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Energy Efficiency or Eco Efficiency?

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Abstract
A major factor in the ecological sustainability of housing is the considerable amount of energy consumption, which is necessary to run the housing estates when in use, related to (central) heating, air conditioning, water heating, lighting, ventilation, lifts and other technical services.

It should be kept in mind that the energy demand is heavily affected by user dependent influences. In projects, which are aimed at reducing energy demand by specific (heating, cooling or lighting) systems, detailed research should be done, taking all variables in consideration including the expected lifetime of the systems (which is in general shorter than the lifetime of the building). In 'day-to-day' housing development projects, however, a less detailed approach might be favourable. In these projects the approach of the energy problem comprises optimizing lay-out and orientation characteristics of the building, the physical performances of available building components (e.g. insulation performances of walls and windows) and the service systems as the industry is offering them. In designing a residential building with its systems, it may even be wise to overlook the impact of the behaviour of a specific client or target group, as the useful life of the building usually exceeds the occupancy time of that client or target group.

On top of that, especially if the emphasis is on improving the energy efficiency in the existing housing stock, the reduction of energy usage should be weighed against the ecological impact of the measures for improvement. One of the methods designed to support decision-making in this field is the method of the Eco-costs/Value Ratio (EVR). In "Cost effectiveness of sustainable housing investments" [1] this method is elaborated in a way that it can be used as a tool in housing development projects concerning both new construction and renovation.

The paper will show how architects can use the EVR method in housing (re)development projects to weigh the ecological impact of renovation or new construction activities against the ecological profits of improved energy efficiency.

1 Sustainability in the housing stock

1.1 Existing urban areas

When the sustainability issue is connected to planning and designing the living environment, one of the aspects to take into account is the condition of urban areas already existing at present. In major parts of Europe (and probably elsewhere) the large existing stock of houses and other buildings, has an impact on the qualities and potentials of the living environment. This impact is linked to the characteristics of the buildings, concerning questions like: are they (still) fit for use and what about their energy consumption?
The buildings also determine to a high degree the urban configuration by their very presence in the places they were once erected. In this respect, questions could be: does the orientation of the buildings allow them to benefit from sun energy or what is the effect of the spatial lay-out of neighbourhoods on commuting? and so on.

1.2 Expressing ecological burden in economic terms

Ever since the Brundtland-report [2] was published, throughout the world people have started to make efforts to produce in a more sustainable way than they used to do. In the building sector several initiatives have been made to improve sustainability on a practical level. Researchers created decision-making tools to support architects and other participants in building projects on the subject of ecological burden of buildings. In order to implement sustainability issues in general decision-making referring to product design, research has been conducted to express ecological burden in economic terms.

In several approaches, a distinction is made between internal and external costs of a product. The difference between the two types is that external costs do not affect the cost-price of a product, while they are not paid for by the individual producer or customer. If prevention or repair of ecological burden is paid by the government (i.e. the general tax-paying public), this ecological burden is marked as an external cost. Not prevented or repaired ecological burden can also be marked as an external cost. However, as soon as the government charges prevention or repair costs on the producer, these costs are marked as internal costs.

1.3 Emphasis on existing houses

To improve the sustainability of our living environment, research may be directed to determining the needed qualities of new building designs and urban forms. In addition to and maybe even prior to that, we should look for strategic measures in the existing urban areas, which are cost effective, in ecological as well as social and economic sense.

It is obvious that (the initiative and design stages of) renovation or redevelopment projects are the most suited moments to influence the sustainability of the housing stock. Whether the involved persons are aware or not, design decisions in building projects will influence the sustainability of the stock anyway. To improve ecological sustainability in the housing sector, directing decision support tools to the building design process seems the right thing to do. However, since the starting point should be the existing stock, tools should support decisions on questions like whether to renovate or to (demolish and) redevelop, in the first place.

2 Decision-support tool for eco efficiency

2.1 Quantifying ecological burden

The most systematic method that can quantify the ecological burden of (building) projects is the Life Cycle Assessment (LCA), as published by the ISO [3]. The LCA method aims at a systematic analysis of all environmental impacts of a product in all its stages of life. LCA provides a systematic approach to measuring resource consumption and emissions associated with products, processes and services. However, the traditional LCA is often considered to be too complicated and specialised to serve as a decision-support tool in development projects. Only environmental experts are able to interpret them, and even their complex decisions are not easy to communicate to the stakeholders in the projects. Therefore, in literature several models can be found that express the ecological burden of buildings in a single indicator. All of these models have slightly different goals and scopes. One of them is the model of the Eco-costs/Value Ratio (EVR).

2.2 EVR as decision-support tool

The model of the Eco-costs/Value Ratio (EVR) is an LCA-based assessment model that expresses the ecological burden of a product or service in *eco-costs*. The ratio compares these *eco-costs* to the value of the product or service. A low EVR indicates that the ecological burden of the product is relatively low, and – by consequence – that the product is fit for use in a future sustainable society. A high EVR indicates that the value/costs ratio of a product might become *less than one* in the future, if the external costs of the ecological burden will become part of the internal cost-structure. This means that there is no market for such a product in the future [4]. In principle, EVR supports assessments of all kinds of buildings, as long as the values of the buildings are comparable. Moreover, on that very basis, it allows comparing new construction to renovation or maintenance.

One of the central concepts of the EVR model is defining *eco-costs* as the costs of technical measures to prevent pollution and resource depletion to a level, which is sufficient to make society sustainable. More specifically, the model is based on the virtual eco-costs '99 being the sum of the marginal prevention costs of the depletion of materials, energy consumption, toxic emissions, labour and depreciation related to the production and use of products and services. The actual values of eco-costs are linked to the depletion and emission levels, which are agreed in the Kyoto Treaty. Like all models based on LCA do, the EVR model includes the whole life cycle of a product. In case of houses or other buildings, at least three phases of the product should be discerned to look at in particular: the production phase, the operating phase and the end-of-life phase.

2.3 Production phase

An important characteristic of building projects is that every project consists of a combination of semi-finished products, which are assembled at the building site – as can be seen in figure 1. Therefore, the environmental burden (the eco-costs) of a building in the production phase can be considered as consisting of the eco-costs of those semi-finished products plus the eco-costs of the assembling activities (including all additional works like preparation works, building site facilities and management). So, in principle it is possible to estimate the eco-costs of a building applying *eco-cost unit prices* of building elements. As is done in a traditional cost estimate based on unit prices, the composition of the concerned elements is determined in terms of quantities of characteristic semi-finished products and assembling activities. For these products and activities, the emission and depletion data, which serve as a basis for eco-costs assessments, can be found in data bases like IDEMAT [5] and Eco-Invent [6]. Hence, the eco-costs per unit of element can be determined by inserting the eco-costs of the semi-finished products and the assembling activities into the recipes of the elements.

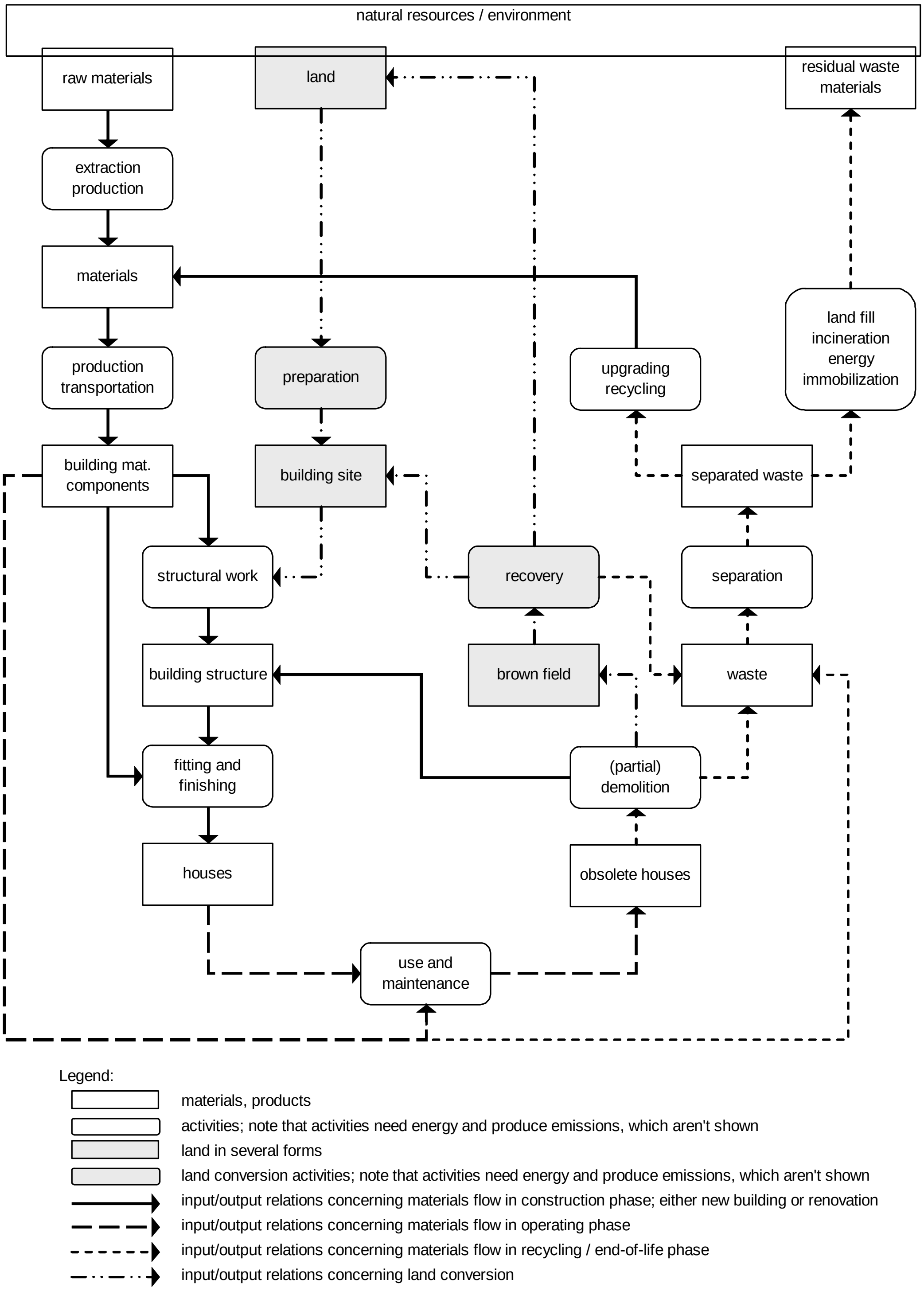

Figure 1: Materials flow and land conversion in the lifecycle of housing

Finally, the elemental bills of quantities (for estimating traditional economic costs) can be transformed into eco-costs estimates by substituting eco-cost unit prices for the traditional economic unit prices. In this way, eco-costs have been implemented in the materials database of an estimating system that is used to produce elemental bills of quantities for the construction costs of new construction and renovation projects. This way a tool has been acquired for estimating eco-costs in the production phase of these kinds of projects. (Note that in figure 1 is indicated that renovation and refurbishment are considered to be projects in the production phase of housing, in which a *new* building structure is obtained by partial demolition of an existing building.)

2.4 Energy costs determining the operating phase

In the operating phase, the most important factors of ecological burden are the energy demand and the maintenance of the building in use. To support decisions in the design stage, related to the energy demand, a model has been used, which was developed for the Netherlands Agency for Energy and the Environment [7]. Architects can estimate the energy demand of residential buildings (in the Netherlands) with this model. It requires limited input, related to the main formal characteristics of the buildings, which enhances its applicability for decision-making in design. The energy demand estimating facility of this model can easily be integrated in the EVR approach.

In recent years, several management models for maintenance have been developed in the Netherlands. However, these models seem to be too complicated for use in (early) design stages. In these stages, elaborated calculations of maintenance efforts are very unusual. At Delft University of Technology, an estimating model was elaborated for investigating the impacts of design decisions on the maintenance costs of residential buildings. Because of its basic structure, this model can be suitable for application by (Dutch) architects in early design stages. It can be integrated in the EVR assessment approach.

In the housing sector, management and administration costs are usually rather independent from the specific building design. For estimating the related eco-costs, these costs can be considered as mainly related to labour in offices.

2.5 End-of-life phase

The costs of demolition and the separation of waste are covered by traditional economic costing. The pollution prevention costs of these activities can be estimated without considerable problems. The eco-costs of recycling or upgrading are assigned to the new products emerging from these processes. So, all eco-costs in the end-of-life phase after the separation of waste are related to the waste fraction that is not fit for upgrading or recycling. This fraction is charged with *eco-costs of land fill*.

2.6 Estimating tools for the Eco-costs/Value Ratio in housing projects

So far, a conceptual model has been developed for estimating the eco-costs in the entire lifecycle of housing. At this stage of the research, for calculations referring to the production phase and the end-of-life phase, a so-called Reference Projects Model is operational. For calculations referring to the operating phase the spreadsheet facility for Estimating Energy Demand [7] and the Delft Maintenance Calculating Model can be combined and connected to the input interface of the Reference Projects Model. Some engineering is still needed to make this combination of tools for the operating phase available for architects in real life projects.

3 Sustainability is more than energy efficiency

3.1 A case study

In this section, a case study is presented to illustrate the type of results that can be obtained by means of the developed models, and to show that energy efficiency is just a – however important – part of the sustainability problem. The case study demonstrates how the model of the Eco-costs/Value Ratio can be applied in practice. A housing association is landlord of an estate that consists of several apartment blocks with clear obsolescence problems. What can the association do to cope with the situation? In view of the unpopularity of the apartments hardly any demand can be expected if the apartments are put up for sale. Especially, because of the large number of the apartments the expected proceeds will hardly exceed their indirect yield value. Moreover, the landlord does not consider selling these unwanted flats in line with its objectives as a housing association. Therefore, the possibility of selling is not taken into consideration. In principle four strategies – i.e. four types of interventions – remain possible for the apartment blocks:

1. *Continued operation*
   Any feasibility study should start with analyzing the result of an unchanged continuation of the existing situation. So, first of all, the economic consequences of continued operation are mapped out.

2. *Refurbishment*
   In case of refurbishment, improvements of the apartments are executed without major changes in the existing lay-out. In this case, refurbishment consists of replacing windows and external doors, thermal insulation of elevations, adjusting roof covering and edges, enlarging balconies, improving kitchens, adjusting electrical and mechanical systems, and major repair of common areas.

3. *Extensive renovation*
   Extensive renovation is an intervention that is considered to improve the building to a level that is similar to new construction. Maybe some quality dimensions are slightly inferior, but other dimensions may even be better than can be obtained by new construction. In practice, the feasibility of extensive renovation is related to the possibilities for changes in the lay-out offered by the existing structure of the apartment block [8]. Usually, these changes in the lay-out are intended to enlarge the apartments produced by the extensive renovation. After the intervention, the block will contain a reduced number of bigger apartments. In the case study, the extensive renovation consists of the same interventions as the refurbishment and, on top of that, the lay-out of the flats will be changed completely. Of course, all fitting and finishing will also be replaced.

4. *New construction*
   This strategy can achieve qualities that are beyond the possibilities of renovation. For instance, the lay-out of the site can be rearranged and car parking can be accommodated in the basement of a new apartment building.

First of all, the housing association should consider what purpose the intervention is aimed at. Which target group is going to be accommodated with the renewed estate? What kind of dwelling type is needed? How much can the new tenants afford to spend on rent? It is clear that – if an estate consisting of single-family houses with access at ground level is wanted – the only option is demolition followed by new construction. In many cases, however, good housing accommodation can be obtained by refurbishment or renovation in a more or less extensive form.

In this study, all considered strategies are assumed to result in a more or less break-even operation (in the context of providing housing facilities for different target-groups). This assumption allows us to investigate the results of eco-cost estimating for all the strategies. It implicates that the building values produced by the discerned interventions approximately equal the investment-costs. Under these conditions, balancing eco-costs to *value* can be executed by balancing eco-costs to *investment-costs.* Now, Eco-costs/Value Ratios on the level of housing expenses (per year) can be assessed by allocation both traditional economic costs and eco-costs of investments and maintenance. This is simply done by computing the (cost-price) rent for all strategies based on both types of costs. The housing expenses (rent as well as energy costs) that follow the discerned interventions can be compared as in figure 2. In this figure, along the positive Y-axis, the (*traditional economic*) *costs* of both the rent and the energy (per dwelling) are depicted, while the *eco-costs* of the rent and the energy are "mirrored" along the negative Y-axis.

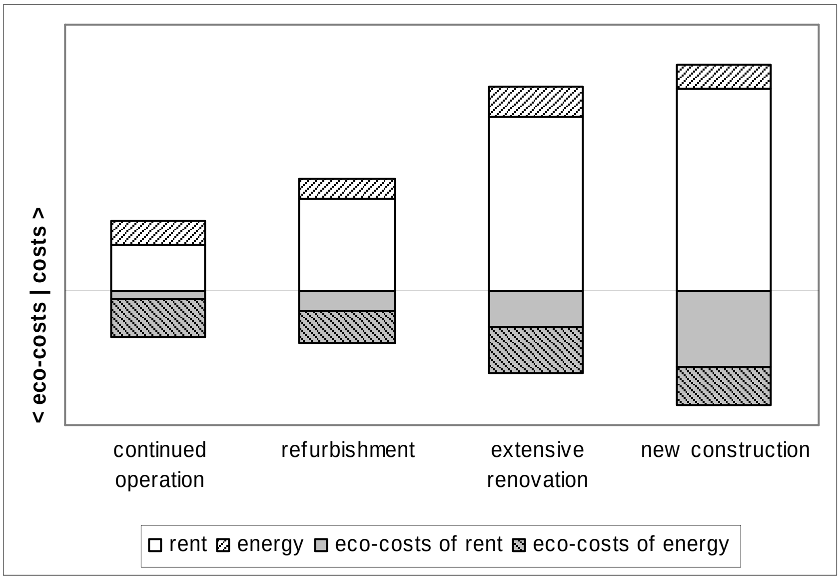

Figure 2: Costs and eco-costs of housing expenses (per dwelling) at several intervention strategies

Figure 2 shows that the rents following extensive renovation and new construction are clearly higher than the rent following refurbishment. A close look at the graph also shows that extensive renovation produces the highest energy costs. The energy efficiency, which can be obtained by thermal insulation in refurbishment and renovation scenarios, is usually inferior to the possibilities of new construction in this respect. Consequently, the energy costs of refurbished and renovated apartments are assumed to be higher than the energy costs of newly-built apartments in the same size category. However, per dwelling, refurbished apartments have lower energy costs, because of their smaller sizes compared to apartments that result from extensive renovation and new construction. Along the negative Y-axis, the eco-costs indicate the importance of the varying energy demands in respect of the involved ecological burden.
Provided that all of the considered approaches produce *good value for money*, the Eco-costs/Value Ratios of the discerned strategies can be computed by dividing the involved eco-costs by the corresponding traditional economic costs. This action results in figure 3, which shows that, in the studied case, extensive renovation produces the lowest EVR, and by consequence the lowest ecological

burden. So, if the considered approach of extensive renovation provides the wanted housing quality, this approach can be considered to be the most sustainable intervention in the case.

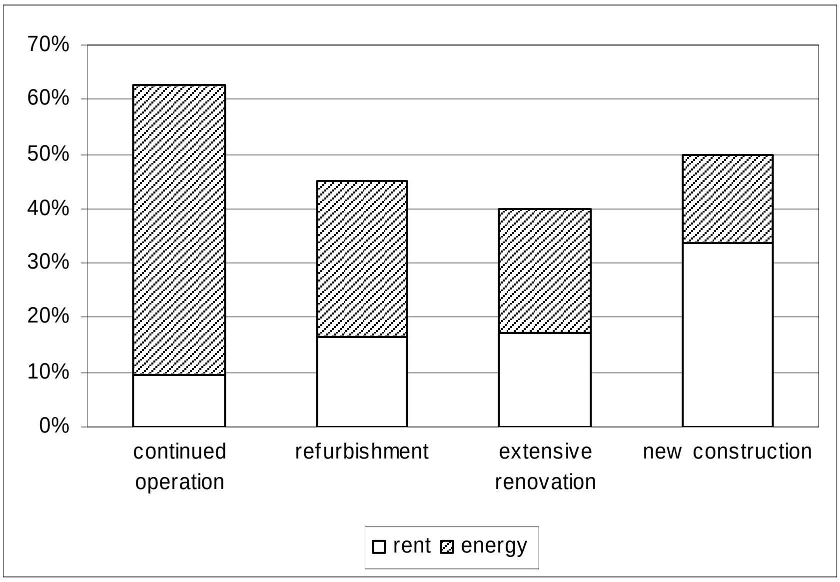

Figure 3: Eco-costs/Value Ratios of housing expenses at several intervention strategies

Figure 3 also shows that, if refurbishment or renovation is at stake, the mayor opportunities for ecological improvement can be found in optimizing energy efficiency. In case of new construction, however, ecological improvement should be found in applying less or different building materials.

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