Re-assessing no-regret Potentials - The Example of High Efficiency Electric Motors.
In: European Council for an Energy-Efficient Economy (Hrsg.):
Further than ever from Kyoto? Rethinking Energy Efficiency can get us there
: Proceedings of the 2001 eceee Summer Study. June 11th - 16th 2001,
Mandelieu, France, Volume 1
Paris: ADEME Editions, 2001, S.304-317
(ISI-P-33-02)

Re-assessing no-regret potentials - The example of high efficiency electric motors

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1. SYNOPSIS

We re-assess the no-regret potential of high efficiency electric motors by combining theories on investment, transactions costs, market failure and diffusion.

2. ABSTRACT

Energy conservation proponents, often with an engineering background, claim that a range of measures exists which allow to save energy and CO_2 at negative net costs, but that these so-called no-regret measures are not being realised autonomously by market actors. This view is being challenged by traditional economic analysis, which argues that no-regret advocates neglect transaction costs and do not apply appropriate investment appraisal methods. Furthermore, the no-regret advocates' explanations for the non-exploitation of no-regret measures are often criticised as unsubstantiated or as inconsistent with the observation of profitability, e. g. when they refer to high information costs. This paper re-assesses the no-regret potential of high efficiency electric motors (HEM). It draws on a theoretical framework which defines criteria for identifying *phenomena* and *causes* for no-regret potentials and for distinguishing between "true" and "false" no-regret potentials. The framework combines investment theory (including real option theory), transactions cost economics, market failure theory and the theory of diffusion. The re-assessment procedure is illustrated using the example of HEM. A microeconomic re-revaluation of the profitability of HEM investments delivers the first component for determining a phenomenon of no-regret. It is followed by a discussion of causes, why HEM remain underrepresented despite their economic advantage. The existence of a no-regret potential related to HEM is confirmed, but its size in energetic and financial terms is modified. In the conclusions some implications for policy intervention are indicated.

3. INTRODUCTION

This article presents the results of a case study on the size of the no-regret potential related to higher efficiency electric motors (HEM) in industry. The case study starts from a brief definition of no-regret potentials and an introduction into the theoretical background for their re-evaluation. We then summarise the results of an engineering economic study on the HEM no-regret potential. In a step-by-step procedure this is re-assessed in a more rigorous micro-economic framework. Priority is given to the re-assessment of the investment appraisal.

4. THEORETICAL BACKGROUND AND DEFINITION OF NO-REGRET POTENTIALS

According to the IPCC's Second Assessment Report the "no-regrets" potential comprises measures to reduce GHG-emissions that "... are worth undertaking whether or not there are climate-related reasons for doing so." (Bruce, Lee, Haites 1996, p. 271). The external effects of these no-regret measures with respect to climate change are *by definition* not considered in their evaluation. For the purposes of our study, we further exclude other environmental external benefits (or costs). This means that the measures have to be worth undertaking even without taking into account the benefits which they are expected to create in terms of avoided climate change and other environmental damages.

A controversial debate exists on the existence and true size of the no-regret potential. In simple terms, the no-regret positions claims that "... an energy efficiency gap exists between actual and optimal energy use" (Jaffe, Stavins 1994, p. 804). On the opposite side, the opponents to the no-regret view state that economic efficiency may indeed be opposed to raising energy efficiency (e. g. Sutherland 1996). The opposing arguments in the no-regret debate broach a number of theoretical approaches relevant for the analysis of no-regret measures. The criteria by which no-regret advocates typically ascertain opportunities for simultaneous cost and energy savings are different forms of *quantitative empirical cost-benefit assessments*, which show the economic advantage of energy saving techniques. If these technologies are not implemented, they conclude that economic inefficiencies prevail.

For economists the assertion of inefficiencies is void without a supplementary justification, why the market fails to bring about efficiency. They insist on the identification of reasons for market failures related to the alleged no-regret measures. If this is the case, it further needs to be verified whether policy makers are capable (more than markets) to bring about optimal levels of energy efficiency and whether the *costs of policy intervention* are indeed lower than the benefits gained from it. In a strict no-regret perspective, the benefits of a policy instrument which triggers the exploitation of a no-regret potential, consist in the net cost savings produced by the no-regret measure. In the absence of a market failure justification no-regret critics tend to question the validity of proposed cost-benefit appraisals pointing to cost elements such as *transaction costs* that have possibly been neglected in the empirical assessment.

Our principal approach to re-assessing existing estimates of the no-regret potential is to translate the problem into a problem in terms of market failures in a wide sense. Starting point are the functions that competitive markets ideally fulfil[1]. The analysis of market processes has created a broad consensus, that this comprises static functions, namely the remuneration of factors of production according to their productivity, the allocation of production factors in their most productive use (allocative efficiency), and the mix and distribution of output according to consumer preferences (principle of consumer sovereignty). Further to these static functions, market processes (or competition) fulfil the dynamic functions of adaptation and the promotion of technical progress. These five ideal functions of a competitive market, which represent the *first-best market outcome*, are in reality never fully accomplished but hampered by a number of different frictions which lead to real market performance falling below this first-best market performance. In so far as these frictions are "normal" occurrences for all markets, which cannot be avoided, we consider the outcome of such normal markets as the *second-best solution*. Not all frictions cause market failure, otherwise market failure would be ubiquitous. We will speak of market failure only, when two conditions apply: (i) market performance falls *severely* short of fulfilling one or several of the above functions *and* (ii) specified causes for market failure can be identified.

These considerations imply that for the identification of any market failure – and hence of no-regret potentials – it is essential to develop criteria on two levels: their *phenomena* and related *causes* of market failure. One possible phenomenon of market failure are profitable investment opportunities, which are not taken. Conventional economic theory assesses the profitability of an investment on the basis of the Net Present Value (NPV), which is the sum of discounted expected future cash flows arising from an investment[2]. We point out that not in all cases do no-regret potentials possess positive conventional NPVs. Market failures may induce price distortions which lead to a negative NPV. Or, the measure may only be profitable in a sequential dynamic perspective. Each phenomenon is the result of a distinct list of possible causes. These causes have been derived on the basis of conventional market failure theory, transaction cost theory and the theory of diffusion.

Once a phenomenon of a no-regret measure has been identified in the investment appraisal, the next step consists in verifying, whether the causes that can theoretically produce the identified phenomenon, can be empirically observed for the given case. If so, the identified causes are the basis to determine whether effective policy instruments exist to remedy them. This brings us back to the level of assessing the phenomenon. If effective policy instruments have been identified, their costs have to be estimated and compared to the benefits from realising the profitable energy saving measure. This final step concludes the reassessment. The following case study on electric motors will demonstrate our re-assessment approach more concretely. However, it is outside the scope of the paper to cover the last step of policy evaluation in detail.

5. THE ORIGINAL HEM NO-REGRET POTENTIAL

For Germany, a detailed engineering study on the technical and economic energy saving potential of HEM has been provided by Landwehr et al. 1996. Electric motors are a generic technology which is applied across the whole economy. A large part of total electricity consumption can be attributed to this technology - for Germany roughly 60 %, or 250 TWh. In the industrial sector this share is even higher (68 %) (Landwehr et al. 1996). This shows the importance of this individual technology, which is also one the reasons why we chose it as an example. The study claims that the technical energy savings potential associated to high efficiency electric motors is large and that a large part of it is profitable.

Landwehr *et al.* (1996) use non-energy related statistical data, e. g. production and trade statistics on electric motors in order to derive estimates of the actually installed motor capacity in Germany. A major part of this study is concerned with distinguishing different motor categories depending on motor size and "quartiles" which indicate the intensity of use measured by annual average operating hours. The merit of this disaggregation – which requires a considerable amount of data transformation and assumptions - is to allow the deduction of empirically well founded assumptions on operating hours, but also on other parameters (such as the load factor). On the basis of the installed motor capacity and these assumptions quantified estimates of motor electricity consumption and saving potentials are derived.

The technical savings S_T are evaluated per kW of substituted HEM capacity according to the following formula:

$$S_T = L * O * \left(\frac{1}{\eta_S} - \frac{1}{\eta_{HEM}} \right)$$

with L: load factor; O: operating hours (per year); η_S: efficiency of standard motors; η_{HEM}: efficiency of HEMs

For the calculation of the technical potential across all motors in use, it is assumed that the actual share of HEM among the motor stock is negligible. They derive an *aggregate technical savings potential of 6,2 TWh*. For the monetary evaluation, on the benefit side, the kWh saved are evaluated at a constant electricity price, which Landwehr et al. (1996) assume at 0,07 €. On the cost side the additional costs for a HEM are estimated at 25 % per kW compared to the price of standard motors. Based on the annual energy cost savings and the initial excess costs the pay back time is calculated for each kW of HEM-capacity installed. Referring to frequently observed management practice they use the decision rule that a pay back below 3 years indicates profitable investments. Based on this criterion they show that any kW of standard motor capacity which is substituted in the upper and second quartile in each power range is profitable. Since these two quartiles together account for 85% of each range's electricity consumption, the same share of technical savings are considered profitable. In absolute terms, the *economic savings potential amounts to 5,3 TWh.*

Table 1. Original profitability assessment (Source: Landwehr et al. 1996)

Quartiles	1.	2.	3.+4.	Total
AC poly phase, 0,75 - 7,5 kW	(useful lifetime in years: 12)			
aggregate technical saving potential (TWh)	2,1	0,9	0,5	3,5
HEM excess invest. cost (Euro/kW)				17,13
annual energy savings (kWh/kW*a)	198,84	82,85	24,85	
annual energy cost savings (Euro/kW*a)	13,31	5,55	1,66	
linear pay back time (years)	**1**	**3**	**10**	
AC poly phase, 7,5 - 75 kW	(useful lifetime in years: 15)			
aggregate technical saving potential (TWh)	1,0	0,4	0,3	1,7
HEM excess invest. cost (Euro/kW)				7,88
annual energy savings (kWh/kW*a)	139,75	58,23	17,47	
annual energy cost savings (Euro/kW*a)	9,36	3,90	1,17	
linear pay back time (years)	**1**	**2**	**7**	
AC poly phase, 75-750 kW	(useful lifetime in years: 20)			
aggregate technical saving potential (TWh)	0,5	0,2	0,1	0,8
HEM excess invest. cost (Euro/kW)				7,32
annual energy savings (kWh/kW*a)	74,61	31,09	9,33	
annual energy cost savings (Euro/kW*a)	5,00	2,08	0,62	
linear pay back time (years)	**1,5**	**3,5**	**11,7**	
AC poly phase, >750 kW	(useful lifetime in years: 20)			
aggregate technical saving potential (TWh)	0,06	0,03	0,02	0,1
HEM excess invest. cost (Euro/kW)				4,44
annual energy savings (kWh/kW*a)	34,26	14,27	4,28	
annual energy cost savings (Euro/kW*a)	2,29	0,96	0,29	
linear pay back time (years)	**1,9**	**4,6**	**15,5**	

6. REASSESSMENT OF THE PHENOMENON

The re-evaluation starts with a verification of the underlying data on cash-flows related to the HEM investment. This data is evaluated under different investment appraisal criteria, notably the conventional as well as the sequential NPV, and complemented under the perspective of transaction costs. The re-evaluation relies partly on data from a firm case study in a large multinational firm in the basic chemicals sector and several expert interviews on the side of motor users, producers and intermediaries. These data are used to analyse the decision making context and choose the investment appraisal model accordingly; and to derive additional assumptions which are applied in the re-interpretation of the original data. The expert interviews give also qualitative evidence on market mechanisms and causes for market failure presented in chapter 7.

(Re-)Assessment of the conventional NPV

Compared to the pay back criterion used in the original assessment, the NPV is much better founded in economic theory. And it has the additional advantage that it reveals the total financial benefit (net cost savings) produced by HEM installation. This figure is important as a benchmark for admissible policy costs. We have, therefore, calculated the NPV for the different size classes and quartiles of motors based on the data provided by Landwehr et al. 1996 (see Table 2). These data were only corrected for the load factor. A closer look on the calculations by Landwehr et al. (1996) reveals that they are indeed based on a load factor of 100 %. The more appropriate figure, which they also state as their assumption is 60 %. This means that the annual energy savings, and consequently the annual energy cost savings in **Erreur! Source du renvoi introuvable.** need to be reduced to 60 % of the indicated level. Taking this amount as the expected future annual cash flow and the HEM excess investment costs as the initial investment expenditure we can calculate the NPV on the basis of the formula indicated in end note 2. For discounting we assume an interest rate of 15 %, following the choices made in other engineering analyses (see e. g Sanstad *et al.* 1995, p.740).

Table 2. Results for the NPV of HEM (in €/kW)

	Quartiles		
Motor size	**1.**	**2.**	**3.+4.**
0,75 - 7,5 kW	26	1	-12
7,5 - 75 kW	25	6	-4
75-750 kW	11	1	-5
>750 kW	4	-1	-3

These figures support the original results on profitability, except for one segment – the second quartile of the largest motors, where the NPV turns negative. This is not surprising, because the cut-off point of three years (as chosen by Landwehr et al. 1996) is very strict and neglects the energy cost savings that accrue for the rest of the – rather long – useful life of the motor. We note however, that under the given assumptions the NPV of the second quartile is generally very close to zero[3]. Sensitivity analyses to evaluate the robustness of the results are therefore recommended. For this purpose we calculated the critical value of the assumed electricity price and the assumed discount rate, i. e. the value of these parameters at which the NPV turns zero. This analysis revealed that, except for the second power range (7,5 – 75 kW), the profitability of the second quartile is not robust due to uncertainty on future electricity prices. In quantitative (energetic) terms, the original no-regret potential of 5,3 TWh is, therefore, reduced to 80 % of its original size, or 4,1 TWh. In addition, we can also quantify the net *financial savings* related to the implementation of the no-regret potential by evaluating the installed capacity in each profitable quartile at the specific conventional NPV of this quartile. In total, the present value of possible net financial savings amounts to over 1.000 Mio. €, or ca. 150 Mio. € annually.

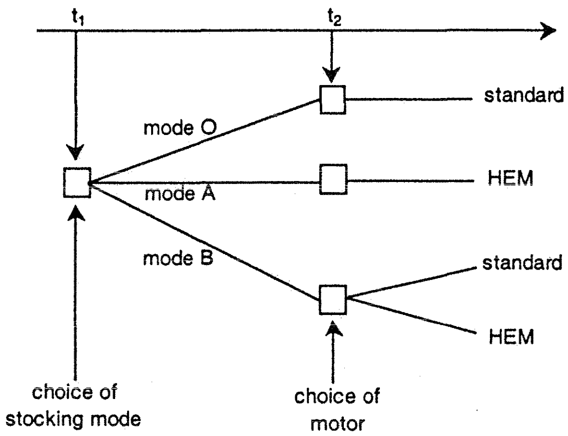
Assessment of the sequential NPV

The conventional NPV is the appropriate investment appraisal criterion in motor replacement decisions which are taken in one single step, i. e. if the motor purchase takes place at the time of replacement, so that purchase choice and replacement choice coincide. However, it is frequently stated by motor users, that a certain number of motors are kept on stock to minimise the time required for replacement, especially to minimise production downtimes (see e. g. Ostertag *et al.* 1997). As our firm case study revealed this is different for motors of the largest size class, because they are specialised "transnorm" motors. We will therefore exclude the largest size class from the sequential evaluation. For the other size classes, the three-step purchase-stocking-installation procedure turns the motor choice into a sequential decision, i. e. a sequence of two decisions as illustrated in

Figure 1. The first decision concerns the size and composition of motor stocks, the second decision concerns the choice of the motor for replacement. In this context, the motor available for replacement does not depend on the types of motors available on the market, but on the motors in stock. If no HEMs are stocked, no standard motor can be replaced by a HEM. In order to have the choice between standard motors and HEM, the stocking policy needs to allow full or at least partial double stocking of motors, i. e. to provide motors of different efficiencies for each motor type. This means, the different stocking modes differ in the degree to which they render the initial motor choice (ir-)reversible in the second step. We differentiate three stocking modes:

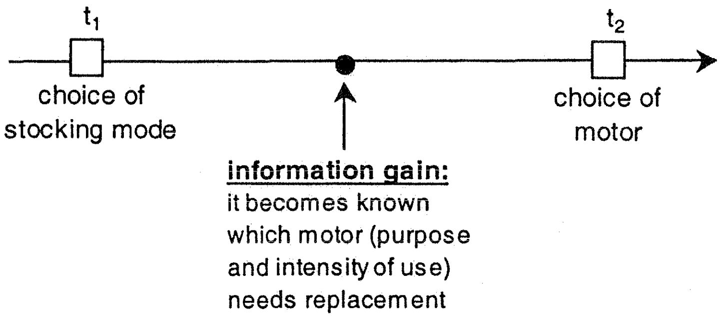
stocking mode O:	only standard motors are stocked
stocking mode A:	only HEM are stocked
stocking mode B:	full or partial double stocking, i. e. a HEM and a standard motor version for each motor type or for certain size classes

Figure 1. Sequentiality of decision



It has been shown within the approach of Real Option Theory that the sequentiality of an investment decision and the different degrees of flexibility of the available alternatives only make a difference in the investment appraisal if a third condition applies, namely that the future is uncertain and better information is acquired in the course of time[4]. A closer look on the replacement procedures reveals that at the time of replacement the application context of the motor is known. On the contrary, at the time of the purchase of a motor, which is then put on stock, its later application, especially its intensity of use as a major determinant of the economic energy saving potential, is not yet known. We conclude that we have a case of uncertainty with respect to the intensity of the motor's use in the first decision, i. e. the purchasing decision. This is completely resolved before the second decision, i. e. the choice of the replacement motor from the motors on stock, is made (see Figure 2).

Figure 2. Information Structure



We conclude that all three conditions for the pertinence of the sequential NPV as investment criterion are given. Real option theory has shown, that generally in this evaluation scheme the most flexible decision is also the most profitable one. This is true, if the flexibility gain comes at no cost. In our case, however, the different storage modes are not only linked to different degrees of flexibility but also to different levels of storage costs. The latter consist in the interest earnings lost on the capital that is bound in the stocked motors. They differ between the different storage modes. Due to the existence of these opportunity cost the most flexible storage mode is not necessarily the most advantageous solution. A quantification of the costs and benefits of increased flexibility is necessary in order to determine the optimal solution.

In our firm case study we analysed the stocking routines more closely. A number of 1000 – 1500 motors in stock compared to ca. 130.000 motors on site suffices to assure smooth replacement. This number explains itself mostly by the variety of motors in use, as it allows to just cover all sizes and construction designs needed. Under these conditions stocking mode B leads to a doubling of the number of motors stocked. Thus, in mode O, one standard motor per model is stocked, while mode B requires to stock two motors per model – a standard version and a HEM version. The doubling of the volume stocked will also double the length of time that each motor rests on stock. Based on this duration and the extra amount of capital bound in the stocks – derived from excess investment costs of HEM - we can calculate the lost interest on bound capital which corresponds to the stocking costs. In our firm case study the stocking periods are rather short due to the relatively small size of their stocks. From their information we derive our assumptions on the stocking period, which we generalise to all motor users and can then deduce the extra stocking costs per kW for each mode (see Table 3).

Table 3. Assumed length of stocking periods and resulting costs for different stocking modes

	Assumed stocking periods		stocking costs (€/kW)	
motor size	Mode A	Mode B	Mode A	Mode B
0,75-7,5 kW	3 months	6 months	0,64	6,42
7,5-75 kW	6 months	12 months	0,59	5,91
75-750 kW	12 months	24 months	1,10	10,98

We now have all components to calculate the sequential NPV. We will present one specific operationalisation, which is suited to our case. The calculation of the sequential NPV follows the principle of backward induction in dynamic programming. This means the sequential NPV can be calculated as the expected value of maximal results when working backward from the end of the branches of a decision tree by means of a stepwise optimisation. The procedure is illustrated in Figure 3 for one power range. In the right column entitled "NPV" you rediscover the conventional NPV values indicated in Table 2. The probability (Q_i) that the motor to be replaced falls into a specific quartile is (by definition of quartiles) 25 %. In the period before the information gain, i. e. before actual failure of a motor, the expected NPV from optimal motor replacement corresponds to the probability weighted sum of maximal achievable NPVs, called gross sequential value (VSG). The latter depends on the flexibility of the stocking mode. A comparison of VSGs shows, that it is highest for the most flexible stocking mode, i. e. mode B.

In a second step stocking costs need to be accounted for, i. e. subtracted from the gross sequential value. The result for the (net) sequential value (VS) is indicated on the very right of Figure 3. A comparison reveals that the flexibility advantage of mode B is exceeded by the additional stocking costs of this stocking mode. The optimal stocking mode is mode A with the highest sequential value. This implies that the choice of motors is reduced to HEM only, across all quartiles.

The results on net sequential values for all motor sizes are summarised in Table 4. In the largest power range the sequential NPV is negative for both stocking modes compared to stocking mode O. This means that the optimal solution is mode O, i. e. to stock and employ only standard motors in this power range. This is true even though the NPV of a HEM employed in the first quartile is positive and large enough to cover the specific stocking costs under stocking mode A as well as B. But since the chances of a motor replacement falling into the first quartile are only 25 %, this does not suffice to equilibrate the losses incurred in the other quartiles.

For the second power range (7,5 – 75 kW) both stocking modes show positive signs. This means, first, that any stocking mode that allows the choice of a HEM is superior to stocking and employing exclusively standard motors. Interestingly, the most advantageous solution is not the most flexible one – stocking mode B – but the cheaper stocking mode A, even though this forces to install HEM also in less intensive uses. The value of the flexibility gain under mode B - i. e. the possibility to install HEM only in the quartile where they are profitable and standard motors in the other quartiles – is offset by the costs of this flexibility gain to an extent that makes the added flexibility not worthwhile. The recommendation for the second power range therefore is to stock and install only HEM throughout all quartiles. The gains made in the first and second quartile will cross-subsidise the losses in the lower quartiles, while the extra stocking costs to reach these gains are kept to a minimum.

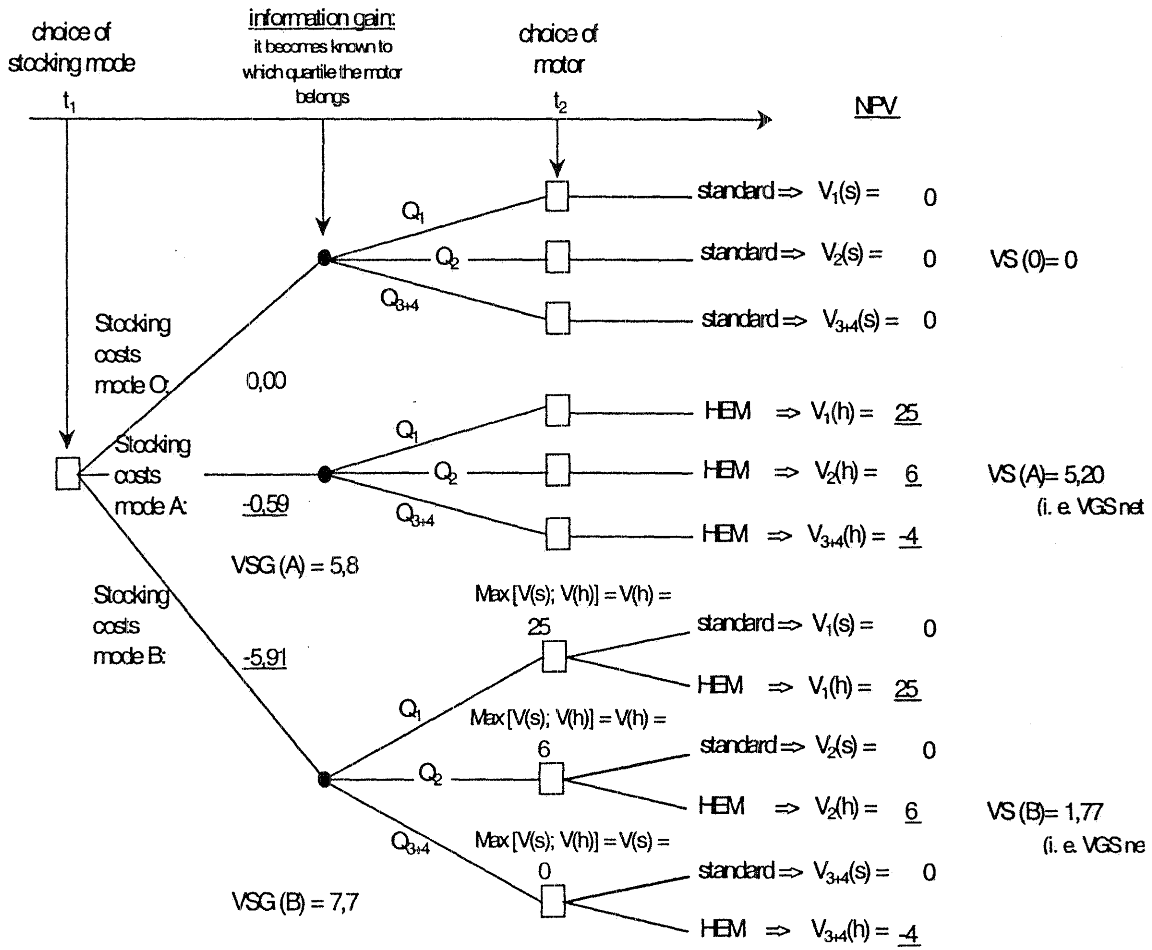
Table 4. Synopsis of results on sequential NPVs of optimal motor choice (€/kW), resulting optimal stocking modes and implications for the energetic no-regret potential

Power range	sequential NPV			optimal stocking mode
	mode O	mode A	mode B	
0,75-7,5 kW	0	0,27	0,12	mode A
7,5-75 kW	0	5,20	1,77	mode A
75-750 kW	0	-0,60	-7,99	mode O

Motor size	1. quartile	2. quartile	3. + 4. quartile	Σ (n.g. quartiles)
0,75-7,5 kW	X (2,1 TWh)	X (0,9 TWh)	(0,5 TWh)	3,5 TWh
7,5-75 kW	X (1,0 TWh)	X (0,4 TWh)	(0,3 TWh)	1,7 TWh
75-750 kW	X (0,5 TWh)	X (0,2 TWh)		
Original Total (w/o largest motors)	3,6 TWh	1,5 TWh		

X = original no-regret; shaded = confirmed resp. added no-regret

Figure 3. Example calculation of the sequential NPV (Power range 7,5 – 75 kW)



In the power range of the smallest motors, we first note that the inclusion of stocking costs narrows the profitability of HEM considerably but does not reverse it. There is a slight advantage of HEM over standard motors which is maximised under the stocking mode A, i. e. exclusive stocking and installation of HEM in the lowest power range is preferable[5]. We note, that the addition of the third and fourth quartile in the two lower power ranges is not due to a flexibility advantage. The stocking mode A is just as inflexible as mode O in the sense that it *shifts* the domain of possible choices without enlarging it. However, the sequential perspective shows the inseparability of the stocking and installation choice which explains why HEM are also installed in – statically – unprofitable quartiles.

The integrative perspective on stocking and motor choice changes the size of the no-regret potential. In fact, it turns out that in none of the power ranges is it optimal to leave the choice of the motor open until the moment of replacement (mode B). Where stocking mode A is optimal, all quartiles qualify as "no-regret", in the case of stocking mode O none qualify. The original no-regret potentialin energetic terms is exceeded by 2 % (5,2 TWh instead of 5,1 TWh originally[6]).

For the net financial savings these considerations imply a reduction caused by two factors – the inclusion of stocking costs and the cross-subsidisation of HEM in statically unprofitable quartiles. We can quantify the net financial savings by evaluating the installed capacity in the entire first and second power range at the specific sequential NPV under stocking mode A. Our results show possible savings of a total present value of 287 Mio. € or 43 Mio. € annually. Compared to the original results (ca. 150 Mio. € annually) this represents a considerable decline.

(Re-) Evaluation of transaction costs

According to transaction cost economics the procurement of an electric motor creates costs not only when it is actually purchased but already before (see Ostertag 1999, Bieniek 2000). Table 5 shows that the costs for the planning and purchasing of a motor - cost components which we interpret as transaction costs - can be higher than the purchasing price itself and are therefore worthy of a separate analysis. Note, that this analysis must focus on possible *additional* transaction costs for choosing a HEM as opposed to an ordinary electric motor.

Table 5. Transaction costs of standard motors (absolute levels, in €)

Motor size	1 kW	10 kW	100 kW
(for information: purchase price)	(200)	(800)	(5.100)
Transaction costs (engineering & procurement)	300	300	600

(Source: Bieniek 2000, and personal communication by Bieniek)

From a heuristic perspective the relative level of HEM transaction costs compared to standard motor transaction costs can be deduced from possible differences in transaction cost *determinants*. With respect to frequency as one of them no transaction cost differences should be expected. But the determinant of asset specificity – i. e. the degree to which an input can be productively used only for the specific transaction considered – indicates higher transaction costs for HEM. This is due to the necessity of specialised technical knowledge on the side of motor users to assess efficiency differences and to compute resulting energy (cost) savings. In addition higher asset specificity of HEM follows, on the supply side, from the requirement of installing a different or additional production line for the production of a further motor type.

For the quantification of extra transaction costs related to HEM we first calculated the value of HEM of different sizes in each power range based on the re-evaluated specific conventional and sequential NPV (see Table 6)[7]. Only if transaction costs are above this threshold value they would reverse the profitability. Considering first the conventional NPVs and assuming a labour cost of 50 € / hour, they would allow between 30 minutes and 3 days extra time to be spent on selecting a motor on efficiency criteria. However, the firm, whom we interviewed, stated that extra costs of HEM anywhere near these thresholds would be completely unacceptable. This is partly explained by the more appropriate sequential NPVs which produce significantly lower thresholds. They indeed suggest that barely any extra costs are permissible for small motors of 1 kW. But for larger motors some extra transaction costs in terms of money or time (ca. 20 min – 3,5 hours) could be born.

Table 6. Threshold levels for transaction costs for reversing profitability (rounded)

Motor size (kW)	1	3	10	50	100
Conv. NPV (€/ motor)	25	80	250	1250	1150
Seq. NPV (€/motor)	5	16	35	170	(neg.)

In a further step, the additional activities related to HEM employment need to be considered. The consideration of energy efficiency as an extra criterion of choice represents an extra effort, as it may be difficult to infer and compare the energy efficiency level of two models from the technical data provided due to diverging measuring standards in the past. Since the purchasing personnel has no technical background they depend on information from the engineers for estimates on permissible extra costs for higher motor efficiency. Only if the information provided on efficiency levels and permissible extra costs is presented in a simple unambiguous form the purchasing personnel is able to choose the appropriate motor in the given time limit, given their purely commercial qualification. We conclude that on the side of the purchasing personnel easy routines need to be developed that can comply with both the restraint on time and the restraint of their (purely commercial) qualification. The latter increases the need to have simple and precise information from the side of the engineers.

On the engineering side the personnel responsible for the motor specification and replacement is also responsible for running the given production process. Given that their work schedule is very tight the opportunity cost of their time is best reflected in the cost of production delays caused e. g. by identifying the optimal motor for a given use. This category of potential losses easily annihilates the possible energy cost savings. Therefore, the time budget deduced above is not valid for extra activities required from engineering personnel. Here, the constraints are so tight, that the consideration of energy efficiency must be integrated in a way, that does not take longer than previous motor selection routines.

We conclude that limits on permissible extra costs per motor are so tight and opportunity costs of time as well as qualification constraints are so important that transaction costs may easily reach an order of magnitude that annihilates the profitable energy saving potential. Any deviation above the actual time budget in provisioning (standard) motors and any higher demands on qualification levels should be avoided in order to maintain the economic advantage of HEM. Together with the two preceding sections we can conclude the following: **The re-assessment of the investment appraisal of HEM confirms their profitability; however, this only holds under the condition that transaction costs can be mastered.**

7. REASSESSMENT OF CAUSES

Generally, several causes of market failure are conceivable to produce the phenomenon of profitable but idle energy saving potentials. In the case of HEM we identified two main causes, related to information deficiencies and to diffusion failures.

Market failure related to information deficiencies

The absence of HEM from the motor market can be interpreted as a collapse of the high quality end of this market. Defining energy efficiency as a quality feature of a motor, the underlying reason for this lies in the general *ignorance of quality* on the side of the motor users. The difficulty lies in the interpretation of indicated efficiency levels. In fact, different measuring standards for motor efficiency – developed in different regions of the world, notably the U. S., Japan and the EU - prevail on market. The variation in the results delivered by the different measurement methods are in the same order of magnitude as the efficiency differences between motors. As a result, a change in measuring standards may reverse the efficiency ranking of motors, and efficiency levels measured by different standards are not easily comparable. This seriously hinders screening as autonomous market solution to remedy ignorance. Since the electricity consumption of an individual motor is not measured separately, the true level of energy efficiency of a motor can neither be easily assessed after purchase. Therefore, HEM qualify as "confidence goods"[8]. This aggravates the information deficiency because market solutions from the side of the potential suppliers of HEM, such as the building up of a good reputation, work less well, if at all, for confidence goods.

A second information deficiency in the motor market is related to the *ignorance of the utility* of a HEM. The key utility or benefits of a HEM compared to a standard motor are the energy (cost) savings, which it produces. These depend not only on the efficiency level of the motor, but also on the pattern of use, i. e. the number of operating hours and the load. In order to know the HEM benefit the user needs to know the motor's pattern of use. However, this is not recorded for an individual motor and it is hard to observe. The benefits can only be estimated, provided that the user disposes of the necessary knowledge and qualification to derive such an estimate. The autonomous market solution that potential suppliers of HEM inform about the product's benefits in order to increase their possibilities for sales is hampered, because they depend on information on the pattern of use that the user would need to provide.

Both information deficiencies are further aggravated by the fact that motors rarely pass directly from the producer to the end-user. Most motors are sold to equipment producers and reach the end-user as a component of a larger device (see Ostertag *et al.* 1997). This gives rise to "split incentives" between the intermediaries and the motor users. The presence of intermediaries need not pose a problem, provided that the intermediaries can pass on the price premia for HEM to the beneficiaries of the energy cost savings. But at this point the information deficiencies interfere. Due to the ambiguities in the interpretation of motor efficiency and due to the ignorance of the benefits in quantitative terms the intermediary cannot be sure to succeed in conveying the advantages of HEM to his clients and in assuring their willingness to pay for these advantages. As a result, intermediaries will be reluctant to integrate HEM as components into their devices.

Diffusion failure

In a dynamic perspective the incidence of profitable but idle energy saving potentials may be caused by interferences with typical mechanisms of diffusion. For the case of HEM a first problem can be observed concerning the "learning by using" mechanism. Generally, no systematic records or measurements are made on the performance of a motor with respect to energy consumption. Even if motors had different levels of efficiency, the users would not learn about the resulting impact on energy consumption simply by using the device. As a result they will not communicate the disadvantage of an inefficient motor to the producers. The interview at our example firm confirmed that motor efficiency is not an issue in the information and training courses followed by the firm's motor experts and provided by the motor manufacturers. Hence there is no pressure to innovate and to produce post-innovative improvements of this technical feature of a motor or to commercialise it more widely.

A further limitation is evident with respect to informational increasing returns to adoption. The lack of observability of the energy consumption of a motor not only impedes the communication with the manufacturers but also the information exchange among the users themselves. Objective and perceived benefits of a HEM may therefore diverge for a considerable amount of time. Even actually realised energy saving benefits will not attract more users of HEM, if they are not communicated between the actual users and potential future adopters.

8. CONCLUSION AND PERSPECTIVES

The engineering study which builds the starting point of our re-evaluation shows that certain "quartiles" of electric motors, characterised by power range and intensity of use, are profitable fields of HEM application. The quartiles qualifying as no-regret potential are indicated by the shaded areas in Figure 4. The aggregate size of the no-regret potential is estimated at 5,3 TWh in terms of energy savings; and 5,1 TWh respectively, when excluding the largest power range of motors (see Table 7).

Figure 4. Illustration of re-evaluation results

Original			
power*	Q_1	Q_2	Q_{3+4}
1			
2			
3			
4**)			

=>

1. Re-evaluation		
Q_1	Q_2	Q_{3+4}

=>

2. Re-evaluation		
Q_1	Q_2	Q_{3+4}
(...)	(...)	(...)

*) 1= 0,75-7,5 kW; 2 = 7,5 – 75 kW, 3 = 75 – 750 kW; 4 = >750 kW

**) excluded from the 2. re-evaluation (mostly do not conform to standard norms, implying different procedures)

(shaded cases correspond to quartiles qualifying as no-regret potential)

Table 7. Synopsis of original and re-assessed no-regret potential

	Original * No-regret potential	Re-assessment Conventional	Sequential
Energy savings (p.a.)	5,1 TWh	4,1 TWh	5,2 TWh
Financial savings (p.a.)	no data	150 Mio. €	43 Mio. €

*) Figures for first three power ranges only – as in re-assessment

Our first re-evaluation of the investment appraisal based on the conventional NPV confirms HEM as a profitable, unexploited energy saving opportunity in some quartiles. But for most of the second quartile profitability of HEM is rejected. This is mainly due to the lack of robustness of the positive NPV results to uncertainties on the electricity price. In a second step, the evaluation is extended to a sequential perspective, in which the additional decision on the size and composition of motor stocks is accounted for. This has two implications: stocking costs in terms of bound capital occur as extra costs; and depending on the stocking mode chosen, the choice of motors for replacement is limited, which may lead to the employment of HEM in quartiles where they are per se not profitable. In the sequential evaluation, new quartiles qualify as profitable that did not before. But others are dismissed. The resulting "true" no-regret potential in terms of energy savings shows a slight rise; the financial savings, on the contrary, suffer a considerable slump. These results apply under the precondition that governance structures for the application of HEM can be found that respect the time budget and qualification levels on which current procedures are based. Otherwise transaction costs easily climb above critical limits.

Causes that explain the persistence of the idle profitable HEM investment opportunity relate to information deficiencies which lead to a collapse of the high quality (efficiency) end of the motor market. The problem lies is quality ignorance and ambiguous energy efficiency indications as well as the problem of ignorance of utility, i. e. of the energy (cost) savings. The problems are such that autonomous market solutions necessarily fail, e. g. because HEM qualify as confidence goods impeding the building up of a good reputation. A second cause are interferences with the mechanisms of diffusion.

In order to exploit the identified no-regret potential policy instruments are needed, which can effectively address these causes of market failure. Some of the actually pursued policy initiatives are very well targeted in this respect. The energy efficiency labels for motors introduced in April 1999 by the EU and CEMEP (the European association of motor producers) exactly address the information problem associated to the interpretation of energy efficiency levels. It differentiates three efficiency classes – eff 3 as the lowest and eff 1 as the highest. A major achievement is that the parties agreed on a measuring standard (the IEC standard) by which to determine the efficiency of a motor. The label is not compulsory, but 19 European producers have signed the agreement and committed themselves to its application. Further activities on the European level include the preparation of a motor systems inventory data base (EURODEEM), which is intended as an information tool for motor users or energy service companies to evaluate the best installation of replacement option in a specific motor use. In Germany, regionally organised professional training seminars additionally address the issue.

Considering the attractive size of the energy savings inherent in HEM, further policy initiatives might be considered. The possible financial savings from HEM indicate their potential benefits regardless of any possible climate or environmental benefits. These amount to 43 Mio. € annually assuming a diffusion of HEM of 100 % in the profitable quartiles. Staying in a no-regret perspective, any envisaged policy intervention should show a cost-benefit ratio below unity. For deducing a permissible policy budget it should also be taken into account, that the rate of response to a policy instrument is generally far below 100 %. Further, part of the achieved financial benefits should be left to cover potential extra costs to be born by the implementing firms. On the basis of these considerations we suggest a conservative permissible budget for policy costs of 10 % of the financial savings, i. e. 4,3 Mio € / year for Germany. According to our preliminary estimates the actually incurred expenditures for policies promoting HEM in Germany – including i. a. preparatory engineering studies, the German share in the EU policy instruments, and administrative manpower – amount to approx. 0,5 Mio. € / year only. The permissible upper limit is nearly a full order of magnitude higher. We conclude that there is ample financial scope for intensifying policy support for the promotion of HEM.

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10. GLOSSARY

GHG	Green House Gases
HEM	High efficiency electric motors
NPV	Net Present Value
VSG	Gross sequential value
VS	(net) sequential value

11. END NOTES

[1] On the following see e. g. Fritsch, Wein, Evers 1999.

[2] $NPV = \frac{\overline{R}_1}{q} + \frac{\overline{R}_2}{q^2} + \frac{\overline{R}_3}{q^3} + ... + \frac{\overline{R}_n}{q^n} - I_0$ with $\overline{R}$ as the "safety equivalent" of a randomly distributed cash flow; q = 1 + r, r= (risk free) interest rate; I_0: initial investment.

[3] The values for the NPV may generally seem very small. But one must not forget that they represent the NPV of one kW of HEM power. The NPV of a larger HEM needs to be multiplied accordingly. For example, for a HEM of average size in the second power range (i. e. ca. 30 kW) the NPV is 750 €.

[4] For an easily readable textbook representation of real option theory see e. g. Bancel, Richard 1995.

[5] We note that this result is only true when we exclude the choice of a HEM in the second quartile for reasons of lacking robustness of its profitability to electricity price variations. Would we trust the profitability of HEM the optimal stocking mode would switch to mode B with the respective consequences for the no-regret quartiles (confirmation of first and second quartile only).

[6] This excludes the largest power range (>750 kW) for reasons of comparability.

[7] For the calculation we adjusted the assumptions to better reflect the conditions of our firm case study, which means lower electricity prices (0,04 €) and higher average operating hours. Note that under our prior assumptions the threshold levels would be considerably lower still.

[8] See Fritsch, Wein, Evers (1999) on the theoretical distinction of confidence goods.