ENERGY CONSERVATION INVESTMENTS OF FIRMS: ANALYSIS OF INVESTMENTS IN ENERGY EFFICIENCY IN THE NETHERLANDS IN THE 1980's

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ABSTRACT
Energy efficiency improvements may be stimulated by several policy measures, like subsidies, energy taxes and standard setting. In this paper, one specific policy measure in the Netherlands is analysed: the 'energy bonus'. The energy bonus was a large-scale subsidy scheme that existed between 1980 and 1988 for stimulating investments in energy efficiency improvement and renewable energy. The data on energy efficiency improvement have been analysed.

The total of subsidized investments in energy efficiency improvement amounted to 5.7 billion Dutch guilders* (Dfl), and the subsidies amounted to nearly 0.8 billion guilders (14% of investments). These subsidized investments led to an estimated annual energy savings of 130 PJ, and account for half the energy savings in Dutch firms in this period. The average specific investment costs are derived for 20 different energy conservation technology categories. The average specific investment costs ranged from Dfl 27 to Dfl 56 per annually saved GJ, for the different technology categories. From the total investment and savings figures we calculated an average weighted specific investment of 43 Dfl per GJ saved annually. The average pay-back periods, calculated with saved energy purchase costs and taking the subsidy into account, were under 2 year from 1980 to 1985, and rose considerably in the years thereafter. We did not encounter differences in profitability and specific investment costs between small and large investments.

The subsidy measure seemed to suffer from a considerable 'free-rider effect'. We estimate that over 85% of the energy savings would also have occurred without the investment subsidy. If we assume that the remaining 15% energy savings was stimulated by the subsidy, then the subsidy measure costed (to the government) approximately 40 Dfl per GJ of annual savings.

INTRODUCTION
Energy efficiency improvements may be stimulated by several policy instruments, like e.g. subsidies, energy taxes and standard setting. A large uncertainty still exists about effectivity and efficiency of the different instruments. In this paper, one specific policy measure in the Netherlands is analysed: the 'energy bonus' in the 'investment account act'. Between 1980 and 1988 the 'energy bonus' existed as an incentive for firms to invest in (a.o.) energy conservation. The energy bonus was part of the 'investment account act', a set of subsidy measures embedded in the income and corporate tax systems. We used the data on the energy bonus to investigate the some characteristics of investments in energy efficiency improvement, and to correlate the resulting energy savings with the total energy savings in the Netherlands in the same period.

Two objectives are addressed in this paper. In the first place, we characterize the investments in energy conservation that were subsidized, by investment costs and pay-back period. We give an estimate of the energy savings that resulted from these investments and relate these to the total energy savings that occurred in the same period in the Netherlands. In the second place, the effectiveness and efficiency of the energy bonus will be addressed.

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* 1 Dutch guilder equals 0.5 U.S. Dollar (exchange rate at the beginning of 1990).

THE ENERGY BONUS

General description of the energy bonus

The first phase of the investment account act (IAA) was enacted on May 24th of 1978[1]. This first phase consisted of a general investment tax credit. This meant that firms could deduct a certain percentage of every investment from their corporate (or income) tax. On the 19th of July 1980, the energy bonus was enacted as part of the second phase of the investment account act. The second phase of the IAA was meant as an extra set of tax credits which were granted for desirable investments, like investments in energy conservation, in environmentally friendly processes and investments in specific regions of the country.

The IAA was meant to stimulate investments in general, and with it economic growth and employment. The energy bonus was meant to stimulate investments in energy conservation *over* other investments. Another reason for the energy bonus was that the high energy prices in those days were an increasing burden to trade and industry. Though these high energy prices made investments in energy conservation already more profitable the high energy prices had, according to the government, already decreased the firms' resources to invest, which seriously endangered the possibilities to carry out the necessary energy conservation programmes[2].

The energy bonus procedure

Investments that could be subsidized with an energy bonus were described in a limitative list (the 'energy list'). The energy bonus was granted to several categories of investment projects. The main categories that were distinguished were investments in:

A. insulation and improved heating of buildings
B. energy efficient production equipment
C. combined heat and power
D. equipment to use heat derived from wastes
E. solar energy
F. wind energy
G. equipment for the use of coal as fuel
H. energy efficiency improvement of means of transportation
I. hydropower energy

A further division in subcategories is given in appendix 1. The categories A, B and H aim at efficiency improvement of the end-use of energy. Investments in category C improve energy conversion efficiency, while the categories D through F. and I aim at stimulating the use of untapped and sustainable energy sources. Category G was meant to stimulate the use of coal, which in those days fitted in the governmental policy of diversification of the energy use in the Netherlands. In this analysis we focus our attention at investments in efficient energy conversion and end-use in firms. These are the categories A, B and C.

Investments in energy conservation that were described in the 'energy list' were subsidized with a 10% investment tax credit. This bonus came on top of the general investment tax credit which was between 12 and 13% for equipment. The energy list was adapted seven times between 1980 and 1988, mainly to include new energy conservation technologies. In the years 1982 and 1983*, the bonus was temporarily increased to 20% to accelerate investments in energy efficiency.

In the energy list a distinction was made between two kinds of investments: investments for which a minimum energy conservation per invested guilder was applicable, and investments without such a limitation (cf. appendix 1). At the introduction of the energy bonus, the minimum energy conservation (for the selected subcategories)

* Investments that were taken into operation after January 31st of 1982 and before December 31st 1984.

was 0.5 m^3 natural gas equivalents* (approximately 15.8 MJ)** per invested guilder. At January 1st 1983, the conservation requirement was lowered to 0.4 m^3 natural gas equivalents (approximately 12.7 MJ) per invested guilder. The reasons for lowering the conservation requirement were twofold. The government reasoned that due to inflation the requirement had become more severe. Furthermore, the ongoing process of investing in energy conservation exhausts the very profitable energy conservation investments[3].

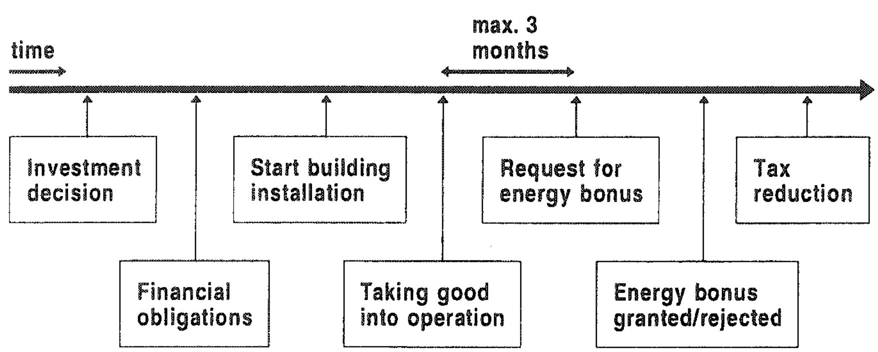
The investment categories without a minimum energy savings requirement were believed to at least achieve comparable annual savings, i.e. more than 0.4 m^3 natural gas equivalents per invested guilder[2]. They were exempted from the requirement because verification was difficult for these investment categories[2]. Furthermore, investments had to be above the investment limit of Dfl. 10,000 and a franchise of Dfl. 5,000 was regarded (meaning that Dfl. 5,000 was deducted from the investment before the energy bonus was calculated). The investment limit was lowered to Dfl. 5,000 in 1985. At the same time, the franchise was abolished.

It should be noted here that firms could also apply for the energy bonus if their investments were not done with the *objective* to save energy. The only restrictions were that the investment had to be awarded a general investment credit, had to be in the energy list, and that (if applicable) the energy conservation requirement was met. This implies that firms replacing old and worn equipment could also be granted an energy bonus.

Application for the energy bonus was due within three months after the goods were taken into use. Applications for the energy bonus were handled by the 'investment account department'. There the investment category of the investment was attributed, and the investment amount itself was assessed. Only the part of an investment that was *relevant* for the energy savings was taken into account. For instance, "fancy tilework was not considered necessary for energy conservation in a building that was built around a CHP installation"[4]. The investment account department also assessed the energy savings requirement.

If the requirements were fulfilled the investment account department gave a declaration to the investor with which the tax reduction could be asked for. Because of the described procedure, it generally took more than one year between the actual investments and the tax reduction. Especially for large investments with a long installation or building period the time lapse could even be several years. The time frame for an investment that was subsidized with an energy bonus is depicted in figure 1.

Figure 1. Time frame for the energy bonus



An important date in the time frame is the date on which financial obligations were made. With this date it was decided which amount of energy bonus (10 or 20% of the investment) was attributed.

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* For calculation of the conservation requirement the following conversion factors were used: 1 kWh of electricity = 0.34 m^3 natural gas equivalent (nge); 1 tonne of coal = 925 m^3 nge; 1 tonne heavy fuel oil = 1300 m^3 nge; and 1000 litres of light fuel oil = 1200 m^3 nge [2].

** Throughout this study we applied the lower heating value of Groningen natural gas (31.65 MJ/m^3) to convert one m^3 of natural gas equivalents to heat values.

Evaluation of the energy bonus

Before we turn to the available data on the energy bonus, and the analysis of these data, we describe briefly a background of the analysis.

The energy bonus was granted for investments for which a financial obligation was made between 1980 and 1988 (cf. figure 1). In a large part of this period (1981-1985), the energy prices in the Netherlands were the highest since the second World War. Furthermore, the first years of the 1980's were years of economic recession. The energy bonus should, of course, be analysed with these backgrounds in mind.

An investment subsidy may be called 'effective' when the subsidy is a condition without which the desired investment would not have occurred. This implies that we have to find out which investments would have occurred without an energy bonus. To this end we make a distinction between two types of energy conserving investments:

- add-on investments
- replacement investments

With add-on investments we indicate (mostly small) investments in goods that come 'on top' of the existing equipment. These investments may be done mainly for the sake of energy conservation, or with other intentions but with an energy saving effect. Examples of such add-on investments are a.o. insulation, heat recuperation, automatic controls. A larger investment in this category is e.g. investment in combined heat and power. With replacement investments we indicate the substitution of old equipment with new equipment. Because of technological progress the new equipment can be more energy efficient than the substituted piece of equipment. We assume that adoption of add-on investments is governed mainly by the profitability of the specific investment, and that the replacement investments are mainly governed by the lifetime and age of equipment.

The profitability of an investment (in energy efficiency) can be expressed with several economic variables. In industry the simple pay-back period is often used as investment criterion, sometimes together with other investment criteria[5-8]. In this analysis we also used the pay-back period, based on saved energy purchase costs, to indicate the profitability.

METHODOLOGY

Data on the Energy Bonus

Two sets of data were available for the analysis: annual statistics[9] and an electronic database[10]. In the annual statistics, the number of approved requests are given, as well as the matching figures for the 'relevant' investments, the energy bonuses and the expected energy savings. These data are given per investment category and per year in which the investment was granted. These statistics concern 26298 investments. The second set of data consists of an electronic database that was kept by the investment account department starting (gradually) in 1982[10]. Because the start of the digital database lies two years behind the introduction of the energy bonus, the database is far from complete. We used the electronic database for calculations, and the annual statistic data for verification and extrapolation purposes.

The data in the electronic database had to be cleared and adjusted before we could use them. The original electronic database contained 20071 records. First we removed the approximately 5000 'doubles' from the database. Investments were inserted 'double' when the subsidy on one investment had to be shared between several owners of a partnership. After removal of the doubles we had to remove some incomplete records. For 72 records no investment category (cf. appendix 1) was included. For 496 records no investment figure was included. We then removed all the records concerning an investment category greater than 20 (because only the main categories A, B and C are analysed). This left us with 12759 records which included at least data on the investment category, the investment and the energy bonus.

Sometimes an applicant objected against the decision of rejection or against the part of the investment that was considered 'relevant' for the energy bonus. The figures after appeal are taken instead of the initial figures for investment and bonus. The 'energy bonus relevant' investment figures were reconstructed with the energy bonus figures. This energy bonus was either 10 or 20% of the relevant investment, depending on the year of investment.

Of the 12759 records, only 2611 records contained data on the projected energy savings of the investment. This implies that the electronic data that we can use for calculating profitability constitute approximately 10% of the total number of investments.

Calculation of pay-back periods

For 2611 records in the electronic database we were able to calculate an energy-related pay-back period. To this end we calculated the annual saved energy purchase costs by multiplying the energy savings with the energy costs. The annual savings are reported in m^3 of natural gas equivalents. It is not clear which energy carrier was saved in a specific investment project. Because most investment categories of the energy bonus relate to heat savings we chose the natural gas price for our calculations (natural gas is the most important fuel for heating purposes in the Netherlands). For savings on coal and oil this may lead to too short calculated pay-back periods. For savings in electricity it may lead to too long calculated pay-back periods. Energy costs were derived from EnergieNed[11]. We took the natural gas price for large consumers*. The natural gas prices that were used in calculating the PBP's are given in table 1.

Table 1. Energy prices used for the calculation of pay-back periods

Year	Energy price (Dfl/m^3 nge)
1980	0.28
1981-1983	0.40
1984-1985	0.45
1986	0.26
1987	0.21
1988-1992	0.19

A simple pay-back period was calculated by dividing the initial investment by the annual saved energy purchase costs. Because all investments were also granted the general investment tax credit (12-13%), we took this credit into account. The tax credit was given after taxes. The actual (financial) benefit is therefore larger than with a normal subsidy. On the other hand, the time lag between the actual investments and the tax deduction reduces this difference (if a discounted cash flow method is used). For reasons of simplicity, and in order to link up with the easiness of the PBP criterion, we chose the following formula to calculate the pay-back periods:

$$PBP_i = \frac{Inv_r \times (1 - \{IC_g + IC_{eb}\})}{ES_a \times EP_{ng,i}}$$

With: PBP_i = the pay-back period for a good that was taken into operation in year i; Inv_r = relevant investment; IC_g = general investment credit (we used 12.5%); IC_{eb} = energy bonus (10 or 20%); ES_a = annual energy savings; and $EP_{ng,i}$ = the energy price (for natural gas) in year i.

The pay-back period was calculated with and without taking the energy bonus into account to determine the profitability effect of the energy bonus in terms of a shorter PBP. It should be noted that our calculated PBP's

* Consumers with an annual consumption of 10-50 million m^3 natural gas annually.

Table 2. Overview of investments and energy savings per investment category.

	Investment category	Nr. of investments (nr)	(%)	Amount of investments total (10^3 Dfl)	(%)	average (10^3 Dfl)	Savings (PJ)	Sp. Inv. weighted (Dfl/GJ_a)	(nr)*	Sp. Invest. unweighted (Dfl/GJ_a)	St. dev. (Dfl/GJ_a)
1.	building insulation	21279	80.9	1109 057	17.8	52	***27.7***	***40.0***	1280	44.2	21.1
2.	waste heat/space heating	33	0.1	2 997	0.0	91	***0.1***	***40.0***	-	-	-
3.	heat pumps/space heating	189	0.7	20 913	0.3	111	***0.3***	***80.0***	-	-	-
4.	equipment insulation	355	1.3	78 274	1.3	220	5.1	15.2	123	26.6	19.4
5.	control measures	184	0.7	60 044	1.0	326	2.3	25.9	79	27.0	19.9
6.	heat recovery	819	3.1	329 938	5.3	403	14.3	23.1	262	32.7	20.5
7.	heat pumps/prod. equipment	75	0.3	36 371	0.6	485	***0.5***	***80.0***	-	-	-
8.	waste heat/prod. equipment	13	0.0	64 622	1.0	4 971	***1.6***	***40.0***	-	-	-
9.	power recovery	32	0.1	50 227	0.8	1 570	2.0	25.4	14	28.7	18.7
10.	improved firing	364	1.4	175 344	2.8	482	6.1	28.7	103	34.6	22.8
11.	evaporation/distillation	237	0.9	836 233	13.4	3 528	16.9	49.4	112	37.1	23.9
12.	drying equipment	251	1.0	140 911	2.3	561	2.6	53.7	96	56.1	17.9
13.	cooling/sterilization	169	0.6	46 451	0.7	275	0.9	49.9	74	43.8	18.3
14.	melting/kilns	185	0.7	598 116	9.6	3 233	11.7	51.3	79	50.8	21.1
15.	electrochemical equipment	4	0.0	25 069	0.4	6 267	0.7	35.6	1	36.2	-
16.	electric./fuel switch	58	0.2	4 638	0.1	80	0.1	36.1	18	44.9	19.3
17.	drives/transformers	229	0.9	200 041	3.2	874	***5.2***	***38.3***	45	38.6	21.9
18.	vacuum pumps	112	0.4	41 581	0.7	371	1.9	22.1	65	30.7	21.6
19.	computer control	32	0.1	58 467	0.9	1 827	1.4	40.5	23	46.4	24.5
20.	combined heat and power	619	2.4	1777 556	28.5	2 872	***29.6***	***60.0***	1	33.3	-
21.	waste combustion	342	1.3	71 470	1.1	209					
22.	adapt. waste combustion	30	0.1	16 020	0.3	534					
23.	waste fermentation	34	0.1	30 351	0.5	893					
24.	solar collector	76	0.3	3 044	0.0	40					
25.	wind energy	167	0.6	21 931	0.4	131					
26.	coal as fuel	280	1.1	269 052	4.3	961					
27.	coal gasification	0	0.0	-	0.0	-					
28.	efficiency aircraft	25	0.1	157 363	2.5	6 295					
29.	efficiency ships	63	0.2	4 500	0.1	71					
30.	wind guide trucks	42	0.2	410	0.0	10					
31.	water power energy	0	0.0	-	0.0	-					
	Totals	26298	100.0	6230 995	100.0	237					
	Totals Cat. 1-20	25239	96.0	5656 853	90.8		131.1	43.1			

The figures in bold italic are estimated (see main text). The last three rows are derived from the electronic database[10], while the other figures are from the annual statistics[9]

* *number of investments used for calculation of the unweighted specific investment and standard deviation.*

are energy-related PBP's. Other costs (e.g. increased operation and maintenance costs) and benefits (e.g. labour cost reduction) are not taken into account. Therefore, the calculated PBP only gives a limited insight in the actual profitability of the investment.

RESULTS

Investments and energy savings

Between 1980 and the end of 1990 an energy bonus declaration was given for 26298 investments. The investments involved amounted to 6.23 billion Dutch guilders, and the energy bonus amounted to 0.88 billion guilders[9]. These figures imply that an average energy bonus of 14% of the investment costs was granted. The number of requests per year, and the number of granted energy bonuses per year are depicted in figure 2. We can see from this figure that it took some time between the application for the energy bonus and the granting of the energy bonus. The requests that were done after termination of the subsidy measure in 1988 relate to projects that were already started before the end of the energy bonus program. From figure 2 we can also see that it took some time before investors started to send in requests for the energy bonus. After 1985 a decrease in the number of requests can be seen. This may possibly be explained by the large decrease in energy prices after the year 1985. In figure 3, the investments that were granted an energy bonus are related to the total investments by firms. From this figure we see that the subsidized investments in energy efficiency improvement constitute only a very small part of the total investments.

Figure 2. Number of requests for the energy bonus per year, and number of granted energy bonuses.

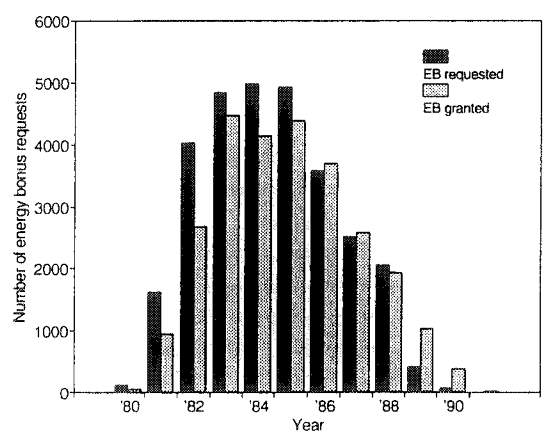
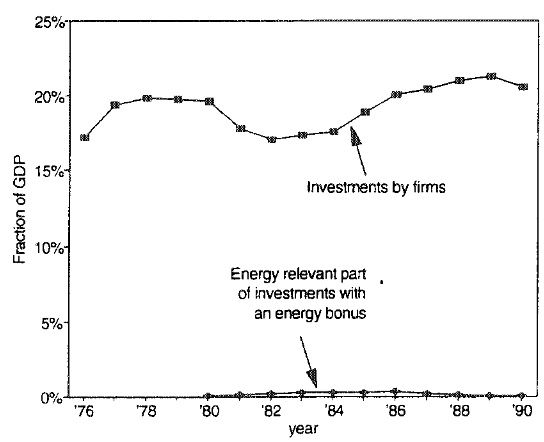


Figure 3. Total and 'energy bonus' investments by firms, related to the gross domestic product.

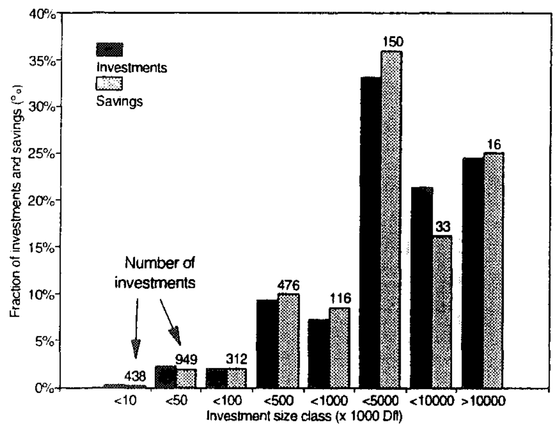


The investment projects that were granted an energy bonus are given in Table 2 per investment category. From table 2 we see that 96% of number of investments and nearly 91% of the invested money relate to energy efficiency (categories 1-20). In table 2 we also give the projected energy savings as assessed by the investment account department. Together with our own estimates for the categories for which the energy savings were not given (figures in italic in table 2), we arrive at a total of energy savings of 132 PJ annually. With the results from a previous study[12] we can correlate these energy savings to the total energy savings in this period. The primary energy consumption in the Netherlands (except residential and transport) decreased with approximately 250 PJ (net), between 1980 and 1988, when taking only efficiency improvements into account. This means that about 50% of the (net) energy savings in the Netherlands (excluding residential and transport energy use) can be attributed to investments in energy efficiency that were granted an energy bonus. The remaining energy efficiency improvement may be caused in part by operational changes requiring no major investment (good housekeeping). Another part may be explained by investments that were not granted an energy bonus, including investments for which no application for an energy bonus was made, and investments that were not eligible for the energy bonus (e.g. investment smaller than the investment limit).

Characterization of investments in energy efficiency

With the data in the electronic database we were able to divide the investments in size classes according to the amount of money invested. The total investments, savings and number of investments are depicted in figure 4.

Figure 4. Investments and savings per investment size class (as fraction of the total).



From this figure we can see clearly that the larger investments make up for the largest part of the savings. Furthermore, we found that the specific investment and profitability (PBP) do not differ significantly among the different investment size classes.

With the data on the energy bonus we are able to characterize the investments that lead to energy efficiency improvement. For thirteen investment categories full energy saving data were available (see table 2). The ratio of the total investment and energy savings per category corresponds to the weighted mean specific investment*, expressed in guilders per GJ saved annually. These figures are also reported in table 2. For seven investment categories no full information on the energy savings was available. For these categories, a specific investment figure was introduced with which the total energy savings per category were calculated. The specific investment for the categories 1 and 17 were derived from the electronic database. The specific investment figure for the categories 2 and 8 was derived from the database ICARUS[13], a database with over 800 energy conservation measures for a large number of sectors in the Netherlands. For the 'heat pump' categories (3 and 7) we introduced a specific investment of 80 Dfl/GJ_a**. Finally, the specific investment in combined heat and power production (investment category 20) is calculated with an average investment of 1500 Dfl/kW, 7000 running hours per year, and a national power generating efficiency of 40%.

The weighted average investments show a large variation between the different categories, ranging from Dfl. 52,000 for insulation measures to over Dfl. 6 million for improvement or replacement of electrochemical and metallurgical equipment. From the total investments (cat. 1-20) and total savings we calculated a weighted specific investment of 43 Dfl/GJ_a. We also calculated the average (unweighted) specific investments with the electronic database. These are also reported in table 2, together with the sample standard deviation. The average specific investments range between 27 and 56 Dfl/GJ_a. The standard deviations are all in the order of 20 Dfl/GJ_a.

* Because we used the totals of investment and savings, the specific investment figure is 'weighted' with the size of the investment; large investments have a larger weight in calculating the mean value.

** This figure is the highest specific investment that fits in the conservation requirement of 0.4 m^3 per invested guilder. The figures in ICARUS[13] suggest that the specific investment figure for heat pumps is higher (approximately 110 Dfl/GJ_a). However, this difference will only have a minor influence on the total energy savings because of the relatively low investments in these categories (see table 2).

With the formula in the previous section we calculated the pay-back periods for the 2611 investments in the electronic database. These calculations were performed with and without taking the energy bonus into account. These are depicted in figure 5, after ordering the investments according to increasing pay-back period. From figure 5 we see that 40% of the investments has a PBP of under 2 years. In figure 6 the same data are plotted against the cumulative energy savings. This yields logically a different picture. Nearly 70% of the total savings resulted from investments with a PBP of under 2 years.

Figure 5. Pay-back periods plotted against the cumulative investment.

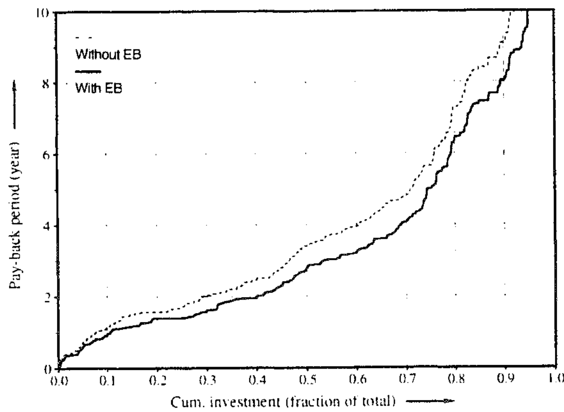
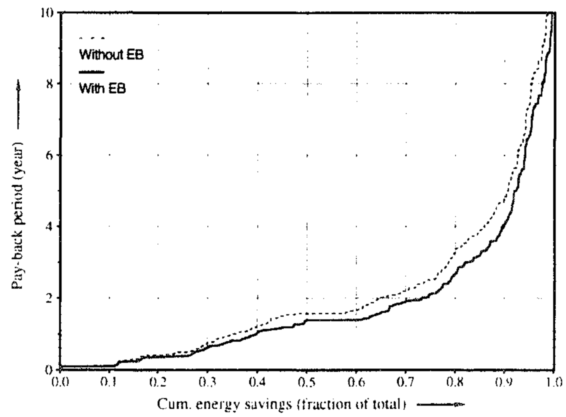


Figure 6. Pay-back periods plotted against cumulative savings.



Developments in time

We calculated the average pay-back period per year from the specific investment figures and the gas price in that year. To calculate the PBP we also took the general investment credit and energy bonus into account. The development is depicted in figure 7. From this figure we see that until 1985 the PBP's are under 2 years, and go up considerably afterwards. This may be partly explained by the high energy prices which made investments more profitable until 1985. However, the data in figure 7 indicate that also the specific investments became higher after 1985. Possible explanations for the increasing specific investment after 1985 are the following. In the first place, the ongoing process of investing in energy efficiency may have reduced the possibilities for very profitable investments in energy efficiency. In the second place, the increasing specific investment may have resulted from more risky (replacement) investments due to a growing confidence in the improving economy.

EFFECTIVENESS AND EFFICIENCY

In the previous section, we saw that a large fraction of the energy savings resulting from the energy bonus investments had very low pay-back periods. This leads us to believe that a large fraction of these investments might also have occurred without the subsidy measure. In the following subsection we assess the effectiveness of the subsidy measure: what part of the investments is stimulated by the energy bonus. Furthermore we assess the efficiency: the ratio of costs and benefits of the measure.

Figure 7. Development in time of the average PBP and the average specific investment.

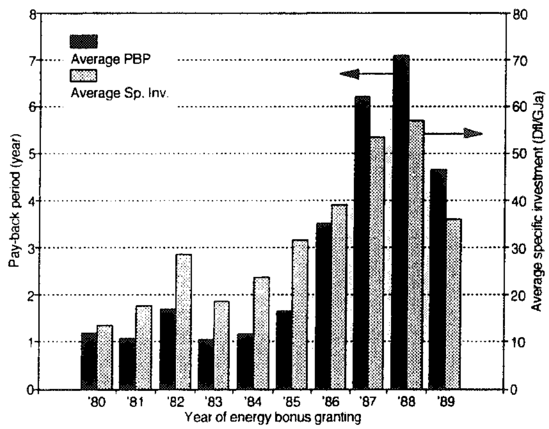
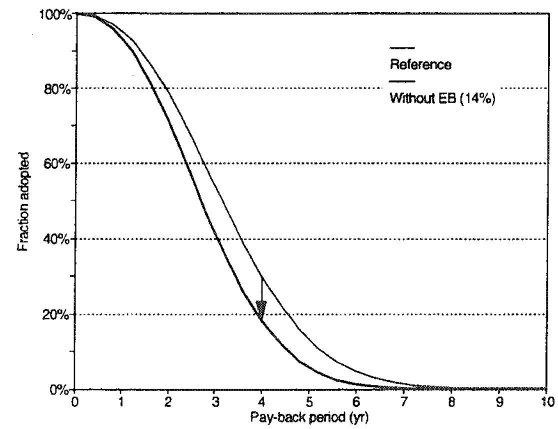


Figure 8. Modeled relation between adoption of an energy conservation measure and PBP.



Effectiveness

In this section we want to find out what part of the investments in energy conservation were induced by the energy bonus. Two *financial* effects can be attributed to the energy bonus: first, the bonus reduces the pay-back period of an investment, and secondly it lowers the amount of capital needed. The second effect is not taken into account because the investor had to invest the full amount of money in advance of getting the credits back.

The effectiveness of the energy bonus is assessed with a simple investment model. This model indicates what part of the investments with a certain PBP would also have been carried out without the energy bonus. The profitability criteria of firms are have been generalized by Hein *et al.*[14], on the basis of studies by Gruber[6] and Koot[7]. In table 3 the cut-off pay-back periods are given. Table 3 indicates that e.g. 95% of the firms would adopt an energy efficient technology with a PBP of 1 year. The data in table 3 were interpolated for our calculations[14]. The interpolated line is depicted in figure 8. The other line in figure 8 indicates the fraction of measures that would have been implemented if no energy bonus had been granted. We took the average value of the energy bonus of 14% for our calculations.

Table 3. Relation between PBP and adoption of energy conservation measures

Simple Pay-back period (year)	**Adoption** (% of technical potential)
1	95
2	80
3	55
4	30
5	10

From figure 8 we can, for instance, see that for a pay-back period of 4 years 30% of the available measures will be implemented, whereas this would have been 18% if no energy bonus had been granted. We now set the total number of investments in our electronic database with a PBP of 4 years equal to the 30% in figure 4. Then 60% (=18/30) of these investments would also have been carried out without an energy bonus, and we assume that the remaining 40% is stimulated by the energy bonus. By doing so for all investments, we can get an indication of the projects that would have happened without the energy bonus. The results are depicted in the figures 9 and 10. The measures that would have been adopted without the energy bonus are indicated with 'free-rider'.

Figure 8. Estimate of the investments that were (not) stimulated by the energy bonus.

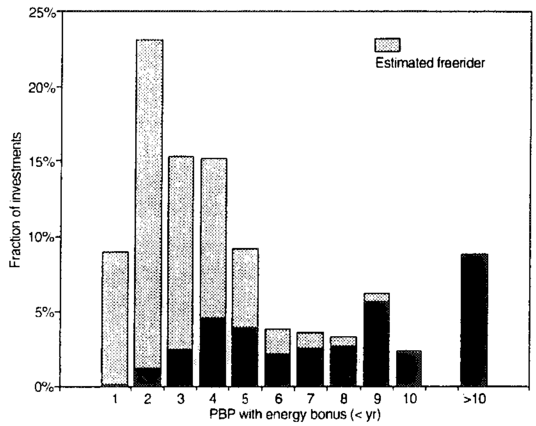
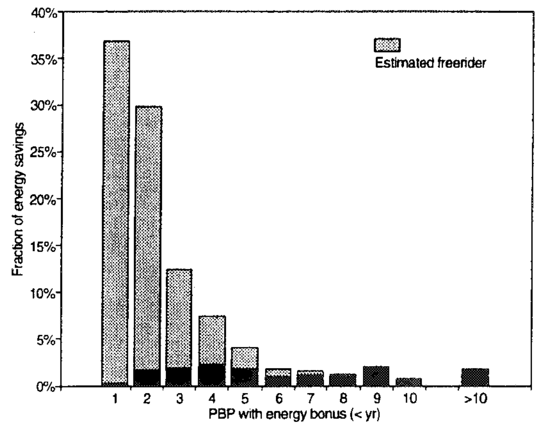


Figure 9. Estimate of the energy savings that were (not) stimulated by the energy bonus.



It should be noted that the investments with a PBP higher than 7 years would, according to the model, not be implemented. It is possible that other reasons were responsible for these investments. These other reasons could have been that old equipment had to be replaced, or that large savings were possible on e.g. labour or material costs.

The fraction of the investments that is attributed to the free-rider effect in figure 9 amounts to 64%. If we look at the energy savings related to these investments, the free-rider fraction increases to 85%. This is caused by the fact that the investments with a low PBP (logically) have a larger energy saving per invested guilder.

Efficiency

In this section we want to assess the ratio of benefits and costs of the energy bonus in the investment account act (as seen from the government point of view). We measure the benefits in the form of investments in energy conservation that were stimulated by the energy bonus, and the resulting energy savings. The costs are composed of the remitted energy bonuses and the organizational costs of the energy bonus.

The investments that were stimulated by the energy bonus (cf. figure 9) amount to Dfl. 2 billion (36% of 5.7 billion). The annual energy savings related to these investments amount to 20 PJ. This is calculated with the 15% of the energy savings that would not have occurred without the energy bonus, and the total energy savings calculated previously to be approximately 130 PJ.

The costs related to the energy bonus can be split into the direct costs, and the indirect costs. With the direct costs we refer to the granted energy bonuses, estimated at Dfl. 0.8 billion[9]. The indirect costs consist of the personnel costs related to designing and carrying out the measure. The number of man-years is estimated at 100-200[15], which implies that the indirect costs are negligible (1-2%)* in relation to the direct costs.

Taking the above together, we arrive at 20 PJ of energy savings at a cost of Dfl. 0.8 billion. This implies the specific savings to be 40 Dfl per MJ of annual energy savings.

* Based on annual hiring costs for personnel of Dfl. 80,000 per person.

DISCUSSION AND CONCLUSIONS

The data on the energy bonus gave us the opportunity to investigate what kind of investments lead to the improvement of energy efficiency in firms. However, we should bear in mind the specific circumstances in the period in which the energy bonus existed. In the first place, the early 1980's were years of economic hardship in the Netherlands. The second oil shock had increased energy prices to the highest in the Netherlands since the second World War. After 1985 these energy prices decreased, and the economic performance already began to grow in 1983-1984. Against these macro-economic developments, the energy bonus seems to have had only a limited impact on investments.

Unfortunately the data did not allow us to examine the energy savings per branch of industry. The total amount of savings could be compared with the net energy savings in the Netherlands in the same period. The subsidized investments are responisble for approximately 50% of the total energy savings in firms (including agriculture, excluding transport) between 1980 and 1988. We may conclude that only a very small part of the total investments in the Netherlands (namely these energy bonus subsidized investments) led to a large part of the savings in the observed period.

The data on the energy bonus allowed us to calculate an energy related pay-back period. These calculated PBP may in fact have been too high, because often other benefits can be attributed to new investments, e.g. product quality improvement, labour cost reduction and automation of the process (see e.g. Farla and Blok[16]). On the other hand, increases in maintenance and operation could also no be taken into account. We found a large amount of very profitable energy efficiency investments. Especially in the early 1980's very low average PBP's are encountered. After 1985 the average specific investment rose. The decrease of energy prices contributed to the fact that the PBP's in those years were far higher. The figures also suggest that the increasing economic performance led to more (replacement) investments, not carried out for energy efficiency in the first place. This is supported by the overall increase of investments by firms after 1985.

No real differences were found between the different investments size classes. This means that, on average, both large and large investments showed the same specific investment costs and pay-back periods.

The very low PBP's encountered in the first years of the 1980's give us the idea that these investments would also have been carried out without the energy bonus. The impact of the energy bonus on the financial resources of a firm are believed to be low, because the firm had to invest the money a long time before the energy bonus could be deducted from the tax. The free-rider effect was examined with a simplified model, with which add-on investments are predicted. With this model we calculated large free-rider effects; we estimate that 85% of the energy savings would also have been carried out without the energy bonus. These free-riders consist of very profitable investments that were also profitable without the energy bonus. Besides these investments, investments with long PBP's may have been carried out for several other reasons besides energy conservation.

This leads us to the conclusion that the energy bonus seemed not very effective in stimulating investments in energy efficiency, and was therefore a very expensive (cost-ineffective) policy measure. We should, however, be careful with our judgement because financial incentives are not the only effects exerted by subsidy measures. Other effects of subsidy measures include the (implicit) governmental approval of the subsidized investments and the drawing of (management) attention to the subsidized measures. The effect of *accelerating* the adoption of energy efficient technologies could also not be assessed. The energy bonus may have accelerated investment decisions, especially during the temporary increase of the bonus from 10 to 20% in the years 1982-1983.

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Appendix 1. Energy list: category division of efficiency measures that were eligible for an energy bonus under the investment account act

A. Investments for the benefit of improved insulation and heating of buildings, by

1. a) insulation of walls by cavity insulation
   b) insulation of walls by other means*
   c) insulation of roofs and floors*
   d) insulation of buildings by multiple glazing and double (window) frames
   e) insulation of greenhouses and warehouses by double skins/walls
   f) insulation of greenhouses and warehouses by movable screens
   g) insulation of equipment, piping and ducts of the climate control equipment*
   h) reduction of ventilation losses*
   i) improvement of control equipment for climate or lighting*
   j) heat recovery from flue and waste gases and process streams*
   k) efficiency improvement of heating equipment*
   l) total replacement of heating equipment*
   m) improvement of the heating equipment in greenhouses and warehouses**
   n) improvement of lighting in existing buildings*
2. using waste heat generated outside the firm, or by delivery of generated waste heat outside the firm*
3. heat pumps and related equipment*

B. Investments aimed at efficient energy consumption in production equipment, by

4. insulation of equipment*
5. improved production control*
6. heat recuperation*
7. heat pumps and related equipment
8. the use of waste heat generated outside the firm, or by delivery of generated waste heat outside the firm
9. the use of expansion energy*
10. improved firing equipment*
11. improvement or replacement of evaporation and distillation equipment*
12. improvement or replacement of drying equipment*
13. improvement or replacement of cooling equipment, and pasteurization and sterilization equipment*
14. improvement or replacement of melting equipment and kilns*
15. improvement or replacement of electrochemical and electro-metallurgic equipment*
16. replacement of electric heating (in the production process) by heating with fossil fuels*
17. replacement of electric drives and transformers with equipment with better matching capacities*
18. substitution of steam ejectors with vacuum pumps*
19. computer control of the production process*

C. Investments in combined heat and power

20. investments in installations for combined heat and power generation

D. Investments to use heat generated from the combustion of wastes, by

21. new installations for the combustion of waste*
22. adaptations to existing installations to make these suitable for waste combustion*
23. equipment for anaerobic fermentation of waste and for the burning of the fermentation gases*

E. Investments in equipment to use solar energy, by

24. the use of solar energy collectors

F. Investments in equipment to use wind energy, by

25. the use of windturbines

G. Investments in equipment to use coal as a fuel, by

26. direct use of coal as a fuel
27. coal gasification

H. Investments in the energy efficient use of means of transportation, by

28. the adaptation of existing aircraft*
29. the adaptation of existing ships*
30. a detachable wind guide on trucks

I. Investments in equipment to use hydropower, by

31. the use of water turbines

* Categories for which a minimum energy conservation requirement was applicable (** until January 1st, 1983).