THE HOUSE OF RE-USE

ASML has adopted a circular economy model. To contribute to this, fewer new parts are designed and the re-use of used parts is increased with a goal of more than 95 percent of re-used parts in 2025. The aim is to drive forward to zero waste in mechanical modules – challenging machine builders to create re-useable hardware to be compatible across multiple platforms and able to recondition to One Quality Level while transforming re-use lessons learned into design rules and design requirements. Re-use requires keeping parts both applicable and functional; for as many products within the product platform as possible, for as long as possible. As an example, the re-use of returned metrology frames is considered.

STEF CALON, JAKE PLATZ AND ELENA QUESADA ORTEGA

Circular economy

Since ASML's lithography systems contribute to society by creating faster, smaller, cheaper and more energy-efficient microchips, the Re-use team is conscious of the company's unique position in the semiconductor industry. Although many companies have made great strides along the path to sustainability, there is potential for businesses to become sustainable. With this responsibility, ASML has adopted a circular economy model by restoring hardware to One Quality Level – i.e., re-used parts meeting the same quality level as the original parts – and driving towards zero waste. To achieve this, architects and engineers will focus on keeping products both applicable and functional, for as many products within the product platform as possible, for as long as possible.

Waste can be minimised or prevented by considering three different R-strategies [1]:

1. Reduce: minimise the use of materials in design.
2. Re-use: use parts again and extend the product lifecycle.
3. Recycle: break parts down in different parts or raw materials.

This article focuses on re-use.

Design for Re-use

Design for Re-use consists of 'Design for…' and 'Re-use'. Re-use is defined as using a returned item (e.g., part or module) including its functionality again in the same application (first-time use to equivalent first-time specifications) or a different application (first-time use to future upgrade). Hereby, waste will be minimised when returned parts can be used again.

'Design for' means that hardware is designed such that it can be brought back with or without reconditioning/conversion into a desired condition to be used again to meet the current demand that exists for that item. Design for Re-use contributes to preventing future waste from materialising. To minimise this waste, we look to the House of Re-use.

Re-use design rules

ASML has developed four fundamental design rules to be applied to certain designs scenarios. The design rules and their applications are as follows:

1. There shall be a method to convert or harvest predecessor hardware at risk of excess and obsolescence to a configuration that has demand (preferably the latest). The number of components that cannot be re-used for the redesign versus the predecessors shall be quantified. Apply this design rule whenever redesign is needed.
2. All spare parts shall be repairable. There shall be a feasible repair scenario for all identified failure modes that are not mitigated by design. Apply this design rule for all spare parts.
3. The design of the system infrastructure or system lay-out (e.g., flow and thermal, electronics, volumes, mechanical interfaces) shall be prepared with regards to the planned upgrades. It is mandated to check the roadmap to future upgrades, to minimise the frequency of redesigns. Apply this design rule whenever redesign will be impacted by a planned upgrade.
4. Module design shall be compatible with the next performance node. Check the roadmap with regards to future performance nodes, to minimise the frequency of redesigns. Apply this design rule when a new design is needed, where re-use is not possible.

Circular design principles and the House of Re-use

The principle behind Design for Re-use is to design products such that they can be kept applicable and

AUTHORS' NOTE

Stef Calon (architect), Jake Platz (team lead) and Elena Quesada Ortega (project lead) are all members of the Mechanical Development Re-use Team at ASML in Veldhoven (NL). This article is based on a presentation at the euspen International Conference 2023.

stef.calon@asml.com
www.asml.com
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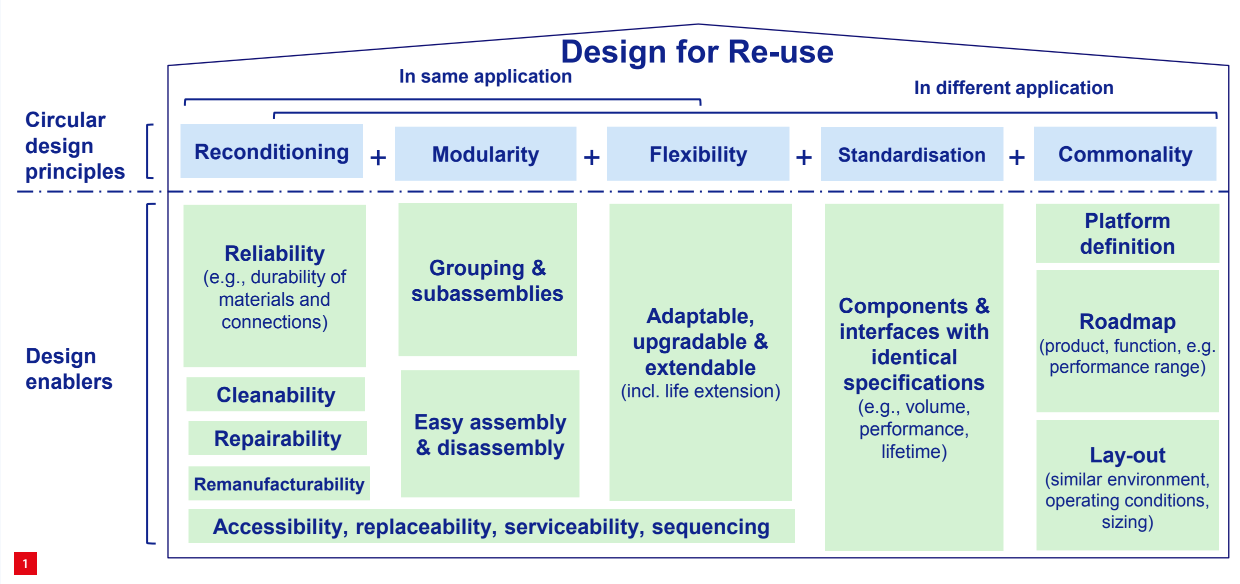


Circular design principles making up the House of Re-use [2].

functional, for as many products as possible, for as long as possible, due to both the compatibility and the reconditioning/conversion capability. The House of Re-use design framework [2] (Figure 1) has been constructed to describe principles and enablers to be used by ASML architects and engineers while designing items with re-use in mind.

As seen in Figure 1, the framework comprises circular design principles and design enablers that are leading to empower re-use during the design phase. The circular design principles consist of:

1. Reconditioning
2. Modularity
3. Flexibility
4. Standardisation
5. Commonality

The circular design principle Reconditioning is necessary to enable re-use. The other circular design principles are helping to design re-useable items.

1. Reconditioning

Reconditioning is a principle for designing items in such a way that after operation, the hardware can be restored to a desired condition. The following design guidelines are related to Reconditioning:

- Ensure ease of access to vulnerable/valuable parts.
- Design for a maximum factor of safety by increasing margins on lifetime and strength.
- Consider using a redundancy approach for critical parts (intentional duplication of high-wear, low-lifetime components); for example, once an alignment mark of sensors has degraded the system switches to the redundant one in order to extend life of the sensor.
- Design critical components with regards to potential performance risks; for example, increase dimensions where critical mechanical load is expected.
- Consider designing with higher wear resistance.
- Allow easy access and removal of the fasteners using standard ASML tooling.
- Consider assembly of components in a chronological sequence.
- Limit the variety of tools required.
- Consider the separation method, including tooling, when designing a fit between two parts.

2. Modularity

Modularity is a design principle focused on creating separable (sub-)modules. This is done based on interfaces and can be defined considering lifetime (reliability), maintenance, functionality, risks (e.g., risk of part failure), or upgrade time that is required to swap or change a module instead of changing the entire hardware. Grouping components and creating subassemblies during the design phase is a process of sub-dividing a complex system into smaller, more manageable modules. The modules can be defined and designed based on the module characteristics described in Table 1.

'Easy assembly & disassembly' (Figure 1) suggests that the modules should have an interface with each other so that they can be replaced easily. Practical examples may be demonstrated by locking systems, bolted constructions, and plug and de-plug constructions that enable easy (dis)assembly.

Table 1
Overview of modularity characteristics.

Module characteristic	Reasoning
Lifetime (reliability)	Module consists of items with similar lifetime. Therefore, this module can be replaced in one action.
Maintenance	Module consists of items with similar maintenance intervals. Therefore, this module can be maintained in one action.
Function	Module consists of sub-components, which combined together could perform a specific function.
Risk of unproven design (upgrade)	Module consists of new items, which do not yet prove the functionality or performance.
Risk of components failure	Module consists of items that contain a certain risk of failure.
Upgrade	Module consists of items that are able to adapt to changing conditions
Recycling	Module consists of items with similar materials, for example, material value.
Manufacturing	Module definition is based on manufacturing possibilities. It can be easier to manufacture a part with smaller dimensions than parts with larger dimensions.
Change	Module consists of components that can be used again in similar or other platforms, products, or other modules.
Specific configuration	Module consists of components that can only be used for a dedicated product.

3. Flexibility
Flexibility is a design principle concerned with designing items so that they can be modified based on changing conditions, requirements or environment. The following design guidelines are related to Flexibility:
- Use material and assembly methods that do not prevent upgrade and rebuilding of the product.
- Structure the part or module to facilitate ease of product upgrade.

4. Standardisation
Standardisation is a design principle focused on designing items that are compatible within other applications or configurations. The goal is to design items in such a way that they match the requirements of multiple applications, which implies that standardised items can be interchanged between different applications (e.g., modules, platforms). This can be done by defining components and interfaces with identical specifications. The following design guidelines are related to Standardisation:
- Standardise modules on multiple levels.
- Standardise components.
- Simplify and standardise component fits.
- Standardise interfaces.
- Standardise volume.
- Standardise performance.
- Standardise lifetime.

5. Commonality
Commonality is a design principle focused on designing hardware products and modules so that identical modules and components can be used for different purposes (e.g., a vacuum pump being used in two different modules). Commonality serves the purpose of roadmap development considering multiple applications (backward, current and future). The following design guidelines are related to Commonality:
- Ensure a long-term roadmap is available.
- Refer to the roadmap to prepare for the next-node design.
- Freeze module and component dimensions for multiple generations.

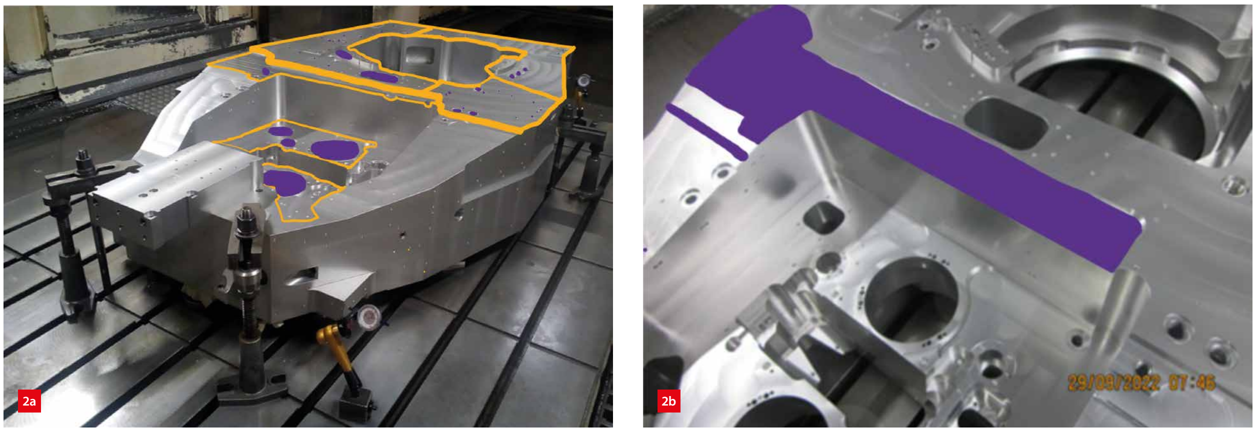
Application example: DUV metrology frame

ASML is currently applying the circular design principles in all projects and designs, specifically the deep-ultraviolet (DUV) metrology frame. The metrology frame is the carrier frame for the projection lens. Other mounted parts include all measuring systems needed for measurement and/or positioning of the reticle-chuck, lens, wafer and wafer-chuck, as well as immersion components and contamination- and temperature-control units.

This metrology frame has been returned for upgrades and is incompatible with any successor or predecessor systems. The Re-use team investigated the successor system and analysed what had to be changed to make it applicable. When doing nothing, the entire metrology frame would have to be scrapped, leading to 13 tons of scrap each year.

By identifying the additional features needed, marked by the purple colour in Figure 2, the team confirmed what had to be machined in order to make it compatible to both the predecessor and successor systems. During this investigation, the team also identified that the water-cooling channels needed to be cleaned during each rework cycle to remove corrosion build-up. In collaboration with ASML's fluid-infrastructure architects, the Re-use team defined the 0.1 mm of parent material removal per cleaning using sandpaper polishing. Additionally, the team identified as an improvement opportunity the design of easy-access water channels to ensure cleaning as a permanent design guideline. This design guideline has now been embedded within the Fluid Infrastructure team to ensure re-use capabilities on all future systems.

Prior to re-use, these metrology frames were machined with only the features and interfaces needed on the target system, thereby limiting their forward and backward compatibility potential. The Re-use team confirmed and proved that it was not only more effective, but also cheaper to machine all interfaces to make the metrology frames compatible with multiple possible systems. Furthermore, it will improve



Analysis of the changes required to make the DUV metrology frame applicable for re-use. The orange colour indicaties potential interface plates as lessons learned for future designs. Additional features needed are marked by the purple colour.
(a) Overview.
(b) A zoom-in of the middle part.

interchangeability of matching hardware, depending on the target system's needs. Taking into consideration the compatibility of interfaces in the early design phases ensures metrology frames can be re-used as much as possible.

Conclusion

Re-use is a core part of ASML's sustainability strategy. Using the circular design principles defined, re-use is leading the way to achieving the goal of ninety-five percent of re-use parts by 2025. Our ambition of making all our parts and modules both applicable and functional has proven to be successful, with 13 tons of scrap saved from the metrology frame alone.

Approaching designs with Reconditioning, Modularity, Flexibility, Standardisation and Commonality in mind will increase savings by using materials again, minimise risk of scarcity, save design effort, minimise CO_2 footprint, and prevent further landfill. ASML is embedding re-use circular design principles in the way of working for all new and existing designs. By expanding re-use across all projects these savings and benefits will grow exponentially, creating a more sustainable world for ourselves and future generations.

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