

## Re-use of building components. (Towards zero waste in renovation)

**Citation for published version (APA):**

Erkelens, P. A. (2003). Re-use of building components. (Towards zero waste in renovation). In *Deconstruction and Materials Reuse : Proceedings of the 11th Rinker International Conference, Gainesville, Florida (United States), 07. May 2003 - 10. May 2003* (pp. 124-136). In-house publishing.

**Document status and date:**

Published: 01/01/2003

**Document Version:**

Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

**Please check the document version of this publication:**

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

**General rights**

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

[www.tue.nl/taverne](http://www.tue.nl/taverne)

**Take down policy**

If you believe that this document breaches copyright please contact us at:

[openaccess@tue.nl](mailto:openaccess@tue.nl)

providing details and we will investigate your claim.

# **RE-USE OF BUILDING COMPONENTS (TOWARDS ZERO WASTE IN RENOVATION)**

Author: Peter A. Erkelens (Technische Universiteit Eindhoven, The Netherlands)

## **ABSTRACT**

The enormous amount of waste produced during building and renovation is a serious environmental problem, which is worsening as building activities increase over the years. This paper investigates, in a case study, the possibilities for reducing waste production in renovation activities. A different approach to the planning phase results in more materials being left on the site or being re-used, and a change in floor plans leads to more re-use of materials, less waste, and less need for new materials. The achievable reduction of environmental impact is calculated with Life Cycle Analysis (LCA) calculations. The environmental impact of this renovation project could be lowered by 5-10%, which is promising for other ones. More precise data on impact of waste reduction will be obtained if LCA is improved. Better coordination during demolition will provide for more re-use.

**KEYWORDS:** Building Components; Environment; Housing; Renovation; Re-use; Waste

## **INTRODUCTION**

Huge amounts of waste are produced during building and renovation of buildings, not only in the Netherlands, but also in other countries. This phenomenon is the reason for looking more critically into these processes, as they create many unwanted situations. This paper presents a different approach to building projects, particularly renovation projects, in order to reduce some of the negative effects like waste.

Ten percent of the materials used in building and construction end up as waste. But waste does not end there; it actually increases several-fold during the lifetime of a building due to maintenance, renovation, and finally, demolition. Also, in other parts of the world this building and construction waste is a matter of concern. Smith (1) noted that in the USA, 20% of the total materials were wasted. Typical construction generated 20-35 kg of solid waste per m<sup>2</sup> of floor space. Vingerling (2) reported that the total amount of building and construction waste produced in the Netherlands per annum could be used to build 30,000 houses. In 1997, the reported amount of building and construction waste was 16.1 million tons (3), and 23 million tons in 2001.

Building and construction is one of the engines of the economy considering their contribution to the Gross Domestic Product, Gross Fixed Capital Formation, and employment. The general expectation is that economic growth will continue into the future. Due to the strong relationship between building activities and economic development, there will be an increased need for more and bigger housing and utility buildings (4). This, in turn, will demand more building materials. From the environmental point of view, the above-described situation will cause more:

- Depletion of resources. The built environment accounts for up to half of the raw materials taken out of the earth (5);
- Waste; and
- Emissions, pollution, etc.

In the Netherlands, a report published as far back as 1988 by *Zorgen voor Morgen* (Take care for Tomorrow) (6), revealed an alarming picture of the environment. It indicated grim consequences for agriculture, traffic, industry, and households. The following year, in response to this report, the Dutch government launched the National Environmental Policy Plan, which is still in force today (7), and is of interest to other countries as well. This plan presents three basic concepts for an environmental policy that supports the idea for sustainable building and construction:

- Integrated life cycle management of materials;
- Energy reduction through higher efficiency, use of renewable raw materials, and reduction of energy consumption; and
- Quality improvement of products and processes, minimization of the use of resources, and where necessary, the use of renewable resources.

## CONTEMPORARY SOLUTIONS

The building construction industry is taking a number of measures to address this situation.

### **Dematerialization**

One of the solutions can be found in dematerialization (8), which leads to the use of less materials and, consequently, to less waste. Other ideas are deconstructable buildings and components that can be easily decoupled from the building.

### **Recycling**

Buildings can be comprised of products that are designed for recycling. Löfflad (9) investigated the possibility of using globally recyclable materials. He distinguished three categories of materials: global recycling material (straw etc.), conditional global recycling material (bricks), and not-global recycling material (plastics). If well designed, he found that 90% of a house can be built of global recycling material. For new construction, the proposals from (8) and (9) may be useful; yet for renovation of existing buildings, this is just a partial solution, as we have to deal with a partial replacement of existing materials.

### **Better management**

In the Netherlands, housing alone contributes to 3.1 million tons, or 20% of the waste. Half of this waste comes from renovation activities. In the near future, the number of houses to be renovated will exceed new houses. This means that, unless special measures are taken, waste created by renovation will increase even further. Currently, qualitative and quantitative data on waste, from both renovation and new construction, is available only at the national level. Moreover, detailed data per housing project is limited, and very little data is available for renovation. Here, it is worth drawing attention to three studies. Stroband (10) monitored a building project of 57 new houses, and managed to achieve a 41% reduction of waste, compared

to a reference project, through better management during execution. Although the research was restricted to new buildings, the result demonstrates the feasibility of reducing waste. Nunen (11) investigated the re-use of concrete floor and wall elements from a demolished apartment building. This was a feasible option, and the environmental impact reduction compared to new was 35%. A similar approach is documented by Vries (12) on a building project in Maassluis. An apartment building was topped off and the lowest two stories were converted into detached housing. Although the reported cost reduction was 10%, the environmental impact reduction was lower than expected because of the need for additional stabilizers.

### **Industrial Flexible and Demountable (IFD)**

A different, but still ongoing type of research under the framework of IFD-research is the re-use of foundations of demolished apartment buildings: the so-called IFD today project (13).

## **A NEW APPROACH**

For buildings that have to be renovated, the solutions of dematerialisation, recycling, better management and IFD are not adequate, as renovation is very different from new construction. These are a few of the reasons why we promote a different approach to the renovation process. The proposed process order should be:

1. Initiative, the brief;
2. Inventory of spatial qualities of the building, qualities of the components, etc.;
3. Making provisional renovation designs;
4. Development of various scenarios, different activities over the coming use-period;
5. Checking with LCA on the design proposals;
6. Making an improved design, including IFD and details for deconstruction; and
7. Monitoring the demolition / deconstruction of the components of the building prior to actual construction.

This will be elaborated in more detail below.

### **Ad 1. Initiative**

The client should be willing to accept this different approach of the renovation process, which can be further detailed in the architects brief. He may think of additional costs, although this is questionable, as it depends mainly on how this project is handled during the process.

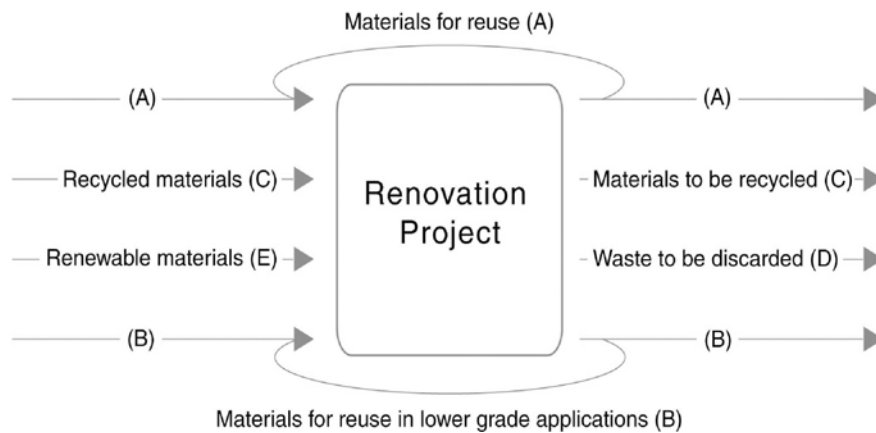
### **Ad 2. Inventory of qualities**

The basic issue is to make an inventory of the spatial qualities of the building, and to inventory the existing building components and their connections. What are the possibilities of taking out/deconstruction without demolition? What is the environmental impact of taking away a component and re-using or discarding it, and what is the impact of using a new one?

### **Ad 3. Design for zero-waste**

With the abovementioned inventory at hand, the architect can draw floor plans, cross sections, etc. He can oversee the consequences of his design decisions. For the specification of building

materials, components, etc., he can use the ‘Zero waste model’ that was developed at the Eindhoven University (14). The purpose of this model (Figure 1) is to depict the material flow in a renovation project and the preferential order of application.



**Figure 1** Zero-waste model (14)

At the right hand side are the out-coming materials. Materials in flow (A) are re-used for the same application in this renovation project or in other projects. Those from flow (B) are re-used for a different application here or elsewhere. (C) will be recycled and flow (D) is discarded as waste. On the left hand (input) side are materials for re-use from flows (A) and (B). Flow (C) consists of recycled materials and flow (E) has new materials. In the case of new materials, the preference is for renewable materials. The goal is a maximum reduction of the materials flows, knowing that transport has generally the greatest impact. In summary, the following preferences for materials use are indicated:

1. Materials for re-use (A);
2. Materials for re-use in a different application (B);
3. Recycled materials (C) ;
4. Renewable materials (E); and
5. Non-renewable materials (only if unavoidable).

The following definitions apply:

Re-usable materials are materials that do not require any treatment apart from cleaning.

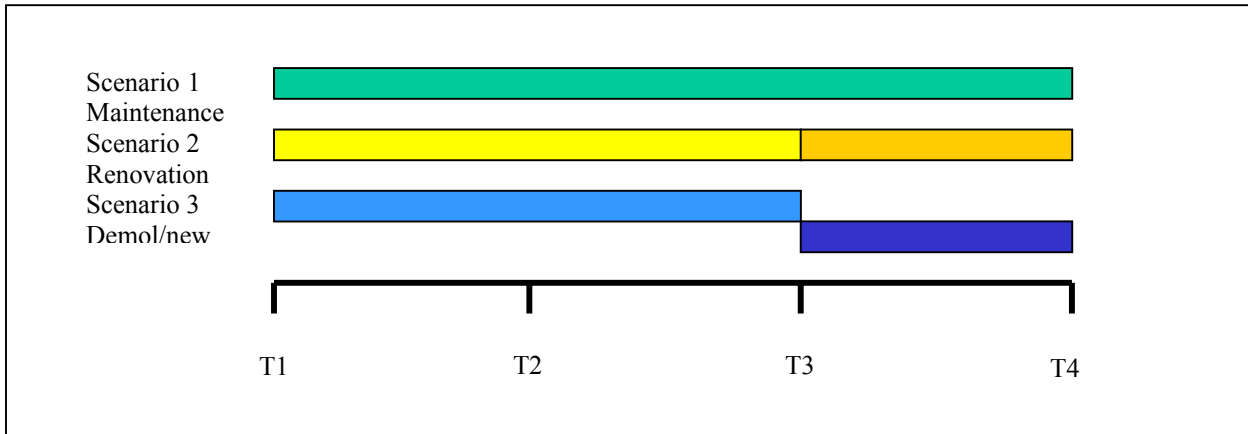
Recyclable materials are materials that may be used as raw material for the production of new materials.

#### **Ad 4. Scenario development**

Improvements of existing buildings can be made in different time intervals over the use period.

One can think of maintenance as necessary to keep the building functioning as it is. Renovation is the next option, whereby the building is partly renewed and used for the same purpose.

Another (extreme) option is demolition and construction of a new building at time interval T3 (Figure 2).



**Figure 2** Life-span scenarios for maintenance, renovation, and renovation/new building

### **Ad 5. LCA studies**

The various design options and scenarios can be investigated based on their environmental impacts through LCA studies. As this still is a rather complex issue, one has to limit the number of options.

### **Ad 6. Improved design**

With the LCA results from the different designs and scenarios one can select the ones most promising for the environment. Of course, there are also other factors involved, which may be a reason why the final design is less favourable for the environment. By doing so, one is more aware of the environmental consequences of changes in the designs. Possibilities for IFD and deconstruction are worthwhile to be included in this phase of the process.

### **Ad 7 Monitoring deconstruction**

During the project preparation, one can develop ideas on re-use of components and materials and make them a part of the project philosophy. However, construction practice is different. That is why it is important to monitor the demolition phase.

## **CASE STUDY AND ANALYSIS**

### **Initiative and inventory of qualities**

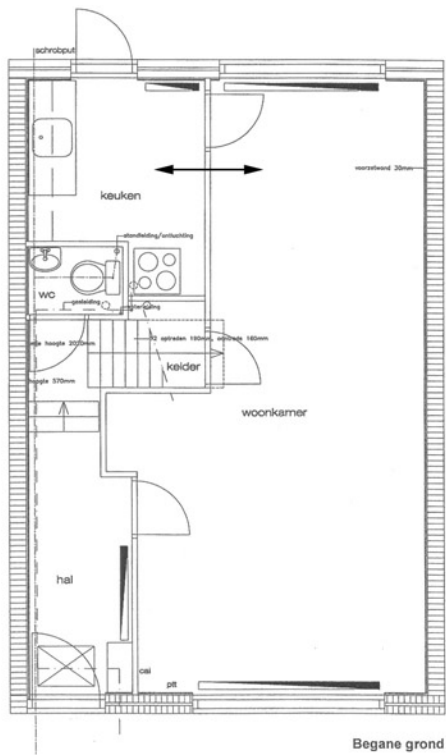
In a case study done by a number of our MSc. students, we tested the different steps of the described “new approach.” As this was a renovation project already being executed, we were able to compare our proposals with the ideas of the project architect, and with the real situation on site.

The project consists of 248 houses (Figure 3). These houses were built in 1949, and were partially renovated in 1977. The family houses have two stories and an accessible attic. There are three bedrooms, one of twelve m<sup>2</sup> and two of seven m<sup>2</sup>, respectively, a dining-sitting room combined with a kitchen of 34 m<sup>2</sup>, a bathroom, and a toilet (see Figures 4 and 5). The exterior walls are of masonry work, and the interior has B2 concrete blocks. The floors consist of

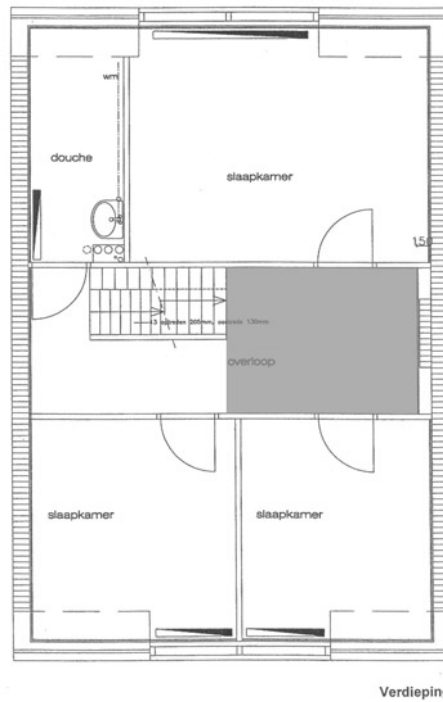
prefabricated concrete and there is a ceramic-tiled roof on bituminised hardboard panels placed on concrete girders and rafters. The actual renovation is planned for 2002/2003, under the supervision of a project architect.



**Figure 3** Typical street in Lievendaal



**Figure 4** Existing ground floor



**Figure 5** Existing plan of the first floor (15)

### Design for zero-waste

Based on the existing plans, various designs were prepared, taking into consideration the ideas of minimization of demolition, maximum re-use of out-coming products, etc.

### Scenario development for renovation

In the second part of the research, six scenarios were developed for the renovation.

Table 1 depicts the lifetimes of the various building components, which are applicable to this project. As can be seen, the lifetime variation is from 25 years to 50 and 75 years, respectively.

1949	1977	2001	2026
Foundation, facades, floors, wall plates, purlins			
Windows and frames Internal door/frames Ceiling plates	Windows and frames Internal door/frames Ceiling plates		
Roofing-plates, tiles, rafters External finishing of dormer window Roof gutters, rain-water pipes		Roofing plates, tiles, rafters External finishing of dormer window Roof gutters, rain-water pipes	
Internal walls Shower, toilet, kitchen, wall tiles Mains, installations	Internal walls Shower, toilet, kitchen, wall tiles Mains, installations	Internal walls Shower, toilet, kitchen, wall tiles Mains, installations	

**Table 1** Renovation Scenarios

### LCA studies

The aim was to find out how the waste production of a renovation project could be reduced by an improved renovation design and by re-use of materials, and what its environmental impact would be. The ECO-Quantum program calculated this impact. The reference scenario (#1) assumed that the houses would be preserved by maintenance for another 25 years. Consequently, the environmental impact was calculated for the planned renovation with new materials (scenario #2). We then looked into the re-use of out-coming materials, whereby scenario (#3) assumed a maximum re-use, and scenario (#4) represented a more realistic percentage of re-use. In scenario (#5) the original renovation plans were critically reviewed and altered, further limiting the production of waste. In particular, the changes in circulation space, location of the staircase and the corridor, resulted in an improved dwelling layout. This scenario assumed the maximum re-use of materials, while scenario (#6) assumed a realistic amount of re-use (15).

Environmental impact calculations gave the following results (Table 2). The figure for maintenance is set at 100 relative environmental impact points. In the case of maximum re-use, the impact of the renovation by the project architect was reduced from 152 to 129 points, and the revised plan gave a reduction from 152 to 122. A more realistic re-use percentage of materials leads to higher totals, 142 and 147, respectively.

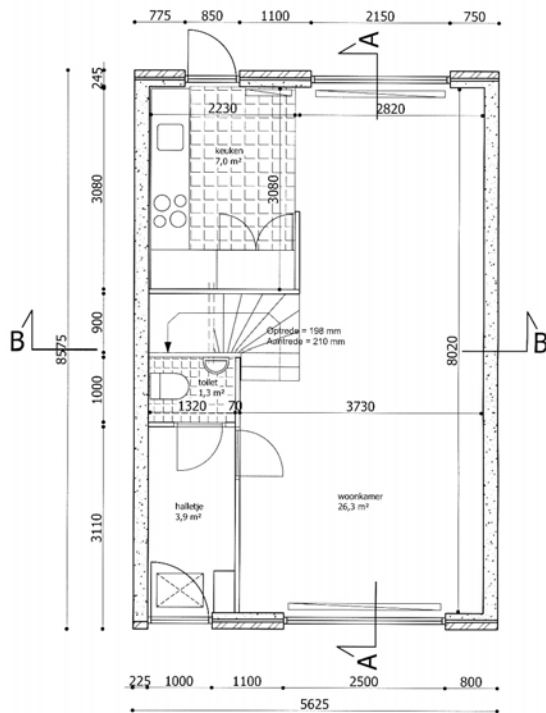


Scenario	Description	(Relative) environmental impact points
#1	Maintenance	100
#2	Renovation by project architect to plan	152
#3	Renovation by project architect maximum re-use	129
#4	Renovation by project architect realistic re-use	142
#5	Renovation revised maximum re-use	122
#6	Renovation revised realistic re-use	147

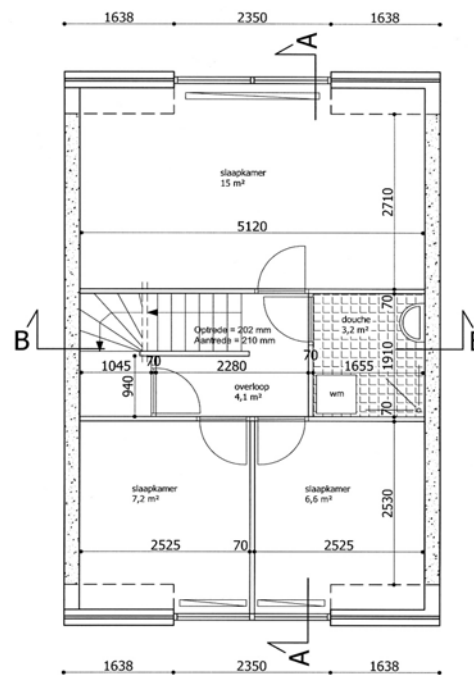
**Table 2** Relative environmental impacts of six renovation scenarios. Maintenance is set at 100, causing the lowest impact.

### Improved design

As a result of the LCA's of the six scenarios, the following plans were developed, which can be considered as an optimum. The façade, internal walls, roofs, and installations give the highest environmental impact. The revised renovation plans give less impact points due to simple measures like re-use (10% less impact of roofing and 50% of inner walls). A better layout and shorter mains, etc., could save materials (figures 6 and 7).



**Figure 6** Improved design, ground floor



**Figure 7** Improved design, first floor

### Monitoring deconstruction

To collect the detailed data on waste production, three students carried out on-site measurements on one house over a period of three days. (16) This house functioned as a test house during the renovation. They monitored the out-coming materials, caused by demolition of parts of that

house. The materials were counted and categorized by visual inspection on their re-use potential: re-use in this project, re-use elsewhere, use for a different application, or discard (Table 3).

Distinguished categories of removed components	Number of different components	% of total
Re-use in this project	29	47
Re-use elsewhere	15	24
Useful application	12	20
Burning	1	2
Discarding	5	7
Total	62	100

**Table 3** Categories of removed building components.

Sixty-two different out-coming components were counted of which 29, or 47%, were considered to be re-usable in the same project. In addition, a check was done on the degree of treatment before the components could be re-used. There were four categories of treatment: no treatment, cleaning, light treatment, and intensive treatment. This was only applied to those in the category, “Re-use in this project” (Table 4).

Categories of treatment before re-use	Number of different components	% of total
No treatment	11	38
Cleaning	6	20
Light treatment	8	28
Intensive treatment	4	14
Total	29	100

**Table 4** Treatment categories for re-usable components

Out of these 29 different components, 38% did not need any treatment, and 20% only needed cleaning. In conclusion, on average, one-third of the different out-coming components can be re-used in the same project. By applying other selection criteria, such as appearance and satisfaction to the contemporary requirements, this total may be lower.

Some observations during the demolition phase are of interest:

- The demolition contractor did not work “neatly”
- The labourers demolished parts of the house at a high speed within three days
- Supervision was absent
- The work methods for demolition were focussed on “rescuing” building components (causing unnecessary breakage of components)
- Many components were fixed, so they were not demountable
- Demolition was done “oversized,” more than was indicated on the drawings, with an increased materials flow (Figure 8).



**Figure 8** A bathroom with some demolished components, but... too many.

With another type of contract, together with proper instructions of the labourers, it was felt that far more different components and building materials could be available for re-use. Figures 9 and 10 depict the final result of the renovation by the project architect.



**Figure 9** Renovated roof with PV panel



**Figure 10** The project site, Lievendaal, after renovation (left) and before renovation (right)

## CONCLUSIONS

1. If the project architect could use precise, as-built drawings and lists of the used materials and their expected environmental impacts at an early stage, he or she would be able to decide which materials should stay in place, and which should be removed before he or she actually starts the design work for the renovation. The case study demonstrated the viability of this option. The housing project in this study can be considered representative of more than these housing estates. In order to obtain more data, estates with different types of housing should also be surveyed.
2. Although just one case was investigated, the results are promising. More materials and components can be re-used if both demolition methods and labour instructions are adapted. Reduction of demolition to a minimum will not only result in less waste, but also in less need for new materials.
3. The achieved reduction of the environmental impact is limited to 5-10 (152-147; 152-142) points only, which may give the impression that this exercise of re-use and reducing waste is just marginal. However, the conclusion still holds that comparison of renovation scenarios, through programs like Eco-Quantum, is a feasible option.

## REFERENCES

- 1 Smith, M., Whitelegg, J., Greening the built environment, Earthscan, London, 1998.
- 2 Vingerling, J.J., Afvalpreventie op de bouwplaats, Lecture notes, Technische Universiteit Eindhoven, 1994.
- 3 RIVM LAE, Monitoring prioritaire afvalstoffen, data 1997, Report, The Hague, 1999.
- 4 Erkelens, P.A., Extending service life of buildings and building components through re-use, In: (no Eds) Proceedings 9DBMC Conference, Brisbane, Australia, on CD-ROM, 2002 paper, 6 pages
- 5 Milford, R. Pro-active approach Theme 1: sustainable construction. CIB Information 2/02 p. 33, 2002
- 6 RIVM, Zorgen voor Morgen, Nationale milieuverkenning, 1985-2000, Report, The Hague, 1988.
- 7 MVRM, National Environmental Policy Plan, NEPP (Nationaal Milieu Beleidsplan) Report, The Hague, 1989.
- 8 Kibert, C. J., Deconstruction as an essential component of sustainable construction, in: (no Eds) Proceedings CIB World Building Congress, April 2001, Wellington, New Zealand, on CD-ROM, paper NOV 54, pp. 1-11, 2001.
- 9 Lofflad, H., Das globalrecyclingsfähige Haus, PHD. Thesis, Bouwstenen, nr. 66 Technische Universiteit Eindhoven, 2002.
- 10 Stroband, J., Israels, E.G., Direct hergebruik van componenten in de woningbouw, Report, Bekker & Stroband, BOOM, 1991.
- 11 Nunen, H. van, Hergebruikt bouwen met naoorlogse systeembouw in: Renovatie & Onderhoud, Juni, Vol. 26, TenHagen & Stam b.v., The Hague, pp. 10-12, 2000.
- 12 Vries, T. de, Aftoppen en weer opbouwen, Renovatie en Onderhoud, Vol. 26, jan/feb, pp. 22-25, TenHagen & Stam b.v., The Hague, 2001.
- 13 Hendriks, N.A., Balancing between functionality and extreme flexibility, in: (Ed. Erkelens P. A. et al), Beyond Sustainable Building, Bouwstenen nr. 65, pp. 21-24, Technische Universiteit Eindhoven, 2002
- 14 Erkelens, P.A., Zero Waste renovation, Internal research report, Technische Universiteit Eindhoven, 2000.

- 15 Rond, K. de, Milieu vriendelijk renoveren, MSc. Thesis, Technische Universiteit Eindhoven, 2002.
- 16 Gort, R., Communications, Bouwcarrousel, 2001.
- 17 Klundert, M. v.d, et al, Renovatie, Milieu en Afval, BSc Thesis Technische Universiteit Eindhoven, 2001.