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CO_2 reduction in the renovation of post-war housing areas: a feasibility study

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1. INTRODUCTION

In the Kyoto Protocol, governments of the industrialised countries agreed to reduce the total 1990 level of CO_2 emissions by 5.2% between 2008 and 2012, thus increasing the pressure on governments to establish CO_2-reducing strategies. The largest energy end-users in absolute terms are households and the tertiary sector (EC, 2001). In the EU new housing production is 1.9 million units per year, approximately 1% of the building stock, and dwellings yet to be built will constitute 15% of the total housing stock in 2020 and 5-10% of the total housing stock in the Kyoto period 2008-2012 (NOVEM, 2002). Consequently, according to the Kyoto agreements, the existing housing stock is an important sector in reducing greenhouse gas emissions. The environment, however, continues to play only a small part in urban renewal projects (Bus, 2001).

From an economic point of view, a firm or a household will invest in energy conservation up to the point where the costs no longer outweigh the financial benefits (Velthuijsen, 1997). According to Sunikka and Boon (2002) and Van der Waals *et al.* (2003), costs are often seen as the main barrier for adopting CO_2 reduction measures in urban renewal, but this concern is related to the impression of costs at face value, rather than any consideration of the actual costs and benefits. The development of operation-focused and long-term policies that support investment in energy improvements in the existing housing stock are key in the promotion of sustainable urban renewal. Successful policies require awareness of both the practical potential and the barriers.

This paper has two goals. Firstly, it examines the feasibility of CO_2 reduction in post-war housing in practice, focusing on the costs. The results are set in the context of relevant policy instruments, namely developments in energy pricing. Secondly, it discusses policy instruments that could make use of this potential and overcome the barriers identified in the case study. This paper aims to answer the research questions: What is the energy saving potential of post war housing renewal? What are the required expenditures and the expected receipts? Which policy developments will make investment in energy efficiency more attractive in the near future?

2. RESEARCH APPROACH AND FIELD OF STUDY

According to some views, anthropogenic interference in the carbon cycle is the most serious of the sustainability issues presently facing the world and in particular the industrialised countries (Bell et *al*., 1996). Considering that energy conservation in buildings is a relatively well-known issue, it is presumed that the housing sector will make a significant contribution to CO_2 reduction, as well as making a clear contribution to energy saving. In the Netherlands, a 3.6 Mton CO_2 reduction could be achieved from existing housing if an average investment of € 2,300 per dwelling was made and the energy tax was increased 2.5 times to shorten the pay-back time (ECN, 1998).

A feasibility study in one national context offers a deeper and location-specific insight into the complexity of urban renewal. The Netherlands is chosen as a case study, because since the mid-eighties it has emerged as an international leader in the environmental field. It has a tradition of effective planning and consensual politics and it uses several creative approaches to environmental policy-making, including at municipal and regional levels. In the Netherlands, demolition followed by new construction has become a common policy in renewal projects (Tellinga, 2004). This research focuses on renovation, because it can reduce energy costs and demand, forestall an increase in demand for new housing and improve the indoor air quality, without the environmental problems of demolition like waste and new resources consumption. The renovation solutions presented in this research are moderate measures, the incremental improvement of present practice, and focus on the dwelling-related energy consumption that means the energy consumption that is influenced by the technical condition of houses, involving natural-gas consumption and part of the electricity consumption and excluding the energy used for domestic appliances.

The case study was selected according to two key criteria: it had to involve a post-war residential district because it is in districts of this type that most of the restructuring operations will be carried out, and it had to involve ambitions and objectives for sustainable building. The selected case study is situated in Hoogvliet in the municipality of Rotterdam, in the Meeuwenplaat neighbourhood that consists of around 3,000 dwellings, located in similar five-storey buildings built in 1959. About 76% of the housing stock is social rental dwellings, mainly in the lowest rent categories. The case study contains 26 dwellings that have an average surface area of $\pm 60m^2$. The exterior walls have a cavity wall structure. Double-glazing and additional external wall insulation (50 mm) were installed in an earlier renovation to some parts of the façade. The floor and the flat roof are not insulated. The energy demand is dominated by the use of natural gas for space heating. Natural gas is also used for domestic hot water and cooking, and electricity is used for other energy services. The building has natural ventilation. The dwellings are heated with individual gas systems and domestic hot water with an instantaneous heater in the kitchen. The annual average indoor temperature was presumed to be 15 degrees. The interior staircase and most of the ground floor are unheated.

Energy evaluations of the different renovation solutions are carried out with the Energy Performance Advice (EPA) tool, a widely-used energy evaluation method in the Netherlands. The life-cycle expectation for the constructions before the next intervention is 25 years. For the installations, the life-cycle expectancy before the next intervention is 15 years. Studying the costs and benefits of a CO_2 reduction at a building level can clarify the practical implementation of greenhouse gas emissions abatement. In this research, the commercial viability of a project is assessed using the Net Present Value (NPV) test which is the present value of the Net Cash Flow associated with it. The decision rule is to proceed with the project only if NPV $\geq$ 0. The investment level is set low as similar renovation measures are implemented in more than 50 dwellings. All costs are calculated without the Value Added Tax (VAT). Due to the elimination of governmental energy subsidies in the Netherlands in 2003, the investment costs are calculated without subsidies. The gas price used is € 0.367, including the Regulatory Energy Tax (REB). The electricity price used is € 0.128, including the REB tax. The costs are based on an inflation rate of 2.9% and an interest rate of 6.5%.

Although forecasting carries obvious risks, and forward-looking policy analysis is complicated by the difficulty to predict innovations in building products, a number of energy price scenarios were used as a background to examine the results. An overview of the policy developments is based on previous research by the author and a literature study (Sunikka, 2001; Beerepoot, 2002; Hasegawa, 2002; Murakami *et al.*, 2002; NOVEM, 2002; Jansen *et al.*, 2003). The selected case study is part of a larger research project on sustainable urban areas where more case studies were examined and local housing associations commented on the results (Boon and Sunikka, 2004).

3. CO_2 REDUCTION IN THE CASE STUDY

Four cumulative energy-efficient renovation solutions are examined in the case study, based on the National Package for Sustainable Management, which is a widely-used collection of standard environmental measures in the Netherlands (SBR, 1998). In renovation solution 1, the thermal performance of a building can be improved by adding insulation to the thermal envelope – the exterior walls, the roof and the floor. In solution 2, new HR^{++} windows are installed as well as the additional thermal envelope insulation. Renovation solution 3 adds to solution 2 an HR107 kettle for space heating and a WP boiler for domestic hot water, with water-saving equipment. In solution 4, the installation of a solar boiler in addition to the previous measures is examined. The reference level is the current situation, standard maintenance without any environmental measures. The energy evaluation in the case study, considering one building, is presented in Table 1.

Table 1: Energy evaluation of the case study.

Options	Reference	Solution 1	Solution 2	Solution 3	Solution 4
	Existing situation	Insulation	Solution 1 + windows	Solution 2 + installations	Solution 3 + solar boiler
Energy index	1.13	0.86	0.78	0.74	0.66
Space heating (m3 gas)	28,000	13,145	9,332	9,370	9,370
Tap water heating (m^3 gas)	15,087	15,260	15,260	0	0
Total gas consumption (m^3)	43,887	28,405	24,592	9,370	9,370
Gas savings (m^3)	-	15,482	19,295	34,517	34,517
Tap water heating (kWh)	0	0	0	61,184	41,608
Ancillary energy (kWh)	7,929	7,929	7,929	11,091	12,591
Lighting (kWh)	9,181	9,181	9,181	9,181	9,181
Total electricity consumption (kWh)	17,111	17,111	17,111	81,456	63,380
Electricity savings (kWh)	-	0	0	-64,345	-46,270
Expenditure (excl. subsidies and VAT) (€)	-	108,179	168,235	322,404	368,046
Extra expenditure (excl. subsidies and VAT) (€)	-	85,263	119,654	258,519	304,161
Gas costs (excl. VAT) (€)	16,107	10,425	9,025	3,439	3,439
Electricity costs (excl. VAT) (€)	2,194	2,194	2,194	10,443	8,125
Annual receipts in total energy costs (€)	-	5,682	7,082	4,419	6,737
Payback time (years)	-	30	45	-	-
Payback time extra investments (years)	-	21	25	-	-
CO_2 emissions reduction (kg)	-	31,641	40,327	39,562	48,177
MJ Gas for EPL calculations	1,721,614	1,096,444	924,809	390,498	390,498
MJ Electricity for EPL calculations	157,945	157,945	157,945	611,444	470,943
Change in the reference energy index (%)	-	24	31	35	42

The evaluation shows that with renovation solution 2, the total gas use is reduced by 44% and a 40,327 kg CO_2 reduction is achieved. In total energy costs, a saving of € 7,082 achieved, which is € 272 per average dwelling. Solution 4 reduces the gas consumption by 79% from the current level, despite a slight increase in electricity consumption. CO_2 emissions are reduced by 48,177 kg. This results in an annual cut in energy costs of € 6,737, or € 259 per average dwelling. Th e results show, however, that the CO_2 reduction requires relatively high investments. The expenditure is € 168,235 for solution 2 (€ 6,471 per average dwelling), and € 368,046 for solution 4 (€ 14,156 per average dwelling). The energy efficient installations (solution 3) increase the investment by 48% compared to the technical improvements to the building, the insulation of the thermal envelope and new windows (solution 2), while the resulting savings in energy costs increase by only 19%, and the CO_2 reduction by a mere 2%. Renovation solution 2, therefore, seems to be the most cost-effective measure to cut the CO_2 emissions in the case study. When the results were discussed with the owner, the housing association, they proposed comparing the results to a standard renovation, a “zero option”, where building components and installations are replaced like with like, instead of the current situation, because some renovation measures would have to be taken anyway. The extra expenditure, compared to a standard renovation, is € 119,654 for solution 2, € 258,519 for solution 3, and € 304,161 for solution 4. Compared to a standard renovation, solution 2 can result in 70% more CO_2 reduction and save 38% more in total energy costs, with 29% extra investment costs. Solution 4 with a solar boiler would result in 75% extra CO_2 reduction compared to the "zero option", with 17% more investment costs. See Table 2.

Table 2: Extra investment costs, receipts in life-cycle energy costs and the CO_2 reduction delivered by the different renovation solutions compared to standard renovation.

Options	Standard	Solution 1	Solution 2	Solution 3	Solution 4
	Standard renovation	Insulation	Solution 1 + windows	Solution 2 + installations	Solution 3 + solar boiler
Expenditure (%)	-	21	29	20	17
Receipts in LCC compared to standard renovation (%)	-	30	38	23	36
CO_2 reduction compared to standard renovation (%)	-	62	70	69	75

If we consider receipts in energy costs over 25 years, it appears that solution 2 can result in a € 135,267 saving in total energy costs, compared to a standard renovation. This is illustrated in Figure 1. The lines represent the cumulative Life Cycle Costs (LCC) in energy consumption, which result from the different renovation options over 25 years, as NPV. LCC includes only energy consumption, maintenance costs are not incorporated in the analysis. The difference between the lines illustrates the receipts in energy costs.

A general rule is that only investments with a non-negative NPV should be carried out. In Table 3 the cumulative receipts resulting from the different renovation solutions are related to the extra expenditures.

The results show that renovation solution 1 can be paid back in 21 years and solution 2 in 24 years, but the NPV of solutions 3 and 4 remain negative even after 25 years. Long payback times make energy investment unattractive to the owner in monetary terms. This, however, could change in the near future depending on policy developments like energy pricing. The policy overview at European, national and regional policy levels shows that the most likely development to have an impact on energy-efficient renovation in the near future is the increase in energy price. Van der Doelen (1989) also concluded on the basis of an empirical analysis that the development of energy costs appeared to have the largest significant influence on energy conservation behaviour. It is expected that energy prices will rise because of regulatory measures, government action, implementation of the Kyoto treaty, a more dynamic energy market, the pressure to satisfy electricity demand with zero-emission technology and taxes. In the Netherlands, gas prices for average households have increased from 29 to 40 Eurocents per m^3 between 1999 and 2003, including the VAT (average annual increase 14%). On the basis of a policy overview, Table 4 presents the NPV of the renovation solutions after 25 years, with three different price scenarios, based on the extra expenditure. Scenario A is based on the current energy price increase with a 2.9% inflation rate. Scenario B is based on the assumption that the energy prices will gradually rise by 30% by 2012, compared to the level in 2003, based on the assumption that the Kyoto Protocol will not be ratified. Scenario C is based on the prediction that the Kyoto Protocol will be implemented, meaning a rise of 60% in energy prices by 2012, compared to 2003.

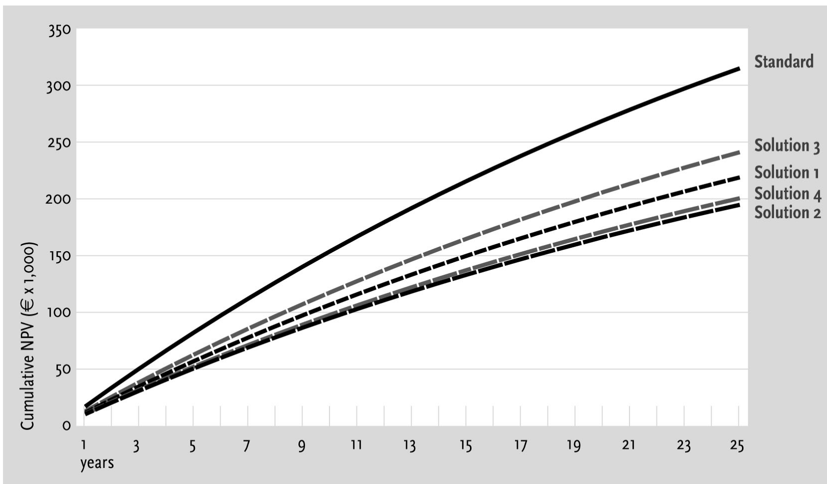

Figure 1: Comparison of energy LCC of the different investment options over a 25-year period (NPV).

Table 3: NPV of the different investment options for the extra expenditure compared to standard renovation after 25 years.

Options	Solution 1	Solution 2	Solution 3	Solution 4
	Insulation	Solution 1 + windows	Solution 2 + installations	Solution 3 + solar boiler
Extra expenditure compared to standard renovation (€)	85,263	119,654	*)655,457	*)771,180
Cumulative receipts in energy costs after 25 years NPV (€)	98,802	123,146	76,840	117,147
NPV after 25 years (€)	13,539	3,492	-578,617	-654,033

*) Since the life cycle of installations is 15 years, the investment needs to be made twice during the 25-year life cycle of the dwelling. The second investment takes account of an inflation rate of 2.9%.

Table 4 NPV of the different investment options in the case of A) the current trend in energy price, B) the expected 30% increase in energy price in 2012 and C) the 60% increase in 2012, based on the extra expenditure compared to standard renovation.

Options	Standard	Solution 1	Solution 2	Solution 3	Solution 4
	Standard renovation	Insulation	Solution 1 + windows	Solution 2 + installations	Solution 3 + solar boiler
Extra expenditure compared to standard renovation (€)	0	85,263	119,654	*)655,457	*)771,180
Annual receipts in energy costs (€)	160	5,682	7,082	4,419	6,737
A. Current energy price					
Cumulative receipts in energy costs after 25 years NPV (€)	2,782	98,802	123,146	76,840	117,147
NPV after 25 years (€)	-	13,539	3,492	-578,617	-654,033
B. +30% increase in 2012 (without Kyoto)					
Cumulative receipts in energy costs after 25 years NPV (€)	3,951	140,321	174,895	109,130	166,375
NPV after 25 years (€)	-	108,179	55,241	-546,327	-604,805
C. +60% increase in 2012 (with Kyoto)					
Cumulative receipts in energy costs after 25 years NPV (€)	5,790	205,600	256,258	159,899	243,774
NPV after 25 years (€)	-	120,337	136,604	-495,558	-527,406

*) Since the life cycle of installations is 15 years, the investment needs to be made twice during the 25-year life cycle of the dwelling. The second investment takes account of an inflation rate of 2.9%.

The results show that if energy prices increase by 30% by 2012, the payback time for renovation solution 1 is shortened from 21 years to 16 years, and the payback time for solution 2 from 24 years to 18 years. If the prices increased by 60% by 2012, as anticipated in the Kyoto Protocol, the payback time for solution 1 would shorten to 13 years and for solution 2 to 14 years. Renovation solutions 3 and 4 could not be paid back in the case study.

4 POLICY IMPLICATIONS

This study has illustrated the CO_2 reduction potential that can be achieved through renovating the existing housing. This contradiction between the environmental potential and the practice where the measures are not taken, raises the question of what factors could influence decision-making for energy efficient renovation at the strategic level. Environmental policies exist at all policy levels in the case study, but their impact on the actual decision-making at the project level is clearly overshadowed by economic, and sometimes social, targets. This is due to the fact that nearly all policies are voluntary and no single party is responsible for an overall environmental or energy policy in the renewal area. It seems that environmental departments at municipalities try to promote environmental improvements in renewal projects, but tend to forget the implications for the inhabitants as well as the costs. Developers and housing associations name costs as the greatest barrier in the adaptation of sustainable housing management (SBR, 2001; Sunikka and Boon, 2002). Different financing possibilities and Public-Private-Partnerships (PPP) do exist, but if the NPV of energy improvements remains negative despite the CO_2 potential, the question arises as to who is willing to take on the investment if the receipts will be smaller than the expenditure. Valuing the environment is not possible through the supply and demand mechanism because the environment is a public good, and de-coupling economic growth and energy use has not been achieved. Therefore, the situation needs to be corrected in terms of policies. This can happen by developing and combining the existing policy instruments, by introducing sustainability to the existing policy instruments or by developing new policy instruments.

The case study shows that the energy price tax that already exists is an efficient policy measure that reduces the payback time of energy-saving investments, if the rate is set high enough. Experience from the Netherlands shows, however, that energy taxes require support from the communicative instruments to be effective. The Regulatory Energy Tax (REB) was applied to Dutch households in 2001, resulting in an increase of a third for their energy. Research shows that only half of the population is aware of the Regulatory Energy Tax and 2% take it into account in their use of electricity (Van der Waals, 2001). Furthermore, the question remains as to how the taxation on energy can be increased without hitting low-income households that have less financial resources to invest in energy-saving measures, especially in the social housing sector. Energy pricing as a sole policy instrument is also very vulnerable to political and global market developments.

The EU Directive 2002/91/EC on the Energy Performance of Buildings demands that energy certificates are issued for the existing building stock by 2006 (EC, 2003). The Energy Performance Directive (EPD) will make energy saving in buildings more mandatory and will help to collect data about energy consumption in buildings, but it also allows each member state to decide whether certain minimum energy criteria should be met and whether to combine the energy certificate with economic policy instruments or to use it only as communicative instrument (Beerepoot and Sunikka, 2004). Experience from Denmark also shows that the energy labelling of buildings should be used with sanctions. Despite the fact that the Danish energy certificate scheme is made mandatory by the Act, only 50-60% of buildings are covered by the scheme and there are great regional differences (COWI consult, 2001). Without support from economic instruments, it is possible that energy improvements suggested in the label will not be implemented, especially in the rental sector.

Direct regulation is often considered as the most cost-effective policy instrument to force the market to change its habits, but apart from ensuring the minimum quality level, it provides no incentive to go beyond the minimum level, and their implementation and control on existing buildings remains problematic. Subsidies can encourage investments in energy efficiency, but it is unlikely that such programs would have a large-scale impact because they require tax revenue expenditures and are at risk from the free-rider effect.

Compared to energy market prognoses, less data exists about the developments in waste policies and prices, and waste management and recycling is receiving less attention in policies than energy. Pricing construction, demolition waste and setting taxes can, however, all play an important role in encouraging renovation and recycling in demolition. In the Netherlands, the landfill tax has reduced the amount of waste going to landfill from 49.7% in 1985 to 4.6% in 2000, and increased recycling from 49.5% in 1985 to 94.3% in 2000 (Hasegawa, 2002). Furthermore, the taxes on landfill can make waste competitive as a fuel in district heating systems.

Sustainability can also be introduced in the existing policy instruments where they are not yet present. Performance agreements for sustainable building, for example, are generally regarded as a suitable instrument for the realization of sustainability ambitions. Boon and Sunikka (2004) distilled from interviews the conditions that need to be in place for the successful implementation and execution of performance agreements for sustainable building. These can be split into conditions for performance agreements in sustainable urban renewal, conditions for performance agreements in the planning process and conditions for the implementation and execution of performance agreements.

If the existing, or prepared, policy instruments are not enough to achieve sustainable urban renewal, there are also new policy instruments that can encourage energy efficient renovation. Fiscal bonus or tax credits can be given for sustainable renovation and a lower Value Added Tax (VAT) rate applied for energy efficient construction materials, as, for example, in the UK. Preferential credit conditions can be allocated for sustainable renovation and setting up specialised funds for sustainable building is already beginning in Germany and the UK. Capello *et al.* (1999) conclude that the system of marketable permits for achieving urban sustainability looks rather promising, although due to the large number of consumers and the relatively low amount of energy use per consumer, the permits could be bought by the producers and importers rather than the consumers of the fossil fuels. In high density areas, developers can be awarded added density allocations for sustainable buildings (Drouet, 2003). Some Dutch housing associations have suggested that energy investments could be compensated through land prices. In the rental sector, energy consumption can also be taken into account in an advisory capacity on the allowed rents, a system that already exists for example in the Netherlands.

The case study presented the dilemma of investment and profit. The owner has to make the investment, while the tenant is the one profiting from less expensive energy bills. This can be the main barrier in sustainable building unless it is considered in policies. Although most people may seemingly espouse pro-environmental attitudes, they engage in environmentally destructive behaviour.

This ‘attitude-behaviour’ puzzle is also related to the question of Willingness To Pay (WTP). At the project level, in order for them to be effective, technical measures in construction should be combined with supporting communicative material for the inhabitants, for example individual measurement systems and material about new installations and their behavioural impact on energy consumption.

5. CONCLUSIONS

The case study illustrates that there is a great potential for CO_2 reduction through the renewal of post-war housing stock even with incremental improvements where considerable field experience has already been gained. In the case study, additional insulation of the exterior walls, the floor and the flat roof, and the installation of new windows reduced the gas use by 44% and CO_2 emissions by 40,327 kg. If energy efficient installations and a solar boiler are added, the gas use is cut by 79% and the CO_2 emissions by 48,177 kg. Compared to a standard renovation, the most cost-effective solution to cut CO_2 emissions, additional insulation and new windows, increased the CO_2 reduction by 70%, with an extra investment cost of 29%. The feasibility of energy efficient renovation, however, is limited by costs. Long payback times emphasise the importance of encouraging innovations that could radically change the energy-saving scenario. Supporting innovations, and finding the ways to implement energy efficient solutions that are also expensive, is a challenge for the government and probably requires adjustments in current policies.

At the operational level, the benefits of energy-efficient renovation seem very clear, but the contradiction between the potential and the practice addresses the question of suitable policy instruments at the strategic level. Policies exist, but in order for them to be effective, they need to be combined. For example the possibilities to support the Energy Performance Directive with taxes needs further research. Also the development of a new kind of policy instrument is taking place, while sustainability should be introduced to the existing policy instruments like performance agreements. An area-orientated approach is needed, because too much standardisation at higher policy levels can lead to sub-optimalisation, so a certain level of flexibility should be allowed. More research on the Willingness To Pay (WTP) and the Willingness To Accept (WTA) of inhabitants and other parties in the renewal process could produce good arguments for a renewal process where some energy improvements are now neglected by developers and housing associations based on the assumption that the inhabitants are not interested in environmental measures. Also linking WTP to structural information, such as household income, could give new insight into the implementation of sustainable urban renewal.

This study has focused on the social housing sector in the Netherlands, with reference to the late post-war housing stock, but many European countries are facing similar developments like liberalisation of energy markets and trends in the housing market, while there is recognition of the limitations of traditional policy instruments. Generalisation of case study results should always be done with great care, especially in housing renewal where every case differs by location, market demand or demolition pressure. Yet post-war housing production was based on standardisation and repetition, and neighbourhoods are characterised by identical housing types. This enables some comparisons between the cases that have similar housing typology, when the study is clearly limited to technical improvements or costs.

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