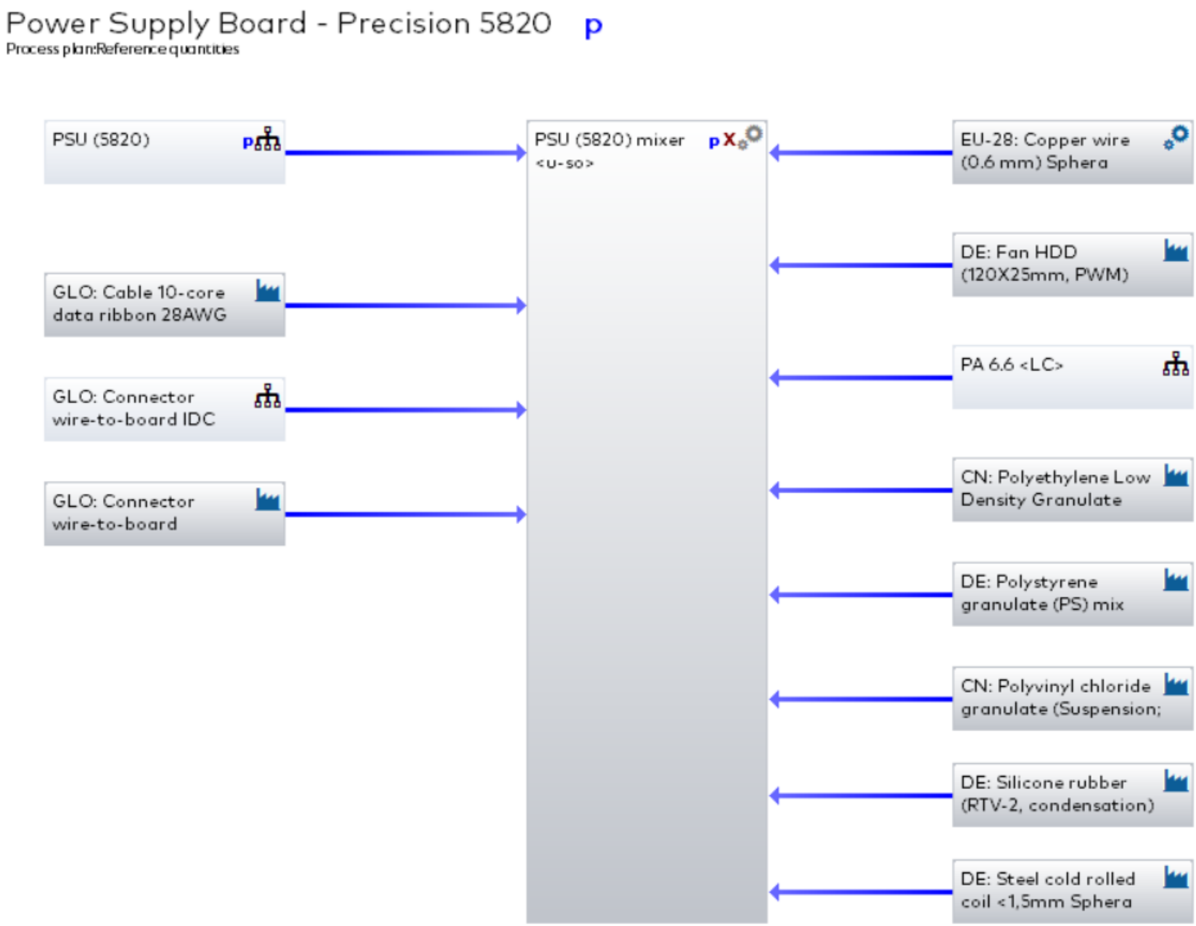

Figure 6-42: Precision 5820 Power Supply Unit plan model structure (same for all Precision Desktops)

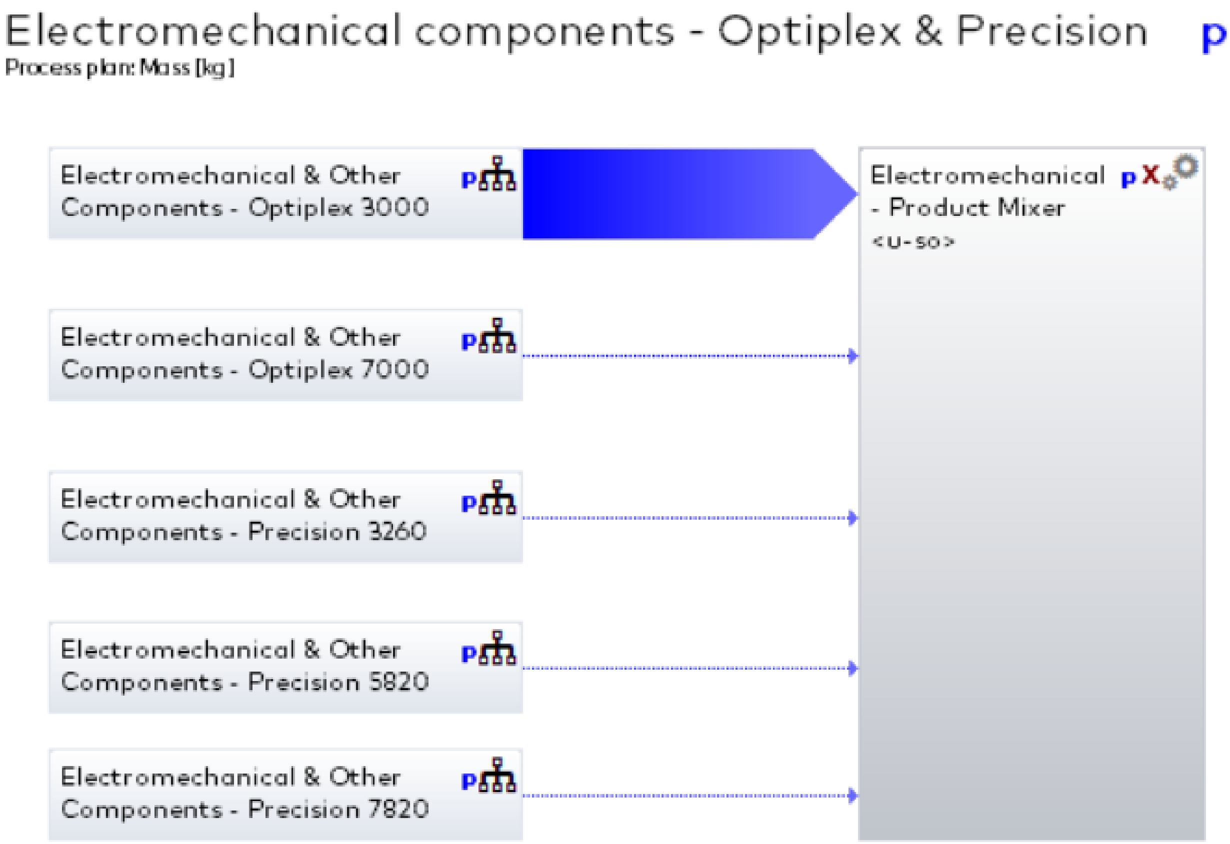

Figure 6-43: Electromechanical components selection for different desktop types – OptiPlex 3000, OptiPlex 7000, Precision 3260, Precision 5820 and Precision 7820

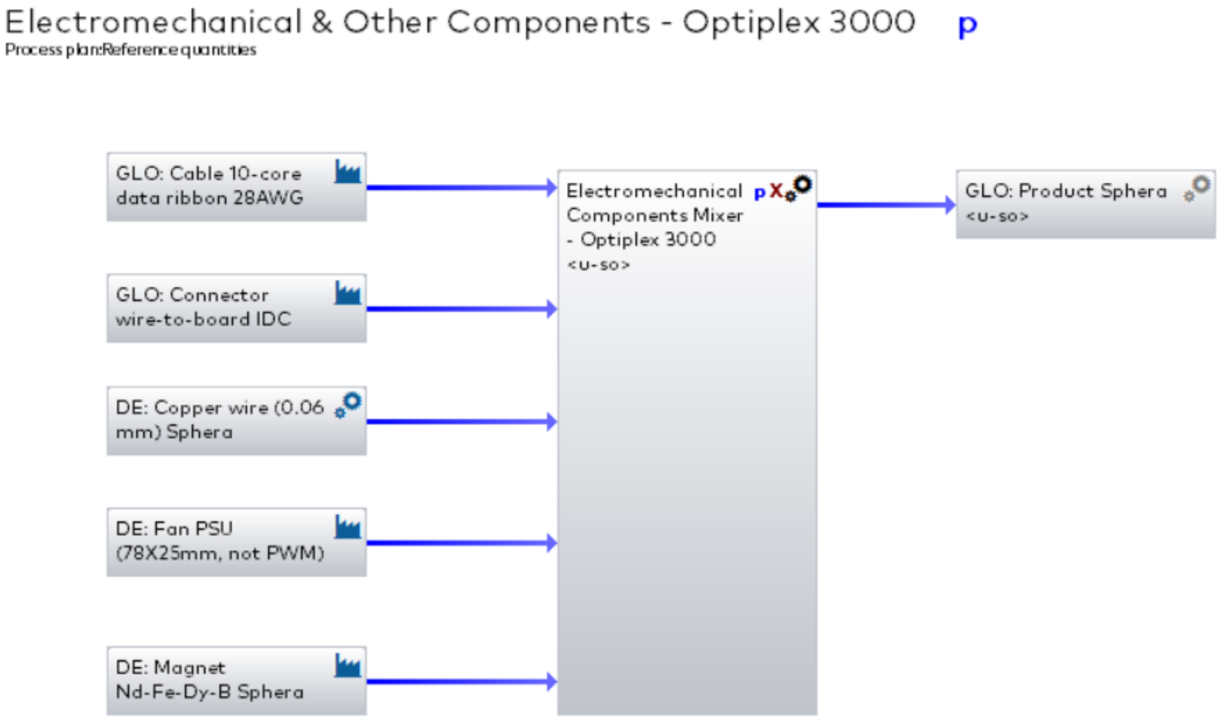

Figure 6-44: OptiPlex 3000 Electromechanical & Other components plan model structure (same for all OptiPlex Desktops)

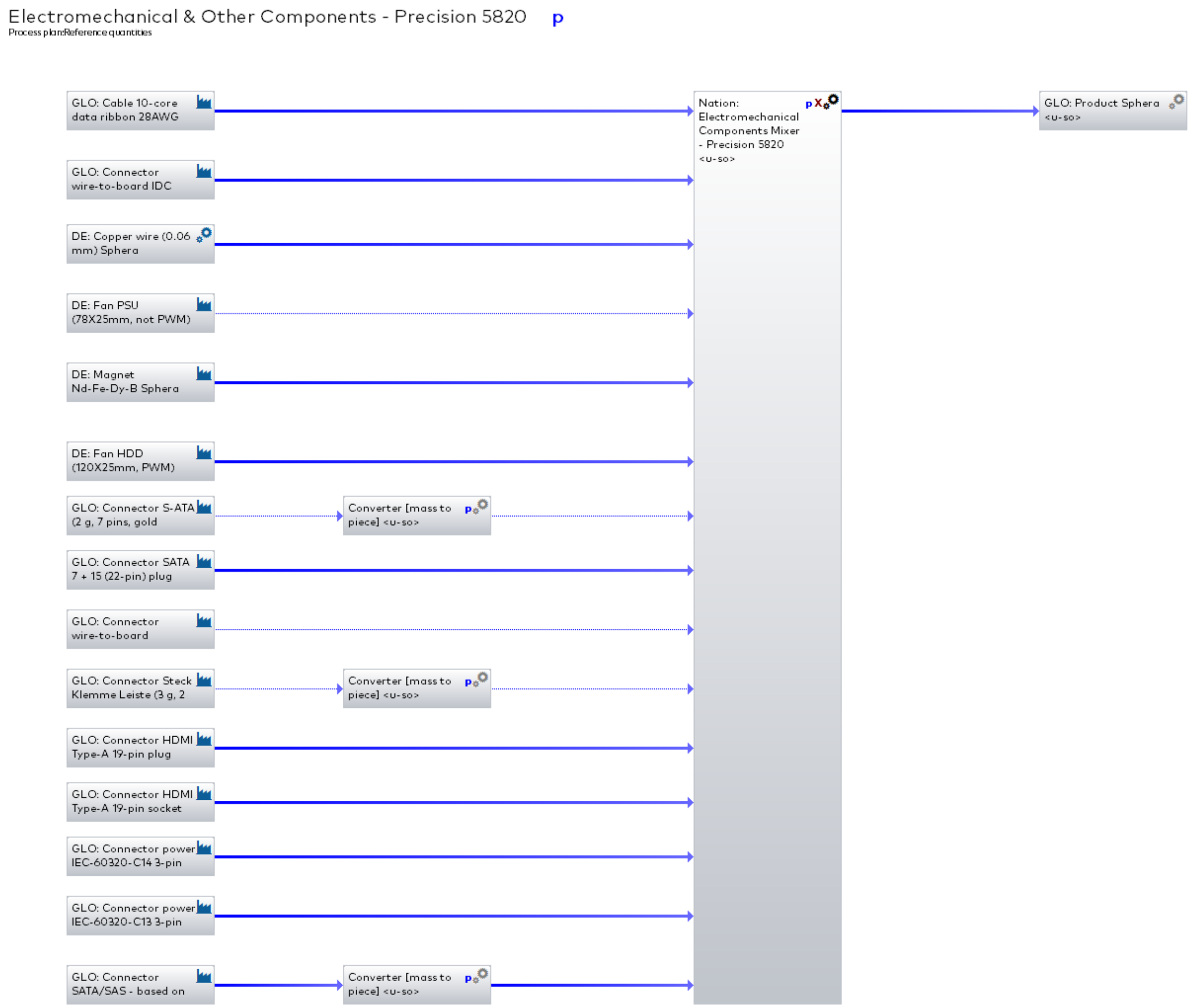

Figure 6-45: Precision 5820 Electromechanical & Other components plan model structure (same for all Precision Desktops)

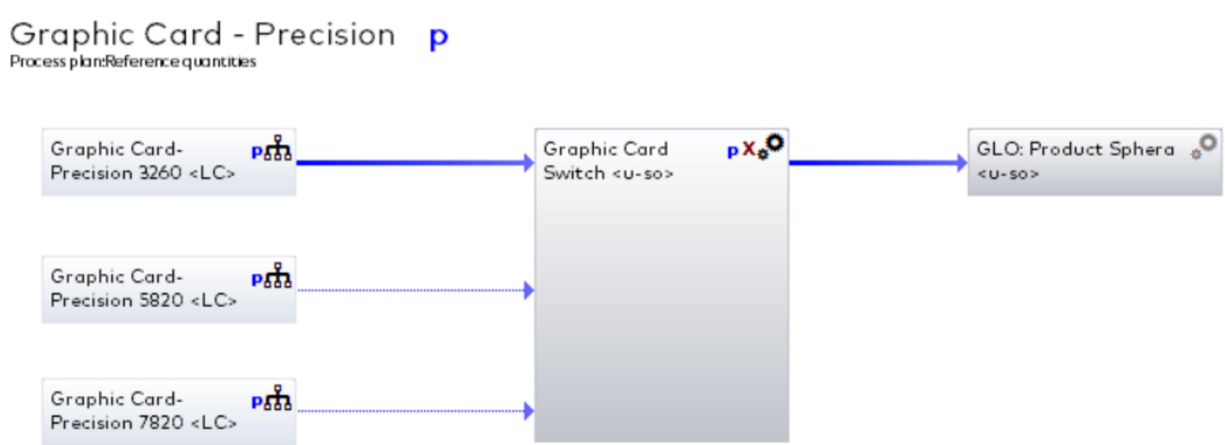

Figure 6-46: Graphic Card selection for different desktop types – Precision 3260, Precision 5820 and Precision 7820

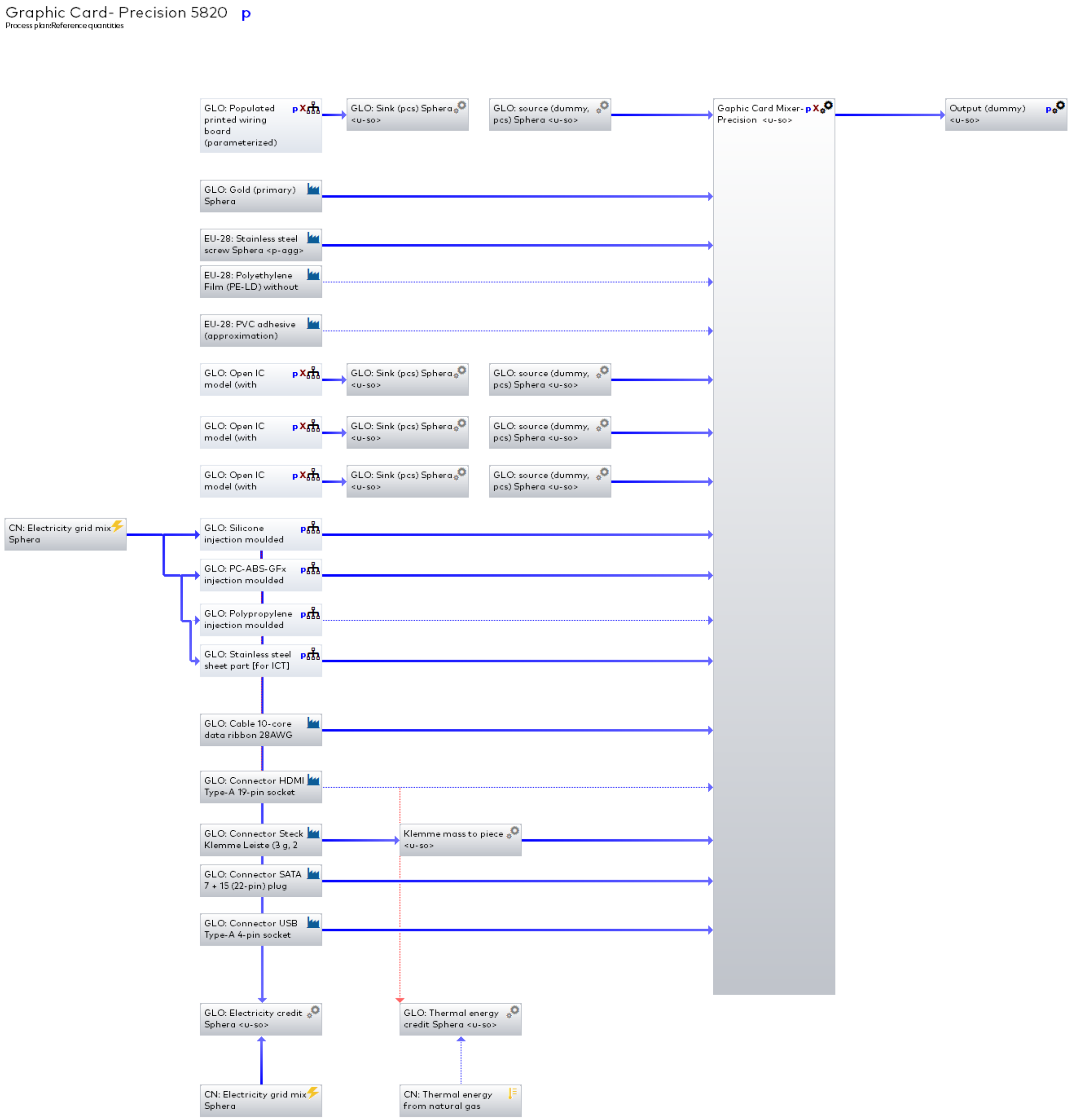

Figure 6-47: Precision 5820 Graphic Card plan model structure (same for all Precision Desktops)

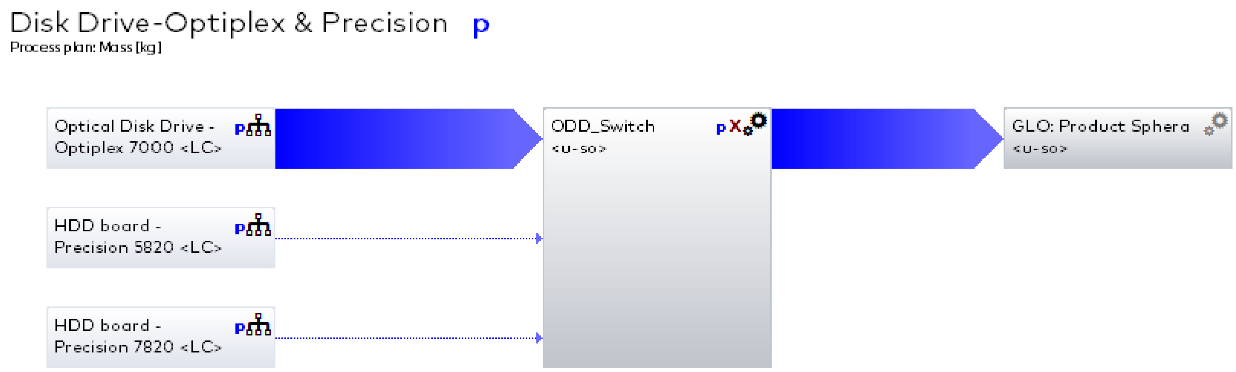

Figure 6-48: ODD and HDD selection for different desktop types – OptiPlex 7000, Precision 5820 and Precision 7820

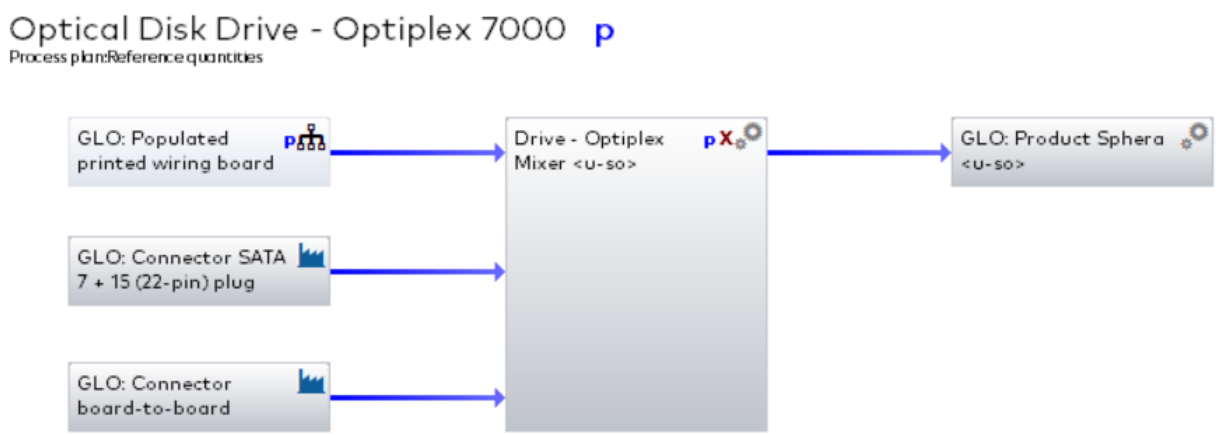

Figure 6-49: OptiPlex Optical disk drive (ODD) plan model structure

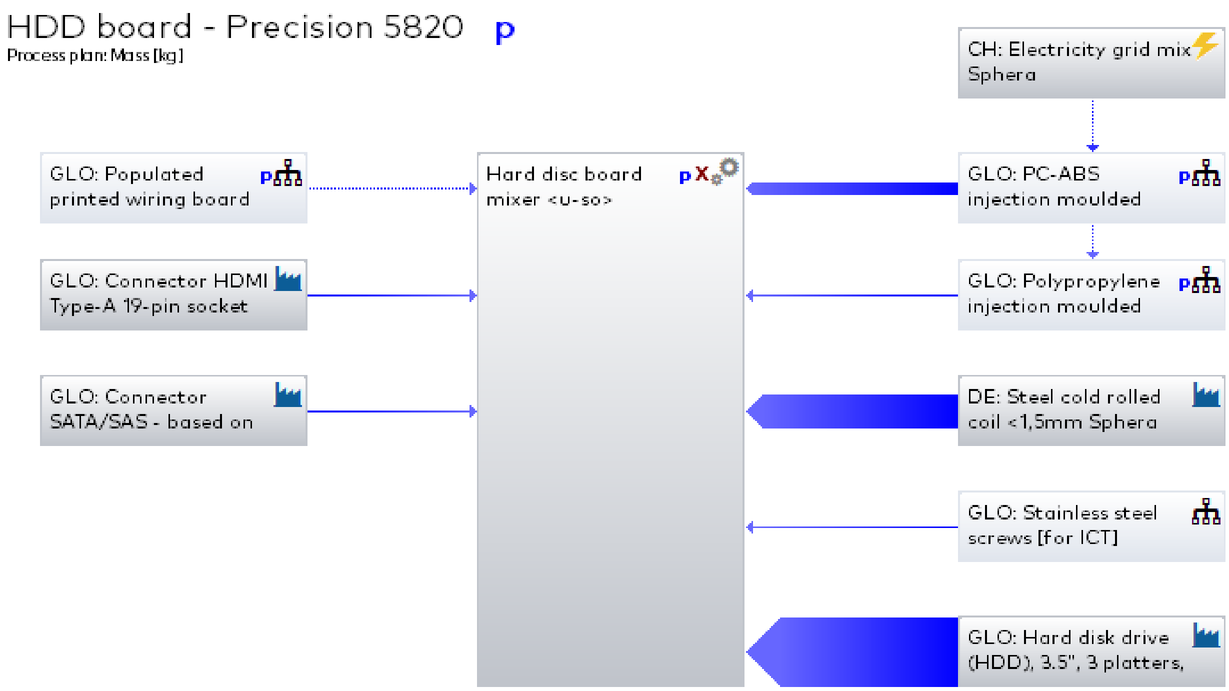

Figure 6-50: Precision 5820 HDD board plan model structure (same for Precision 5820 and Precision 7820)

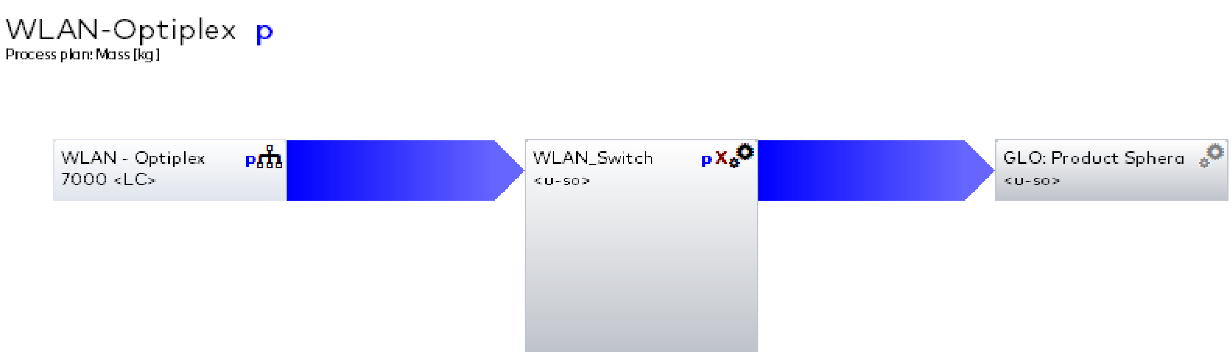

Figure 6-51: WLAN selection for OptiPlex 7000

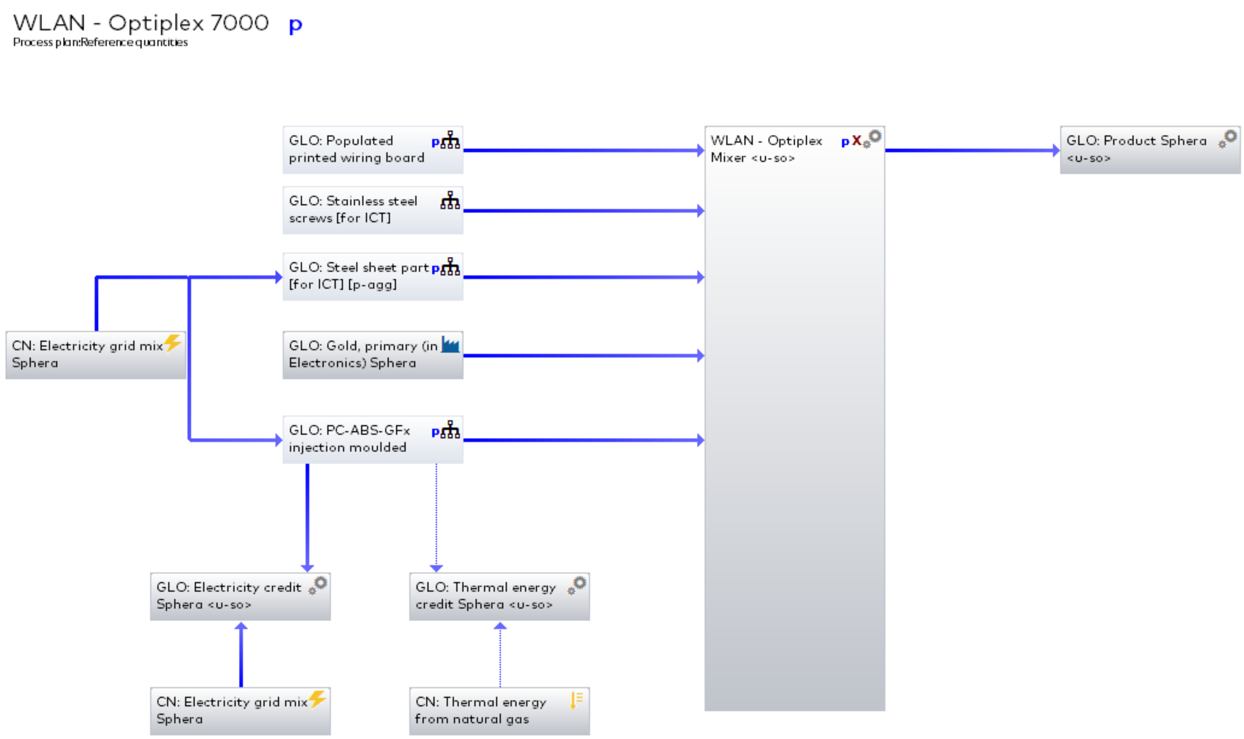

Figure 6-52: OptiPlex 7000 WLAN plan model structure

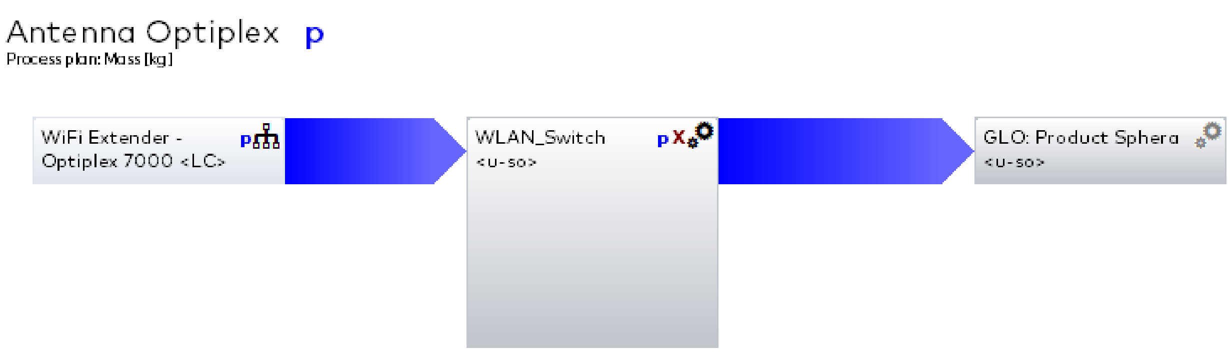

Figure 6-53: Antenna selection for OptiPlex 7000

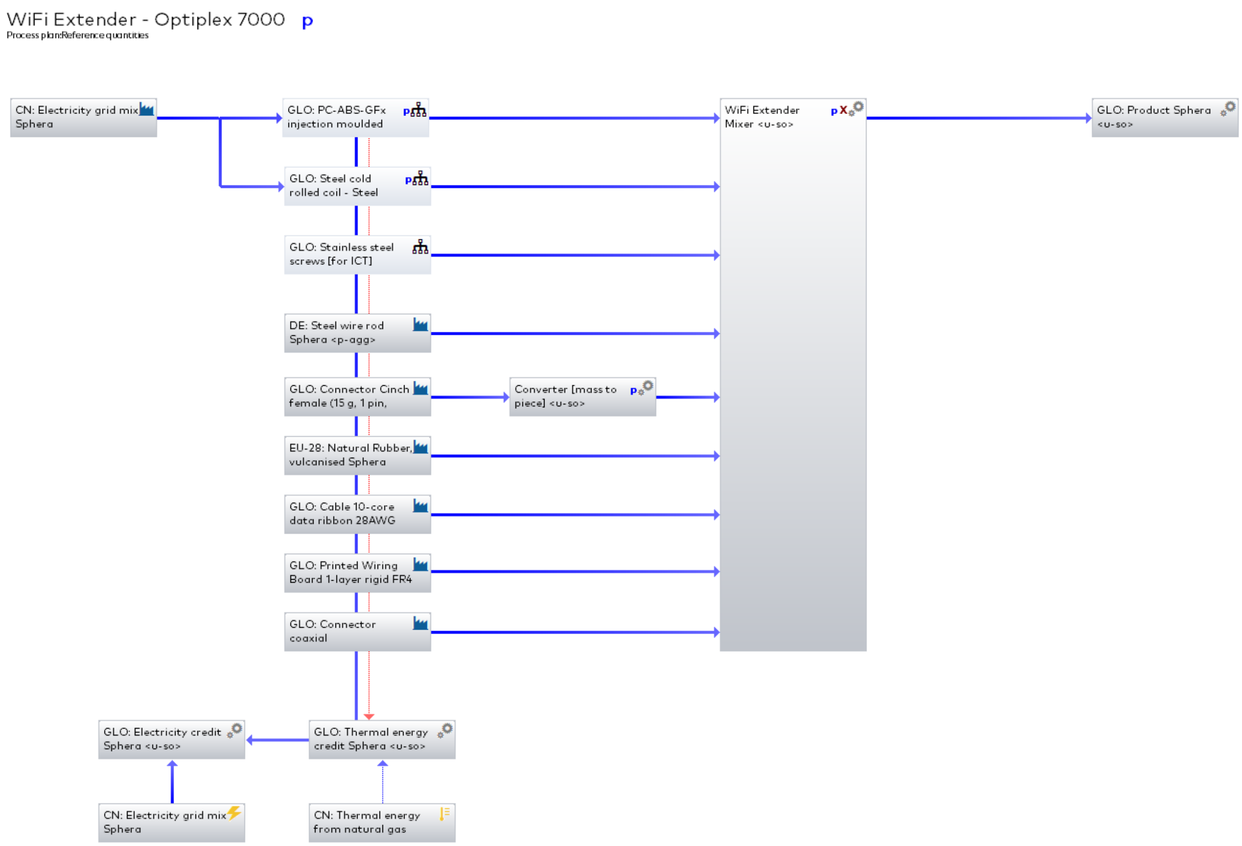

Figure 6-54: OptiPlex 7000 Antenna plan model structure

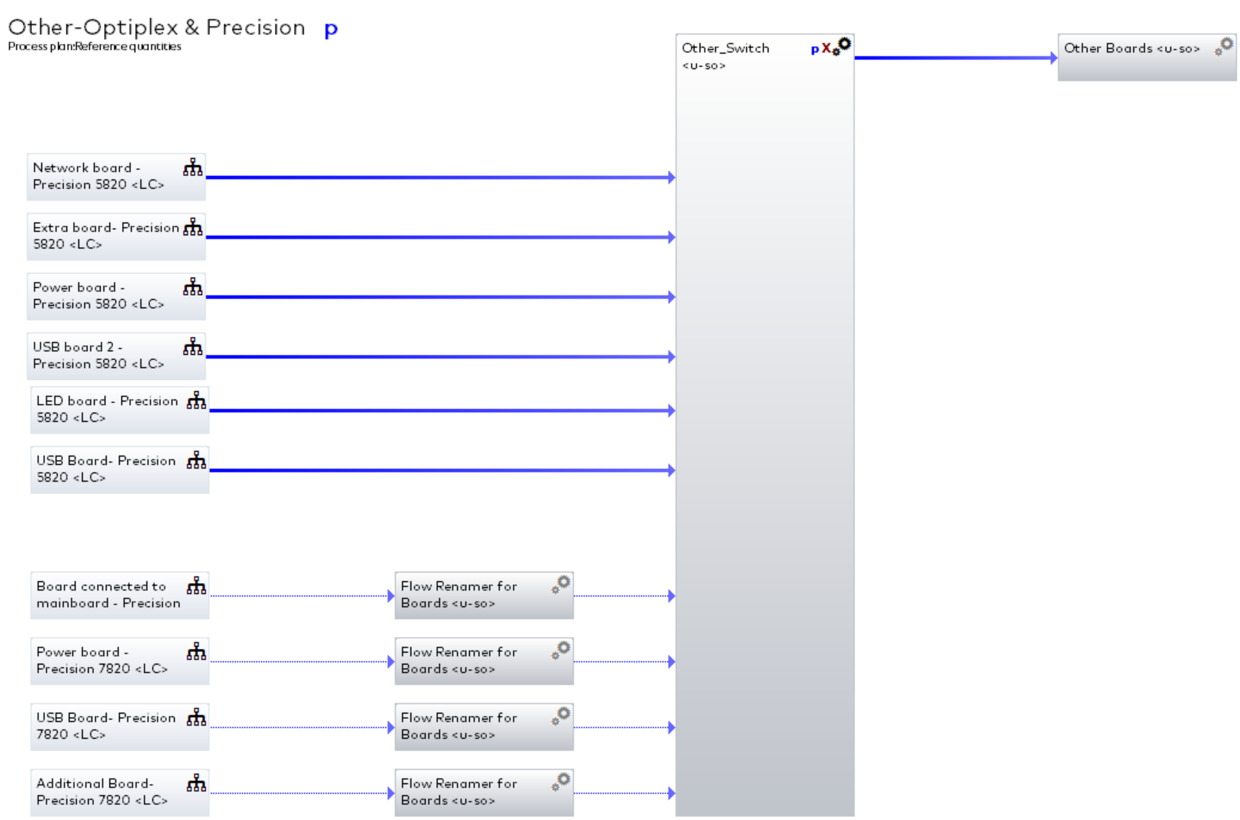

Figure 6-55:Other electronical components selection for Precision 5820 and Precision 7820

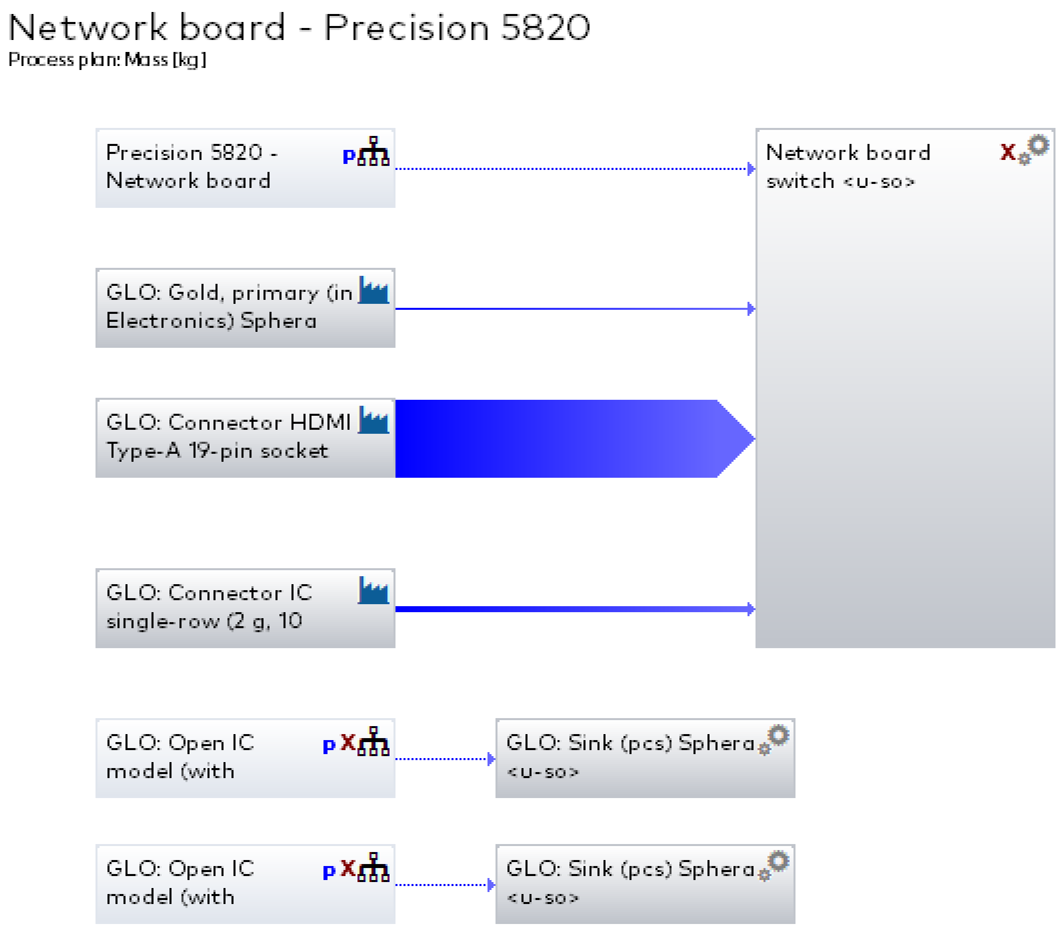

Figure 6-56: Precision 5820 Network board plan model structure

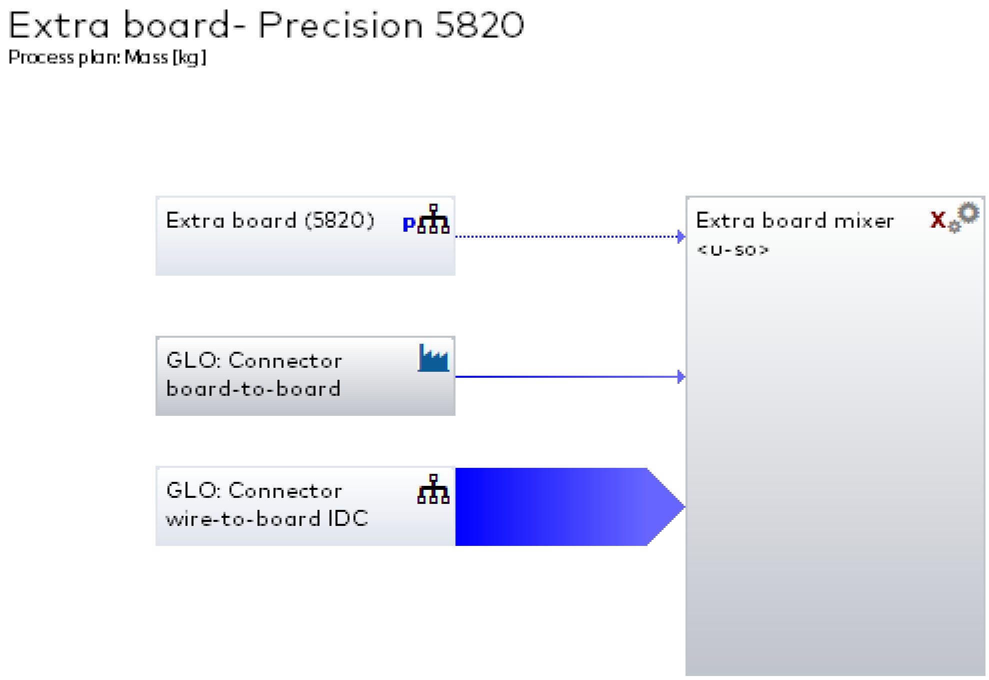

Figure 6-57: Precision 5820 Extra board plan model structure

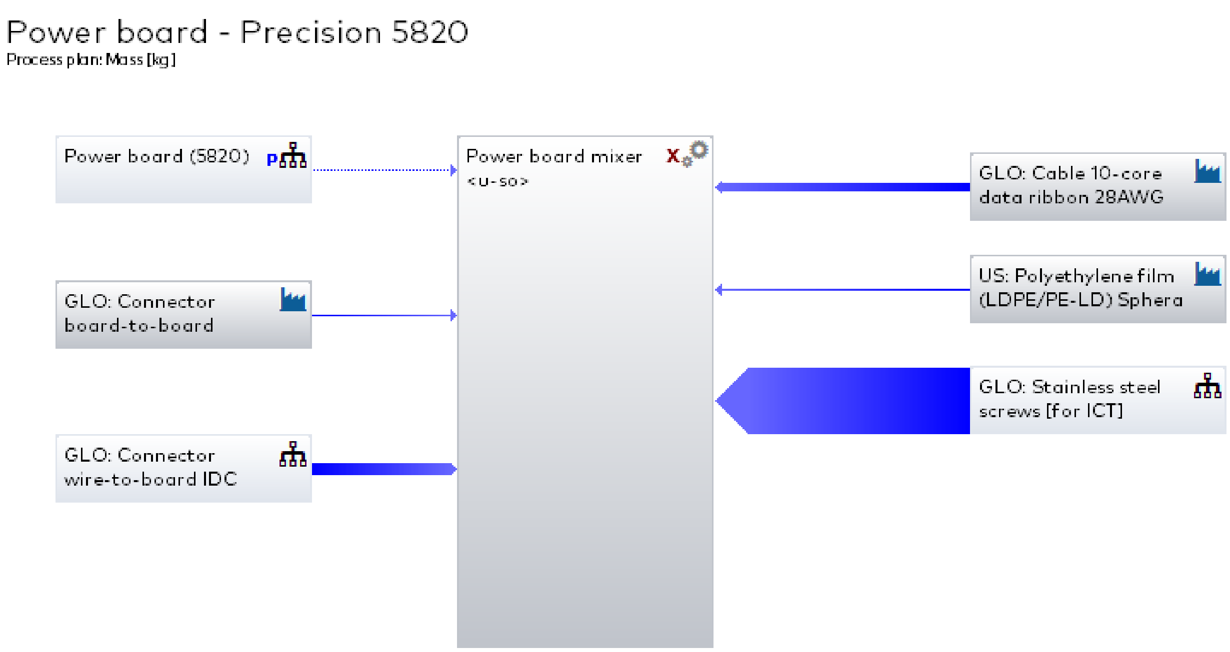

Figure 6-58: Precision 5820 Power board plan model structure

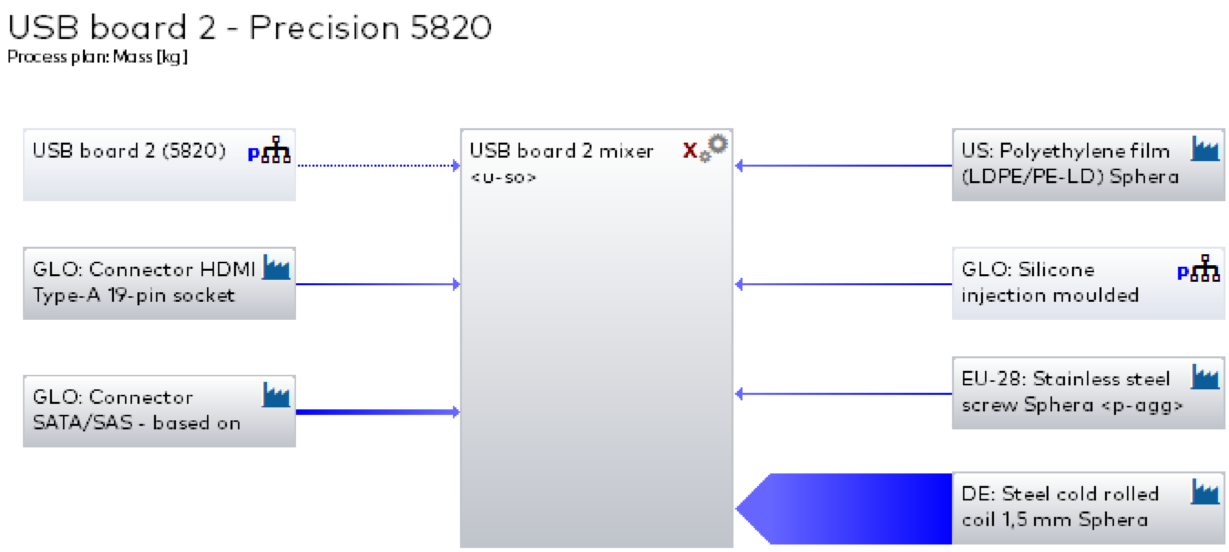

Figure 6-59: Precision 5820 USB board 2 plan model structure

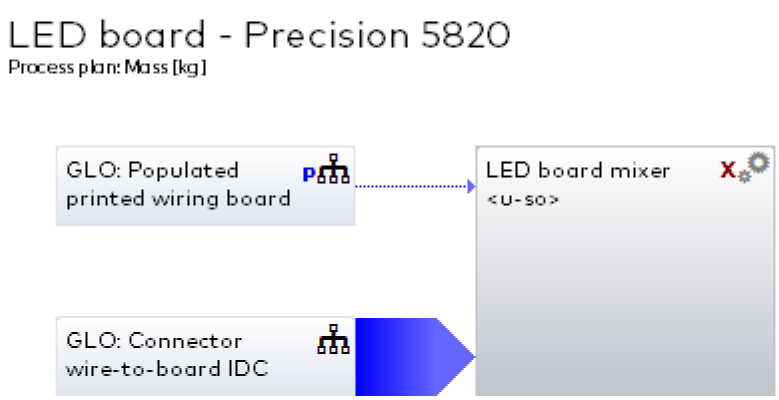

Figure 6-60: Precision 5820 LED board plan model structure

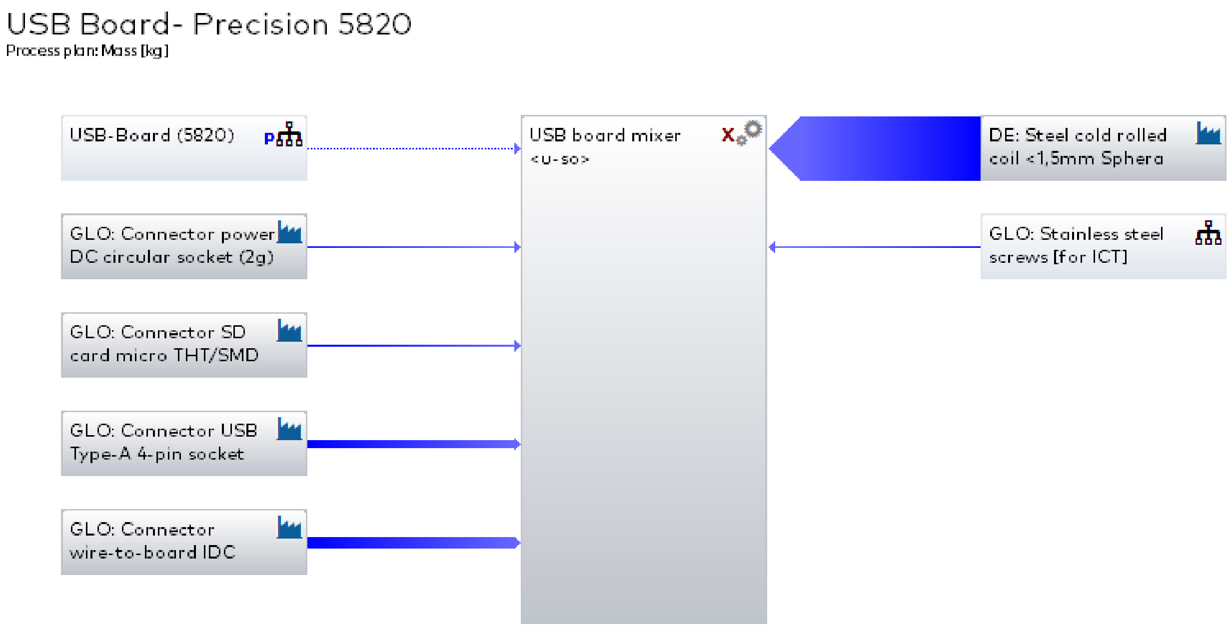

Figure 6-61: Precision 5820 USB board plan model structure

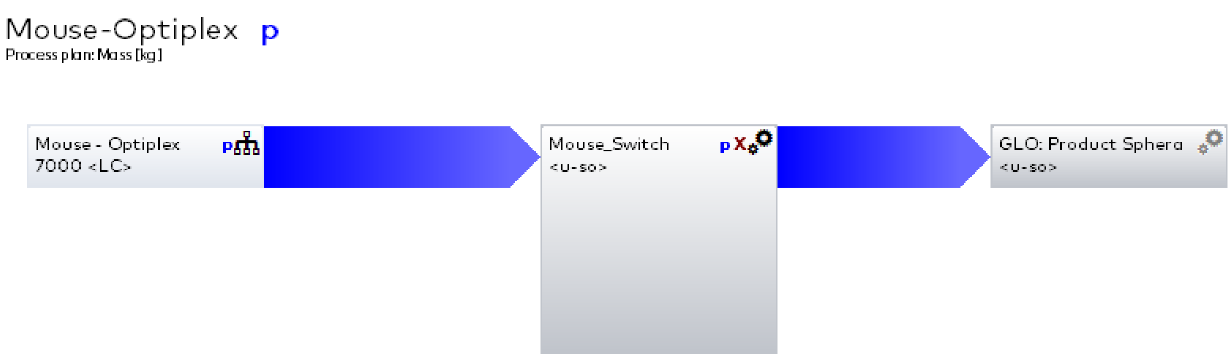

Figure 6-62: Mouse selection for OptiPlex 7000

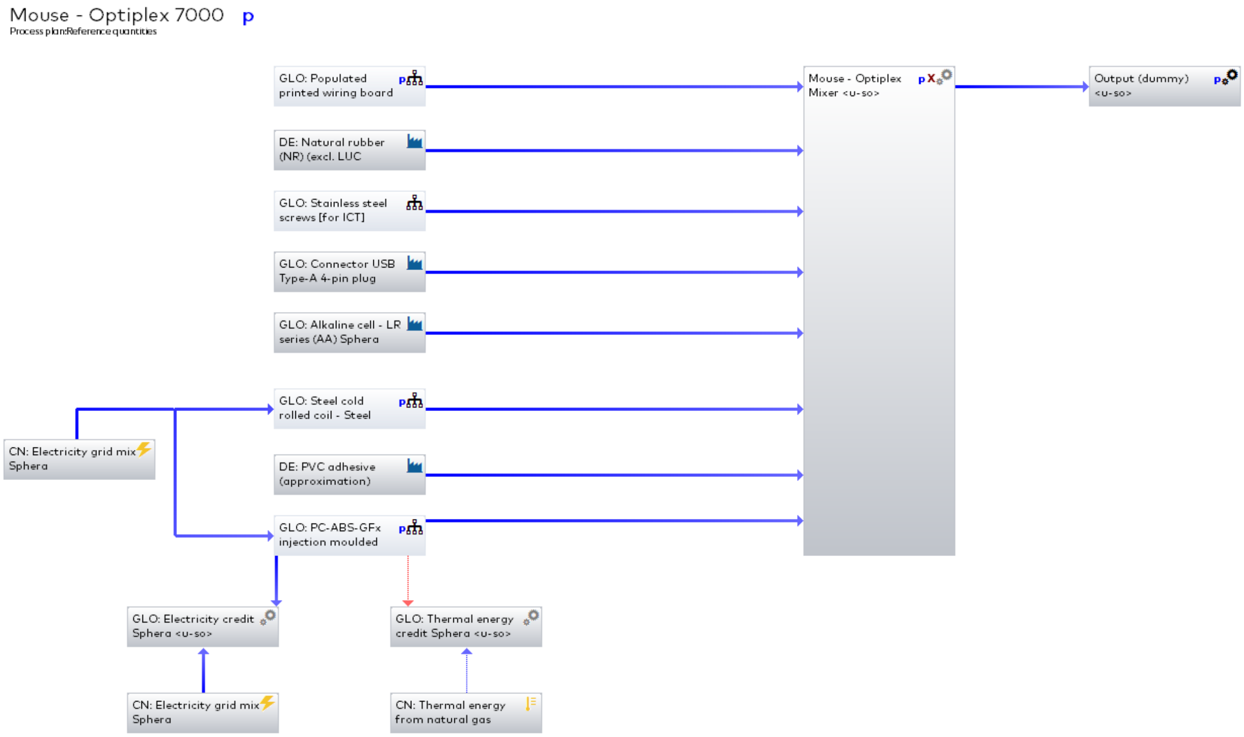

Figure 6-63: OptiPlex 7000 mouse plan model structure

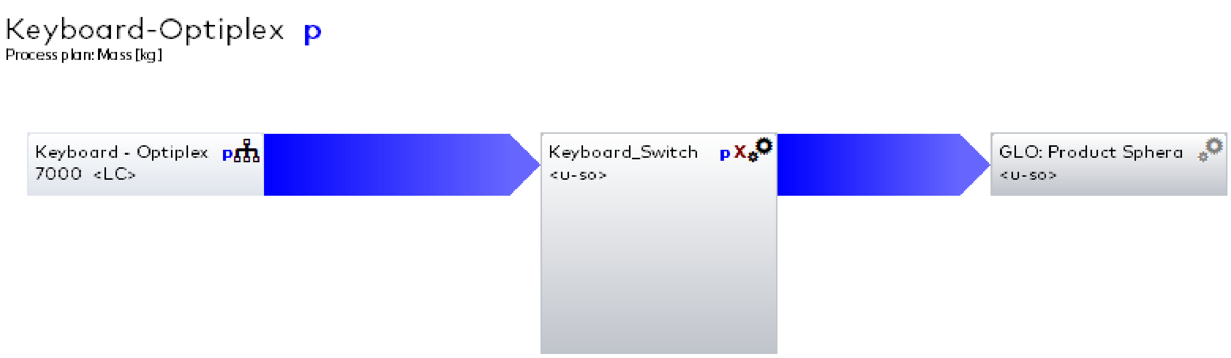

Figure 6-64: Keyboard selection for OptiPlex 7000

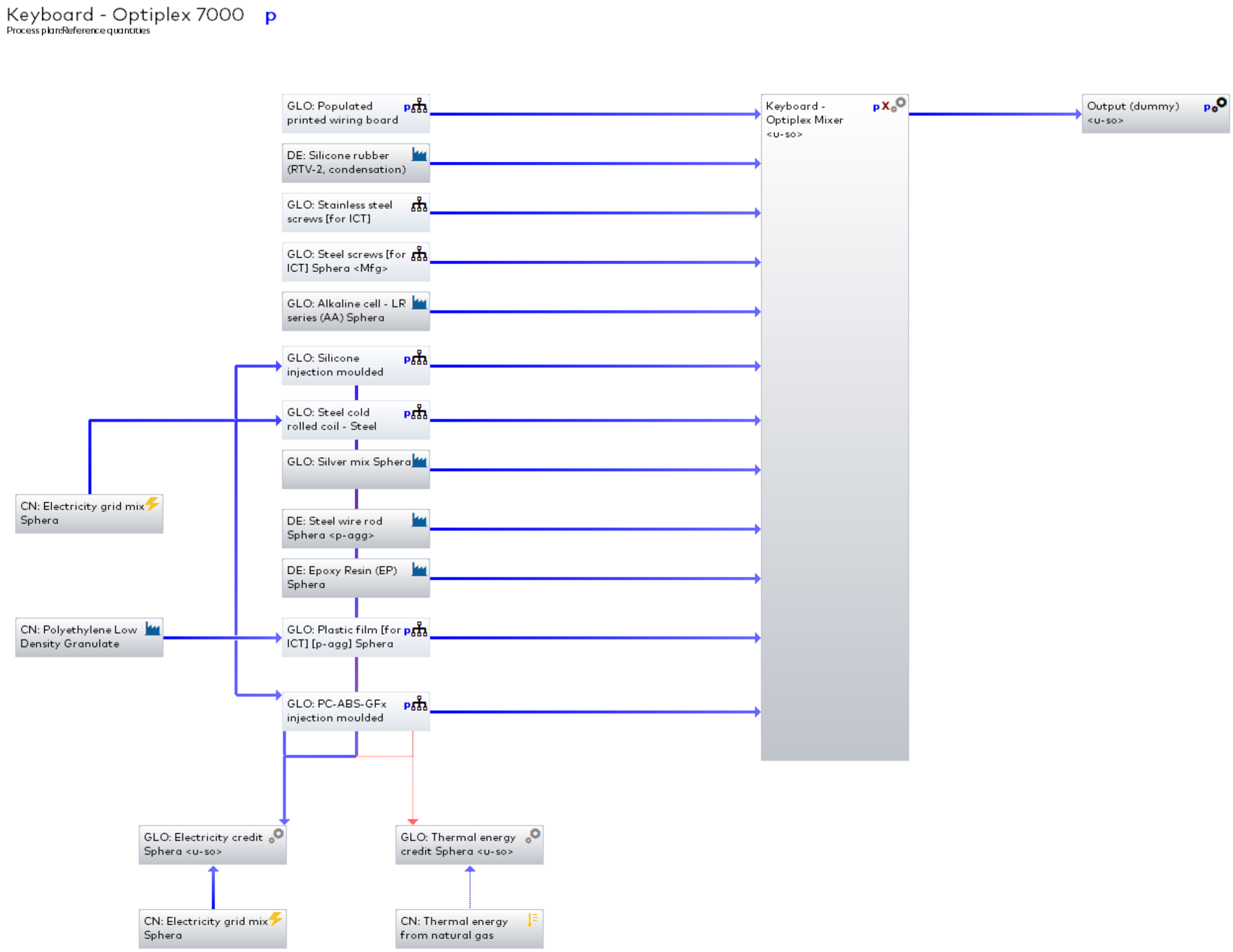

Figure 6-65: OptiPlex 7000 keyboard plan model structure

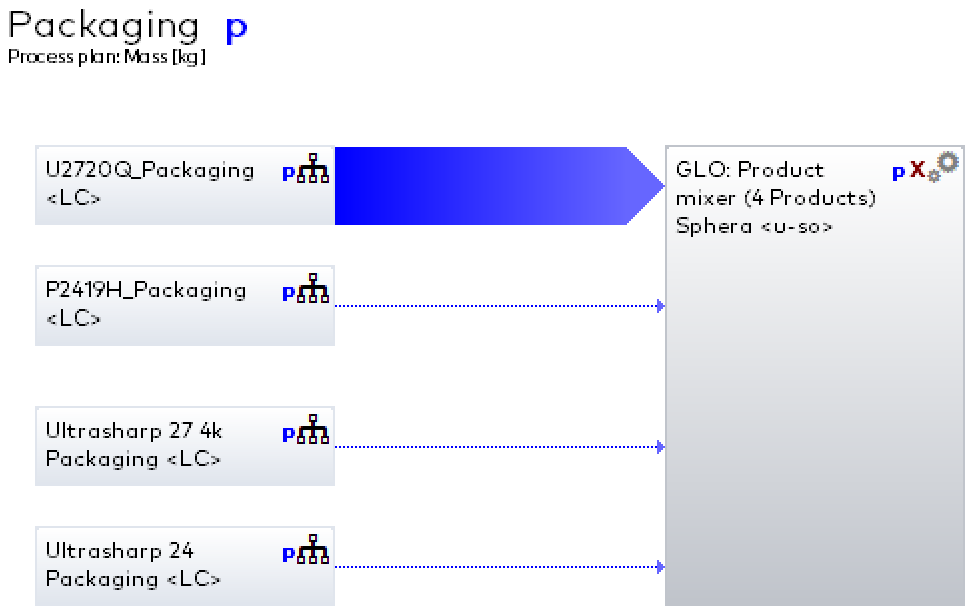

Figure 6-66: Packaging selection for different monitor types – UltraSharp 2720Q, P2419H, UltraSharp 274K, UltraSharp 24

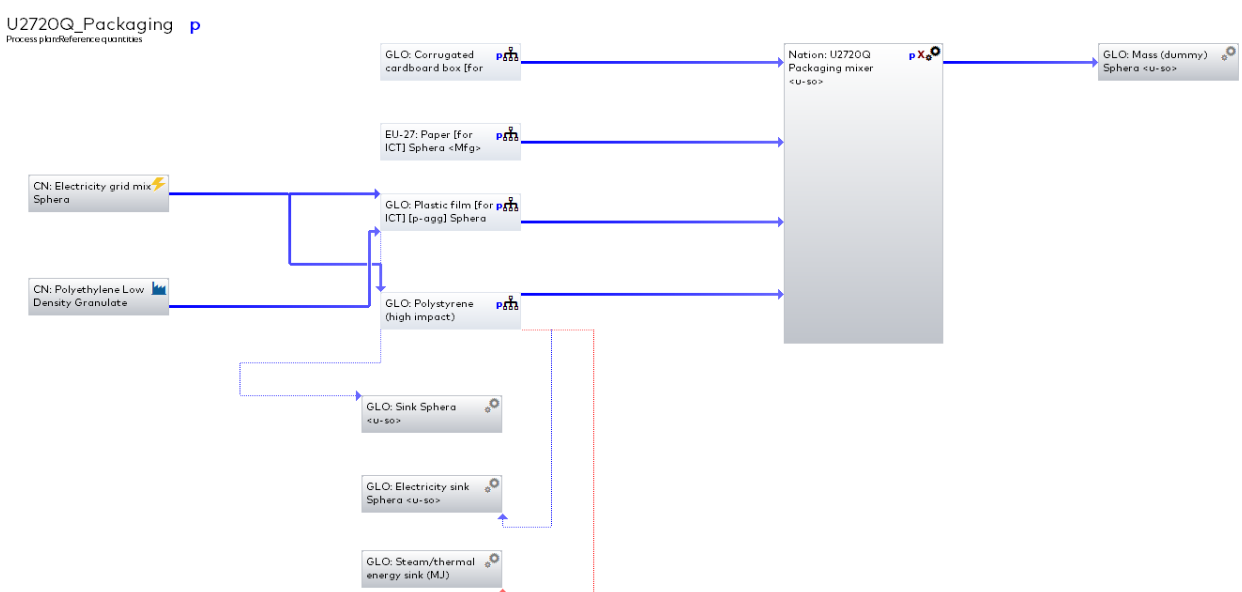

Figure 6-67: Monitor packaging plan model structure (same for all four monitors)

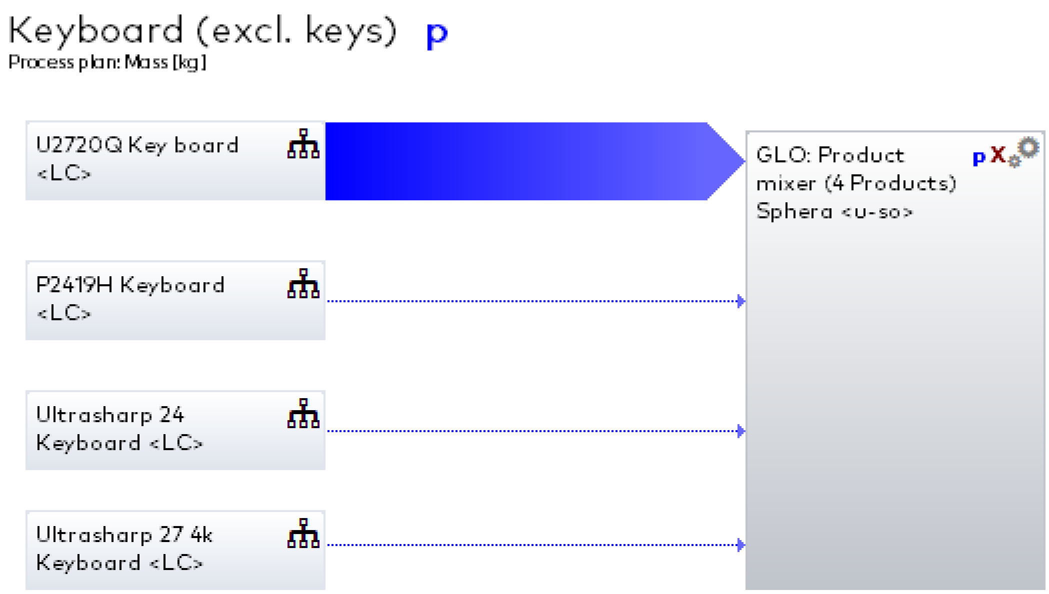

Figure 6-68: Keyboard selection for different monitor types – UltraSharp 2720Q, P2419H, UltraSharp 274K, UltraSharp 24

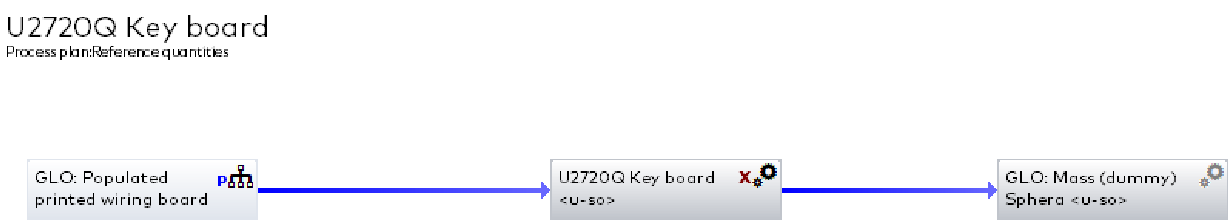

Figure 6-69: UltraSharp 2720Q keyboard plan model structure

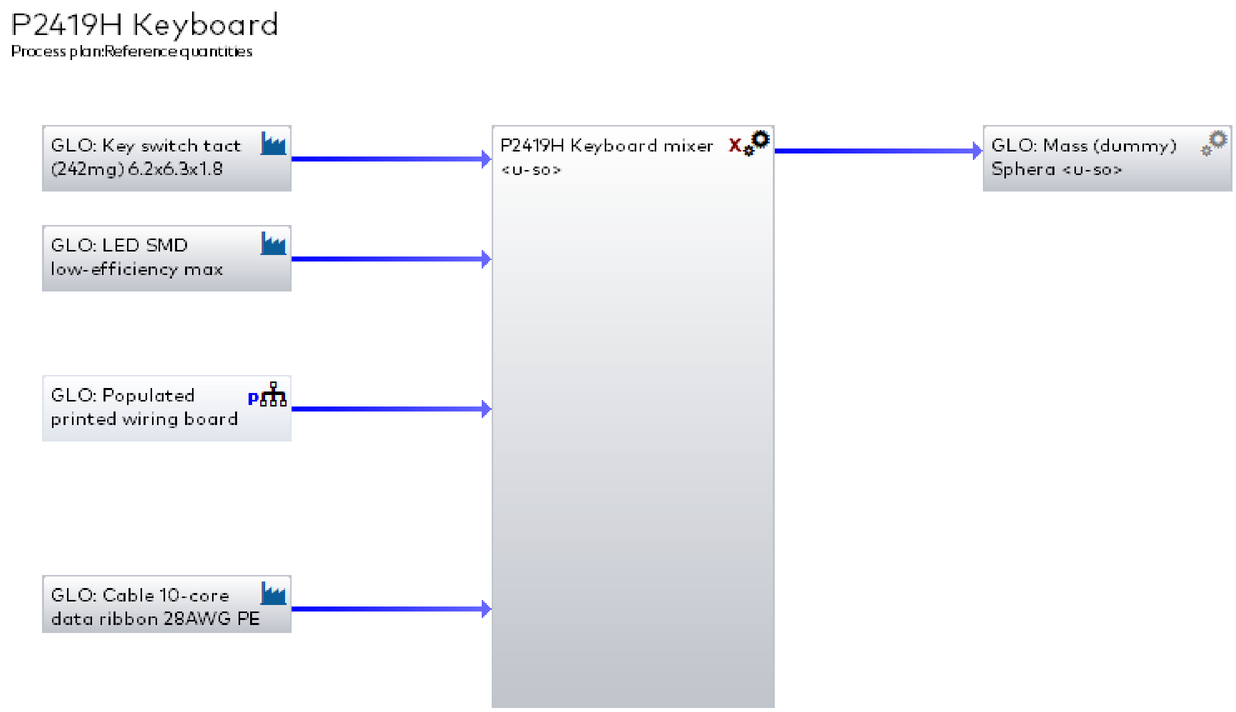

Figure 6-70: P2419H keyboard plan model structure

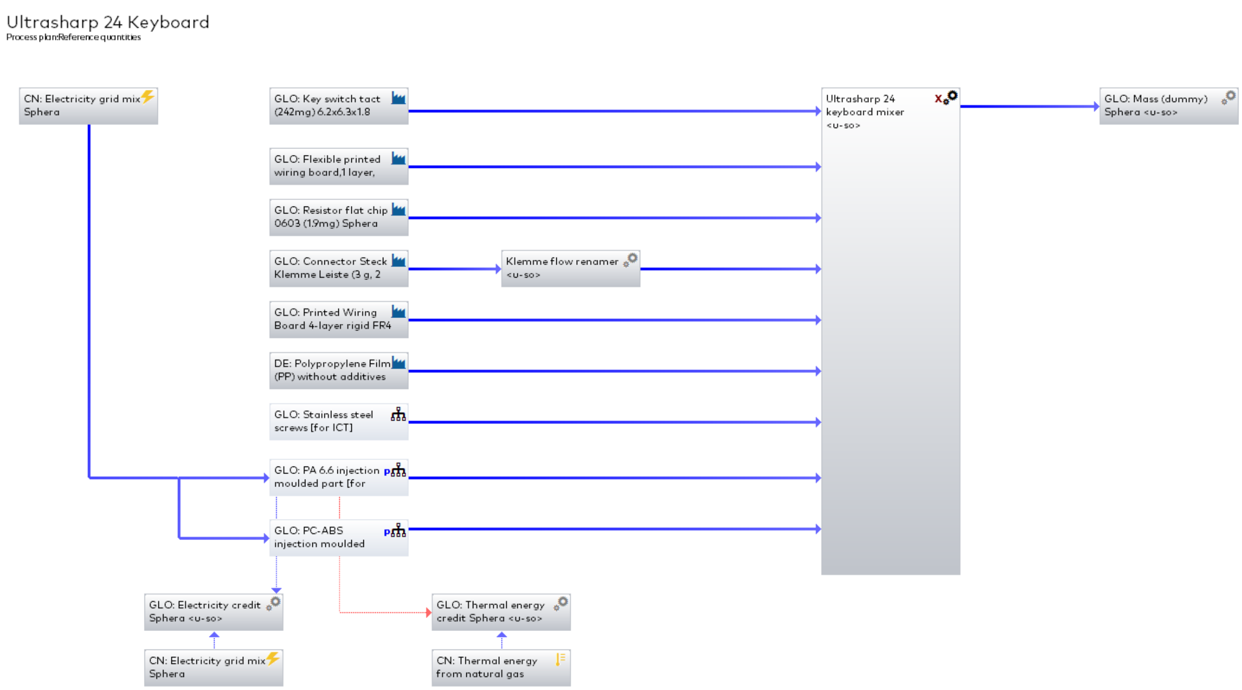

Figure 6-71: UltraSharp 24 keyboard plan model structure

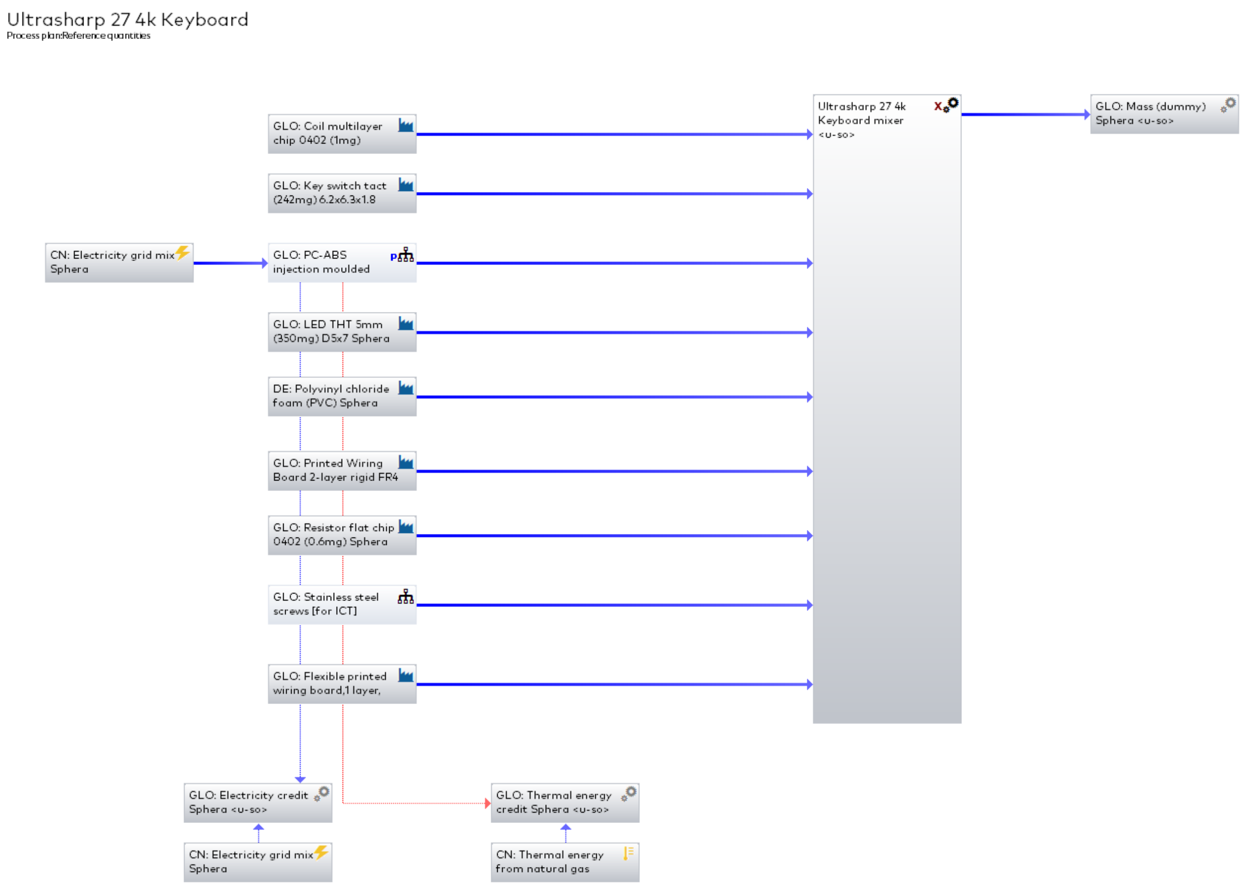

Figure 6-72: UltraSharp 27 4K keyboard plan model structure

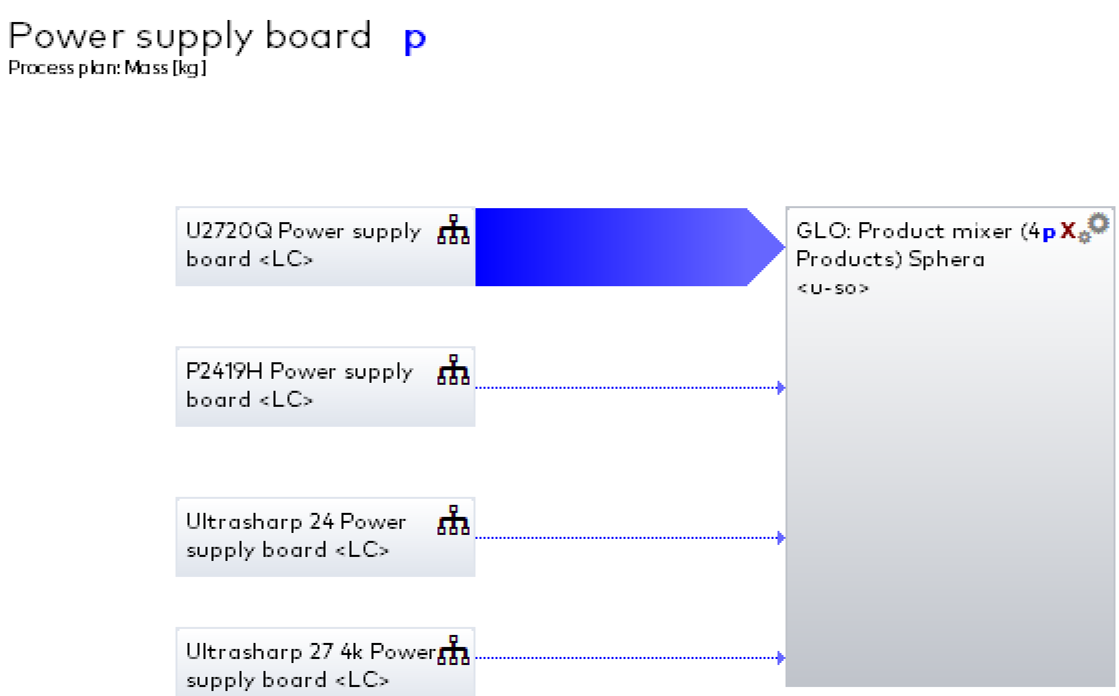

Figure 6-73: Power Supply Unit selection for different monitor types – UltraSharp 2720Q, P2419H, UltraSharp 274K, UltraSharp 24

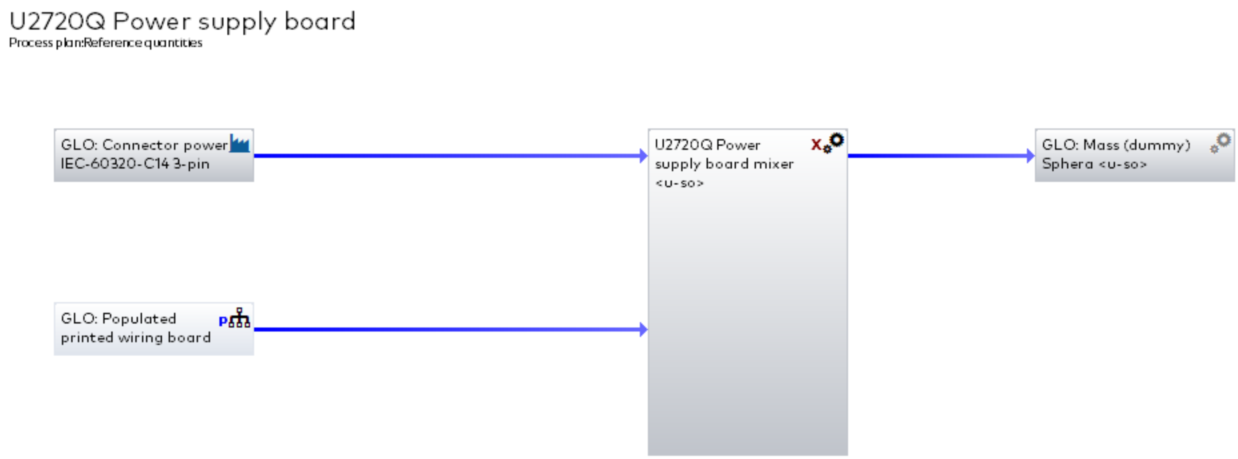

Figure 6-74: UltraSharp 2720Q power supply unit plan model structure

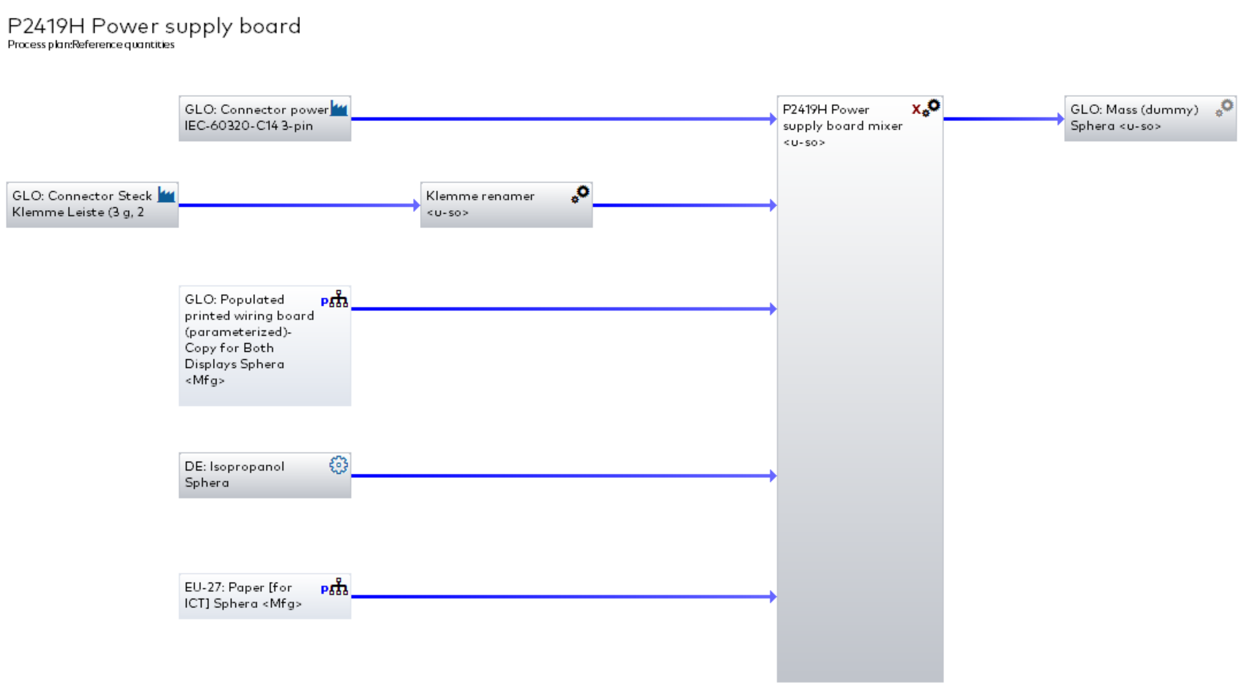

Figure 6-75: P2419H power supply unit plan model structure

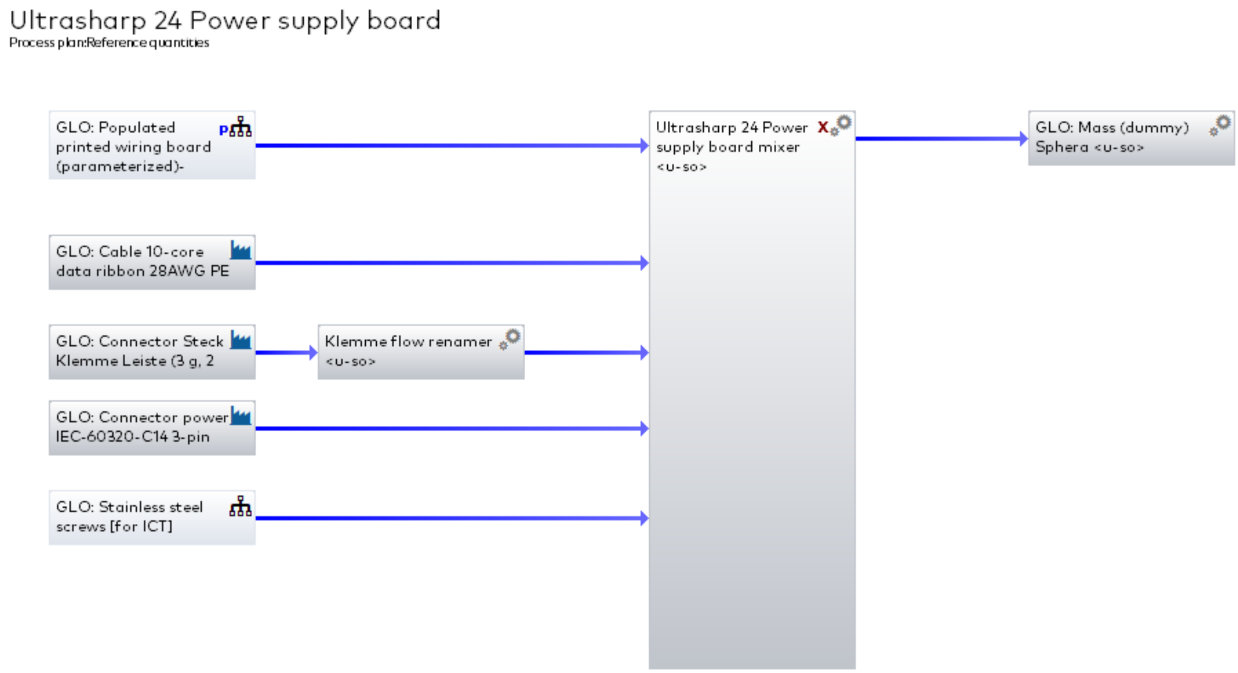

Figure 6-76: UltraSharp 24 power supply unit plan model structure

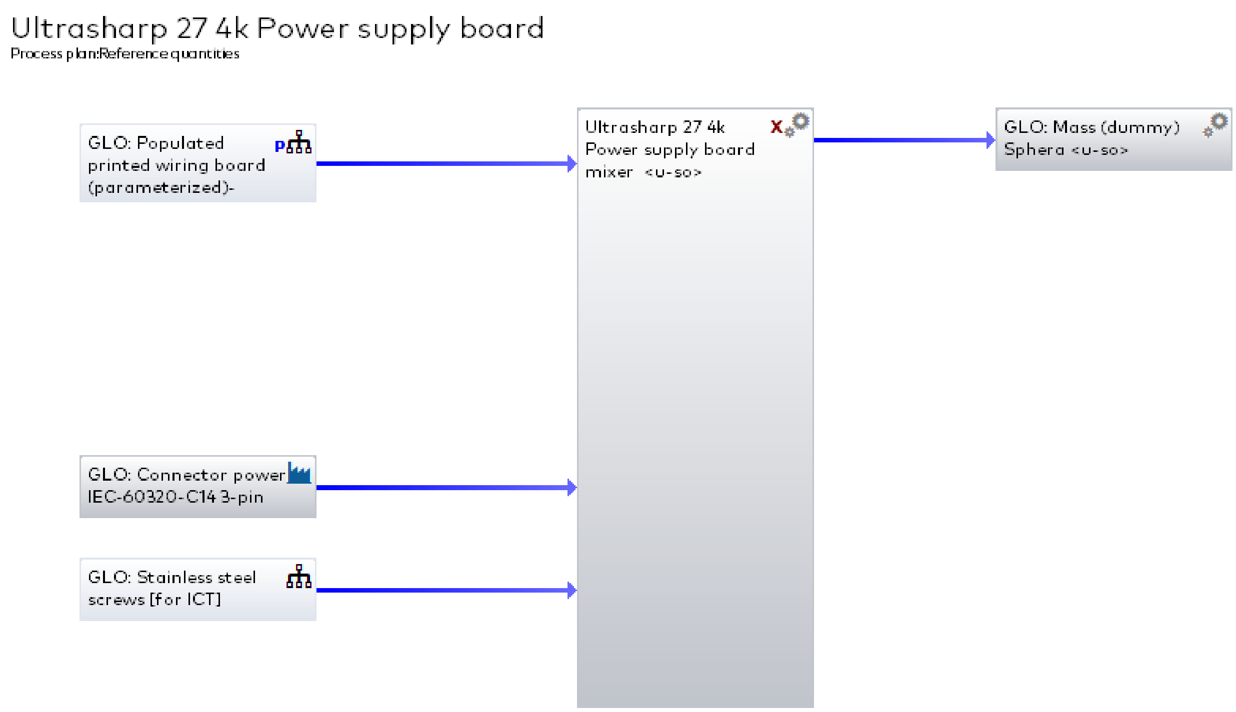

Figure 6-77: UltraSharp 27 4K power supply unit plan model structure

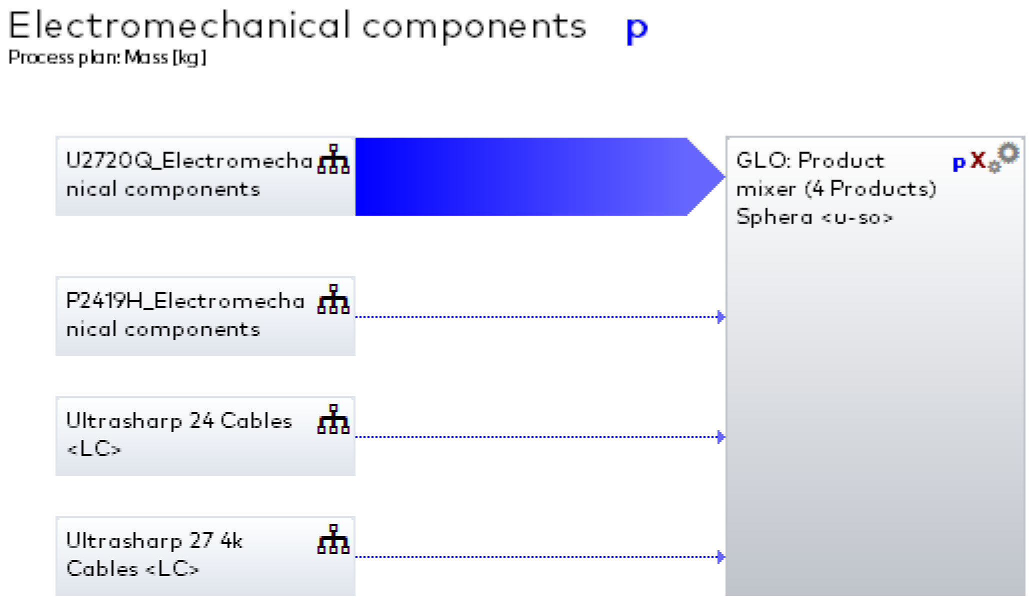

Figure 6-78: Electromechanical components selection for different monitor types – UltraSharp 2720Q, P2419H, UltraSharp 274K, UltraSharp 24

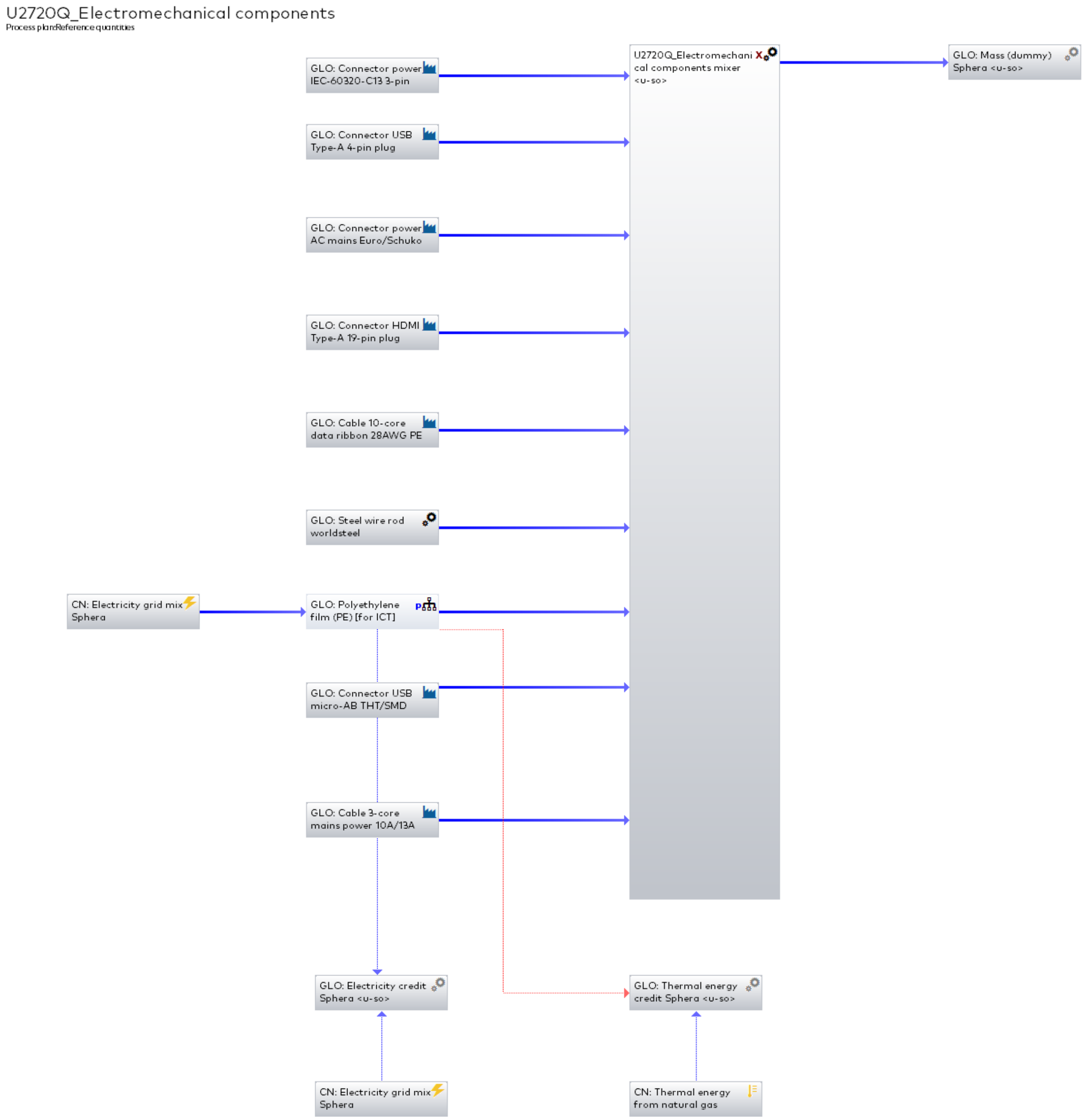

Figure 6-79: UltraSharp 2720Q electromechanical components plan model structure

P2419H_Electromechanical components
Process plan:Reference quantities

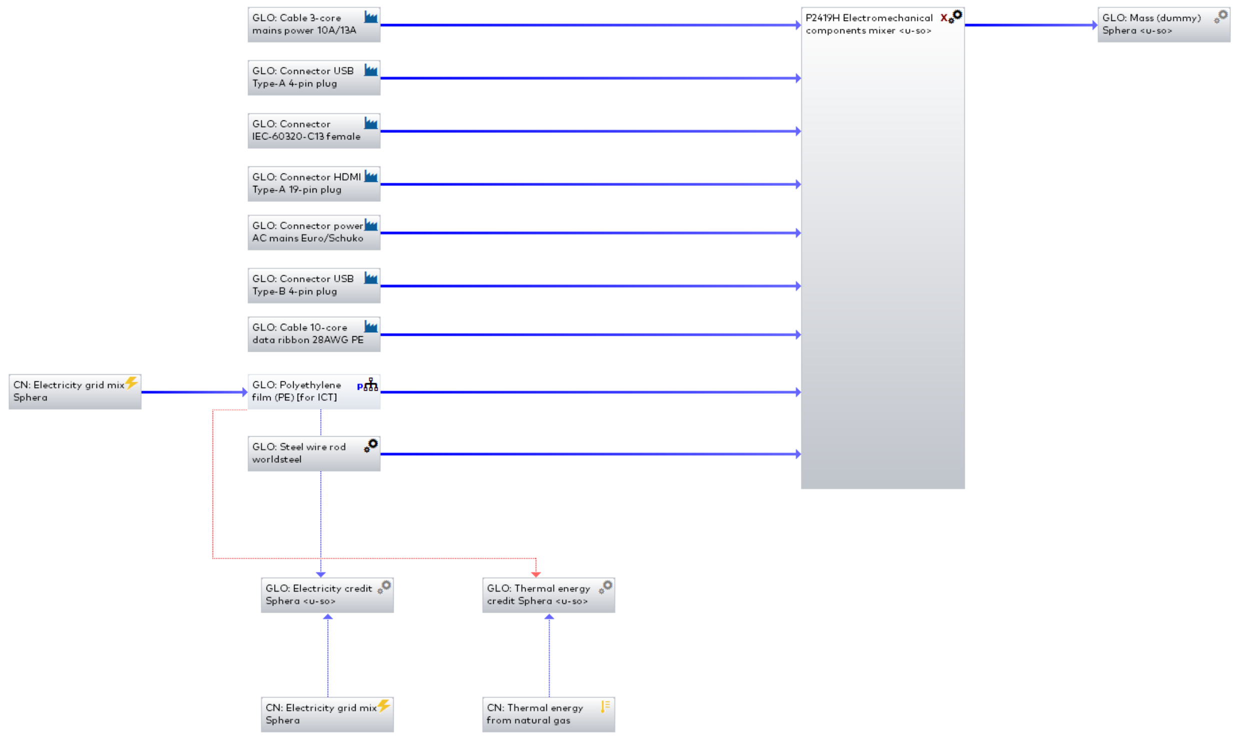

Figure 6-80: P2419H electromechanical components plan model structure

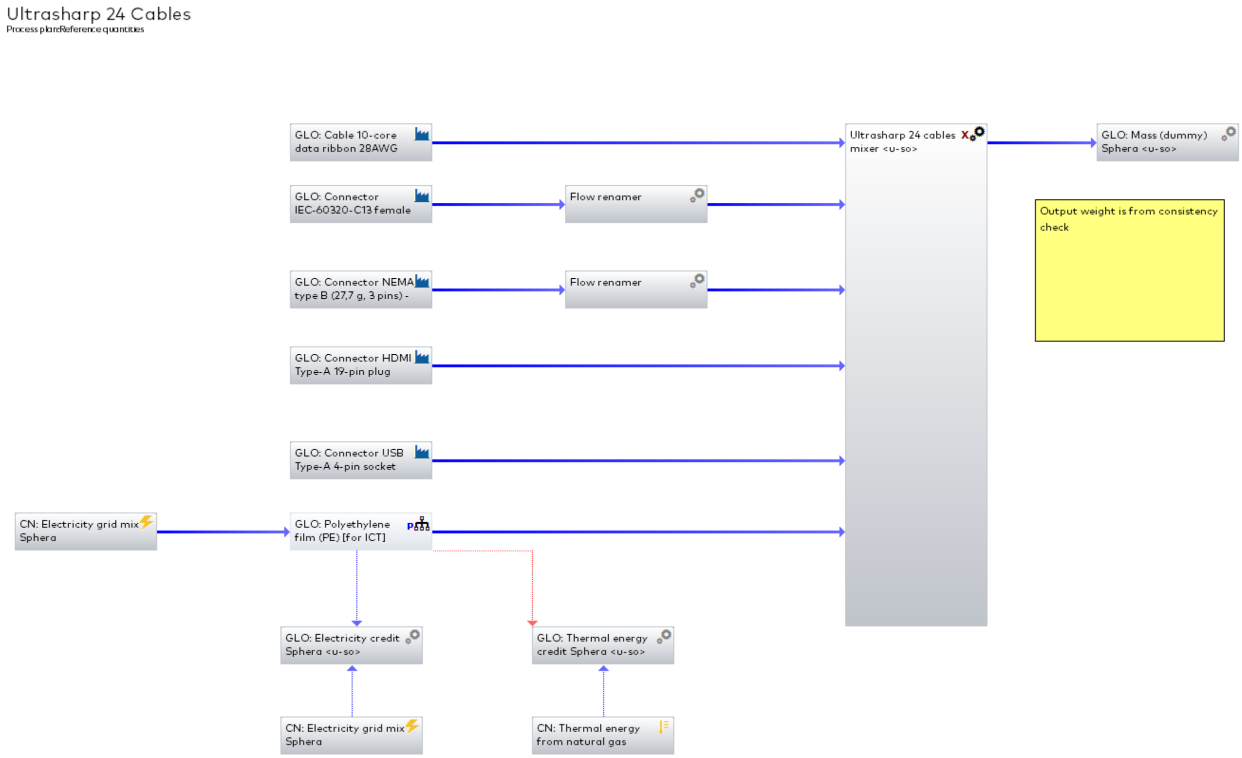

Figure 6-81: UltraSharp 24 cables plan model structure

Figure 6-82: USB-Board selection for different monitor types – UltraSharp 2720Q, P2419H, UltraSharp 274K, UltraSharp 24

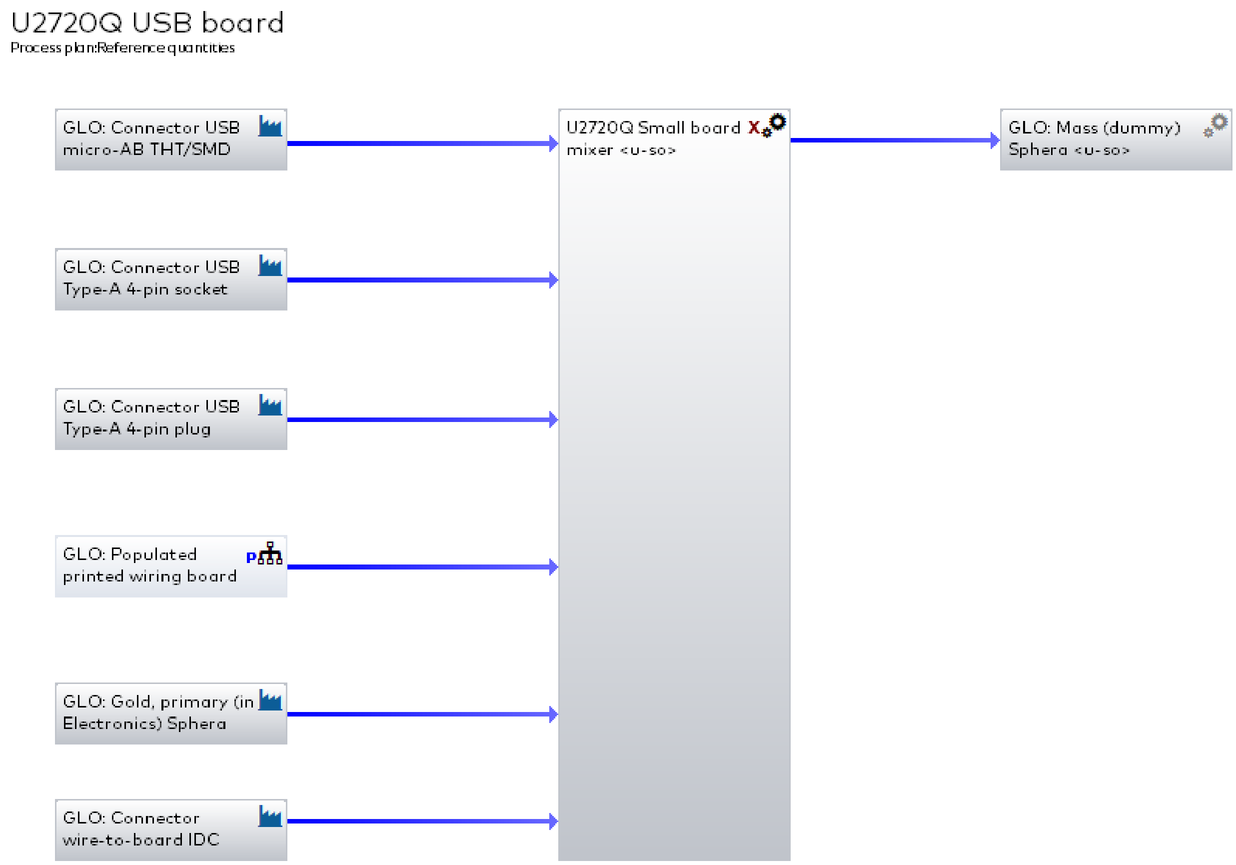

Figure 6-83: UltraSharp 2720Q USB board plan model structure

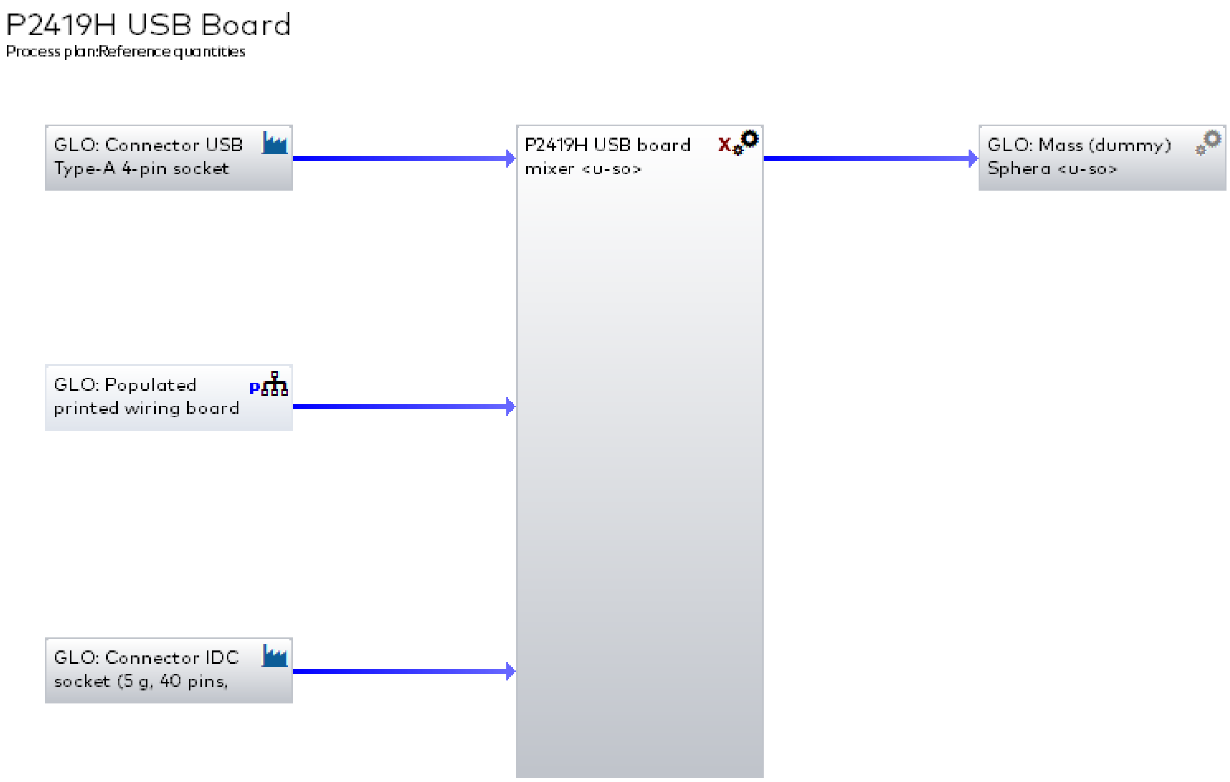

Figure 6-84: P2419H USB board plan model structure

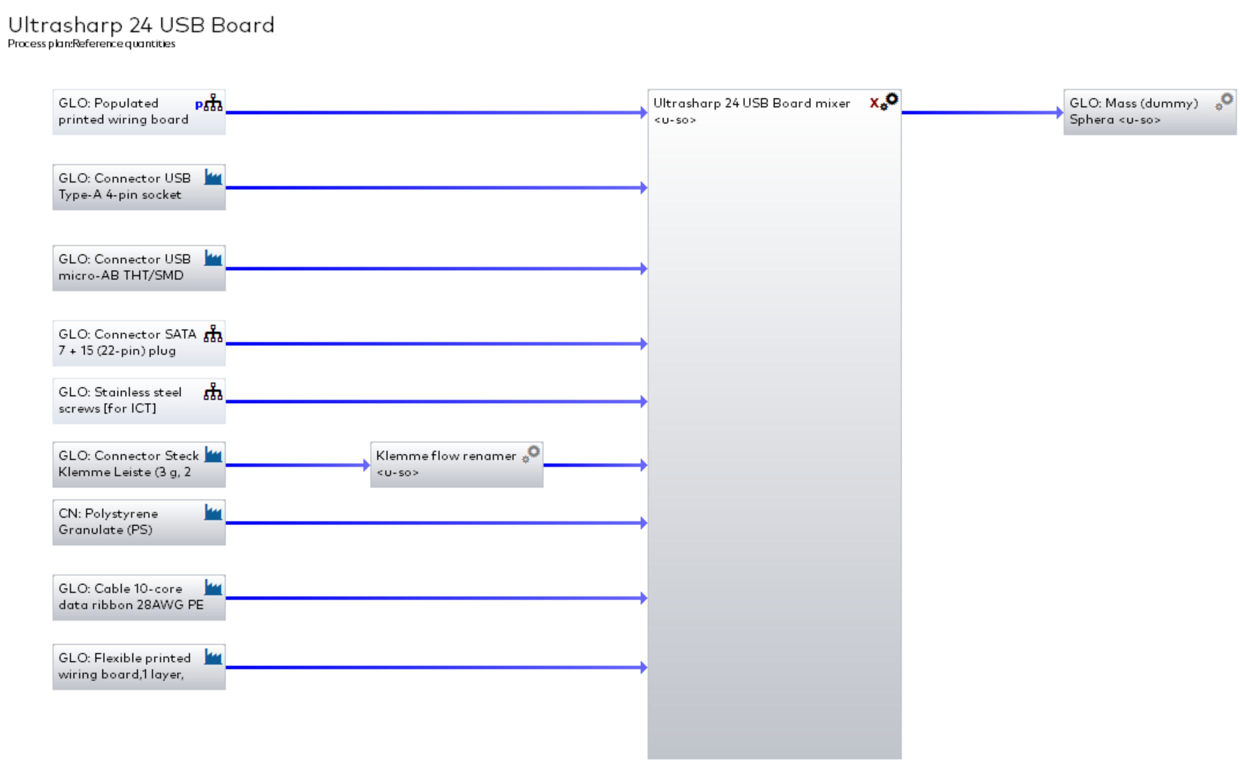

Figure 6-85: UltraSharp 24 USB board plan model structure

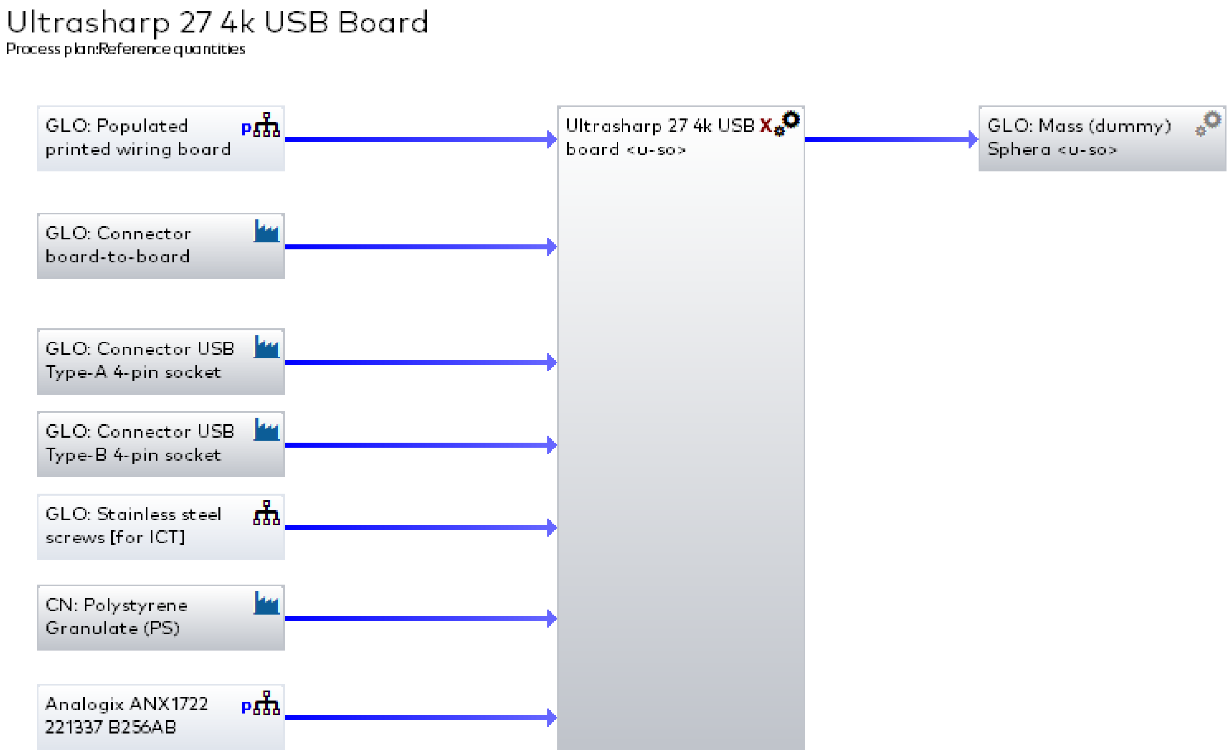

Figure 6-86: UltraSharp 27 4K USB board plan model structure

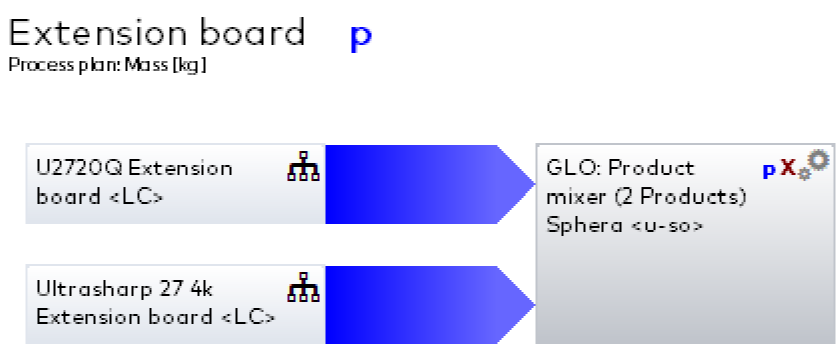

Figure 6-87: Extension Board selection for different monitor types – UltraSharp 2720Q and UltraSharp 274K

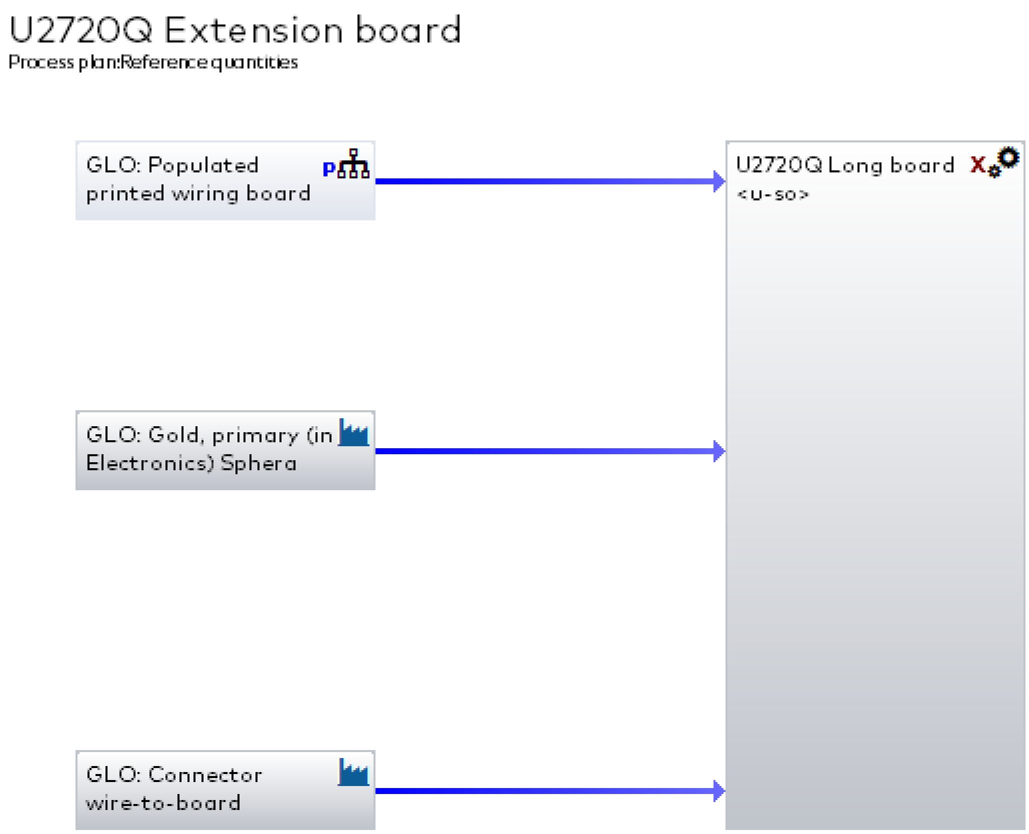

Figure 6-88: UltraSharp 2720Q extension board plan model structure

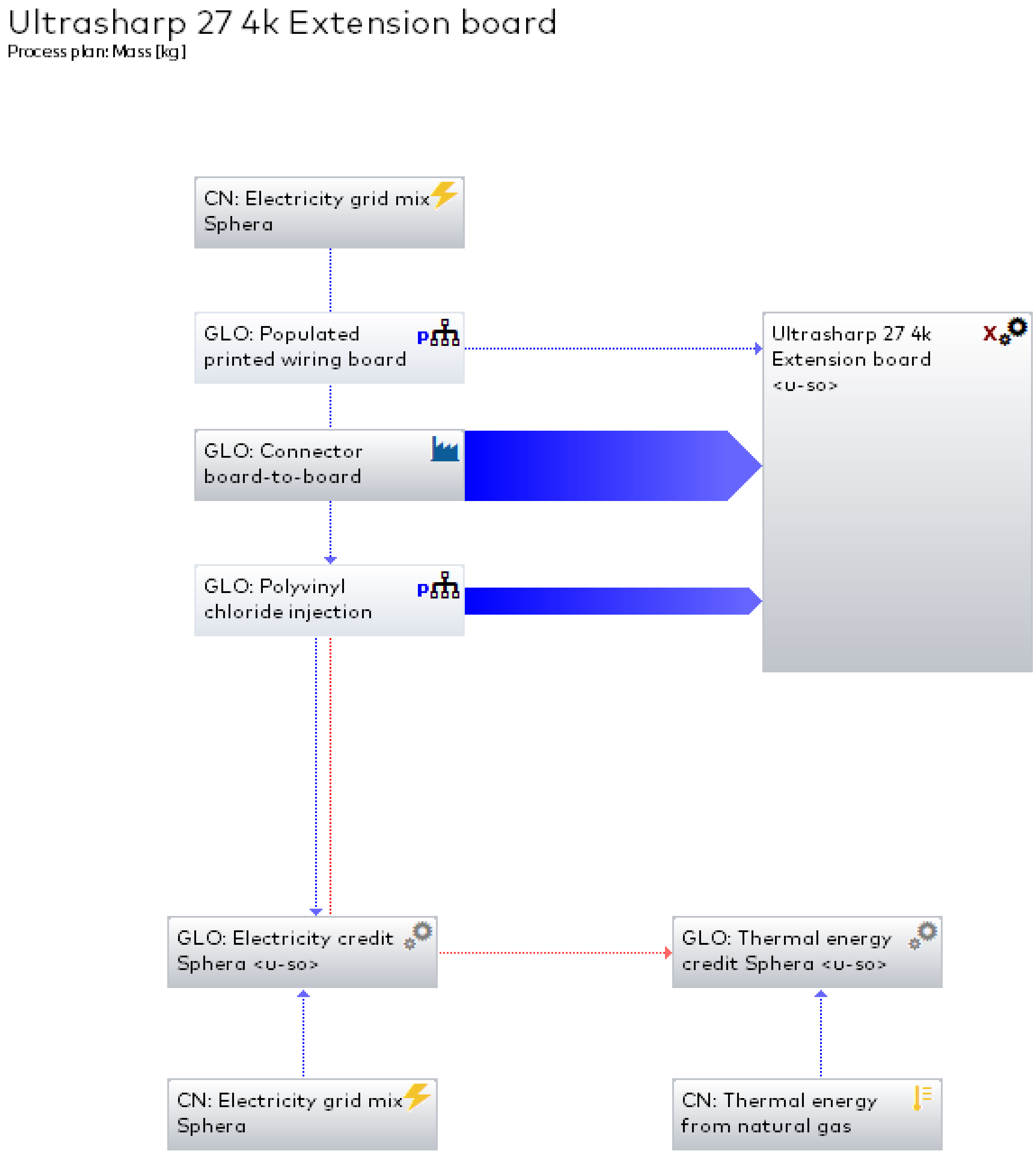

Figure 6-89: UltraSharp 27 4K extension board plan model structure

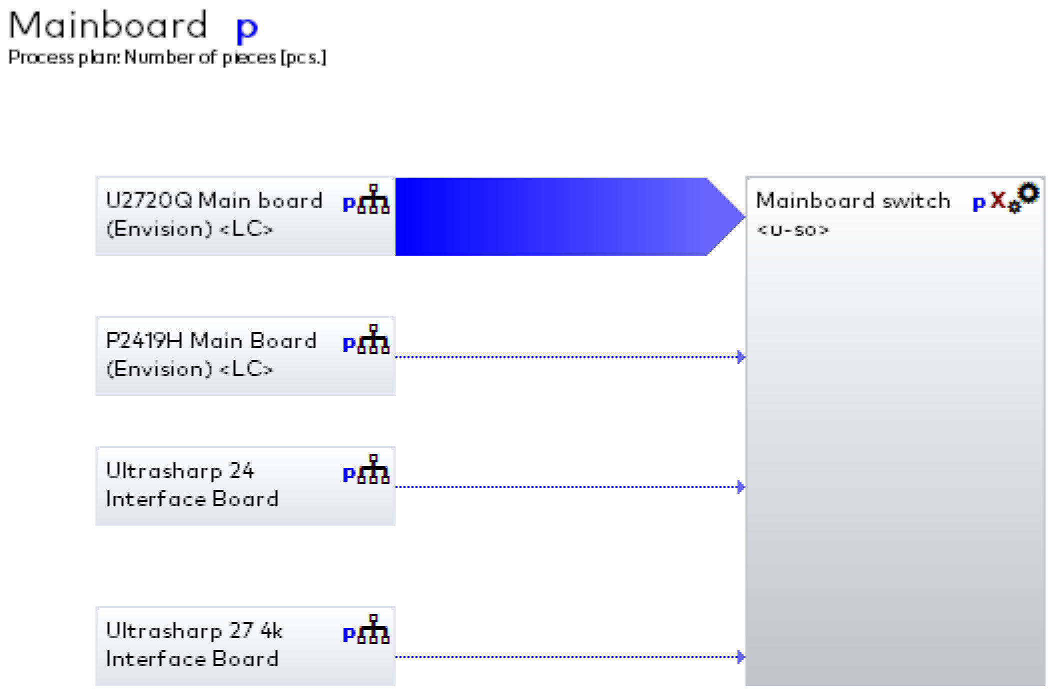

Figure 6-90: Mainboard selection for different monitor types – UltraSharp 2720Q, P2419H, UltraSharp 274K, UltraSharp 24

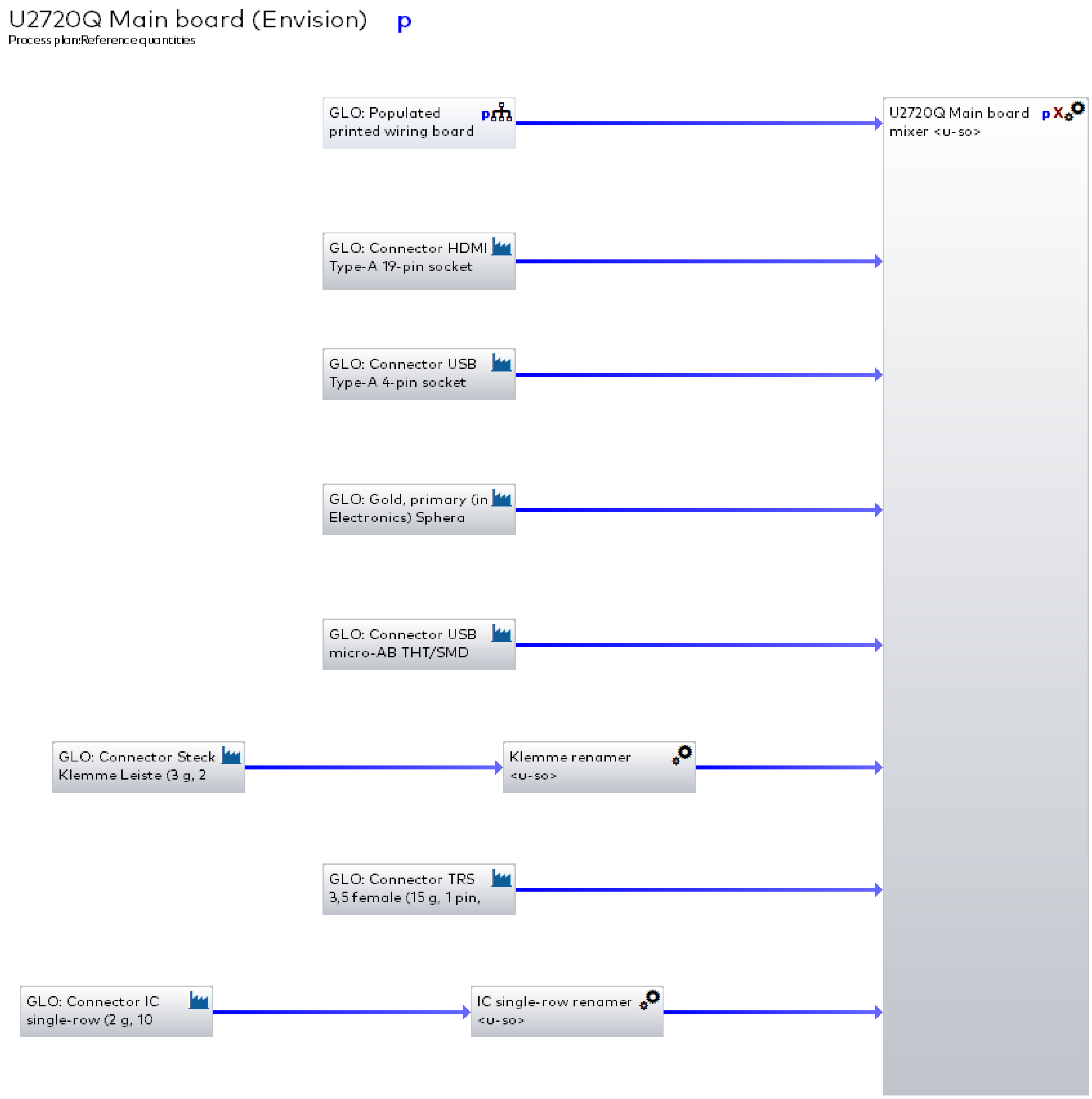

Figure 6-91: UltraSharp 2720Q mainboard plan model structure

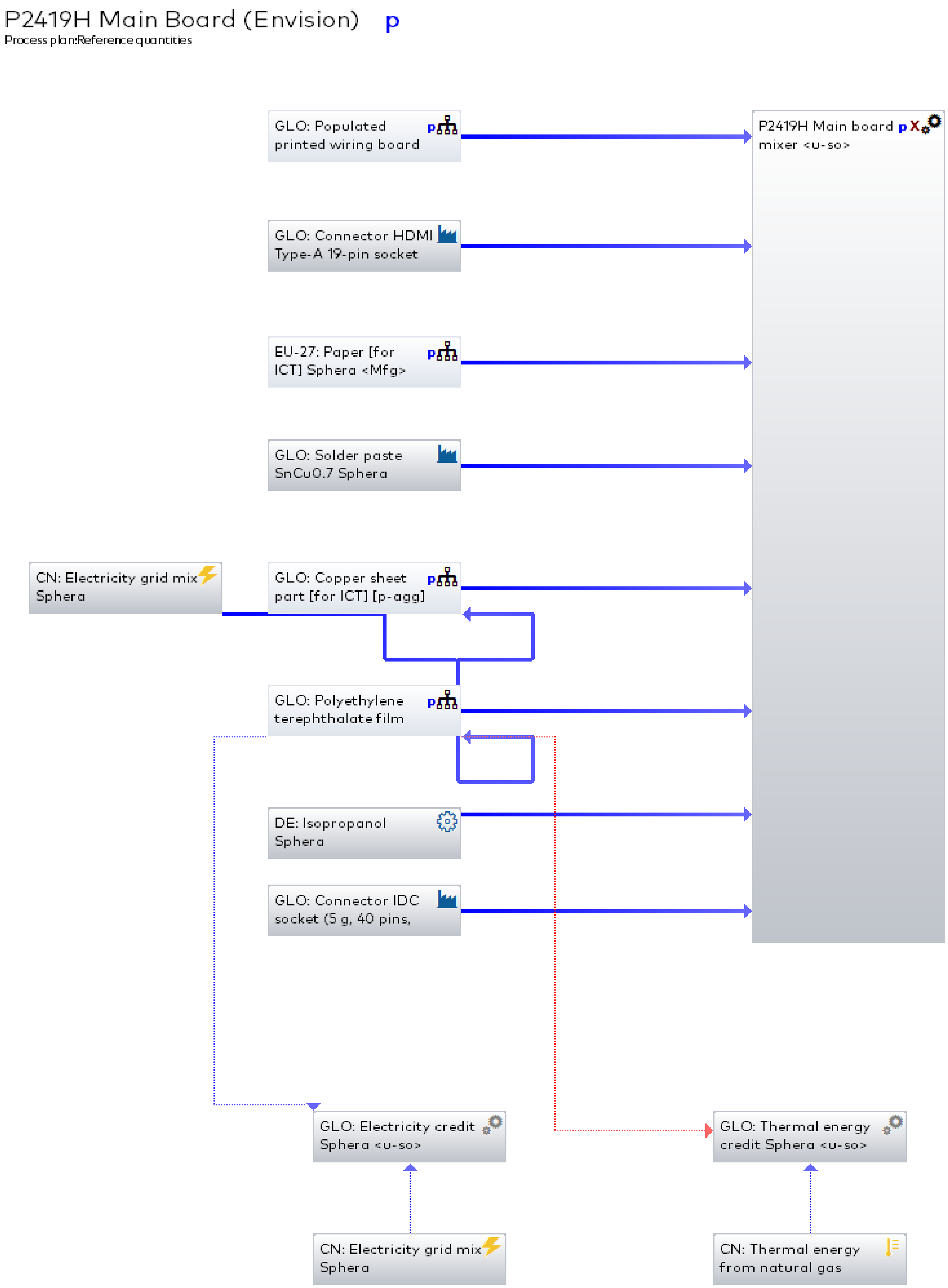

Figure 6-92: P2419H mainboard plan model structure

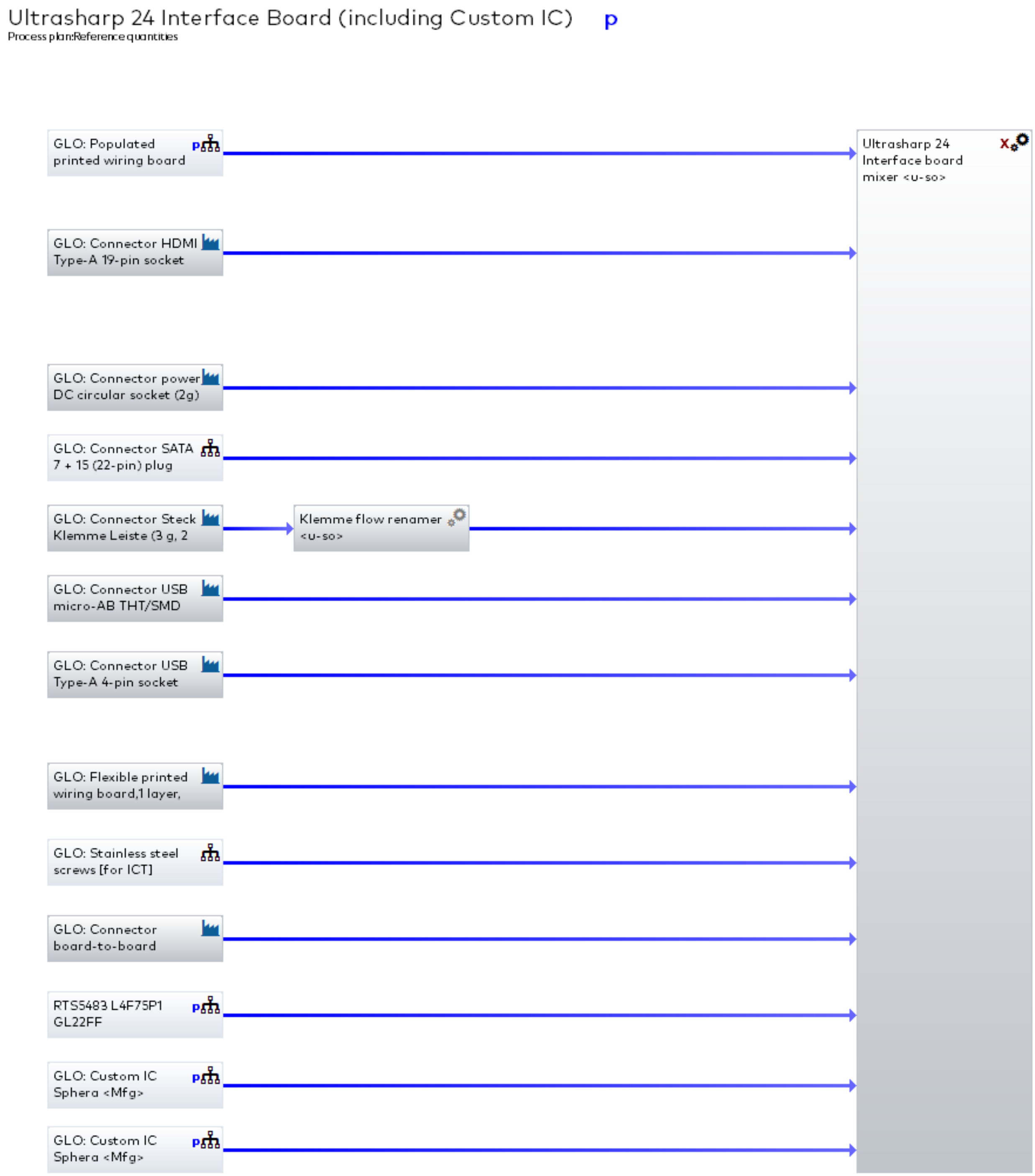

Figure 6-93: UltraSharp 24 mainboard plan model structure

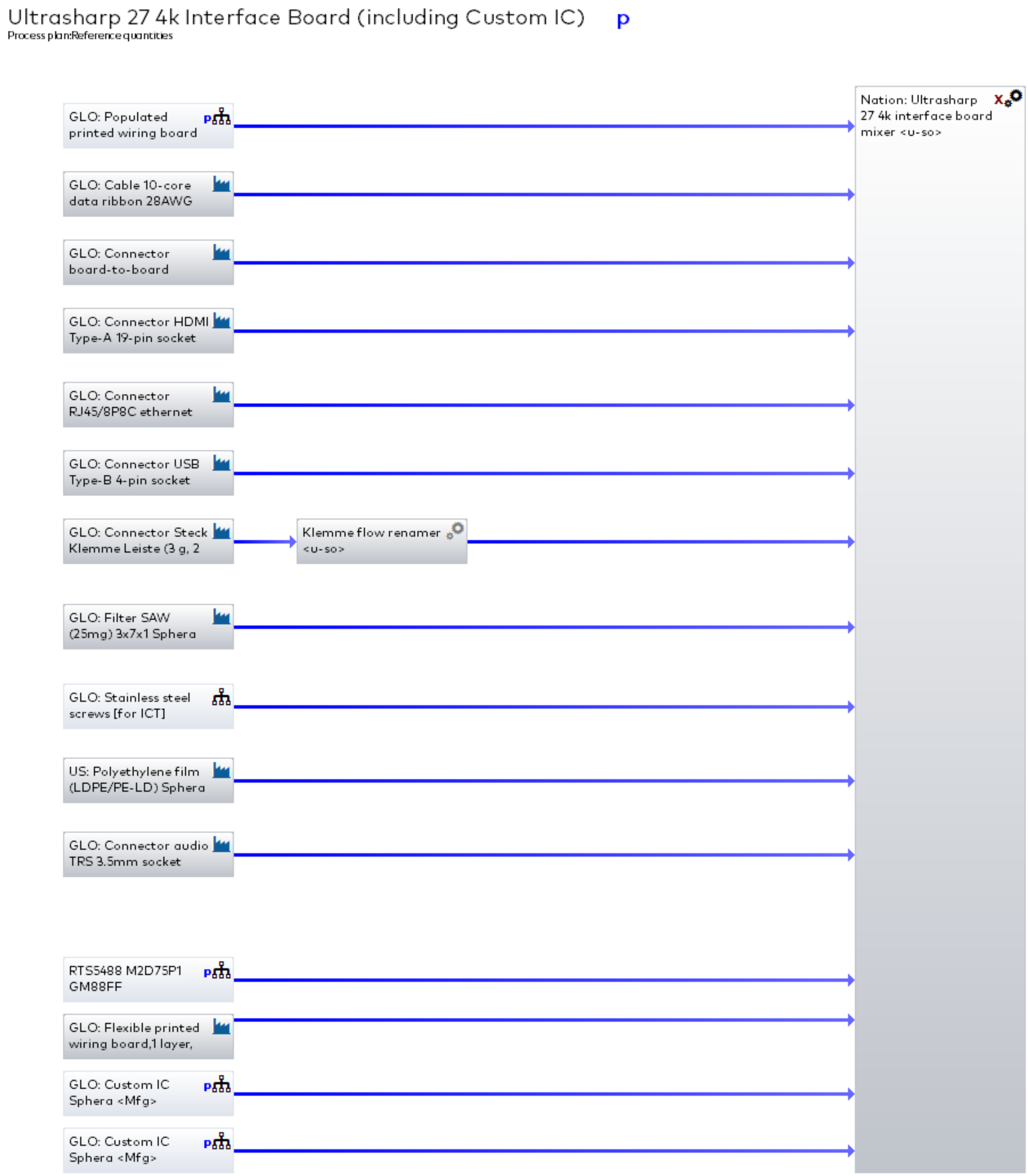

Figure 6-94: UltraSharp 27 4K mainboard plan model structure

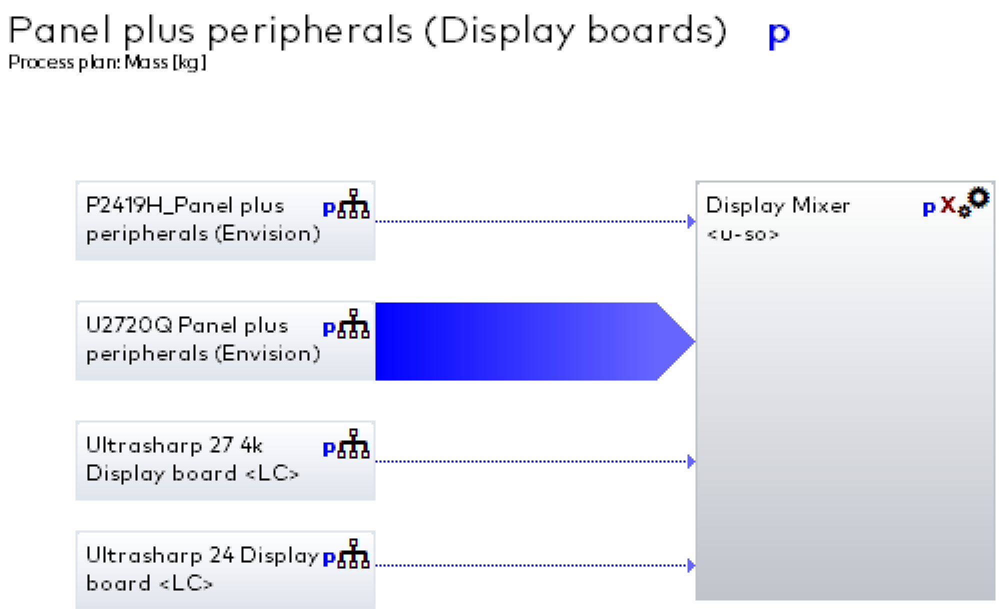

Figure 6-95: Panel and Peripherals selection for different monitor types – UltraSharp 2720Q, P2419H, UltraSharp 274K, UltraSharp 24

P2419H_Panel plus peripherals (Envision) p
Process plan:Reference quantities

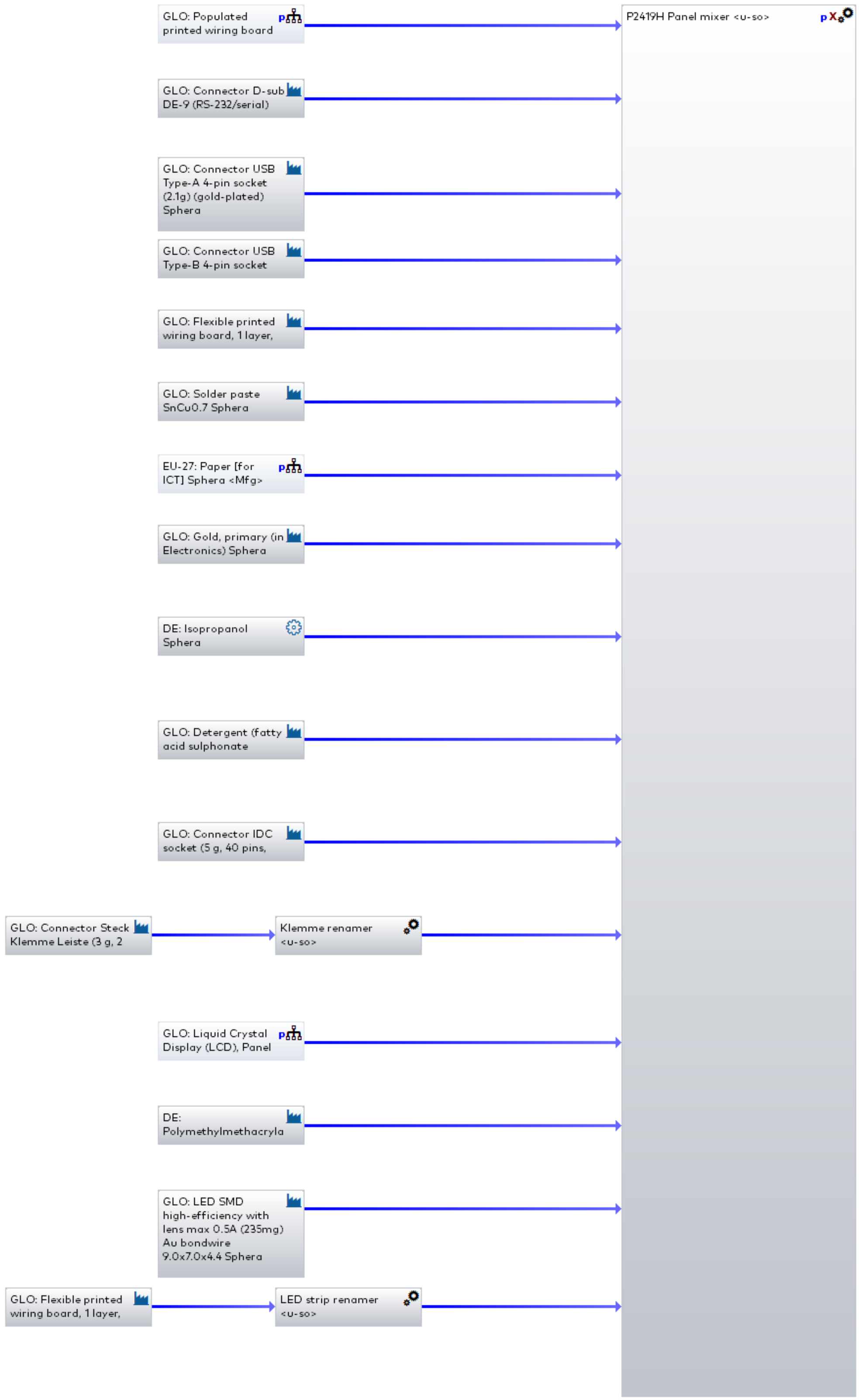

Figure 6-96: UltraSharp P2419H plus peripherals plan model structure

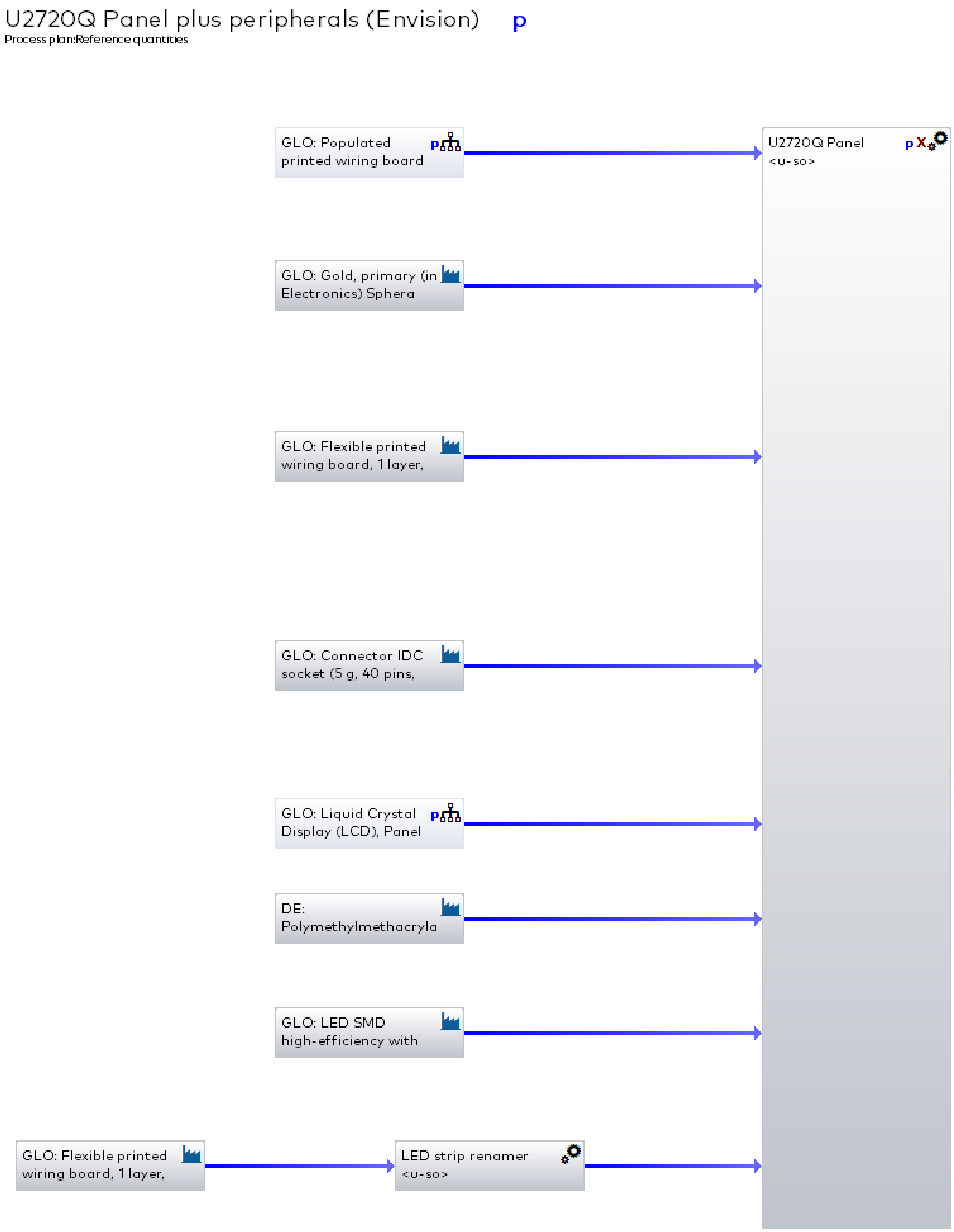

Figure 6-97: UltraSharp 2720Q display plus peripherals plan model structure

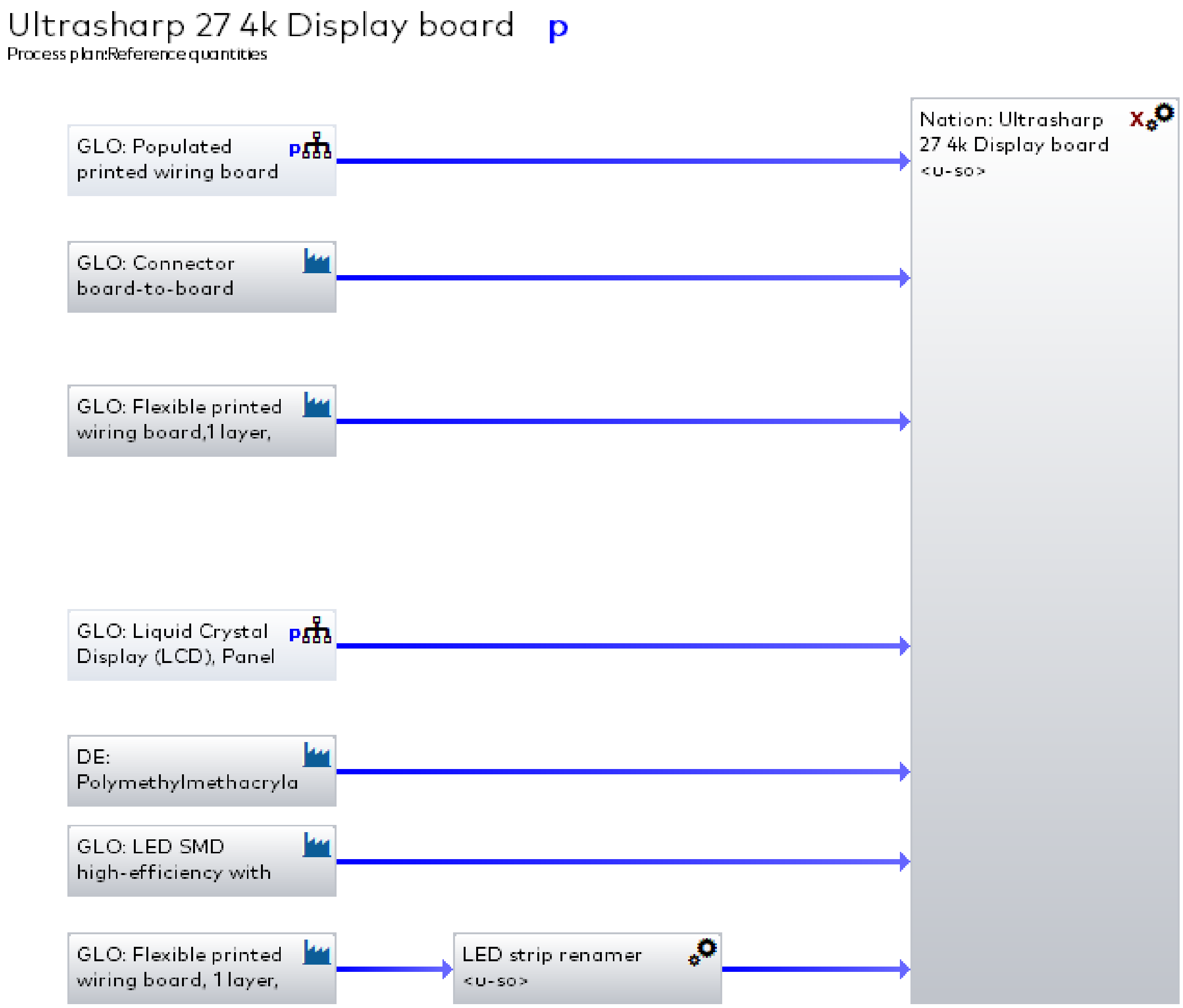

Figure 6-98: UltraSharp 27 4K display board plan model structure

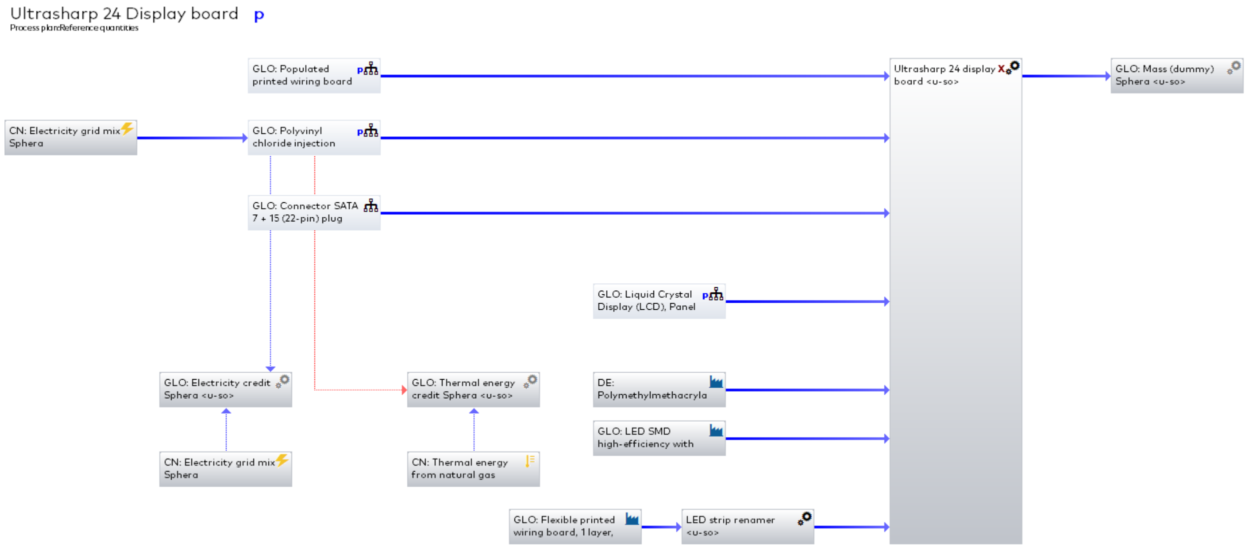

Figure 6-99: UltraSharp 24 display board plan model structure

Mechanical components (Envision) p
Process plan:Reference quantities

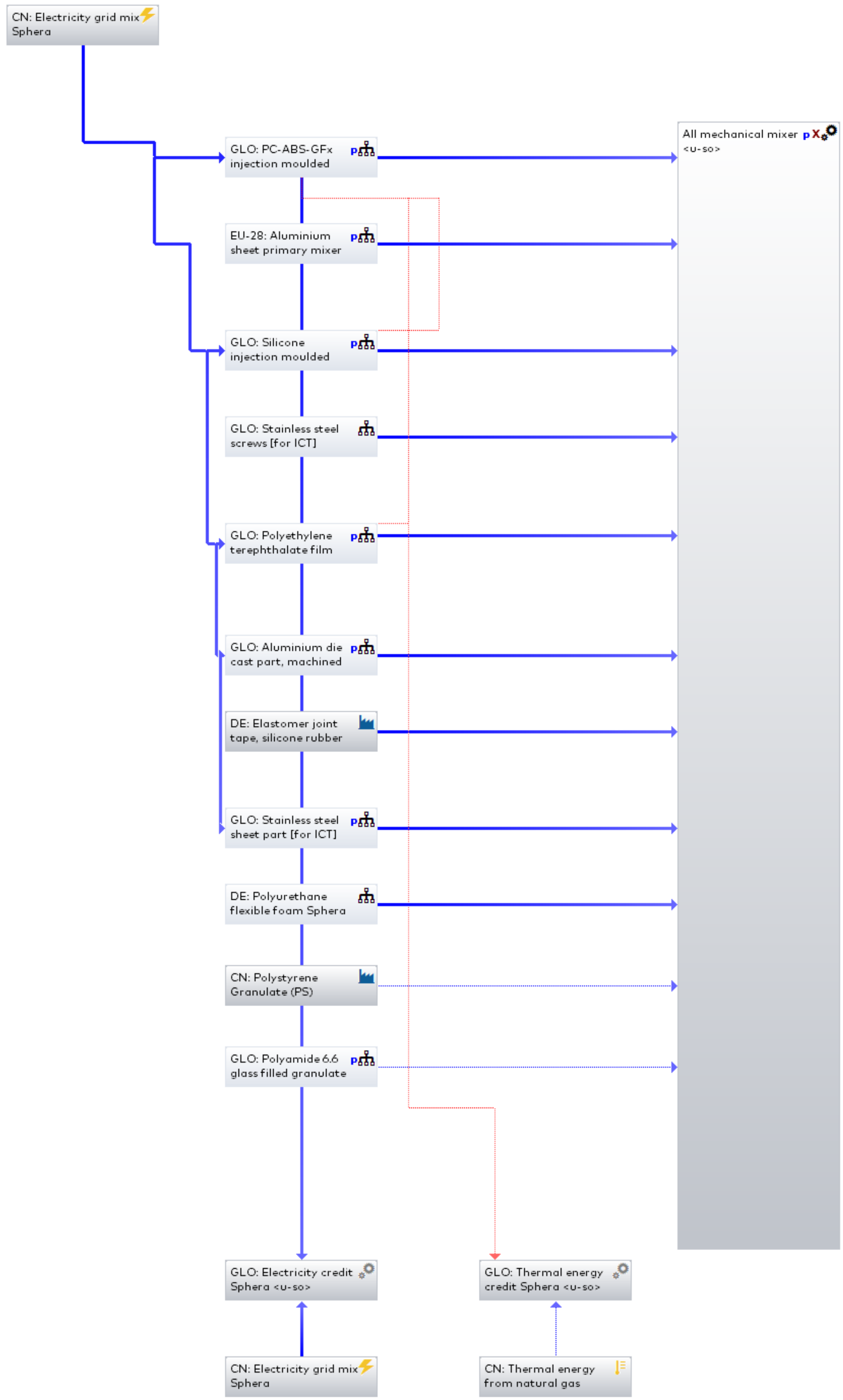

Figure 6-100: Mechanical plan model structure (same for all four monitor types)

Annex D: Additional Documentation

Dell has prepared further guidance on the data collection:

- Data collection sheets (Annex D1: ENV0458 A03)
- Dell's LCA Calculator Tool User Guide (Annex D2: LCA Calculator Tool User Guide)
- Dell LCA-PCF Quality Assurance Document (Annex D3: Dell LCA-PCF Quality Assurance Process)

Please find below the screenshot from the table contents for each document. Each document is saved on the Dell SharePoint and is continuously updated to ensure best possible support for their suppliers in the data collection process.

ENV0458: Product Carbon Footprint Data Collection Template

Table of Contents

LCA CALCULATOR TOOL USER GUIDE
&
WORKING INSTRUCTIONS

Overview

The web based LCA Calculator can be accessed here: https://envision.thinkstep.com/web/login

This document outlines the instructions, processes, and assumptions for PCF modelling using the LCA calculator tool. This document also serves as a work instruction guide to establish a consistent method for modelling Dell Products

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Title: Dell LCA-PCF Quality Assurance Document	
Document Number: RQD0314	**Revision Number**: 1.0
Original Issue Date: January 8, 2024	**Revision Date: Initial Revision**

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