GIVING PURPOSE TO RECLAIMED INTERIOR BUILDING MATERIALS IN THE TRANSFORMATION OF BUILDING 22 OF TU DELFT

By the use of R-strategies Refuse, Reuse, Repair, Repurpose and Recycle

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ABSTRACT

The building industry waste and transportation can be reduced by reclaiming building components. Building 22, Applied Physics on the Campus of TU Delft can be transformed into student housing and public functions by using reclaimed building components of the existing building, in order to achieve the environmental ambitions of the TU Delft and to strengthen the relationship with the city regarding. This research assesses the potential of various interior building components by means of R-strategies for the future functional needs. By distributing the building components amongst the five R-strategies, a basis for a vision of the future of this building can be derived. This case could be an example for reducing costs and be a road towards a more sustainable building industry.

KEYWORDS: *r-strategy, reclaimed components, reuse, repurpose, recycle, building industry waste,*

I. INTRODUCTION

Waste is usually seen as a negative result of producing or living. In the Netherlands the amount of waste produced by the building industry is almost a quarter of all produced waste (CBS, 2019). Although the Netherlands recycles relatively a lot of its produced waste, the efficiency of it is not ideal due to value loss. Furthermore, the emissions of transportation, in which the building industry plays a large role, are rising and the rate of rising is expected to increase (Mathur & Farouq, 2021). Using building components from existing buildings in its original way, an adjusted way or a totally new way, could be part of lowering the carbon footprint of construction. This will not only decrease the need for new materials, but also lower the need for transportation.

The Campus of the TU Delft contains some buildings that are outdated and correspond therefore no longer to today's standards. Furthermore, the TU Delft has the ambitions to become CO_2-neutral before 2030 (T. Blom & A. van den Dobbelsteen, 2019). In order to achieve this goal, amongst other things, some of the buildings need changes to comply with the set standards of 2030. Building 22, Applied Physics, is one of these outdated buildings. The faculty that currently occupies the building will move to a new building that will be constructed in the coming years in the southern part of the campus. Therefore, the building will lose its purpose and has the potential for transformation, since the TU Delft prefers not to demolishing buildings on campus. The TU Delft recently announced that they want to expand the number of students with 40% (Schouten, 2022). The shortage of housing in the Netherlands is a problem and will continue to be a problem in the coming years ("'Woningtekort Wordt Komende Jaren Alleen Erger'," 2022). Furthermore, a housing agreement has been made by the government to provide a million more houses between 2021 and 2030 indicating the general need for housing. This emphasizes the challenge to provide students with housing, if they want to attract students to study at the TU Delft, besides enlarging the campus on educational functions. The TU Delft has the ambition to add more non-educational functions as well. Implementing more public functions will make the campus more lively outside educational hours. Moreover, the Campus would get a stronger relation with the city itself, commuting gets reduced and energy use more balanced (T. Blom & A. van den

Dobbelsteen, 2019). Transforming the building to student housing and some public functions will fulfill the current and future needs of the campus.

Using building components of an existing building in the transformation, is a way to make the construction industry more sustainable. Research into reusing and recycling building components of the building envelope for this specific case, Building 22, has already been conducted (Scheenaart, 2021). However, because of the changed function due to transformation, the interior needs adjustments as well. Hence, this paper will focus on the ways interior building components can be used in order to fit different functions due to transformation. This poses the following research question: *How can reclaimed building components from the interior of building 22 Applied Physics be purposed for the transformation from educational function to public function and student housing?*

The research question will be answered by means of the following sub-questions:

1. What repetitive building components can be reclaimed from the interior of building 22 Applied Physics?
2. What are the requirements for the building when changing it from educational function to public functions and student housing?
3. How can existing interior building components be purposed in order to fit the needed interventions?

The research creates an inventory of what building components are becoming available from reclamation when transforming Building 22. Besides that, it will lead to a methodology to find out how reclaimed building components can be purposed from existing buildings.

II. METHOD

To create an inventory and developing a methodology of reclaimed interior building components of Building 22 on the TU Delft campus, analysis and literature study is conducted. The data obtained by observation on site and plan analysis provides an inventory of interior building components. For reuse of building components it is relevant to evaluate the viability. The indicators of viability are the availability, the effort it takes to detach and repurpose and the future potential of the components (Addis, 2012). In case of transformation, the effort that goes into detachment has to be assessed in a way that makes clear whether it is more feasible and practical to keep the component in place or remove it in order to use another strategy to reuse it. Moreover, the harvested components will stay on the same site as the new building, which is logistically cost efficient, but also reduces the identification, sourcing and planning problems (Gorgolewski & Moretin, 2009). The assessment of the components will first of all be about the availability. More importantly, there will be a focus on how the components can be (re)purposed, rather than whether the components can be (re)purposed or not.

Based on the quantity, the components are researched in depth to understand their potential future purpose within the transformation. The functions of the new building after transformation will lead to different interior needs in terms of layout and components. Therefore the future functions will be explained to be able to assess the building components.

Every component will be assessed on the potential of what kind of purpose it could have, by using R-strategies. R-strategies are approaches to achieve less resource and material consumption to make the economy more circular (Potting et al., 2017). Combined, these R-strategies form R-lists that establish a priority order for waste treatment methods. Nine possible R-strategies are Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover (Appendix A). The order goes from the most to the least sustainable option. In this research a few of these strategies will be left out or combined. The strategies Rethink and Reduce refer to situations that do not involve existing elements. The strategies Refurbish and Remanufacture barely differ from the strategies Repair and Repurpose and will therefore be combined. The strategy Recover has no applicability within building transformation and will therefore be left out of the research. The five R-strategies that will be explored are Refuse, Reuse, Repair, Repurpose and Recycle. These R-strategies are related to how they apply in this case of transforming a building as shown in table 1.

R-strategy	Definition
Refuse	The building component will stay in place without change and serve its same purpose.
Reuse	The building component will serve the same purpose, but removed from its original position and put somewhere else.
Repair	The building component will serve the same purpose, but will be changed and/or repaired to make sure it can serve its purpose in the new situation.
Repurpose	The building component will be used with a different purpose, with or without changing the component.
Recycle	The building component will be disassembled and the individual materials will be taken to factories that turns it into new components that can serve a purpose in the new building.

Table 1 - Definitions of R-strategies within this research

III. Inventory

The interior building components that are assessed are chosen because of their repetitive appearance in the building. The following seven components are being assessed: Doors, floors, ceilings, interior partition walls, windowsills, lighting and sanitary as shown in figure 1. Detailed information about the components can be found in Appendix B.

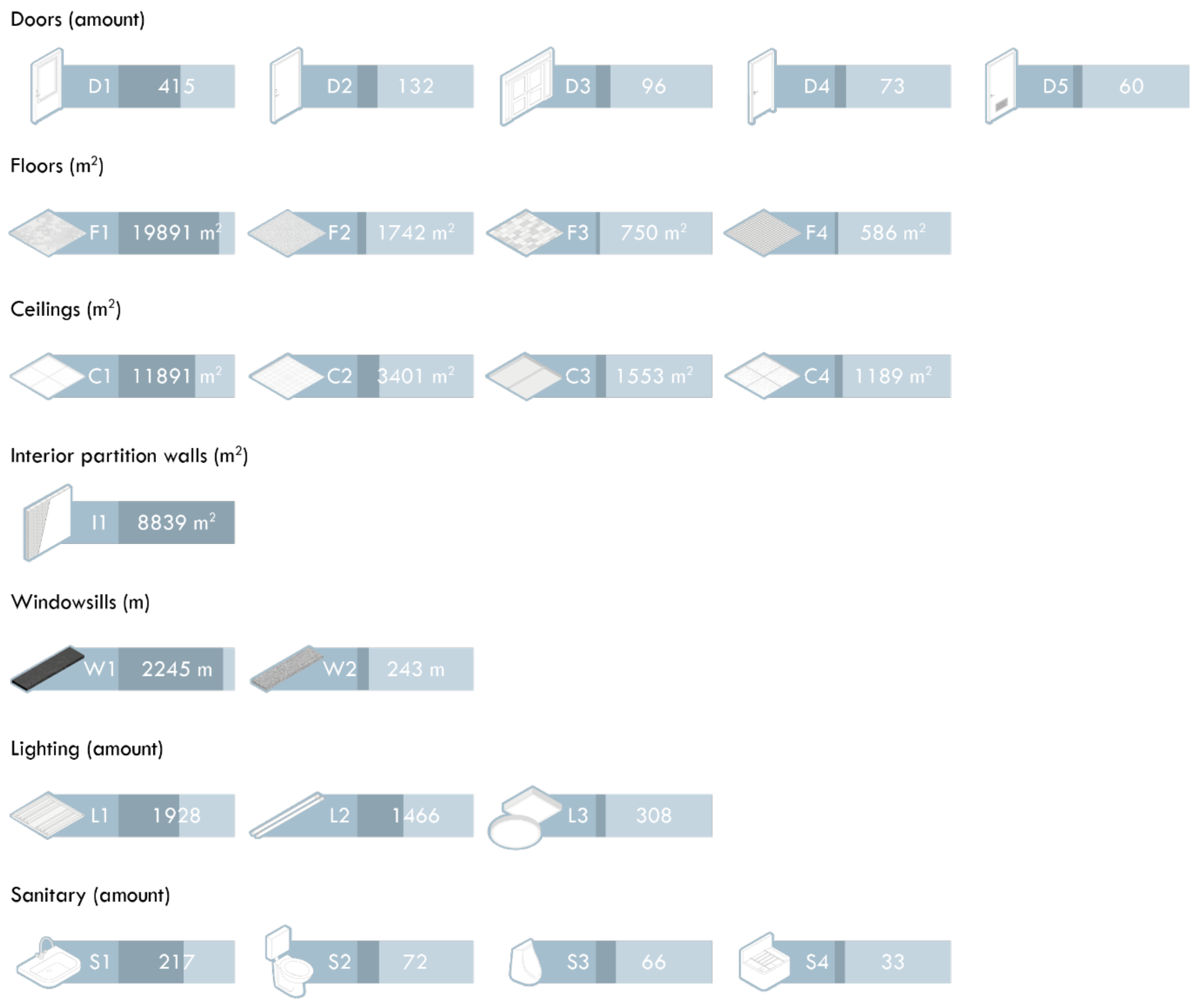

Figure 1 – Inventory of seven interior building components of Building 22

3.1. Doors

The building has a total of about 800 repetitive interior doors. There is a large diversity of door types in the building, but only five types exceed the amount of fifty doors. Those five types will be assessed on their potential. Some of the remaining doors do have similarities with the assessed doors and can therefore be still of value for one or more of the proposed R-strategies.

3.2. Floors

The building has an area of about 42,000 m^2 in total. The total area of recurring floors is about 26,000 m^2. The difference between the total building area and the recurring floors is due to other elements such as walls taking up space, the basement that has no flooring and a few other types of floors that take up too little space to take into account. The hallways and almost all adjoining rooms have linoleum floors. A small part of adjoining rooms have carpet. Central spaces with entrances and stairwells mainly have natural stone as flooring. Parts of the basements and spaces like toilets have small tiles.

3.3. Ceilings

Except a few spaces in which the structural floor above is visible, suspended ceilings behind which a lot of the installations, ducts and wires are hidden, recur throughout the entire building. The estimated area of recurring usable ceilings is about 18,000 m^2. Besides a few other types that also include suspended ceilings, almost two third of the ceilings are drop ceiling tiles in a square system. Except from the foam that is used in the halls with stairwells, there is no clear distinction between the other systems on where they are used.

3.4. Interior partition walls

The floors of the building are supported by concrete columns that are structured in a grid. The columns are placed along the façade and on the inside the corridors are located between the inner columns. Between the columns interior partition walls are placed to separate the rooms. Most of these partitions walls, which are not load-bearing, are made of a solid material. Based on original drawings, it is assumingly brick walls, and otherwise lime-stone or other stone-type walls, covered with plaster. These walls occur in repetition with a length of 5.4 meters and a height of 3.3 meters with a total of about 8,000 m^2.

3.7. Windowsills

There are only two types of windowsills in Building 22. From the ground floor up to the third floor, all windowsills are made from black natural stone. The windowsills on the fourth floor are made of sleek concrete elements, made of a mixture of different types of natural stone, looking a lot like the concrete elements on the façade of the building. In total there approximately a total of 2,500 meters of windowsill in the building.

3.5. Lighting

The building has a large variety of lighting from single tube lights to decorated fixtures. However the vast majority of lamps are tube lights without or with several fixtures. In the corridors and rooms along the corridors tube lights are used, mostly without fixture, unless the ceiling type is a system in which fixtures fit. The total amount of lamps that exceeds the number of 200 is 3,700.

3.6. Sanitary

Striking in the sanitary of the building is that it has a lot of sinks, not only in toilets and in kitchen blocks, but also in other spaces. These sinks, of which 2 types are frequently found, are in the corridors and laboratories. Besides sinks, toilets and urinals are frequently recurring in the building.

IV. FUNCTIONAL NEEDS

When Building 22 changes its function from education to housing and public functions, the requirements of components might change. For all new functions a general description helps to determine the possible R-strategies that are applicable. In Appendix C, a preliminary expectation of the division of functions is shown.

4.1. Student housing

The majority of students that live in Delft with five or less housemates that want a different household, prefer a house with a larger amount of people (Scholts et al., 2020). Above six students per house, the majority of people that want another household, prefer less people per house, although in all situations the majority is content with the amount of housemates. Although most of the students prefer a larger household, the diffusion of responsibility generally increases when a group gets larger (Britannica, 2016). In student housing this results in a lack of maintenance, which has a unfavorable influence on the lifespan of the housing units. Therefore, the student housing units will be houses for four to six students with shared common spaces and a private bedroom for every individual student. Per unit this will result in a number of bedrooms, and shared, a kitchen, living room, bathroom and a hallway connecting all the rooms. Students in general are looking for spaces with low rents, because they do not or barely have an income. Furthermore, students tend to live in student housing for only a couple of years, while they are studying. Therefore the serving spaces should be kept as small as possible, the living room and bedrooms small, but comfortable enough to have a private place for oneself. For bedrooms this would be between twelve and eighteen square meters, exceeding the minimum with a few square meters. The materialization of the housing units should be easy to maintain and change. Approximately 80% of the building will be occupied with student housing, allowing about 800 students to be accommodated (Appendix C).

4.2. Public functions

Approximately 20% of the building will be occupied with public functions, for instance a supermarket, a restaurant, a bar, a gym, an exhibition space or other recreational spaces (Appendix C). Commonly, all these spaces will need large areas of square meters. Accessibility from the outside is important. These functions might also need more installations and space for things like air ducts, compared to the current functions. In materialization these spaces like a supermarket and a gym need to be very functional and decent to endure the intense use. Bars and restaurants or exhibition spaces need materialization that is more decorative. How these spaces will be designed can easily be based on the availability of components, because unlike the student housing, these spaces are of a public nature.

V. POTENTIAL

All seven components are assessed on whether, how and in what quantity they potentially fit in the building with the future functional needs. In order to do so, the components are distributed accordingly among the five R-strategies, Refuse, Reuse, Repair, Repurpose and Recycle. The individual calculations and distributions in R-strategies of each component can be found in Appendix E.

5.1. Doors

5.1.1 Refuse

Whether refusing to take doors out of the existing building, depends on a few aspects. First of all, the requirements for doors are different for new constructed buildings. New buildings need to build conforming the latest requirements. According to the Dutch requirements (Rijksdienst voor Ondernemend Nederland, n.d.) a building that gets transformed, of which the existing structure is preserved, belongs to 'renovation' (Dutch: Verbouw). However, the requirements only apply to parts that are physically changed. Secondly, the door can only stay in place if the walls surrounding it, won't change either. The office-like structure has potential to be used as rooms for the student housing

(Appendix D). The doors in these rooms, D1, however mostly have glass, which is undesirable in terms of privacy for most of the functions of the rooms, such as bedrooms and bathrooms.

5.1.2 Reuse

In case of reusing, the doors are used in other situations. This means it does belong to a part that undergoes physical change. However, even then, in case of doors, current requirements don't apply, because in case of renovation, the doors should be in accordance with the legally obtained level (Dutch: 'rechtens verkregen niveau'). This means the door should be in accordance with the requirements of the new function from the time the building was built. For doors this means it can stay the same. Doors like type 2, 4 and 5 can therefore be easily reused. A small amount of D3 can be reused as well in public functions.

5.1.3 Repair

Doors that do not comply with the needs, might be still usable when repaired. In case of D1, the glass of these doors can easily be covered with foil. The smart locks might not be the conventional door lock option, but as long as it provides privacy for the residents it is usable.

5.1.4 Repurpose

Doors that are left might be up for repurpose. Although a door has a quite specific use, as a whole or the separate parts can be repurposed. The remainders of the doors of D1 can for instance be repurposed into colorful interior partition walls in parts of the building with a public function. D3 has some elements, such as glass, that can be reused in the interior of public functions.

5.1.5 Recycle

The remainders of D3 that do not serve any purpose as a door in the new building can be recycled. D3 includes glass, a wooden framework around the doors and a door panel made of steel. The steel can be remanufactured into new door elements, or other constructive parts. By taking apart the frames, the wood can for instance be recycled into chipboard.

5.2. Floors

5.2.1 Refuse

The linoleum floors cover almost 87% of the counted floors. These floors could fit the functions, since it is a floor with a wide applicability. It's a floor that comes in a wide range of colors and patterns, is durable, lasts long, is hygienic and easy to maintain (Lewitin, 2020). For student housing this could be an ideal floor type. This floor type is also usable for most of the public functions. However, the conditions of the floors might not be suitable anymore. The building dates back almost sixty years and the floors have been used intensively, which caused damages, dirtiness and irregularities. Therefore, it is no longer suitable to serve for a new purpose of the building. The same goes for the carpet flooring, which is in contrast to linoleum even less hygienic. The natural stone can be found around the halls with stairwells. This floor is still in good condition. The halls and stairwells can easily stay in place and be used for the new functions. Therefore, the natural stone can stay. The tiles that are found in the toilets are mostly in good conditions. However, the change of functions will lead to a different layout of, amongst others, the toilets. So most of the tiles will no longer serve its purpose.

5.2.2 Reuse

About one third of the amount of carpet in the building are carpet tiles. These tiles can be removed without damage, and be reused in both student housing other functions in the building. The tiles that will break when removed, can be reused as mosaic for decoration in public spaces such as restaurants.

5.2.3 Recycle

Except the carpet tiles, all other floor types can't be disassembled without damaging the materials. The linoleum and carpet are attached with an adhesive and for the tiles glue or mortar is used. It is hard to repair, reuse or to repurpose these elements, or at least not preferable. For the linoleum the solution could be to recycle the material into new linoleum. This has been done with the linoleum floors of the EWI building, another building on the TU Delft campus, in the recent renovation (Architectenweb, 2022). The linoleum can be stripped off in small pieces and then be turned into new linoleum with binder for cement industry and coating for furniture industry as a by-product. Carpet can be removed the same way and, although expensive due to different fibers, dyes, finishes, and adhesives, recycled into new carpet, structural composites or insulation (Chang et al., 1999). Tiles or the debris that is not suitable for reuse can be recycled into concrete or cement, possibly usable in a new building envelope (The Tile Emporium, 2021).

5.3. Ceilings

5.3.1 Refuse

Whether to refuse to remove the ceilings or not, depends on the change in layout of the building. The suspended ceilings can be used in public functions such as a gym. It is not unconventional in Delft to use these ceiling systems as well in renovated student housing (e.g. student housing in Korvezeestraat, Delft and Abtswoude Bloeit!, Delft). The layout of the building would partly be suitable for student housing and therefore part of the suspended ceilings can be kept in place. The foam in the halls can stay as well.

5.3.2 Reuse

Although the layout of the building might change, the suspended ceiling systems are relatively easy to disassemble and can therefore be easily be reused for the same purpose.

5.3.3 Repurpose

The acoustics of the ceiling system is a property that can be materialized in more ways than by ceiling only. In public functions with a lot of people, reducing noise can be done by repurposing ceiling panels into walls or furniture. Panels that no longer serve their use as ceiling due to damages or remainders from cut panels can get a new purpose in this way.

5.3.4 Recycle

The fiberboards that are attached to the floors above, and panels or parts that aesthetically no longer serve their purpose, or are not even in conditions to be repurposed, can be recycled into new ceiling panels.

5.4. Interior partition walls

5.4.1 Refuse

The partition walls are built in the grid of the structure. The sizes of the spaces these partition walls create are varying through the whole building. The occurrence of these partition walls is mainly found in the part that connects all the wings and is some of the wings (Appendix X). The spaces of two grid widths are eighteen square meters, fitting the sizes for bedrooms for student housing. Therefore partly the partition walls can stay in place.

5.4.2 Reuse

Partition walls that are not in preferable positions could partly be reused. There are different ways to reuse brick walls. However, these brick walls are covered with plaster and the mortar that was used is most likely so strong, making it hard to salvage the bricks from the walls (Nordby et al., 2009). There is the possibility to cut out parts of the wall and use these as blocks to build a new wall. Although, due to the cutting, the strength of these walls might be less than the original it could work, since these partition walls won't be load-bearing.

5.4.3 Repair

Partition walls that are staying in place might not always comply with the regulations regarding sound-proofing. As mentioned before, it should be in accordance with the legally obtained level. The requirements for sound-proofing of walls are stricter in for housing than for education and office function (BREAAM NL, no date). Therefore the walls between different housing units need to be improved on sound-proofing.

5.4.4 Repurpose

When using the approach of cutting blocks out of walls, there will be some grit left that will not be reusable. Therefore, if this part cannot be repurposed as gravel it could be used through crushing it together with other concrete and masonry materials to being used as hardcore bed for foundations.

5.5. Windowsills

5.5.1 Refuse

The building envelope will change, due to the currently poor insulation conditions. Consequently, the dimensions of the façade components and therefore, most likely also the windows will change. There might be places where the windowsills can stay in place, because the windowsills are attached to the inner walls.

5.5.2 Reuse

If the design of the new façade results in a change of dimensions and the windowsills will be removed, it could be done, although with some effort because of the mortar, without damage. Then it can be reused as a windowsill again.

5.5.3 Repurpose

The sleek stone and concrete of which these windowsills are made, can, in case no longer needed as windowsill, be repurposed into many other things within the building, such as wall covering, a bar counter or stair treads.

5.6. Lighting

5.6.1 Refuse & Reuse

From the recurring types of lighting, only part of the ceiling lights can stay, because these lights are mostly found in the halls and stairwells. Lighting, contrary to most of the other components, is relatively easy to disassemble and to reuse somewhere else, so all the ceiling lights can either be refused or reused. The other two types, both tube lights, with or without fixture, are mostly not to be reused, because this type of lighting doesn’t aesthetically fit housing and most of the public functions. The fixtures of the tube lights can be partly reused in for instance hallways.

5.6.2 Recycle

The aesthetical reason is however not the only reason why this lighting can’t be reused and neither be repaired or repurposed. The Dutch government recently prohibited the sale of TL, because it no longer meets the efficiency requirements (Ministerie van Onderwijs, Cultuur en Wetenschap, 2021). So when one lamp breaks, it has to be replaced by a different kind of lighting. Therefore it is more future-proof to use different lighting and recycle the TL all together right away. TL contains hazardous substances such as mercury and phosphor, that can, when recycled be used in new devices (Thomas, 2019). When separated safely, the other materials such as glass and metal can be recycled and remanufactured into new other lighting. So except for the fixtures, all the lights should be recycled due to the hazardous substances.

5.7. Sanitary

5.7.1 Reuse

Since the sanitary facilities will most likely move, the toilets, urinals and sinks will not stay in place, but can be reused, because these are objects that are relatively easy to disassemble. There are quite a lot of sinks, not only in the toilets, but also in laboratories. However, with the functional needs, the amount of sinks are most likely all needed (Appendix C). Partly, the urinals can be reused in public functions, such as restaurants or a gym and the toilets can all be reused throughout the whole building.

5.7.2 Repurpose

The remainders of the urinals and the small sinks that were installed for safety around the laboratories, can be repurposed. Examples of repurpose are planters or decorative stair treads, which can be used in restaurants.

VI. Results

6.1. Overall Potential

There are different approaches for a total overview of the potential strategies of all the assessed components. Figure 2 shows the overview of potential strategies based on approximate volume. The counting is done in units, meters and square meters in and the comparative quantity is based on estimated volume (Appendix E). This overview is relevant in terms of the future potential for function change of the building. However, this overview could also be based on mass, when assessing the transport costs or the environmental impact based on embodied carbon. In case of mass, the strategy reuse would turn out even higher, due to the heavy components like interior partition walls and windowsills. Diagrams showing the potential strategies per component can be found in Appendix G.

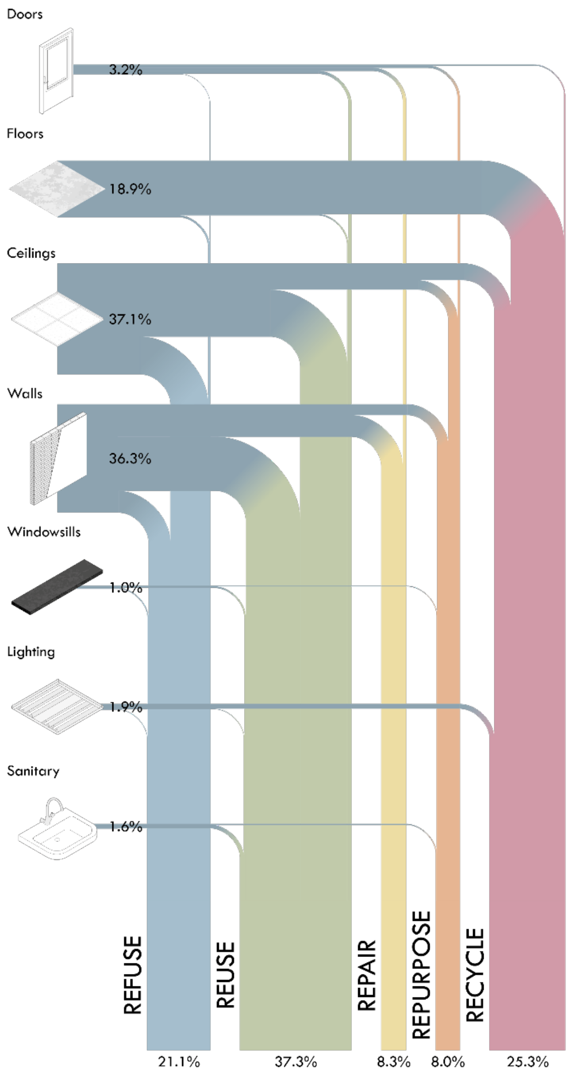

Figure 2 – All components and the distribution over R-strategies

6.1. Methodology

The results show the potential for using R-strategies on building 22. However, throughout the research, the methods and it's order form a methodology that can be used on other buildings as well (figure 3). This case is a transformation of an existing building, in other cases it could also be a project in which a new building will be built or transformed by using other buildings to reclaim building components from. However, it is important that the radius, within which building components are reclaimed and the new project is built, is taken into account, due to aforementioned transportation. When the location and project radius is defined, the next step is to research the function and its properties of both the existing building and new building to be able to apply the five R-strategies on the components. The third step is to create an inventory of recurring building components. The extent of this inventory depends on how much time can be spend on it. The components and its types can then be assessed by using R-strategies by using them in order from Refuse to Recycle, to ensure the most sustainable outcome. Within the assessment its important to investigate whether the components fit in the new project based on firstly regulations. If the regulations allow the components to be used within the strategy, the next step is to examine whether the component fits within the function of the new building. If it does not fit within the strategy based on regulations and function, the component can be assessed on the next strategy until it does fit. With this method, a project can be approached in a way where reclaimed building components are used in the most sustainable way.

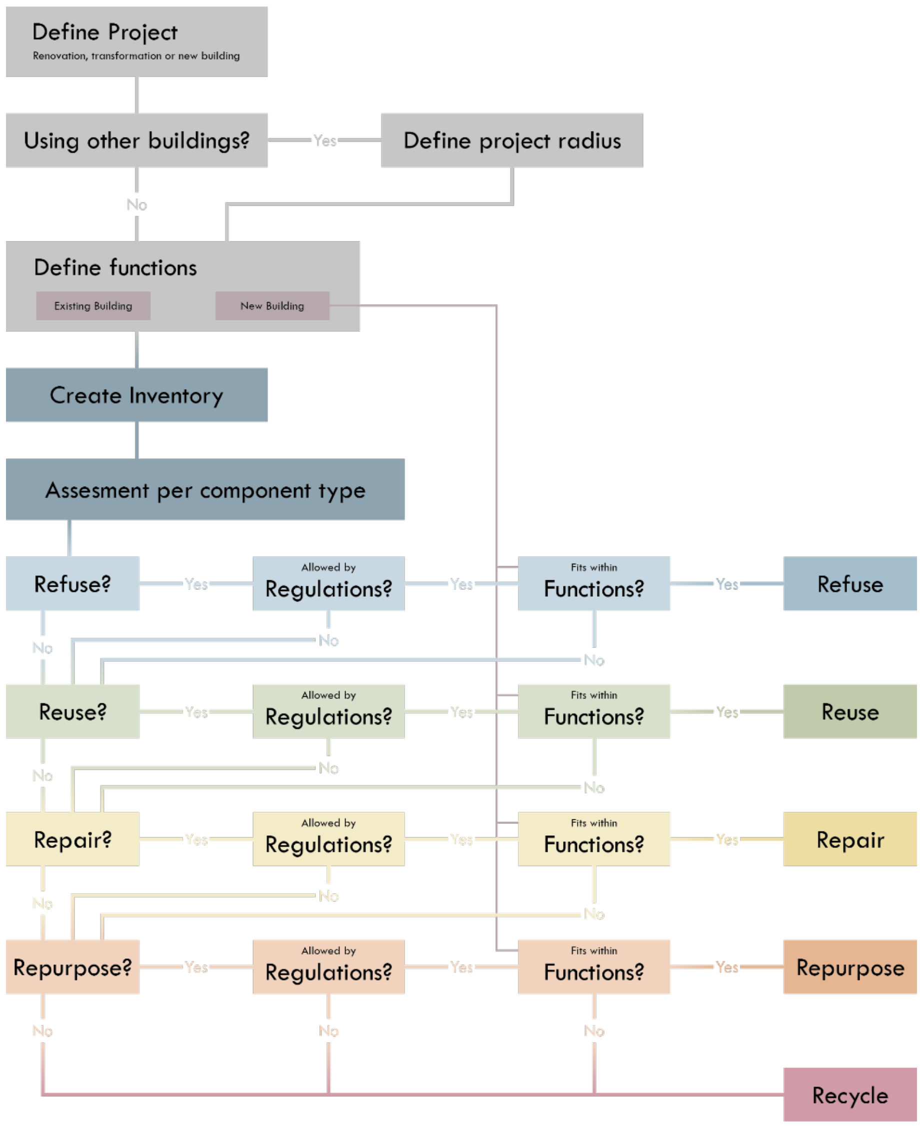

Figure 3 – Methodology to asses reclaimed building materials with R-strategies

VII. CONCLUSIONS

There are various strategies to deal with reclaimed building components from Building 22, Applied Physics. It is important to create a vision on the future purpose of the building in case of transformation, in order to be able to categorize the components in strategies. Starting with the Refuse Strategy, assessment is needed on how much fits with that strategy before deciding to determine what will go along with the next strategy, arranged from the least to the most effort. Due to the office structure of the building, what partly fits with the vision on the layout of student housing, some of the components can stay, and if not, there is a significant number of components that can be reused and repaired. Repurposing components seems harder with the requirement of student housing. However, the more free and decorative nature of some of the public functions make room for repurposing components. Due to aging, hazardous substances, difficult disassembly without damage, there will always be components that will not have a purpose in the building, unless recycled into new materials and manufactured into new components. However, almost 75% of the components fit in the strategies Refuse, Reuse, Repair and Repurpose. For these strategies, components do not have to leave the site, saving time, energy and costs on transportation and manufacturing.

The order of the strategies might not always be from the most sustainable to the least sustainable, based on unconsidered factors or the properties and complexities of one component. For instance, repairing interior partition walls by improving their acoustic properties might be less effort than reusing them, in which case parts of the wall have to be cut out, moved and assembled to create a new wall. Hence, the order of strategies will never be fixed, but always an approach.

If more time was available more components or more types that were less in count could have been explored. For instance, corridor closets, installations, ducts or radiators could have been assessed as well. Moreover, the large variety of lighting has not been mentioned, except the three prevailing recurring types. There are a lot of decorative fixtures that could easily be reused. Consequently, the outcomes could differ and result in a different emphasis on one or more R-strategies. Further research could be done by assessing more components, or assessing components on environmental impact, or costs.

The research leads to a methodology to find out how reclaimed building components can be purposed from existing buildings. However, it would be intriguing to create a more systematic approach that makes it cost-effective to actually conduct the proposed strategies. It takes a lot of time to asses components and this will consequently increase costs in projects. Co-operating designers, contractors and manufacturers could contribute to a database in which components are linked to their possible R-strategies and outcomes, including information on environmental impact, costs and transport. This could be a tool to constantly keep improving the methodology and consequently reduce costs and be a roadmap to a more sustainable building industry.

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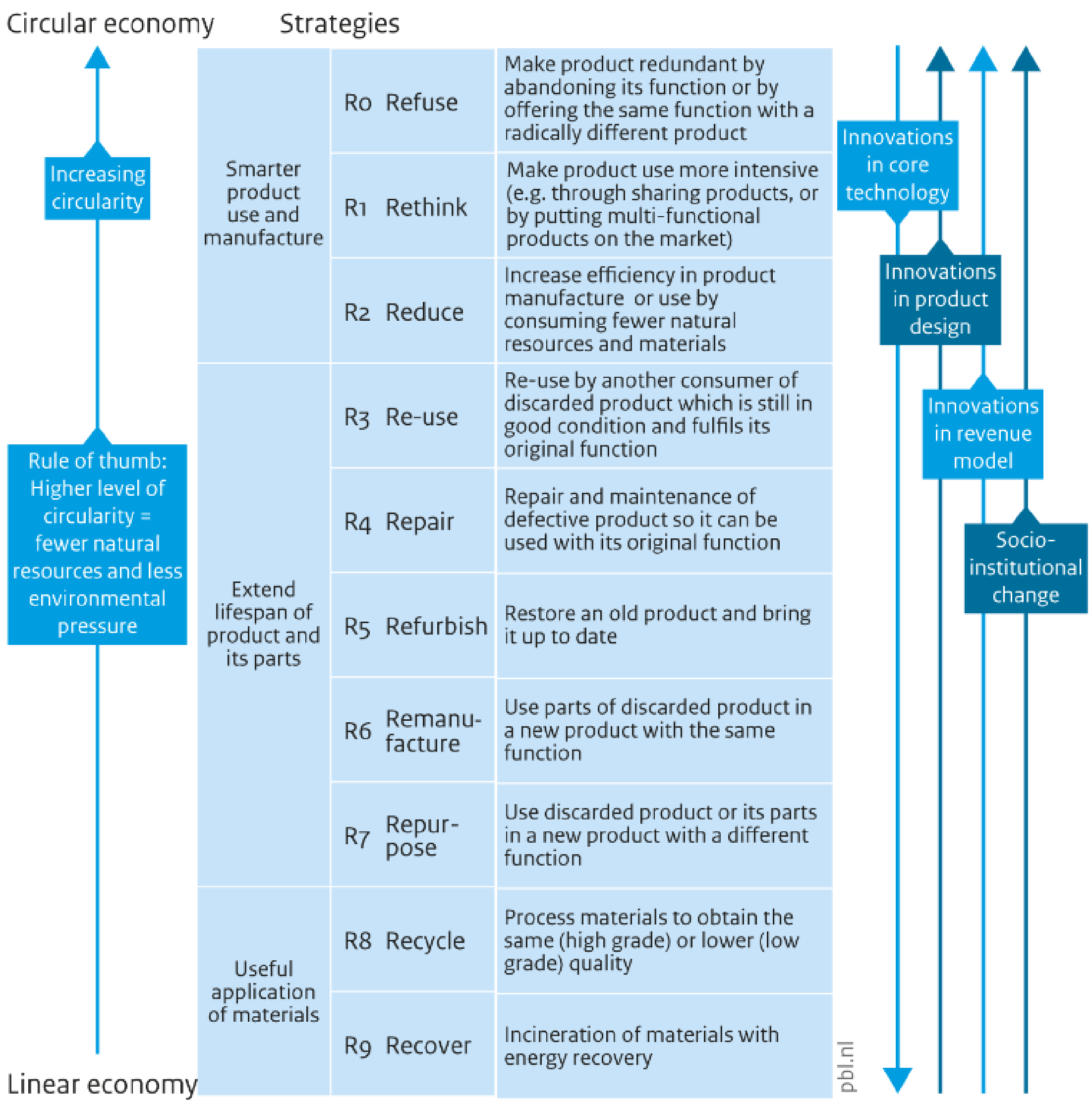
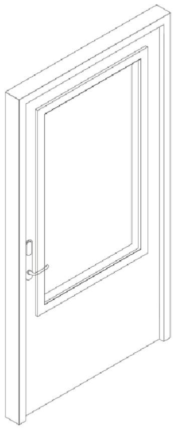
Appendix A – R-strategies

Figure 1 - Circularity strategies within the production chain, in order of priority (RLI 2015; edited by BPL)



APPENDIX B – COMPONENTS PER TYPE

Door | D1 | Door with window

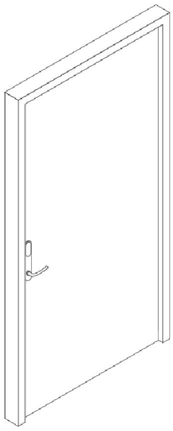


Dimensions
Height: 2.1 m
Length: 1 m
Width: 0.05 m

Description
A door with a smart lock and a window, used for offices, laboratories and classrooms.

Properties
Panel material: Wood
Frame material: Wood
Glass window
Door handle with smart lock (aluminium)
Steel hinges

Door | D2 | Regular door

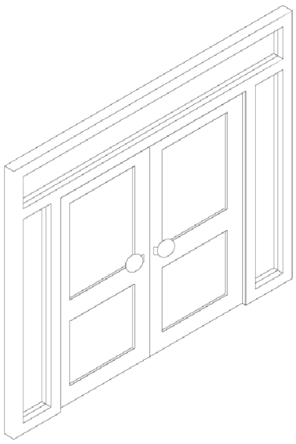


Dimensions
Height: 2.1 m
Length: 1 m
Width: 0.05 m

Description
A door with a smart lock, used for offices, laboratories and classrooms.

Properties
Panel material: Wood
Frame material: Wood
Door handle with smart lock (aluminium)
Steel hinges

Door | D3 | Double hallway door

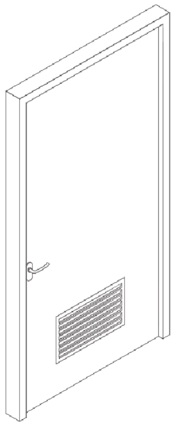


Dimensions
Frame Height: 2.7 m
Frame Length: 2.8 m (2 m in total
Frame Width: 0.1 m
Door Height: 2.1 m
Door Length: 1 m (2 m in total
Door Width: 0.05 m

Description
Double doors made of steel and glass, used between coordors and hallways, ensuring fire safety.

Properties
Panel material: Steel
Doorframe material: Wood
Glass windows in both doors and frame
Metal doorhandle
Steel hinges

Door	D4	Toilet door

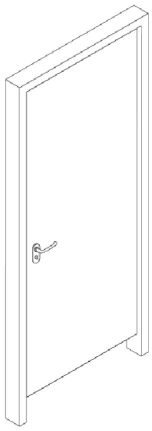


Dimensions
Height: 2.1 m
Length: 1 m
Width: 0.05 m

Description
Door used between sanitary spaces such as toilets, with grilles to ensure ventilation.

Properties
Panel material: Wood
Doorframe material: Wood
Alluminium grille
Metal doorhande (aluminium)
Steel hinges

Door	D5	Door with grille

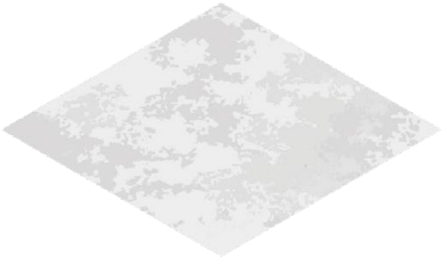


Dimensions
Height: 2 m
Length: 0.8 m
Width: 0,05 m

Description
Door used for toilets with a twist lock.

Properties
Panel material: Wood
Doorframe material: Wood
Metal doorhandle (aluminium)
Twist lock
Metal hinges

Floor	F1	Lynoleum

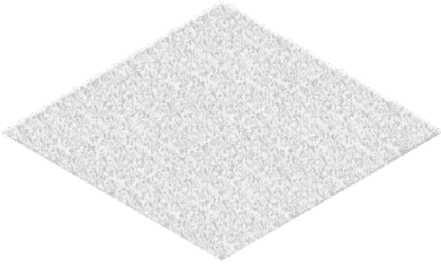


Dimensions
Thickness: 2.5 mm

Description
Sleek floor in all different kinds of colors used thoughout the whole building.

Properties
Material Linoleum
Attached with adhesive
Various colors

Floor | F2 | Carpet

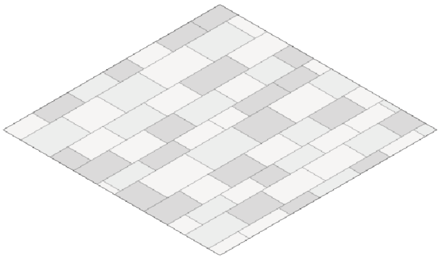


Dimensions
Thickness: 15 mm
Carpet tiles: 600 x 600 mm

Description
Soft floor used in different spaces of the building, mostly in offices or quiet spaces. Some of the carpet is made of carpet tiles

Properties
Material: Nylon, Polyester
Attached with adhesive
Color: Shades of grey

Floor | F3 | Natural stone

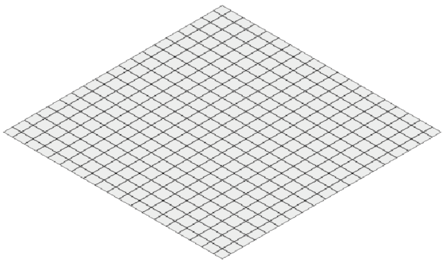


Dimensions
Thickness: 30 mm
Length: 300 - 800 mm
Width: 200 - 400 mm

Description
Tiles made from natural stone in various dimensions, found in the halls and stairwells.

Properties
Material: Natural stone
Uneven surface
Attached with mortar
Color: dark grey

Floor | F4 | Tiles

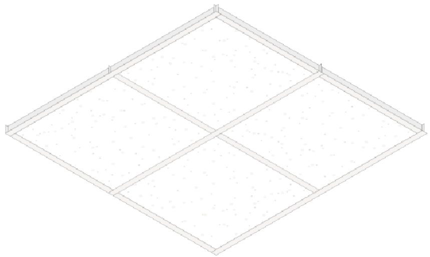


Dimensions
Thickness: 10 mm
Length: 150 mm
Width: 150 mm

Description
Small tiles in various colors, used in sanitary spaces and in the basement.

Properties
Material: ceramic
Attached with mortar
Color: various, mainly yellow, grey and black

Ceiling | C1 | System ceiling softboard

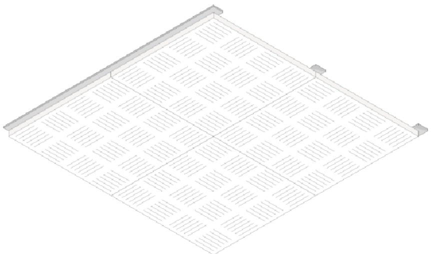


Dimensions
thickness: 20 mm
Length: 600 mm
Width 600 mm

Description
Softboard ceiling tiles appear everywhere in the building, in all kinds of spaces as a suspended ceiling.

Properties
Material: Gypsum, mineral wool, paper and starch
Material profiles: aluminium
Color: white
Acoustic qualities
Suspended system

Ceiling | C2 | System ceiling perforated boards

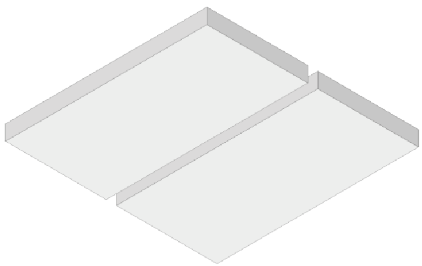


Dimensions
thickness: 10 mm
Length: 600 mm
Width 600 mm

Description
Perforated ceiling tiles appear everywhere in the building, in all kinds of spaces as a suspended ceiling.

Properties
Material: aluminium or steel
Suspended system
Color: white
panels are painted

Ceiling | C3 | Foam

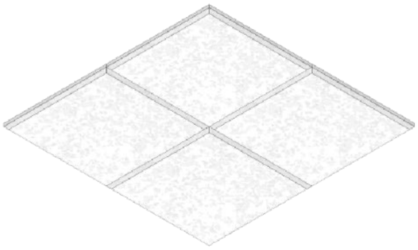


Dimensions
Thickness: 100 mm
Length: 1200 mm
Width: 600 mm

Description
Foam panels appear in the halls next to the stairwells, as an acoustic addition to reduce the noise.

Properties
Material: rubber foam
Attached with adhesive

Ceiling | C4 | Fiberboard

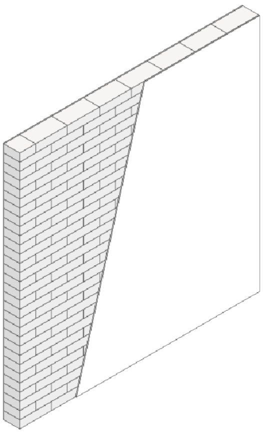


Dimensions
thickness: 20 mm
Length: 600 mm
Width: 600 mm

Description
Fiberboard panels is the oldest ceiling the building has and appears in a few corridors and laboratories.

Properties
Material: wood fibers
Color: white/grey
Painted white
attached most likely with adhesive

Interior partition wall | I1 | Brick wall with plaster

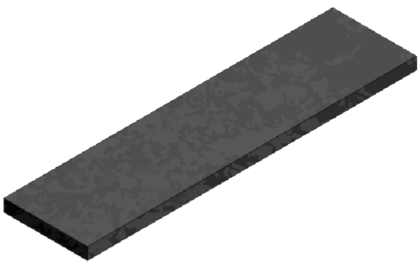


Dimensions
Brick height: 50 mm
Brick length: 210 mm
Brick width: 100 mm
Plaster thickness: 5 mm
Wall height: 3.3 m
Regular wall length: 5.4 m

Description
The interior partition walls, most likely made from brick and plaster appear on the grid lines throughout the building. They are ot load-bearing.

Properties
Brick walls with mortar
covered in plaster
Plaster color: white

Windowsill | W1 | Natural stone windowsill

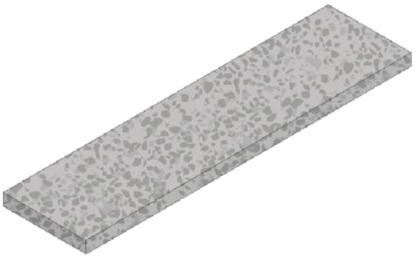


Dimensions
Thickness: 20 mm
Length: 1350 mm/3150 mm
Width; 200 mm

Description
The sleek natural stone windowsills are used in every window, except on the fourth floor.

Properties
Material: Natural stone
Color: Black
Coated

Windowsill | W2 Concrete windowsill

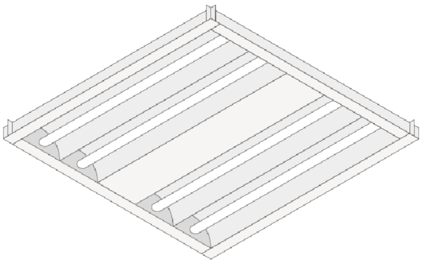


Dimensions
Thickness: 20 mm
Length: 1350 mm
Width; 200 mm

Description
The sleek concrete windowsills are used on the fourth floor inevery window and look a lot like the concrete from the facade material.

Properties
Material: Concrete with different types of natural stone gravel
Color: Grey
Coated

Lighting | L1 | Tube ligth with fixture



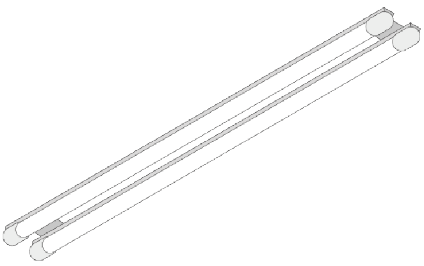
Dimensions
Armature height: 50 mm
Armature length: 600 mm
Armature width: 600 mm
Tube light length: 600 mm
Tube light diameter: 25 mm

Description
These fixtures are found everywhere in the building where ceiling type 1 is used.

Properties
Fixture material: aluminium
Color: white
profile material: aluminium
Lamp material: Glass, metal, polystyrene

Tube lights contain hazardous substances such as argon, xenon, neon, or krypton, and mercury vapor

Lighting | L2 | Tube light without fixture



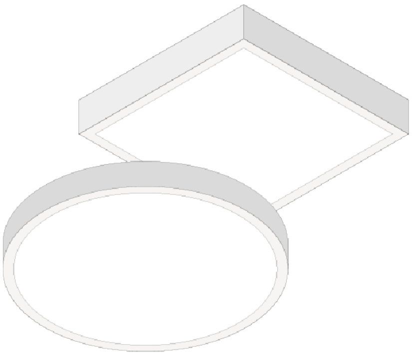
Dimensions
Tube light length: 1213 mm
Tube light diameter: 25 mm

Description
These fixtures are found everywhere in the building where ceiling type 2 is used.

Properties
Color: white
Lamp material: Glass, metal, polystyrene

Tube lights contain hazardous substances such as argon, xenon, neon, or krypton, and mercury vapor

Lighting	L3	Ceiling lamps

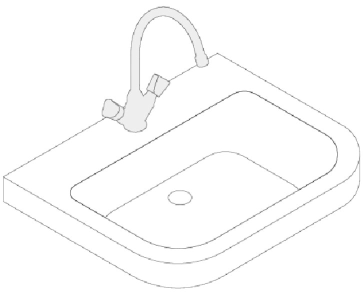


Dimensions
Height: 50 mm - 100 mm
Length: 400 mm - 600 mm
Width: 400 mm - 600 mm

Description
Various ceiling lamps in different shapes, mainly used in the halls and stairwells.

Properties
Light type: LED
Fixture material: Glass, steel, aluminium, polystyrene
Color: White and grey

Sanitary	S1	Sink

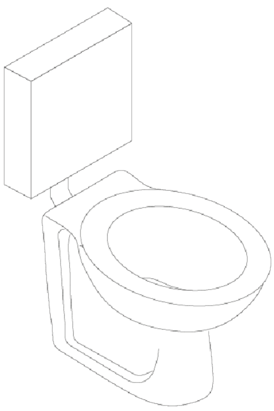


Dimensions
Height: 150 mm
Length: 600 mm
Width: 400 mm

Description
These regular sinks are in toilets, classrooms and laboratories.

Properties
Sink material: Composite
Water tap material: Brass and steel
Attached to wall with screws

Sanitary	S2	Toilet

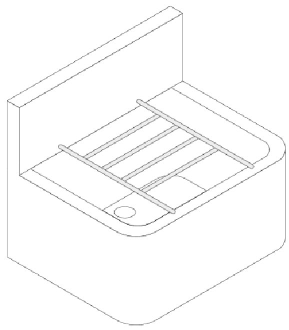


Dimensions
Height: 700 mm
Length: 720 mm
Width: 490 mm

Description
Regular toilets are divided in blocks around the stairwelss throughout the building.

Properties
Material: ceramic/porcelain, steel, copper, brass, plastics

Sanitary	S3	Small sink

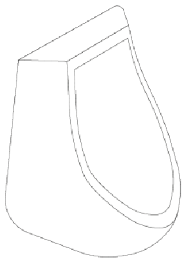


Dimensions
Height: 300 mm
Length: 460 mm
Width: 360 mm

Description
These small sinks are twice in every wing of the building for safety reasons around the laboratories.

Properties
Sink material: Composite
Attached to wall with screws
Grille material: Steel

Sanitary	S4	Urinal



Dimensions
Height: 500 mm
Length: 360 mm
Width 300 mm

Description
In every toilet block there are a few urinals.

Properties
Material: Composite/ceramic, plastics and steel
Attached with screws

APPENDIX C – FUNCTIONS BUILDING 22

Tabel 1 – Building area estimation per floor and wing

Area	Total	42290	33832
Elevation	Building part	Gross floor area (m^2)	Net floor area 80% (m^2)
00	00	2581	2065
	01	1425	1140
	02	1218	974
	03	1476	1181
	04	1263	1010
	05	1311	1049
01	00	2570	2056
	01	1484	1187
	02	1222	978
	03	1421	1137
	04	1265	1012
	05	1310	1048
02	00	2575	2060
	01	1291	1033
	02	1220	976
	03	1420	1136
	04	1262	1010
	05	1307	1046
03	00	2550	2040
	01	0	0
	02	0	0
	03	0	0
	04	0	0
	05	1109	887
04	00	1600	1280
	01	0	0
	02	0	0
	03	0	0
	04	0	0
	05	0	0
05	00	136	109
	01	0	0
	02	0	0
	03	0	0
	04	0	0
	05	0	0
KL	00	2581	2065
	01	1425	1140
	02	1218	974
	03	1476	1181
	04	1263	1010
	05	1311	1049

Tabel 2 – Building area estimation Total

	BVO		NVO
Excl Basement	33016	Excl Basement	26413
Incl Basement	42290	Incl Basement	33832
Kelder	9274		

Totaal Area GF+	30000
Totaal Area Bsaement	8000

Tabel 3 – Estimation calculation Student housing

Student housing unit	Amount	m^2	Total m^2	
Bedroom	6	15	90	
Bathroom			0	
Toilet	2	1,5	3	
Shower	1	1,5	1,5	
Other	1	3	3	
Living room	1	20	20	
Kitchen	1	8	8	
Hallway	1	12	12	
Technical space	1	1	1	
Total			138,5	23,1
Student housing unit	Amount	m^2	Total m^2	
Bedroom	5	15	75	
Bathroom			0	
Toilet	1	1,5	1,5	
Shower	1	1,5	1,5	
Other	1	3	3	
Living room	1	20	20	
Kitchen	1	8	8	
Hallway	1	12	12	
Technical space	1	1	1	
Total			122	24,4

Per student	23,7	m^2
Students	842	p

Tabel 4 – Estimation calculation Public functions

Function	m^2
Supermarket	1000
Gym	900
Restaurant/bar 1	200
Restaurant/bar 2	200
Pool bar	250
Shop	400
Shop	300
Shop	200
Exibition room	400

Total	3850

	NVO	BVO	
Total	24000	30000	
	80%	100%	
Public functions	4000	5000	17%
Student housing	20000	25000	83%

APPENDIX D – ANALYSIS OFFICE STRUCTURE

Figure 1 – Ground floor (Red: Stairwells, Blue: Toilets, Green: Repetitive office structure)

Figure 2 – First floor (Red: Stairwells, Blue: Toilets, Green: Repetitive office structure)

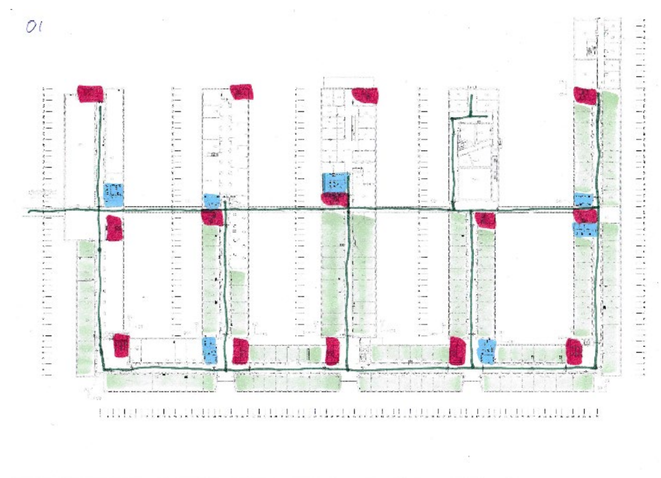


Figure 3 – Second floor (Red: Stairwells, Blue: Toilets, Green: Repetitive office structure)

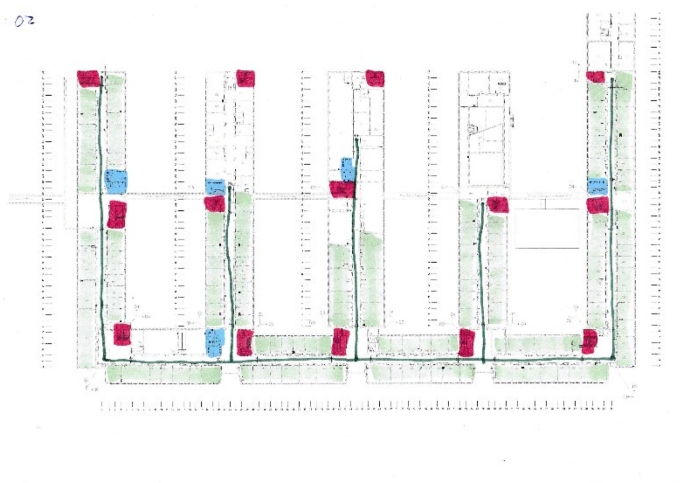


Figure 4 – Third floor (Red: Stairwells, Blue: Toilets, Green: Repetitive office structure)

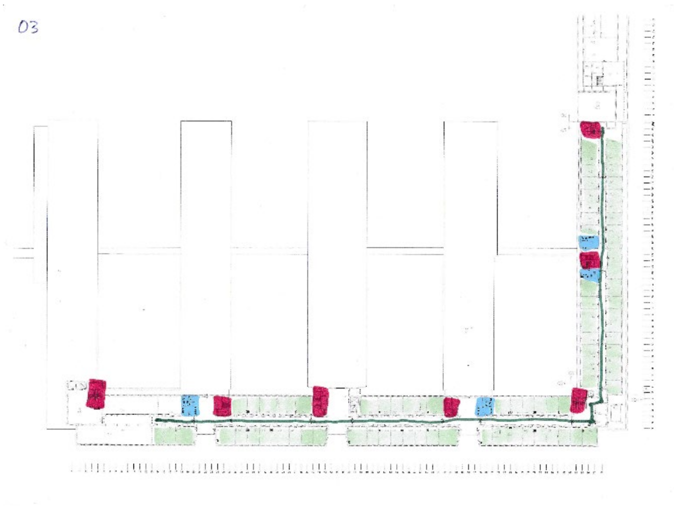


Figure 5 – Fourth floor (Red: Stairwells, Blue: Toilets, Green: Repetitive office structure)

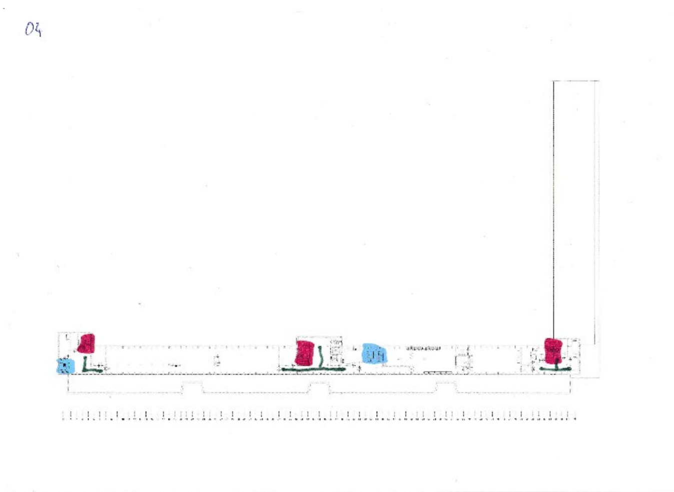


Figure 6 – Fifth floor (Red: Stairwells, Blue: Toilets, Green: Repetitive office structure)

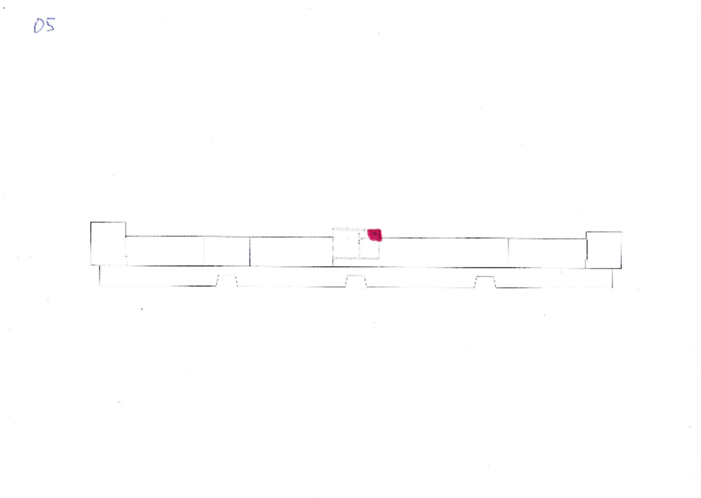


Figure 7 – Basement (Red: Stairwells, Blue: Bicycle parking, Green: Repetitive office structure)

Appendix E – Component calculations (Individual)

Tabel 1 – Door type counts

Elevation		805
00	Type 1	75
	Type 2	11
	Type 3	28
	Type 5	14
	Type 4	24
		152
01	Type 1	124
	Type 2	36
	Type 3	24
	Type 5	20
	Type 4	29
		233
02	Type 1	126
	Type 2	24
	Type 3	24
	Type 5	12
	Type 4	14
		200
03	Type 1	80
	Type 2	6
	Type 3	10
	Type 5	6
	Type 4	6
		108
04	Type 1	3
	Type 2	7
	Type 3	0
	Type 5	12
	Type 4	7
		29
05	Type 1	0
	Type 2	3
	Type 3	0
	Type 5	0
	Type 4	0
		3
KL	Type 1	10
	Type 2	52
	Type 3	10
	Type 5	8
	Type 4	0
		80

Tabel 2 – Floor type counts

	Type 1	Type 4	Type 2	Type 5	Type 3	
Ground floor	6892	304	0	62	159	7417
1st floor	6092	111	1492	0	203	7898
2nd floor	5792	124	0	0	104	6020
3rd floor	2202	112	443	0	77	2834
4th floor	1025	0	0	0	39	1064
5th floor	98	0	0	0	0	98
Basement	0	0	0	0	251	251
Total	22101	651	1935	62	833	25582

Tabel 3 – Floor correction on type counts

		Correction estimation	Usable area (m^2)
Type 1	22101	0,9	19891
Type 2	1935	0,9	1742
Type 3	833	0,9	750
Type 4	651	0,9	586
Total			22968

Tabel 4 – Ceiling type counts

	Type 1	Type 6	Type 3	Type 4	Type 3	Type 5	
Ground floor	2769	1139	344	607	992	0	5851
1st floor	4602	644	138	325	0	748	6457
2nd floor	3655	995	62	327	734	0	5773
3rd floor	1932	709	171	62	0	0	2874
4th floor	158	292	0	0	0	0	450
5th floor	98	0	0	0	0	0	98
Basement	0	0	0	0	0	0	0
Total (m2)	13214	3779	715	1321	1726	748	21503

Tabel 5 – Ceiling correction on type counts

		Boven 1000m2	Correction estimation	Usable area (m^2)
Type 1	13214	1	0,9	11893
Type 2	3779	1	0,9	3401
Type 3	1726	1	0,9	1553
Type 4	1321	1	0,9	1189
Type 5	748	0	0,9	0
Type 6	715	0	0,9	0
	21503			18036

Tabel 6 – Interior Partition walls type counts

	Amount	Length	Height	Total m2
Ground floor	114	5,4	3,3	2031
1st floor	115	5,4	3,3	2049
2nd floor	141	5,4	3,3	2513
3rd floor	64	5,4	3,3	1140
4th floor	0	5,4	3,3	0
5th floor	0	5,4	3,3	0
Basement	62	5,4	3,3	1104
Total	496	5,4	3,3	8838

Tabel 7 – Windowsills type counts

	Type 1					Type 2			Total
	S	Length	L	Length	Total m	S	Length	Total m	
Ground floor	368	1,35	50	3,15	654	0	1,35	0	654
1st floor	368	1,35	50	3,15	654	0	1,35	0	654
2nd floor	394	1,35	40	3,15	658	0	1,35	0	658
3rd floor	206	1,35	0	3,15	278	0	1,35	0	278
4th floor	0	1,35	0	3,15	0	180	1,35	243	243
5th floor	0	1,35	0	3,15	0	0	1,35	0	0
Basement	0	1,35	0	3,15	0	0	1,35	0	0
Total (m)					2245			243	2488

Tabel 8 – Lighting type counts

	Type 1	Type 2	Type 3	Total
Ground floor	572	338	60	970
1st floor	352	440	68	860
2nd floor	480	420	82	982
3rd floor	128	220	62	410
4th floor	120	20	36	176
5th floor	16	0	0	16
Basement	260	28	0	288
Total	1928	1466	308	3702

Tabel 9 – Sanitary type counts

	Sink	small sink	Toilet	Urinal
Ground floor	73	5	19	20
1st floor	38	10	24	18
2nd floor	55	7	15	17
3rd floor	34	2	9	8
4th floor	3	0	5	3
5th floor	0	0	0	0
Basement	14	9	0	0
Total (amount)	217	33	72	66

APPENDIX F – COMPONENT CALCULATIONS (TOTAL OVERVIEW)

Tabel 1 – Total overview of components and expected ratio of R-strategies

Doors								
Type	Name	Count (amount)	Percentage	Refuse	Reuse	Repair	Repurpose	Recycle
D1	Door with window	415	53,5	0	0,1	0,5	0,4	0
D2	Door without window	132	17,0	0,2	0,5	0,2	0,1	0
D3	Double hallway door	96	12,4	0	0,2	0	0	0,8
D4	Toilet door	73	9,4	0	0,8	0,2	0	0
D5	Door with grille	60	7,7	0	0,8	0,2	0	0
	Total Percentage	776	100,0	3,4	30,0	33,6	23,1	9,9
	Overall (based on count)		1,4					
Floors	Overall (based on Approx. Volume)	1	3,2					
Type	Name	Count (m2)	Percentage	Refuse	Reuse	Repair	Repurpose	Recycle
F1	Linoleum	19891	86,6	0	0	0	0	1
F2	Carpet	1742	7,6	0	0,3	0	0	0,7
F3	Tiles	750	3,3	0,2	0	0	0	0,8
F4	Natural Stone	586	2,6	1	0	0	0	0
	Total Percentage	22969	100,0	3,2	2,3	0,0	0,0	94,5
	Overall (based on count)		40,2					
Ceilings	Overall (based on Approx. Volume)	5	18,9					
Type	Name	Count (m2)	Percentage	Refuse	Reuse	Repair	Repurpose	Recycle
C1	System ceiling softboard	11893	65,9	0,3	0,5	0	0,1	0,1
C2	System ceiling perforated boards	3401	18,9	0,3	0,5	0	0,1	0,1
C3	Foam	1553	8,6	1	0	0	0	0
C4	Fiberboard	1189	6,6	0	0	0	0	1
	Total Percentage	18036	100	34,0	42,4	0,0	8,5	15,1
	Overall (based on count)		31,5					
Walls	Overall (based on Approx. Volume)	2	37,1					
Type	Name	Count (m2)	Percentage	Refuse	Reuse	Repair	Repurpose	Recycle
I1	brick wall with plaster	8839	100,0	0,2	0,5	0,2	0,1	0
	Total Percentage	8839	100	20,0	50,0	20,0	10,0	0,0
	Overall (based on count)		15,5					
Windowsills	Overall (based on Approx. Volume)	1	36,3					
Type	Name	Count (m)	Percentage	Refuse	Reuse	Repair	Repurpose	Recycle
W1	Natural stone	2245	90,2	0,3	0,5	0	0,2	0
W2	Concrete	243	9,8	0,3	0,5	0	0,2	0
	Total Percentage	2488	100	30,0	50,0	0,0	20,0	0,0
	Overall (based on count)		4,3					
Lighting	Overall (based on Approx. Volume)	10	1,0					
Type	Name	Count (amount)	Percentage	Refuse	Reuse	Repair	Repurpose	Recycle
L1	Tube light without fixture	1928	52,1	0	0	0	0	1
L2	Tube light with fixture	1466	39,6	0,1	0,1	0	0	0,8
L3	Ceiling lamps	308	8,3	0,5	0,5	0	0	0
	Total Percentage	3702	100	8,1	8,1	0,0	0,0	83,8
	Overall (based on count)		6,5					
Sanitary	Overall (based on Approx. Volume)	8	1,9					
Type	Name	Count (m2)	Percentage	Refuse	Reuse	Repair	Repurpose	Recycle
S1	Sink	217	55,9	0	1	0	0	0
S2	Toilet	72	18,6	0	1	0	0	0
S3	Urinal	66	17,0	0	0,5	0	0,5	0
S4	Small sink	33	8,5	0	0	0	1	0
	Total Percentage	388	100	0,0	83,0	0,0	17,0	0,0
	Overall (based on count)		0,7					
Total	Overall (based on Approx. Volume)	1	1,6					
	Based on	Count (m2)		Refuse	Reuse	Repair	Repurpose	Recycle
	Category percentage	57198	100	14,1	38,0	7,7	11,2	29,0
	Count percentage (m/m2/amount)	57198	100	17,0	25,7	3,5	5,5	48,3
	Volume percentage (1x1x0,1 m3)	24326	100	21,1	37,3	8,3	8,0	25,3

Appendix G – R-Strategy diagram per type

Figure 1 – Door types and the distribution over R-strategies

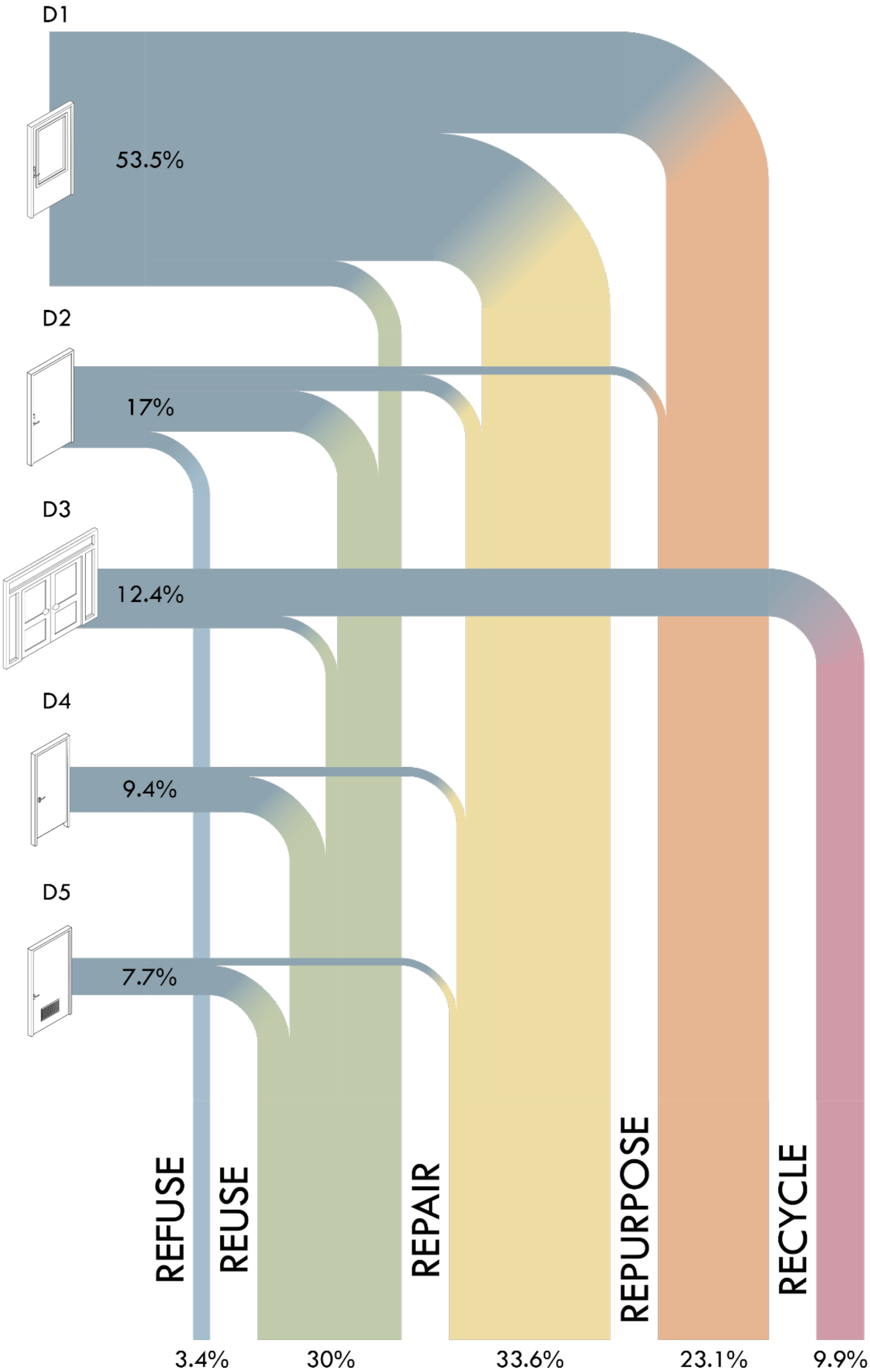


Figure 2 – Floor types and the distribution over R-strategies

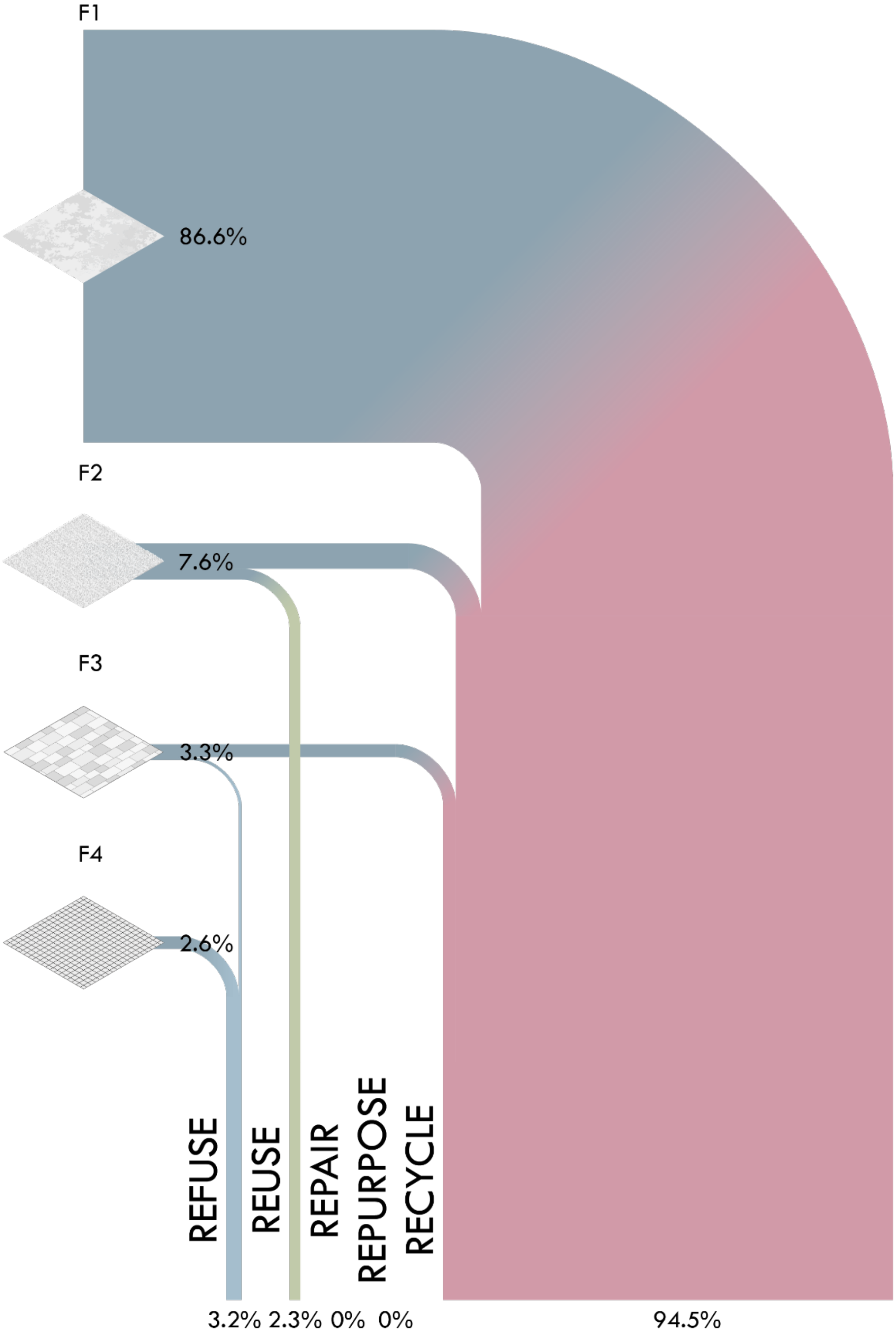


Figure 3 – Ceiling types and the distribution over R-strategies

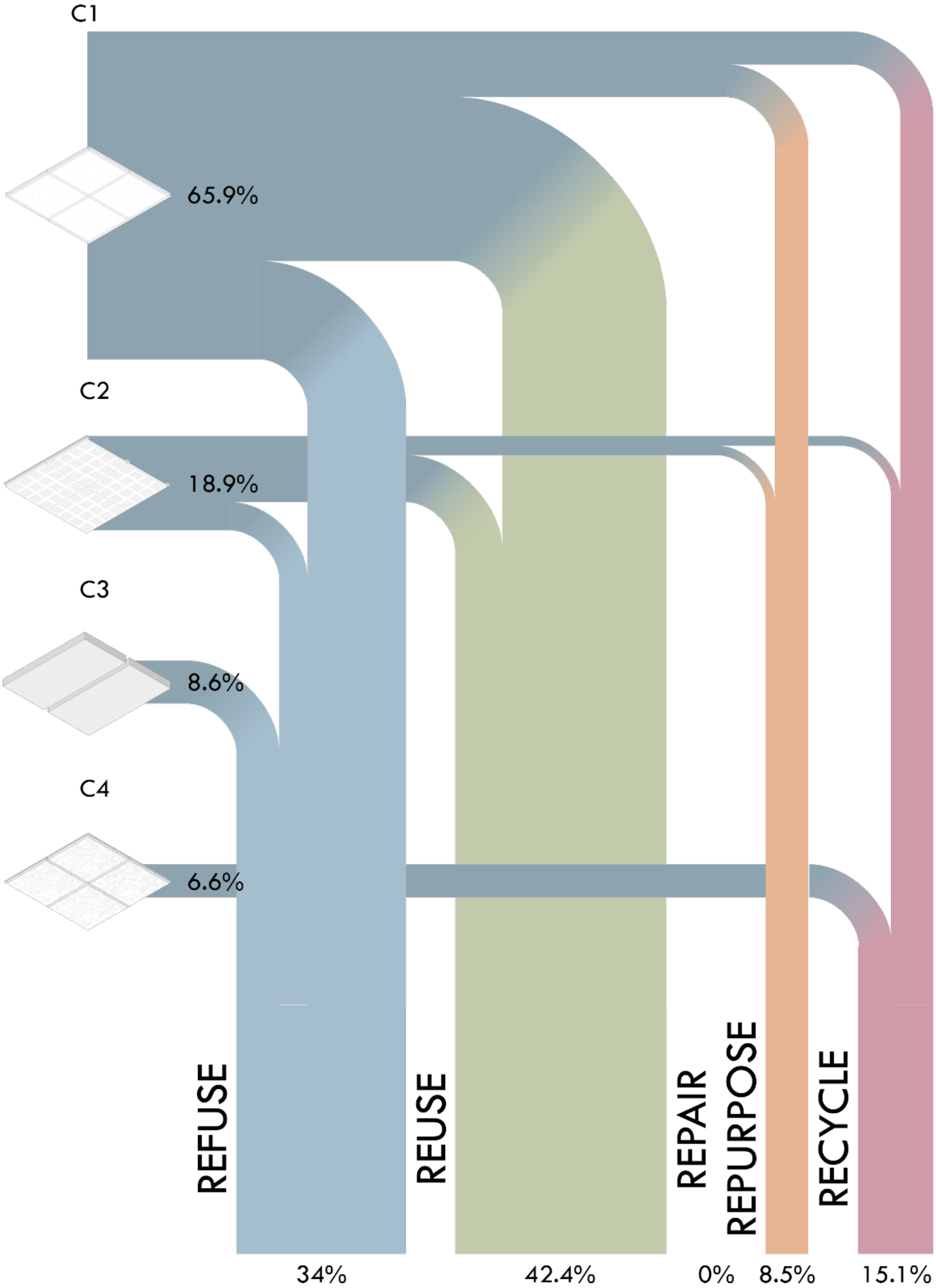


Figure 4 – Interior partition wall type and the distribution over R-strategies

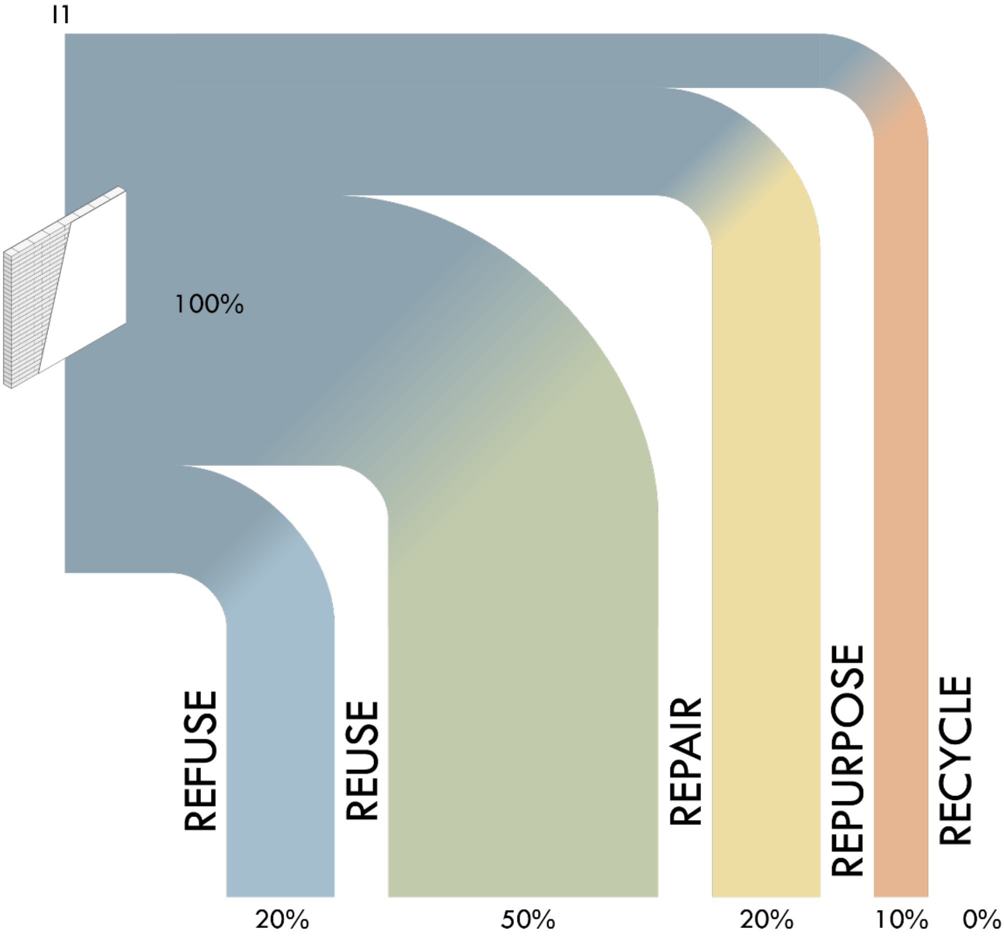


Figure 5 – Windowsill types and the distribution over R-strategies

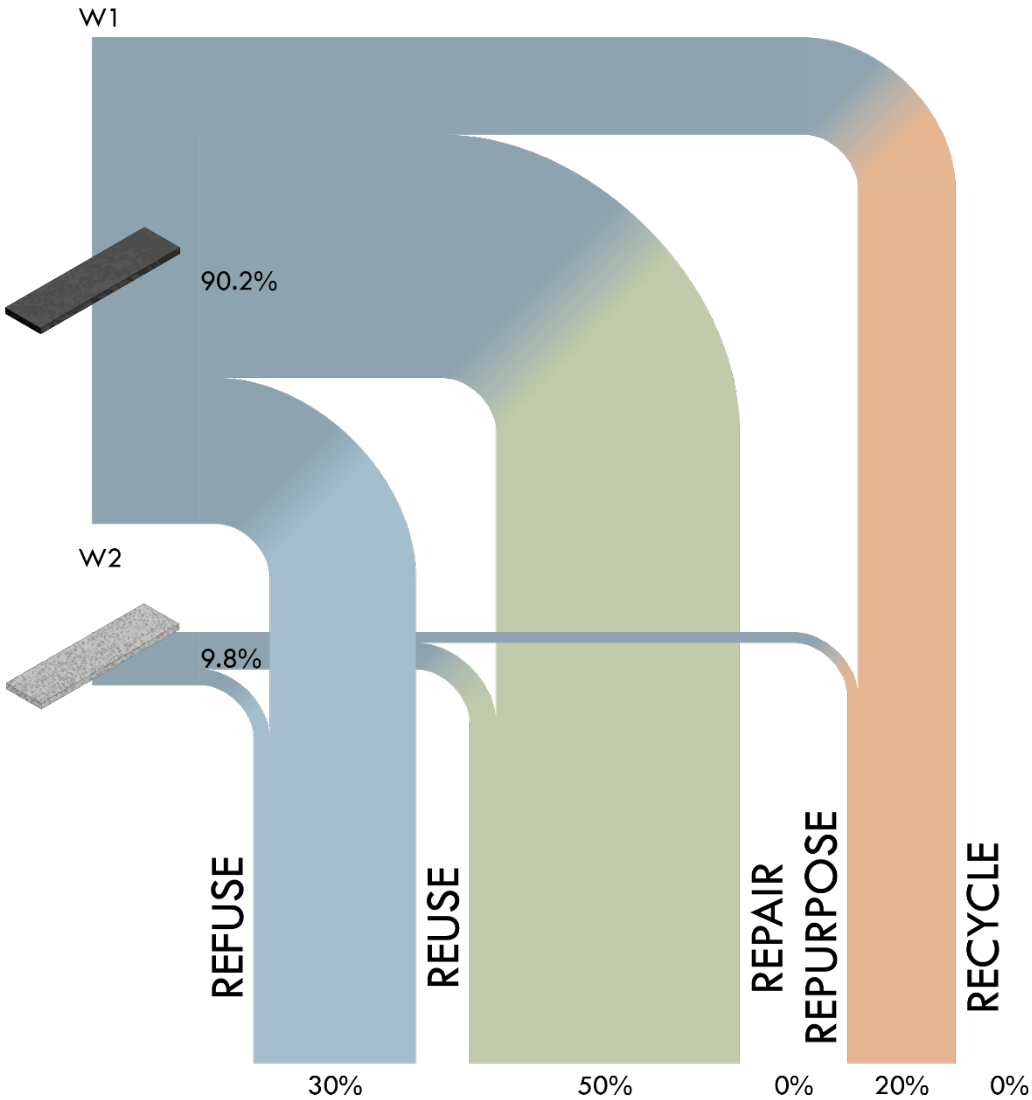


Figure 6 – Lighting types and the distribution over R-strategies

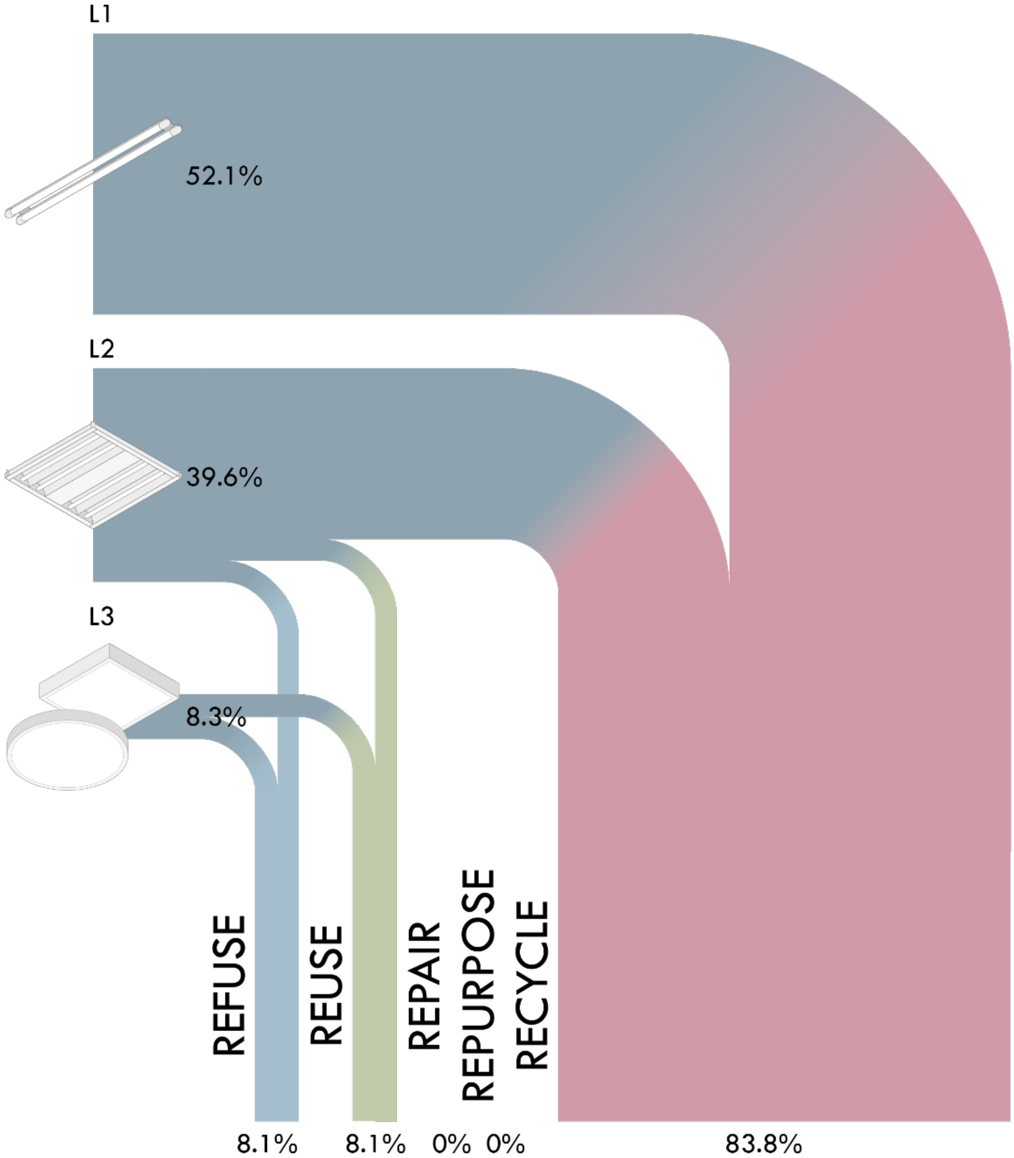


Figure 7 – Sanitary types and the distribution over R-strategies

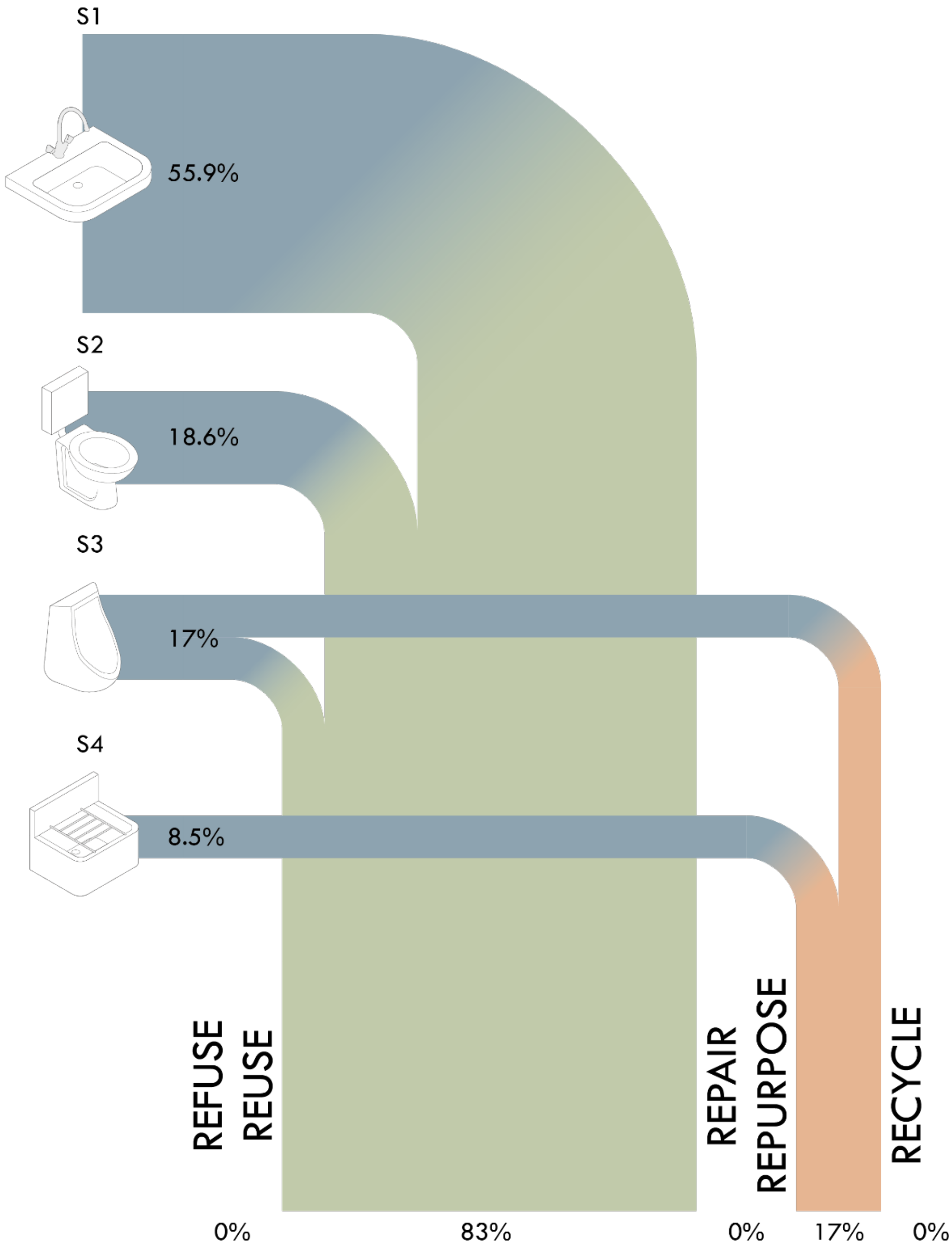


Figure 8 – All components and the distribution over R-strategies