Ex-post estimates of costs to business of EU environmental legislation

Final report

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Preface and acknowledgements

This report is the result of a project under the 'Framework contract for economic analysis in the context of environmental policies and of sustainable development' (ENV.G.1/FRA/2004/0081). It addresses the question to what extent the *ex-ante* and *ex-post* estimates of costs to business resulting from EU environmental legislation differ, how these differences can be explained, and what the implications are for cost assessments.

The project was carried out by IVM (coordinator), BIO, Ecologic, GHK, PSI, TME, and VITO. The Commission's contact person was Jakub Koniecki. The authors want to thank the many people who provided valuable suggestions and information, including the participants in the expert meeting that took place on 10 November 2005.

Executive summary

Evidence on divergence between *ex-ante* and *ex-post* cost estimates

This report addresses the question to what extent the *ex-ante* and *ex-post* estimates of costs to business resulting from EU environmental legislation differ, how these differences can be explained, and what the implications are for cost assessments. This report is the result of a project which involved a literature review, the writing of a methodological paper, six case studies, and an expert workshop. The case studies (which are summarized in Appendix I) were on the following pieces/areas of EU environmental legislation:

- The Large Combustion Plant Directives;
- The Integrated Pollution Prevention and Control (IPPC) Directive (focusing on the ceramic industry in Belgium);
- Ozone depleting substances;
- Car emissions;
- Packaging and packaging waste;
- The Nitrates Directive.

Previous evidence suggests that overestimation of ex-ante costs is common, though not a universal rule. The case studies carried out in the present study confirm this. In many cases, the ex-ante estimates were about twice as large as the ex-post results, but in some cases the differences were either much larger or there was hardly any difference at all.

Factors explaining the differences

A large variety of factors can be responsible for the observed differences. The following categories of factors are distinguished:

- the concept of costs (issues such as the definition, attribution, calculation and measurement of costs, including the availability, quality and reliability of data, and total costs versus unit costs);
- the role of assumptions in cost estimates e.g. on the context, the baseline (counterfactual scenarios) and the expected policy response by market parties;
- differences between planned, adopted and implemented policies (including differences in interpretation of targets and measures; in policy instruments; and in the extent of compliance or objectives achievement);
- the potential for innovation, economies of scale and other cost reducing dynamics.

The importance of each factor appears to differ from case to case. However, evidencefrom literature and case studies suggests that especially the potential for (unanticipated) innovations and cost reductions often plays a major role. In particular, large differences between ex-post and ex-ante estimates are usually due to the introduction of new technologies (after the introduction of the legislation) with low or even negative net cost. Considerable underestimates of the cost reduction potential of innovation may also occur if ex-ante costs are based on data for prototypes or first applications that have not yet benefited from economies of scale and ‘learning curve effects’.

There seems to be little evidence of industry knowingly providing biased cost estimates. However, in the face of uncertain future technological development, the affected industry will tend to come up with relatively high cost figures. These might be based on early policy drafts, nevertheless tend to stay in debate to follow. They may also be reluctant to make cost data publicly available, as this is often commercially sensitive information. On the other hand, suppliers of environmental technology may have an incentive to give low cost estimates in order to influence decision making. The involvement of independent experts may provide additional, relatively 'neutral' cost information, but it is up to policymakers to assess the quality of data provided to them.

Scope for narrowing the gap

Cost assessment procedures will have to deal with many uncertainties, which are to a large extent inevitable. Sensitivity analyses and explicit consideration of the assumptions and the extent to which they turned out to be false are therefore needed. The sensitivity analyses should identify the key parameters that are expected to influence costs, and assess how changes in these parameters affect expected costs. Identifying the key determinants of costs ex-ante helps when designing ex-post evaluation.Given the tendency in environmental policy towards more flexibility, leaving Member States and firms as much room as possible to find their own solutions for meeting the requirements and objectives, the scope for making precise ex-ante cost estimates is not likely to become larger. Nevertheless, it should at least be possible to follow some guidelines which might lead to better accuracy and comparability.

Suggestions for better cost estimates

The reliability of ex-ante cost data can be improved by carefully selecting and evaluating the information sources. Ideally, data from different sources (suppliers, operators, researchers, etc.) should be analysed to arrive at reliable cost estimates.

'Avoided costs' related to environmental policy measures (e.g. lower energy costs due to energy saving) are likely to be at least as challenging to estimate as conventional costs of compliance, but their inclusion in the ex-ante estimate is essential to prevent overestimation of net cost.

Ex-ante estimates should keep track of the development of the policy process, as changes in the policy proposals inevitably will imply changes in the estimates. Ideally, each amendment should be accompanied by a revision of the estimated costs.

The construction of the 'counterfactual' scenario is a difficult part of cost estimation. A better understanding of business behaviour and the likely response to a given policy measure may be needed.

The issue of strategic versus marginal responses needs to be examined in much more detail, with consideration of the heterogeneity of businesses and of their likely responses and of the technological uncertainties that surround these responses.

Further research should reveal whether it is possible to formulate general 'rules of thumb' regarding the extent to which cost decreases can be expected as a result of unanticipated substitution options, innovation, economies of scale and learning curve effects. This might

lead to some standard reduction factors to be applied in ex-ante cost estimates, dependent upon the specific technology and context at hand.

The planning of ex-post estimates needs to be built into regulations in order to generate learning about the degree to which they have succeeded.

Comparisons of ex-ante and ex-post estimates should ask whether entities complied as they were expected to do, and aim to find out why (or why not). Ex-post assessments should also take account of how the regulation changed during the period of its negotiation and implementation. Obviously, changes in contextual factors should also be considered.

When comparing ex-ante and ex-post annualised cost estimates of (in principle) the same phenomenon (or technology) the following should be considered to arrive at comparable figures:

- exchange rates and the price basis;
- the number of units ex-post and ex-ante;
- unit costs ex-post and ex-ante;
- the way in which costs are estimated or expressed: annualised costs, investments, net present value;
- interest rates and discount rates applied in the calculation of costs;
- depreciation periods;
- treatment of operating and administrative costs;
- the inclusion or exclusion of indirect or “welfare costs” (such as the attributed loss of market share) in the calculation.

For a policy instrument in which targets are periodically revised it should be possible to establish a feedback process that draws on the ex-ante and ex-post evaluations of each stage. ‘Learning loops’ that involve progressive tuning of the assessment method and benefit from the improvements in the data should facilitate more accurate estimation of compliance costs for target revisions over time.

Investments in costs estimates will usually be very small relative to the cost of implementation. It would be interesting to investigate the potential efficiencies provided by high-quality cost estimates (in terms of better policy measures).

Finally, as ex-ante estimates are to make the policy making process more transparent (by revealing potential trade-offs, etc.) ex-ante and ex-post assessments should be kept as 'simple' as possible.

1. Introduction

Since 2002 major EU policy proposals are subject to an impact assessment procedure. One of the elements of this procedure is to provide an *ex-ante* assessment of costs and benefits of a proposed measure. There is no such requirement to always check the *ex-post* results, although it is often done as part of the evaluation programme of the Commission.. Systematic ex-post analysis would allow a number of lessons to be learnt for policy-making. For example, if the ex-post costs are lower than originally estimated it may indicate that the environmental ambition could have been higher. If compliance costs are ex-ante expected to be higher than will actually be the case in practice, the ex-ante cost-benefit test may lead to a decision not to proceed with the policy change, whereas knowledge of the ex-post results would have led to the opposite decision. Alternatively, if the ex-post costs are significantly higher than anticipated, there may be unwanted distributional effects, e.g. the poorest groups would be hit worse than designed cushioning instruments (if any) could handle. Moreover, higher ex-post costs than predicted may have adverse effects on business competitiveness.

Compliance cost estimates are critical inputs to the appraisal of the socio-economic impact of regulatory change, and the associated political process. Insofar as compliance costs can never be known with absolute certainty, it becomes a matter of management of uncertainty and understanding the probability of alternative cost outcomes. If there is significant uncertainty about the numbers, these then become the focus of the debate, rather than the regulatory change itself. A better understanding of the issues, and of how to manage the potential biases in the cost estimation process offers the prospect of improved efficiency (lower costs, reduced uncertainty) of regulation.

The present report addresses the question to what extent the *ex-ante* and *ex-post* estimates of costs to business resulting from EU environmental legislation differ, how these differences can be explained, and what the implications are for cost assessments. This report is the result of a project which involved a literature review, the writing of a methodological paper, six case studies, and an expert workshop. The case studies (which are summarized in Appendix I) were on the following pieces/areas of EU environmental legislation:

- The Large Combustion Plant Directives;
- The Integrated Pollution Prevention and Control (IPPC) Directive (focusing on the ceramic industry in Belgium);
- Ozone depleting substances;
- Car emissions;
- Packaging and packaging waste;
- The Nitrates Directive.

This report is based on all elements of the project. Reports on the individual parts are obtainable as separate documents.

The structure of this report is as follows. Chapter 2 addresses the empirical evidence on differences between *ex-ante* and *ex-post* cost estimates of environmental policy measures. The main factors explaining these differences are subsequently discussed in the next

chapters. Chapter 3 deals with the concept of costs, addressing issues such as the definition, , attribution, calculation and measurement of costs, including. the availability, quality and reliability of data. In chapter 4, the role of assumptions in cost estimates is explored, e.g. on the context, the baseline (counterfactual scenarios) and the expected policy response by market parties. Chapter 5 highlights the importance of differences between planned, adopted and implemented policies (including differences in interpretation of targets and measures; in policy instruments; and in the extent of compliance or objectives achievement). The potential for innovation, economies of scale and other cost reducing dynamics is the subject of chapter 6. Chapter 7 contains conclusions and formulates some policy implications.

The present study focuses on the (direct, net) costs for business of complying with EU environmental legislation. It does not deal with the wider economic impacts of such legislation. Neither does it address the important issue of environmental benefits brought about by the legislation. Obviously, such elements should also be considered in impact assessments.

2. Evidence on the size of differences between ex-ante and ex-post cost estimates

Several earlier studies have identified substantial differences between ex-ante and ex-post estimates of the costs of environmental policies. An often quoted example is a study by the Stockholm Environment Institute (SEI, 1999; Haq *et al.*, 2001), presenting five cases[1] in which industry's actual costs for implementing environmental regulations were lower than their predictions of these costs during the negotiations prior to the adoption of the regulation.

Anderson and Sherwood (2002) compared the ex-ante and ex-post cost estimates of fuel quality and car emissions regulations in the USA and found that in both cases the ex-ante estimates were substantially higher, even those made by the regulator (EPA). In the case of fuel regulations, cost estimates by industry stakeholders exceeded actual price increases by the largest amounts, by ratios ranging from nearly 2:1 to 6:1.

Ellerman (2003) reports that the total annual costs associated with early proposals to control acid rain precursor emissions in the USA were estimated at $3.5 to $7.5 billion. For the proposal that was ultimately proposed and enacted, ex-ante cost estimates (for the programme with emissions trading) fell to a range from $2.3 billion to $6.0 billion, whereas the current estimates for compliance costs in 2010, based on ex-post figures, are significantly lower still, at $1.0 billion to $1.4 billion.

Overestimation of ex-ante costs thus seems to be common, but it is not a universal rule. For instance, Hammitt (2000) found that estimates published before international regulations on ozone depleting substances (the Montreal Protocol) were adopted, substantially overestimated the costs of limiting CFC-11 and CFC-12 consumption, but modestly underestimated the costs of limiting CFC-113 consumption. Estimates published shortly after the adoption of the Protocol appeared to underestimate the marginal cost of limiting CFC consumption.

Harrington *et al.* (1999) compared ex-ante estimates of the direct costs of individual regulations to ex-post assessments of the same regulations. For 14 of the 28 rules in their data set the *total* costs of regulations tended to be overestimated, while for only 3 rules were the ex-ante estimates too low. For *unit* costs[2], however, the story was quite different. At least for environmental (EPA) and occupational safety and health (OSHA) rules, unit cost estimates were often accurate, and even when they were not, overestimation of abatement costs occured about as often as underestimation.

Box 2.1 presents another example showing that ex-ante cost estimates are often, but not always, 'too high'.

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[1] These five cases related to: (1) the UN-ECE Protocols on Acidification and the (first) EC Large Combustion Plant Directive; (2) Directive 91/441/EEC on vehicle emission standards (Euro I standards and catalytic converters on cars); (3) the European Auto-Oil programme; (4) the US Clean Air Act; (5) the Montreal Protocol on substances that deplete the ozone layer.

[2] I.e. the costs per unit of output, per product, etc. (see Section 3.1.3).

The case studies carried out in the present study seem to confirm this mixed picture, with ex-ante overestimation of compliance costs occurring frequently, but not consistently (see Table 2.1). In many cases, the ex-ante estimates were about twice as large as the ex-post results. In some cases, however (Large Combustion Plants in the UK; specific elements of the ozone depleting substances case) much higher ex-ante:ex-post ratios were found. On the other hand, the IPPC case showed no large differences between ex-ante and ex-post, whereas the evidence in the packaging case is inconclusive. (see Appendix I).

A large variety of factors can be responsible for the observed differences betwee ex-ante and ex-post estimates. Moreover, even if the difference is absent or small, these factors may still be at work if they tend to neutralize or counteract each other (as was for instance observed in the IPPC case). The following chapters will address the factors, by category as distinguished in Chapter 1.

Table 2.1 Ratios of ex-ante and ex-post cost estimates in case studies

Case study	Directive (Sector)	Ex-ante/Ex-post ratio	
		Upstream	Consumers
1	Large Combustion Plant Directive (LCPD) (Power sector)	2 (Germany)	6-10 (UK)
2	Integrated Pollution Prevention and Control (IPPC) (Belgium Ceramics)	>1.2 (operational costs) ~1.1 (capital costs)	-
3	ODS (Ozone Depleting Substances)	2.5 (1.4 -125)	1.25
4	Transport (Netherlands)	2 (1.4 - 6)	-
5	Packaging	-	-
6	Nitrates Directive (Agriculture)	~2	-

Box 2.1 Ex-ante and ex-post costs of the first Dutch National Environmental Policy Plan

For the first Dutch National Environmental Policy Plan (NEPP) (VROM, 1989), a model was built comprising about 400 environmental measures. Each measure was somehow linked with the implementation of certain pieces of regulation. Data were taken from a variety of studies on potential technologies that could be applied to reduce environmental pressure. Specific attention was given to the calculation principles, to enable comparison and ensure harmonisation with statistics on environmental costs of the Central Statistical Bureau of the Netherlands (CBS).

In addition, considerable effort was made to clarify the physical implications of certain pieces of regulation (the intended emission reduction for example) and the business populations affected.

About 12 years after the ex-ante estimate (which covered the period 1988 – 2010), RIVM published an overview of the realised costs (in cooperation with CBS).

Table 2.2 summarises the results of the ex-ante estimate and the ex-post realisation. To enable comparison, the initial ex-ante assessment was inflated by using the consumption price index.

Table 2.2: Comparison of ex-ante and ex-post assessment of direct environmental costs in the Netherlands of implementing the first National Environmental Policy Plan

	Ex-ante	Ex-post	Over/under-estimation
	Jantzen (1989)	RIVM (2001)	
	Million € (price level 2001)		
Total	12,355	10,935	13%
per policy theme			
Acidification	1,928	918	110%
Climate change	454	617	-26%
Eutrophication	1,082	599	81%
Hazardous substances (air water soil)	2,549	2,014	27%
Waste management	3,566	4,004	-11%
Soil Sanitation	672	648	4%
Disturbance	679	561	21%
Other	1,426	1,574	-9%

Sources: Ex-ante assessment Jantzen (1989), ex-post assessment RIVM (2001).

It appears that in general cost estimates do not always overestimate to a large extent. But in the Dutch case it should be noted that from as early as 1979 onwards, good statistics were available on cost, making it easier to “look into the future”. A number of detailed studies were also available at the time of the preparation of the NEPP enabling detailed estimates for various parts of environmental policy.

3. Definition and measurement of costs

3.1 Cost definitions and categories

3.1.1 Compliance costs

The type of costs that is relevant for the present study is 'compliance costs', i.e. the (net) costs to business of complying with specific pieces of environmental legislation.

Generally accepted definitions of 'environmental, compliance costs' (such as the one used by Eurostat) include the following criteria:

- The regulation and response must have the primary objective to protect or improve the environment. This excludes for example "changes in process" driven by economic arguments ("cheaper and better", "pollution prevention pays"), and also excludes measures taken to protect the health of workers (although in both cases, environment may also benefit).
- There are additional costs to the subjects (businesses) addressed by environmental regulation.

This latter point may seem rather obvious, as in the case where the required investments are offset by financial benefits to business, (and no additional costs are made), business would not be expected to require legislation to force a change in behaviour. In practice not all firms act in economically rational ways and business will not always be faced with net additional costs in the event of a policy change.

Compliance costs can be relatively easily identified when only one known technological solution is (and will be) available, which is simply added to the existing production process with little or no effect on the wider operation of the plant or on the product. These are so called "end-of-pipe" measures, and in general they will always create additional (marginal) costs.

However, if many technological solutions are available, the picture may be more complex; and it may be hard to predict which technologies will actually be chosen by businesses, with what effect. This is especially the case with changes in processes, which often go together with re-engineering of (part of) the production process or simply changes in management. This can result in costs which are close or equal to zero. In any case, such changes make it difficult to attribute part of the costs to the environmental regulation.

A further difficulty occurs in the rare cases where a regulation prevents a business from expanding its business (e.g. because of permit limits), but does not require a technological solution.

3.1.2 Investment, operational and administrative costs

Compliance costs include investment as well as operational costs. The first category relates to the capital costs of purchasing and modifying plant and equipment to ensure compliance. These can be annualised by applying a specific interest rate and depreciation period (see Section 3.2.3). Operational costs are the costs associated with the on-going requirement to maintain compliance (e.g. materials, energy, labour). In addition, firms may incur administrative costs as a result of environmental regulations, e.g. due to monitoring and reporting requirements. Administrative costs for the authorities (e.g. for monitoring and enforcement) are usually not considered to be compliance costs, as they are not paid directly by the affected business.

Differences in the interpretation and calculation of these cost categories can in principle result in substantial differences in cost estimates.

3.1.3 Unit costs versus aggregated costs

Compliance costs of environmental legislation can be expressed in absolute, aggregate terms (e.g. total cost for the regulated community or for a specific sector) or they may be expressed in relative terms, related to a relevant parameter (e.g. per tonne of product or of emission abated, or as a percentage of profit or turnover). It is important to keep this distinction in mind when comparing ex-ante and ex-post cost estimates.

For example, if aggregated costs turn out to be (ex-post) x% lower than ex-ante, this may be due to an unforeseen decrease in the polluting activity by x%, whereas the cost per unit of activity was in fact predicted accurately.

Whether unit costs or aggregated costs should be used depends on the purpose of the cost estimate. In cost-benefit and cost-effectiveness analysis, aggregated costs should be compared to the overall environmental impact. On the other hand, if the cost figure is intended to show the relative weight of the environmental costs (e.g. compared to overall production costs) then of course the unit cost figure should be used. Costs expressed as a percentage of profit or turnover of a firm or sector are sometimes used to show the affordability of the policy. The present report does not deal with the appropriateness of these different approaches, but one should be aware of the implications they have for *ex-ante* and *ex-post* comparisons.

3.1.4 Direct and indirect costs

Environmental legislation can lead to marginal or structural changes in many economic parameters. Some companies will see their market opportunities shrink and employment may be reduced as a result of compliance costs being passed on in (intermediate) product prices. Quantifying such ‘indirect’ impacts of measures can either be done by estimating the foregone profits, by applying macro-economic modelling (but with the risk of losing sight of individual technologies) or by estimating welfare effects of the economic changes induced by the application of the (new) technology. Such an approach is for example followed by Touche and Ross (1995).

It is sometimes argued that these indirect (or secondary) effects should be considered as 'costs' of the environmental legislation. However, from a methodological point of view this is problematic. First of all, the negative impacts are often compensated by positive impacts elsewhere: some companies will lose, but other companies (the 'greener' competitors, and the suppliers of environmental technology) may experience increases in turnover, profit and employment. Moreover, an assessment of these indirect effects often requires modelling of the (inter)national economy[3], or at least many assumptions and scenarios regarding economic behaviour that may invoke controversy. It is up to the decisionmakers if and to what extent they want to analyse the complex web of economic responses to an enviornmental policy measure. In any case, when analysing (differences between) cost estimates, the possible impact of indirect costs having been included or excluded should be taken into account.

3.2 Estimating and measuring costs

3.2.1 Approaches and methods

The most common way to make ex-ante estimates of environmental costs, as a result of the implementation of (stricter) regulation, is to carry out technological-economical cost assessments. Basically, a cost-engineer estimates the costs of an installation or a process change (by using a blueprint or certain physical parameters) that enables the required reduction of emissions. Sometimes this is done for all or many existing facilities individually, but in most cases a "modelling approach" is followed: the "population of polluters" is classified (e.g. by size, emissions, energy use, annual throughput, etc.), and a few "model installations"[4] are defined. For these "model installations", investment and operational costs are estimated. Normally, this estimate can be based on empirical evidence (of a comparable installation that already exists). Here, a potential bias enters the cost-equation, as these engineering estimates are normally derived from data on pilot plants or "first applications"[5].

By using engineering parameters (e.g. scale, volume, surface, length of wiring, piping), an individual estimate can be "blown up" to other scales, providing some differentiation of "model installations". By matching it with "population" data, estimates for a whole sector affected can be made. In other words, we move from unit costs to total costs.

Hartman, Wheeler and Singh (1997) point out that a weakness of the engineering approach is the tendency to overestimate costs. One of the reasons is that in the engineering approach no adaptations are normally made for technological and efficiency developments, leading to lower unit costs. We return to this issue in Chapter 6.

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[3] For example by using a General Equilibrium Model

[4] Here the word "installation" is used, but it may also refer to a technology, a vehicle, a source of pollution, an enterprise, etc.

[5] This of course is not always the case. For example, in the cost assessments made for the new member states, data for the ex-ante cost estimates could be derived from experience in the "old EU".

Finally, regarding the quality of the estimates it seems obvious that detailed, rigorous ex-ante assessments (where substantial investment has been made to understand costs and cost uncertainty) will provide a firmer foundation on which to to base cost estimates than rapid policy screening tools, such as initial regulatory impact assessments. It would not be surprising to find that a detailed ex-post assessment produces results that differ from those of a rapid ex-ante assessment – different levels of investment having been made in the estimation process;

3.2.2 Availability and reliability of cost data

Ex-ante data

Limited data availability and reliability may be an important cause of gaps and inconsistencies in compliance cost estimates. Industry itself will usually have more information than the regulator (information asymmetry; cf. Hammitt, 2000), and may have an interest in keeping some information secret or in revealing flawed data. Misspecification may thus arise as a result of bias introduced by specific stakeholder groups overstating the costs of adaptation (deliberately as a negotiating ploy, or inadvertently as a result of overly conservative project costing policies). This bias may relate to the frequency with which a group of operators is regulated and their perceived need to defend their interests;

An underlying weakness in empirical approaches which rely on data from the regulated industry is therefore the inevitable bias towards technical descriptions which imply greater costs. This form of 'regulatory capture' needs careful management using independent third party estimates where available, or careful examination of pilot or 'typical' plants chosen as the basis for cost estimation.

Nevertheless, involvement of business is clearly helpful if credible estimates are to be presented. Suppliers of environmental technology can also be useful sources of cost data.[6] Furthermore, engagement through stakeholder representatives on studies helps to build confidence and encourage the release of information. Use of experienced consultants with a track record in the regulated industry and capable of understanding the finer points of operational detail is also important to gain the trust of business. This can be backed up with legal requirements on consultants to observe strict confidentiality requirements. To the extent that businesses are already subject to environmental regulation, regulators will have some leverage to encourage businesses to participate and to release necessary data.

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[6] However, suppliers of environmental technology may be overly optimistic about their technologies or be tempted to underestimate cost figures to 'open the market'..

Box 3.1 Ex-ante data collection for assessing the benefits of emission trading

In the study on the cost-advantages of emission trading (TME, 1997), the involvement of stakeholders (the industries addressed) in the data collection process was secured by involvement of industrial/business associations, individual industries and the confidential treatment of data by the researchers. Data on emissions of SO_2 and NO_x were collected, data on (investment) costs of reduction measures were either derived from industries (if they had any cost data available) or were estimated by engineers (in close cooperation with operators). This resulted in a detailed, reliable and verified dataset which was very valuable for the analyses.

The conditions for a successful ex-ante data collection in this case can be summarised as:

- sufficient budget and time;
- independent consultants for cost-data collection, who have good relations with both industries and authorities, are specialised and qualified in assessing costs of pollution abatement, and know how to handle data confidentially;
- willingness of industries to cooperate;
- positive incentive to industries, ranging from potential efficiency gains to insight in future costs and policy making.

Ex-post data

Eurostat, in co-operation with the OECD, collects some information on the costs of environmental management in the EU. The collected data are highly aggregated (total sectoral expenditures on air, water, waste), making it impossible to assess costs of individual pieces of legislation in the EU.

However, statistical offices in member states often collect more detailed data, which sometimes enable comparisons of ex-ante and ex-post costs comparison on the level of directives. This is for instance true for the Dutch Statistical Office CBS (though by far not for all legislation), that collects data on environmental (investment) expenditure in industry (2-digit NACE classification), agriculture, transport and also surveys the environmental services sector (so called “specialised producers” which specialise in waste(water) collection/processing). Normally a distinction is made by expenditures per domain (water, air, soil, waste, noise, nature protection, research, administrative costs). In most EU countries comparable data collection systems are in place, but the level of detail and the way data are collected and treated often differs.

Subsidies (including agricultural) registers can sometimes also be a useful source of information.

3.2.3 The time factor

In practice many studies focus on the assessment of additional investment costs only, whereas more advanced studies also assess annualised costs (taking into consideration the depreciation of investments and interest payments, and also operational and

maintenance costs). In some cases the Net Present Value (NPV) is calculated making use of discount rates.

If annualised costs are calculated it is important to know which assumptions have been made about depreciation of investments (linear, annuity, depreciation period), real interest rate and inflation. Different assumptions on interest rates and depreciation period may result in large differences (see Box 3.2).

Box 3.2: An Example of the Effects of Interest Rate and Depreciation Period Assumptions

Assume an environmental investment of € 10 mln. The annualised capital costs are calculated in two alternative ways:

- 10 year depreciation with 10% interest rate, this results in annual costs of € 1,627,500.
- 15 year depreciation with 4% interest rate, this results in annual costs of € 899,000.

This example shows that relatively small differences in assumptions may lead to large differences in annualised costs, as alternative 1 would lead to almost 80% higher estimates than alternative 2.

3.3 Attributing costs to policies

Often proposed environmental policies will impact on businesses already subject to previous regulation, with new changes modifying or tightening previous legislation, or where new legislation complements existing legislation. The complexity of different levels, vintages and policy interactions not only makes it difficult to estimate costs, it also makes it difficult to attribute costs to specific policy changes. The continuing evolution of air quality standards and related measures (e.g. emissions abatement, fuel quality standards) on certain industries (e.g. refineries, vehicle producers, power plants) is one policy example where attribution is often difficult.

This issue is also partly related to the timing of policy and hence to the counterfactual where existing policies may be assumed to continue. The ex-post assessment of the waste packaging directive (see Section 3.4) demonstrates the difficulties – with some EU member states having already enacted similar policies prior to the directive (which are therefore included in the counterfactual or baseline) and others introducing policies only after the directive and attributable to it.

The attribution may become even more difficult where business responses are conditioned by the frequency with which the same businesses are subject to environmental (and other) legislation, e.g. those frequently affected may respond to a perceived range of policies rather than to individual pieces of legislation, This is for example true for air quality regulations. As well as affecting overall costs, it also limits the scope to attribute costs to given cases of legislation.

3.4 Evidence from the case studies

The importance of distinguishing between agrregate costs and unit costs is illustrated by the LCPD case. This case showed that in the UK the costs of complying with the Directive

have been much lower than anticipated. However, this was mainly due to unforeseen responses (fuel switching instead of end-of-pipe measures). In Germany, where implementation was mainly effectuated by means of end-of-pipe measures, ex-ante and ex-post estimates did not differ that much. In other words, the costs per unit of emission reduction (at power plants that did not switch fuels) did not deviate much, whereas aggregate costs for all power plants were considerably lower ex-post than ex-ante.

The LCPD case also shows the importance of technology suppliers as a source of cost data. Whereas the power sector (having little experience with desulphurisation) overestimated ex-ante costs, the ex-ante estimates by the German *Umweltbundesamt* were close to the ex-post costs because they were based on interviews with technology providers. These had made lots of offers for building desulphurisation plants, so had worked quite extensively on cost estimates.

In the IPPC case, it was concluded by comparing the ex-ante and the ex-post cost data that ex-ante estimates of investment costs of the BAT options based on suppliers' information were reasonably realistic (within a range of 20%). However, the operational costs of the flue gas treatment options were overestimated. The analysis also revealed that the emission reduction efficiency for SO_x realised by flue gas cleaning was lower than the ex-ante estimates of emission reductions based on the suppliers' information. These two opposing errors more or less neutralised each other.

The problems involved in collecting cost data are highlighted by the Packaging case. When legislation is applied to an area for the first time (in this instance, packaging waste) there can be significant problems with data availability, reliability and consistency because the infrastructure is not in place to collect the information, and common protocols for measurement, classification, terminology etc. have not been established. These problems hinder ex-ante and ex-post appraisal. Early agreement on common EU-wide reporting frameworks, detailed terminology, scope etc. such that data are more likely to be comparable, can help to resolve this problem. In the ex-pos estimation of impacts on industry, establishing the incremental impacts of the measure in question can be difficult because companies plan, invest and work to the 'with measure' world and have difficulty relating to the counterfactual.

In the Packaging case, a further issue emerging is the attribution of costs. The Directive was conceived in part to counteract a perceived threat to the integrity of the internal market derived from the packaging and recycling laws and systems being established by individual member states. To the extent that the Directive was intended to ensure the proper functioning of the internal market, it should therefore be evaluated also on the basis of the attributed change in costs to business of the market barriers faced by product exporters and the avoided costs of recycling markets disruption.

The Nitrates case study provides another example of the issue of attributing costs. Some measures taken in agriculture have multiple objectives (e.g., nitrates, ammonia, phosphorus and greenhouse gas reduction), causing ambiguity as to what part of the costs should be allocated to what policy. The Nitrates case also revealed large differences between Member States in methods to assess costs. However, to what extent these differences influenced the accuracy and reliability of the estimates remains unclear.

4. Baseline assumptions, counterfactual scenarios and business / market response

4.1 Counterfactual analysis and baselines

One possible reason for variation between an ex-ante and an ex-post assessment is that different counterfactual scenarios or baselines are used. This is one of the reasons why the emphasis of analysis should be on additional or marginal costs rather than on total costs.

Ex-ante assessments aim to quantify the incremental costs of a regulatory change. However, once the regulation is in place and becomes the new context within which those affected operate, it is very often difficult to separate the incremental from the business-as-usual as is required for the purposes of the ex-post assessment. Business plans, investment decisions and corporate behaviour (all of which are in a state of constant evolution anyway) implicitly take into account the regulatory change such that it is no longer possible to discern what the counterfactual (and thus the incremental costs) might have been. This is especially true when:

- there is a long lead-in time (corporate memories tend to be short);
- compliance with a new standard is bundled with a range of other process or efficiency improvements in a given product or technology and/or fits well in natural investment cycles;
- the contextual environment changes in some material fashion, e.g. competitive dynamics, corporate mergers and consolidation, step changes in consumer preferences and expectations, external price shocks.

The assessment of planned or actual policy impacts on businesses depends on the ability to anticipate (ex-ante) or recall (ex-post) the responses of business to the legislation, compared to their actions in the absence of the legislation (the counterfactual). The counterfactual description is important in both ex-ante and ex-post assessments. This may include assumptions about e.g. production capacity[7], number of cars, way of electricity generation[8] or development of cattle.

Counterfactual analysis is useful for identifying the additional costs of a policy action, in some cases, such as the introduction of catalytic converters, it would be important to make explicit that no other changes would have taken place (and hence zero costs in the

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7 This is especially relevant if aggregated costs are used. *Ex-post* costs may be higher or lower than *ex-ante* estimates due to higher or lower production (capacity), even if unit costs remained the same.

8 An example in this category, cited a.o. in SEI (1999) is the decline in Belgium's sulphur emissions in the 1980s. The reasons were an increase in nuclear power, the conversion of oil-fired power stations to coal, increases in energy efficiency and a reduction in the sulphur content of the fuel used. The first three measures are seen as part of the policy of reducing Belgium's dependence on imported oil, but they contributed to meeting the country's obligations under the ECE Helsinki Protocol at low or even negative cost.

baseline) and hence to establish that the full costs of the policy action (the cost of providing and fitting catalytic converters) represent the additional cost. In more complex situations it is possible that policy action although associated with costs actually produces a cost saving when compared to the baseline (for example some recycling initiatives are cheaper than the baseline costs associated with landfill).

In examining differences between the ex-ante and ex-post the consistency of the baseline needs to be tested. Comparability requires that the baseline assumptions are the same in both cases.

In the case of EU environmental policies, ex-ante assessments are essentially exercises in long-term planning, with most EU environmental legislation taking several years to devise, plus several more years to transcribe and yet more time to allow for adoption and adjustment. This creates uncertainty, as the economy and business environment continuously develops (not least because of other policy drivers) requiring consideration not only of current market conditions and technological options but also emerging market conditions, technologies and related policy drivers. This uncertainty is clearly a potential source of variation in counterfactual descriptions between the ex-ante and ex-post costs.

Various methods exist to construct the counterfactual (Box 4.1).

Box 4.1. Methods for constructing a baseline against which the impact of policy can be assessed

Various methods are available to construct a baseline scenario. These include:

• **trend extrapolation**. A simple approach to constructing a policy baseline is to assume that trends visible prior to the policy change would have continued unchanged if the policy measure had not been implemented.

• **econometric methods.** Econometric models may be estimated which, for example, link pollution levels to various economic variables (e.g. the level of gross national product), and which include a "dummy variable" for the date of introduction of the policy measure. The model can then be used to make a "counterfactual" prediction of what would have happened to pollution levels if everything else had remained unchanged, except that the policy had not been introduced.

• **linear programming techniques** can be used to indicate how the decisions of firms might change in response to different constraints and incentives; the problem with these measures is that they assume some form of optimal decision-making, which may in practice be unrealistic.

• **"judgmental" methods** to describe the baseline in the absence of policy. However, one problem with definitions of the baseline scenario constructed purely on the basis of judgment is that the outcome of the evaluation study will depend critically on the judgments made; there may easily be scope for doubts about the realism of such a baseline.

What can be done depends partly on the availability of suitable data. In turn, data availability depends partly on the institutional setting of the evaluation. Issues of commercial confidentiality may obstruct access to some of the key data needed.

Source: OECD (1997), page 97

Ex-post assessments have to make assumptions about the counterfactual as much as ex-ante assessments. For example, an ex-ante assessment may project a drop in output of a

sector that is affected by regulation, but realised output (ex-post) may increase due to changed market circumstances (e.g. unexpected growth in exports), even if the (additional) costs to the affected sector did materialise. The ex-post assessment would need to consider whether the growth in output would also have occurred in the absence of the policy change.

However, it is also important to keep it simple. Too often, full ex-ante and ex-post estimates are not made, because they are perceived difficult. However, simple analysis can always be made and give almost as much information as a full comprehensive analysis. For example, a simple analysis of unit costs and number of businesses affected should always be possible. Doing this, is a good check on estimates, given the difficulty of estimating the baseline.

4.2 Dynamics of prices and costs

Predictions about future compliance costs require assumptions regarding the future development of prices and costs. The cost of a technology may decrease as a result of innovations and economies of scale (see Chapter 6). Furthermore, the cost of compliance may be strongly affected by changes in, for example, the energy price. This is especially relevant for technologies to reduce CO_2 emissions.

These technologies deserve special attention because the cost structure of these technologies differs considerably from more traditional environmental technologies (like waste water treatment, scrubbers, etc.). When applying "traditional" environmental technologies, in most cases only additional costs occur (capital costs, costs of operation and maintenance). However, technologies aiming at reducing energy or replacing fossil fuels by wind, sun, hydropower and so on, also include an economic benefit, as the (fossil) energy inputs are reduced or energy is produced. The net costs of the policy therefore depend to a large extent on the price of fossil fuels.

Table 4.1 gives an example calculation of the costs of CO_2 reduction by the transport sector by using a hybrid passenger car. The additional investment is about € 8,000, which can be translated in € 1,200 annual costs (for depreciation, interest and maintenance). On a yearly kilometrage of 20,000 km, 1000 litres of fuel can be saved compared to a normal gasoline car (that runs 1 litre on 10 km, leading to an annual gasoline use of 2,000 litres).

Table 4.1 Development of additional costs, savings on fuel costs and net costs of a hybrid car, as function of the price of gasoline (including taxes)

Fuel price	0.80	1.00	1.20	1.50	2.00	€ / litre
Gross costs per year	1,200	1,200	1,200	1,200	1,200	€ /year
Savings (fuel)	800	1,000	1,200	1,500	2,000	€ /year
Net Costs per year	400	200	0	-300	-800	€ /year
Cost effectiveness of CO_2 reduction	0.168	0.084	0.000	-0.127	-0.338	€ / kg CO_2 reduced

(CO_2 reduction of 2.37 ton per year (1000 litres of gasoline))

This simple calculation[9] shows that depending on the assumed gasoline price the costs vary from € 400 per year to a cost-saving of € 800 per year. In other words, in case the gasoline price reaches a level of over €1.20 (which is the case in many EU countries in the third quarter of 2005) the total costs of the technology (including fuel savings) are nil. A higher fuel price would even give a financial profit to the owner of the car, compared to the situation where he would have chosen a regular car. Also in cases where the cars runs more than 20,000 km per year, the technology becomes more profitable or less costly.

The example shows that in case of technologies saving energy, savings in expenditure on (fossil) fuels form an important part of the cost equation. This makes it more difficult to apply general cost functions for the (uncertain) future. The cost function should incorporate additional variables in order to enable taking on board price changes that heavily affect outcomes (especially for energy, but more generally also for water, raw materials, etc.).

4.3 Business and market response

4.3.1 Uncertainty and variability

The conventional approach to ex-ante compliance cost estimation assumes that the anticipated response to policy proposals is well defined. Where there is major uncertainty, alternative approaches are required to reflect this, using modelling or scenario based approaches. This uncertainty or variability of response can also be a cause of variation between ex-ante and ex-post, where the ex-ante estimate was based on assumptions about intended response which did not materialise, or only materialised in part. For example, ex-ante compliance cost estimates of producing low sulphur fuels assumed technical changes in refining capacity in the EU, whereas in fact a number of producers simply imported low sulphur fuels and blended it with existing products, resulting in lower costs ex-post. Similarly, practical application/efficiencies of some of new (prototype) pollution abatement technologies might be highly dependent on characteristics (e.g. location, resources used, etc.) of an individual business.

Harrington *et al.* (1999) concluded that where compliance costs were lower than predicted this was mainly due to the unanticipated use of new technology. The more flexibility given to a particular industry or firm in meeting an environmental regulation, the more difficult it is to anticipate the technical responses and the costs of achieving the regulatory requirements.

The conventional approach also tends to assume a degree of homogeneity among the regulated community, and that unit costs can be applied to all units equally. However, businesses with similar processes, products and markets may have different approaches to compliance. For example, there may be early movers anticipating regulatory change in order to better integrate additional costs and to gain added benefits from improved reputation. Any analysis should therefore recognise that the population of regulated

[9] We did not take into account possible changes in kilometrage and thus the amount of fuel consumed due to the changed (increased) price of gasoline.

businesses is not homogeneous. Apart from variations in size, markets and activity, most regulated populations can be divided into those businesses that:

- employ best practice and will be ahead of even new legislation, where compliance costs are (close to) zero;
- employ a policy of standard compliance, where adjustment costs may be relatively high;
- employ an essentially non-compliance policy, where compliance costs are limited by the time it takes for the environmental authorities to respond (but where there are significant enforcement costs).

These variations will cut across standard economic descriptions of the regulated business population. The relative size of the segments will vary depending on the novelty and stringency of the legislation.

It will be hard to quantify the impact of these different responses in an ex-ante assessment, as ex-ante information on the responses will be subjective (it can be imagined that a "non-complier" is not happy to tell this in an interview or questionnaire). However, data held on the regulated community can be used. Moreover, the impact assessment is also likely to be concerned with the administrative costs to the regulator, which in turn will need to be based on some consideration of the likely enforcement action necessary and hence the potential levels of non-compliance.

4.3.2 "End of pipe" and "integrated" environmental technology

Measuring costs is relatively straightforward for "end-of-pipe" technologies that are "simply" added to an already existing production process. Costs of investments, installation and engineering can be estimated from pilot plants and/or from equipment suppliers, operational costs can be measured if the installation is separately administrated in the financial accounts of a firm. This will in practice not always be the case, which often makes estimates of (ex-post) operational costs less reliable than investments.

More difficulties arise when integrated environmental technologies are used. Examples are: low noise ventilators, hydro crackers (refining crude oil), low NO_x burners, water-recycling or saving, electronic motor management, etc.

Assessing the additional costs of integrated technologies is often a matter of judgement, partly because only a part of the investment and operational and maintenance costs are attributable to compliance, and partly because the technologies can have a range of different cost and revenue effects. In theory these costs and revenues can be estimated by comparing the total costs of the "not so environmentally friendly alternative" with the integrated technology. It may then well be that the investment costs are somewhat higher, but for example the specific energy use is lower and more economical use is made of raw materials / process inputs.

For example, in the automotive industry many changes in engine design have both effects on emissions (lower) and efficiency of the engine (higher). Only part of the costs to develop such changes therefore should be addressed to "environment". This approach has for example been followed by Touche and Ross when assessing additional costs of applying technologies to reduce vehicle emissions (Touche and Ross 1995, p. 29 – 55).

Also the Netherlands Statistical Bureau (CBS, 1999) employs this method, by estimating "unit investments" in engine modification.

Integrated responses can also introduce a source of variation between ex-ante and ex-post estimates where these emerge and are not anticipated. For example, the reduction of solvents in paint (due to EU regulation) has provoked the formulation of a variety of new paints, which often make it difficult or impossible to assess the actual costs of the VOC reduction. Many of the assumptions made (on additional costs, on the use of the paint, on durability) when assessing the additional costs of the directive on solvents in paints, did simply not materialise, as new types of paints were developed that were not yet available at the time the ex-ante cost estimate was made.

In the context of integrated responses the "marginal costs" assumption (derived mainly from end of pipe studies), should be carefully considered:

- Investment in integrated responses often implies a strategic change in the design of processes or of products. There is therefore likely to be a profound difficulty in estimating the additional costs (and benefits) since the counterfactual (baseline) option relates to the whole way of doing business in the future – this suggests the need for the use of systems models, internal calculation guidelines (like those of the CBS), etcetera, to capture the full array of impacts;
- Although not formally implied, marginal cost assessment tends to assume that future technical modifications to enable compliance are understood. To the extent that technical change is uncertain (a good example is the scope to increase recycling of materials in car shredder residue in the context of the 'end-of-life vehicles' directive) then it is not clear why marginal cost analysis is appropriate, i.e. all other costs and behaviour can be held constant. At the very least, a scenario approach to describe alternative ways of responding, including institutional as well as technological responses, is required.

This means that the approach to assessment should look first at the nature of the strategic sectoral response required or undertaken, and the extent to which marginal change is in fact the way in which businesses will respond or have responded.

4.4 The incidence of costs

There is often as much concern (at least in ex-ante assessments) with the incidence of the cost (i.e. who pays) as with estimating the additional cost of a policy, because of concerns over the effects of additional costs on competitiveness and equity. The incidence of compliance costs will to a large extent depend on the question whether or not the firms that are subject to the environmental regulation are able to recoup the costs from their customers. This in turn depends on their market power, including their position relative to (international) competitors. Here again, ex-ante expectations about the incidence may differ from the eventual outcome.

4.5 Evidence from the case studies

The Packaging case illustrates the complexities involved in constructing counterfactual scenarios. The Directive as adopted specifies targets which required significant stretch

by some Member States, but did little more than codify the *status quo* for others. It post-dated the packaging recycling systems of certain countries, was coincident with the development of policy in others, and helped prompt the establishment of systems in a further group of countries. Moreover, the counterfactual scenario itself embodies very significant change, in this instance a widespread momentum towards higher recycling rates, changes in packaging technology, changes in markets and consumer preferences, and changes in counterfactual disposal costs.

The issue of cost incidence is present in the Ozone Depleting Substances case. This case study shows that the businesses who helped generate the estimates would not have been the ones who ultimately paid any additional cost. The mandatory nature of the Montreal Protocol often provided a way for business to pass the costs onto the user sectors, and ultimately to the consumers. In addition to this, those companies who led in the development of CFC substitutes achieved a market rent so long as their competitors were in the process of catching up. These lead companies also opposed legislation, but only until they had managed to develop substitutes, after which they moved to encourage the regulations which they then gained from. The laggards were the European companies who therefore lost out due to their delay in innovation.

5. Differences between planned, adopted and implemented policies

5.1 Introduction

Sometimes the consultative and political processes bring about modifications to proposals for regulatory change. As a consequence, the policy ultimately adopted is not necessarily the same as the one for which the costs were estimated. These changes, to scope, timing, technology or standard, may affect the aggregate costs of compliance and in turn generate differences between ex-ante and ex-post assessments.

Harrington *et al.* (1999) found that in a number of instances the variation in the cost estimates was attributable to the regulation delivering a lower change in emissions or outputs than had been predicted. In other words, the ex-post costs were lower, but the benefits were also lower.

A recent study by the European Environment Agency (EEA, 2005) shows large differences in investment costs in wastewater treatment plants between EU countries, but also large differences in the degree of implementation of the Urban Wastewater Directive. Such 'implementation deficits' may be caused by various factors, including for example differences in stringency of enforcement.

Moreover, the way in which the policy or legislation is implemented and the instruments chosen (e.g. market based intruments *versus* direct regulation) may strongly affect the ex-post costs. For example, the compliance costs of the USA's 1990 Clean Air Act Amendments turned out to be substantially lower than anticipated initially, partly due to the fact that the early proposals mandated scrubbers at many units and allowed little emissions trading, whereas the actual policy substantially reduced costs by allowing emission trading and leaving the choice of reduction devices open to the private firms (Ellerman, 2003).

5.2 Evidence from the case studies

In the CFC case, compliance was not always achieved in the way anticipated during ex-ante estimates. For example, regulators moved their focus from the use sectors, as anticipated, to producers and importers which proved to be a significantly more cost effective approach. Also, the Montreal Protocol later changed to permit the interim use of HCFCs.

Changes during the political process leading to the legislation are particularly visible in the Packaging case. That case showed that the costs of compliance may be determined by the detailed specification of the legislation, which can change substantially during the political process of negotiation. The consequences of such adjustments (such as changes in the mandated recovery rate) should be explored through sensitivity tests.

The Nitrates case study illustrates the importance of adequacy of implementation. In the Netherlands the way of implementing the Directive (by means of the 'MINAS' system) was considered to be inappropriate in a Court ruling. Therefore, the ex-post costs of

implementing the MINAS system cannot be regarded as reflecting the costs of the Nitrates Directive in the Netherlands.

6. The potential for innovation, economies of scale and other cost reducing dynamics

6.1 Introduction

The ex-ante estimated costs of a technology (to be applied as a result of the new policy) often do not take into account economies of mass production. Often costs are calculated for new, prototype technologies. Several studies have pointed to the fact that the application of environmental technologies becomes cheaper over time. Part of this is due to technological improvement (for example sizing down installations, better packaging materials, better catalysts, process optimisations), and also economies of scale (research costs are shared over more units, higher rate of the use of invested capital). Learning effects are also important (experience with a technology increases the efficiency of its application). Innovation and new technology may thus deliver compliance at a lower cost than had been anticipated. Ex-ante assessments tend to focus on established technologies, whereas once regulations are in place the 'innovative' can become the norm relatively quickly.

6.2 Evidence from literature

Several studies have been carried out to assess the quantitative relationship between the development of costs of environmental technologies and time. A study of TME (1995) was pioneering this quantification, whereas RIVM (2000) has further explored the consequences of this phenomenon. Also other studies addressing this issue (e.g. Anderson (1999), Touche and Ross (1995)) give or quote quantitative examples.

Both RIVM and TME conclude that the reduction of unit costs of environmental technologies goes faster than the – comparable – technological progress factor that is incorporated in macro-economic models used by the Netherlands Central Planning Bureau. In these models the average factor is about 2% annually. The results of both the RIVM and TME study for the annual cost decrease of environmental technologies are presented in Table 6.1.

Table 6.1: Annual decrease in costs of applying environmental technologies

Technology / Cluster	Annual cost decrease	
	Min	Max
Dephosphating sewage	3.8%	6.7%
Desulphurisation of flue gas at power stations	4%	10%
Regulated catalytic converter	9%	10.5%
Industrial low NO_x technologies	17%	31%
1. High Efficiency Central Heating	1.4%	
2. Energy related technologies	4.9%	
3. End-of-pipe, large installations	7.6%	
4. End-of-pipe, small installations (catalysts)	9.8%	
5. Agriculture low emission application of manure	9.2%	

Source: TME, 1995, p. vi ; RIVM, 2000, p. 13

Both studies show comparable results: the annual cost decrease is mostly between 4 and 10%. Therefore, when modelling environmental costs for the longer term, some form of technological progress needs to be taken on board in addition to what is assumed in the macro-economic model.

In the TME and the RIVM study no attempt was made to differentiate between two types of technological progress (see Krozer, 2002):

- gradual improvements of already existing technologies (for which Krozer assumes that these will mainly lead to cost-savings and not so much to increased reduction potential);
- innovations (or "leap technologies") for technologies which are new and can compete with existing technologies in both efficiency (lower costs) and effectiveness (larger reduction potential).

This distinction is however important, especially concerning the development of the reduction potential, because this will enable us in the future to reduce more pollution than currently thought.

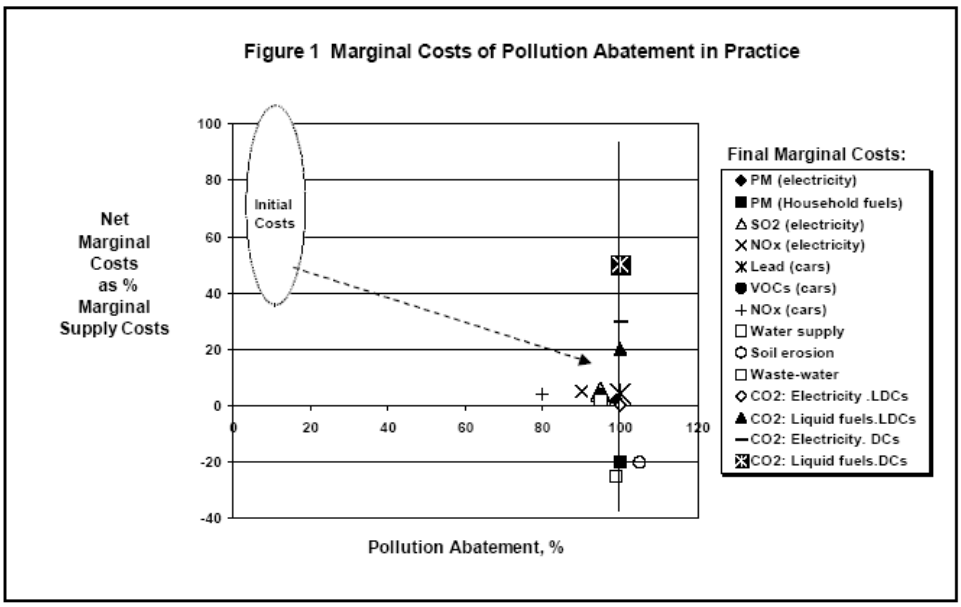
The anecdotal evidence on waste water treatment and low NO_x technologies in industry actually shows both developments:

- increasing reduction potential (to almost 100% theoretical) in a period of about 30 years;
- decreasing unit costs.

So from the empirical point of view both developments are important enough to be separately considered when estimating future costs of environmental technologies.

Anderson (1999) shows the following figure on the development of costs of environmental technologies as function of pollution reduction.

Figure 6.1 Marginal Costs of Pollution Abatement in Practice



Source: Anderson (1999)

From this picture it can be concluded that in early stage of development of pollution control equipment, the application of such technologies may cause the marginal costs of productive activities to increase by 40% - 100%. Also, the efficiency of primary technologies is low. Due to technological development, the efficiency increases and the costs of application decrease, as Anderson concludes on the basis of reviewing various case studies.

6.3 Evidence from the case studies

The LCPD case study clearly demonstrates the impact of unforeseen technological developments on eventual compliance costs. In the UK, power producers complied with LCPD requirements by switching massively to gas fired Combined Cycle Gas Turbine (CCGT) plants, making further expensive investment in flue gas desulphurisation (FGD) largely unnecessary. In the Netherlands, the overestimation of ex-ante LCPD cost estimates is believed to be due to the fact that these estimates were made in the late 1980s, on the basis of data about first small-scale applications of desulphurisation and denitrification technologies, i.e. emerging technologies that improved in the following years.

In the CFC case study, it was concluded that the failure to correctly predict compliance costs was likely to be due to conservative assumptions by some within the industry in the face of uncertain future technological developments and a lack of incentive to provide realistic predictions. As long as the sectors' interest lies in talking-down the prospects of innovation, it is likely that only detailed external reviews of industry assumptions can critically challenge ex-ante cost estimates.

In the car emissions case study, the main reason for overestimation was the ex-ante assumption about the unit costs of environmental equipment and measures. The ex-post costs estimates often tend to decrease over time due to improvements in technology and efficiency. The ex-ante estimates fail to consider these effects. Unit costs of environmental

technology have the tendency to decrease over time with annual changes of around 10%. The additional costs to comply with regulations concerning diesel vehicles were especially overestimated. In reality, the automobile industry was able to supply complying cars at much lower costs than initially thought.

In the Nitrates Directive case study, the comparison of ex-ante and ex-post estimates of the MINAS policy the Netherlands suggested that for some sectors (e.g., the dairy sector), manure and fertiliser policies have resulted in efficiency gains due to a more rational fertiliser management that offset part of the ex-ante expected costs. The extent of these efficiency gains will in general depend on the initial situation (how rational is the current situation) and the design of the policy instruments and associated advisory initiatives around these instruments.

7. Conclusions and policy implications

7.1 Factors behind the gap between ex-ante and ex-post cost estimates

Ex-ante estimates of the costs to business of environmental legislation often (though not always) exceed the ex-post estimates by a substantial margin. Various factors explain these differences, and many of these factors cannot be easily influenced. It is therefore reasonable to expect that the gap between ex-ante and ex-post costs is here to stay. Indeed, Harrington *et al.* (1999) argue that ex-ante estimates can be useful in the development of environmental regulations without necessarily providing good predictions of ex-post costs. According to them, cost estimates should be seen as inputting into environmental regulatory decision-making and not as an output intended to be judged on its own merits.

Therefore, even though there is room for improvement in the quality and accuracy of cost estimates, it is equally important to be aware of the factors behind the gap. In this study, the following categories of factors have been addressed:

- Factors related to the definition and measurement of costs;
- Factors related to baseline assumptions, counterfactual scenarios and business (or market) response;
- Differences between planned, adopted and implemented policies;
- The potential for innovation, economies of scale and other cost reducing dynamics.

The importance of each factor appears to differ from case to case. However, evidence from literature and case studies suggests that especially the potential for (unanticipated) innovations and cost reductions often plays a major role. In particular, large differences between ex-post and ex-ante estimates are usually due to the introduction of new technologies (after the introduction of the legislation) with low or even negative net cost. The LCPD case (CCGT technology) and the ODS case (CFC substitutes) are clear examples. Considerable underestimates of the cost reduction potential of innovation may also occur if ex-ante costs are based on data for prototypes or first applications that have not yet benefited from economies of scale and 'learning curve effects'.

There seems to be little evidence of industry knowingly providing biased cost estimates. However, in the face of uncertain future technological development, the affected industry will tend to be conservative, i.e. to come up with relatively high cost figures. They may also be reluctant to make cost data publicly available, as this is often commercially sensitive information.

Suppliers of environmental technology may have an incentive to be over-optimistic and give low cost estimates in order to influence decision making. On the other hand, technologies eventually delivered to the market usually have a 'safety margin', i.e. a guaranteed minimum efficiency level, whereas the 'real' efficiency is higher. The involvement of independent experts may provide additional, relatively 'neutral' cost information.

The often substantial time lag between the stage in which ex-ante cost estimates are made (during the preparation of the legislation) and the time at which the costs are

actually incurred by business implies that many of the assumptions on which the ex-ante estimates were based may no longer be valid. In addition to the policy itself, market conditions and contextual factors may have changed. Moreover, the response by business may be quite different from what was expected. Cost assessment procedures will have to deal with this inherent and largely inevitable uncertainty. Sensitivity analyses and explicit consideration of the assumptions and the extent to which they turned out to be false are therefore needed.

Differences in implementation are in fact not a separate source of divergence between ex-ante and ex-post costs, but rather a specific case of assumptions not becoming reality (the assumption in this case being full implementation and enforcement of the originally proposed legislation by means of a particular policy).

Relatively reliable predictions of compliance costs might be conceivable in the case of detailed technical prescriptions, uniformly required from all actors involved in the EU. However, the tendency in environmental policy is towards more flexibility, leaving Member States and firms as much room as possible to find their own solutions for meeting the requirements and objectives. From that perspective, the scope for making precise ex-ante cost estimates is not likely to become larger. This does not mean though that estimates are not useful and do not give a very good feel for the costs.

7.2 Implications for cost assessments

Even though, as argued in the preceding section, the hope for perfect ex-ante cost estimates is illusory, it should at least be possible to follow some guidelines which might lead to better accuracy and comparability.

The main challenges for the improvement of cost estimates and for the convergence of ex-ante and ex-post estimates include the following:

- The need for clear definitions and consistency in the use of the term ‘costs’.
- The construction of counterfactual scenarios and addressing the question to what extent the real developments differed from that scenario.
- Taking due account of the complexities involved in environmental regulation (i.e. the difficulty of attributing costs to one particular policy measure).
- Splitting unit costs and volume estimates.
- Dealing with the fact that ex-ante estimates are often done on early proposals that are changed in the subsequent legislative process, and even later – in the implementation phase.
- Coping with the bias caused by ex-ante estimates that are done to fit in with lobbying, and may therefore not be entirely neutral.
- Ensuring to obtain information on costs from a wide range of sources (including e.g. potential suppliers of implementing technology).
- Investigating the mechanisms behind innovation and cost decreases due to environmental policy. This may provide the necessary tools to take these factors into account so as to obtain more realistic *ex-ante* cost estimates.

Estimating ex-ante

The reliability of ex-ante cost data can be improved by carefully selecting and evaluating the information sources. Ideally, data from different sources (suppliers, operators, researchers, etc.) should be analysed to arrive at a reliable range of cost figures.

Legislation can lead to benefits in the form of 'avoided costs'. Avoided costs are likely to be at least as challenging to estimate as conventional costs of compliance, but their inclusion in the ex-ante estimate is essential to prevent overestimation of net cost.

Ex-ante estimates should keep track of the development of the policy process, as changes in the policy proposals inevitably will imply changes in the estimates. Ideally, each amendment should be accompanied by a revision of the estimated costs.

The construction of the counterfactual scenario (i.e. what would have occurred in the absence of regulation) is a difficult part of cost estimation. If one wants to be less dependent on the use of rather complex scenarios vulnerable to many external variables/factors, it is necessary to gain a better understanding of business behaviour and the likely response to a given policy measure.

The issue of strategic versus marginal responses needs to be examined in much more detail, with consideration of the heterogeneity of businesses and of their likely responses (especially where policy impacts on SMEs) and of the genuine technological uncertainties that surround these responses.

Careful ex-ante analysis should include "sensitivity analysis" that identifies the key parameters that are expected to influence costs, and assesses how changes in these parameters affect expected costs. Identifying the key determinants of costs ex-ante helps when designing ex-post evaluation.

Further research should reveal whether it is possible to formulate general 'rules of thumb' regarding the extent to which cost decreases can be expected as a result of unanticipated substitution options, innovation, economies of scale and learning curve effects. This might lead to some standard reduction factors to be applied in ex-ante cost estimates, dependent upon the specific technology and context at hand.

Estimating ex-post costs and comparing them with ex-ante

The planning of ex-post estimates needs to be built into regulations in order to generate learning about the degree to which they have succeeded.

Comparisons of ex-ante and ex-post estimates should ask whether entities complied as they were expected to do, and aim to find out why (or why not). Ex-post assessments should also take account of how the regulation changed during the period of its negotiation and implementation. Obviously, changes in contextual factors should also be considered.

When comparing ex-ante and ex-post annualised cost estimates of (in principle) the same phenomenon (or technology) the following should be considered to arrive at comparable figures:

- exchange rates and the price basis;
- the number of units ex-post and ex-ante;

- unit costs ex-post and ex-ante;
- the way in which costs are estimated or expressed: annualised costs, investments, net present value;
- interest rates and discount rates[10] applied in the calculation of costs;
- depreciation periods;
- treatment of operating and administrative costs;
- the inclusion or exclusion of indirect or "welfare costs" (such as the attributed loss of market share) in the calculation.

For a policy instrument (such as the Packaging Directive) in which targets are periodically revised it should be possible to establish a feedback process that draws on the ex-ante and ex-post evaluations of each stage. 'Learning loops' that involve progressive tuning of the assessment method and benefit from the improvements in the data should facilitate more accurate estimation of compliance costs for target revisions over time. This could also benefit the assessment of future costs by accession countries adopting measures some time after existing Member States.

Finally, investments in costs estimates will usually be very small relative to the cost of implementation. It would be interesting to investigate the potential efficiencies provided by high-quality cost estimates (in terms of better policy measures). This would require an in-depth analysis of cases in which not only the results of ex-ante and ex-post cost estimates are compared, but also differences in investment in the estimation and the methodology used, as well as the role of the estimates in the decision making process.

[10] For EC studies use of the EC recommended discount rate of 4% improves comparability.

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Appendix I. Summaries of case studies

1. Large Combustion Plant Directive

The Large Combustion Plant Directive (LCPD) 88/609/EEC applies to combustion plants with a rated thermal output ≥ 50 MWth. It sets national emission ceilings for emissions of SO_2 and NOx from existing LCPs, and absolute emission limit values for SO_2, NOx and dust for individual new installations based on Best Available Technology (BAT).

This Directive was revised in 2001 (so the former 88/609/EEC Directive is no longer in force). The revised Directive still being in the process of implementation[11], no ex-post costs are available. The present case study had then to focus on the 1988 Directive.[12]

Compliance in the UK

In the case of the UK, ex-ante and ex-post costs for electricity generation related to SO_2 emissions reduction in the electricity supply industry were compared. The data available in the literature are qualitative data reported by SEI[13] (1999) and the Milieu Ltd, the Danish Environmental Research Institute and the Centre for Clean Air Policy (2004). SEI reports that the Central Electricity Generating Board estimated in 1979 that operating costs of equipments controlling sulphur emissions would increase the cost of electricity generated at the power station by about 25 – 30%. The Milieu Ltd (2004) reports that a recent analysis of costs for the UK after adoption of the UNECE Protocols on acidification and the 1988 LCPD found that costs increased by only 2.5 to 5% over a 15-year period. So ex-ante costs provided by industry (electricity generation costs) were a lot higher than ex-post costs.

This very important difference is explained by the fact that the context of UK's electricity supply industry radically changed between the time when the ex-ante estimates were made, and the time when the ex-post costs were assessed. The main change influencing the costs was that a new technology, the Combined Cycled Gas turbine (CCGT) was developed, making the number of coal-fired plants needing FGD (Flue Gas Desulphurisation) retrofitting decrease. This technological innovation was facilitated by the flexibility of the LCPD, which left Member States free to choose the way they would comply with the national ceilings set up for existing plants (and the fact that gas turbines were not covered by the LCPD scope), and the privatisation of UK's

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[11] According to the Directive, Member States must achieve significant emission reductions by 1 January 2008, at the latest, by means of a national plan or adopting an Emission Limit Value approach. The national emission reductions plans (for MSs who chose this option for their existing plants) are actually still under discussion between MSs and the Commission. Some Member States that might be interested in this option have not submitted their national plan yet.

12 Ex-post costs should be available for new plants under Article 4 of Council Directive 88/609/EEC and for new plants under Article 4(2) of Directive 2001/80/EC.

13 Stockholm Environment Institute.

electricity industry. It is also possible that electricity generation costs were influenced by a hypothetical change of the demand on the electricity market, or a variation in electricity imports, etc.

So the important difference between ex-ante and ex-post costs in the UK is due to very different situations in the electricity market before and after the implementation of the LCPD. And, if the LCP Directive certainly influenced these changes by favouring the emergence of the CCGT technology, it is difficult to measure to which extent it did.

Compliance in Germany (for the GFA-VO Ordinance of 1983, very similar to the later LCPD)

The 'GFA-VO Ordinance' of 1983 was a typical piece of command-and-control regulation, setting up ELVs for NOx, SO_2 and dust for both existing and new plants. For a number of reasons, the industry was initially opposed to the proposed German Legislation. SEI (1999) reports that industry claimed costs for FGD installation and operation that were approximately double as had been estimated by the Umweltbundesamt (UBA) officials. No quantitative data were found in the literature to sustain this element, but it was confirmed by a personal communication with UBA's author of the ex-ante estimates. It is believed that industry certainly overestimated costs because they had not much experience with the end-of-pipe technologies and hoped these high estimates would lead to the abandon of the regulation on LCPs.

Regarding the ex-ante estimates provided by the UBA, quantitative investment costs and costs per kW for end-of-pipe equipment were found (cf table below), but the methodology used to assess these costs was not available.

These ex-ante UBA estimates were later shown to be broadly in line with ex-post estimates (ex-post being 1.25 times higher at maximum, see Table I.1).

Table I.1. Investment costs of FGD installations ex-ante (UBA) end ex-post (VB)

Investment required for FGD Installations (Million euros)				
	Capacity of the Plant (MWth)			
	300	700	1100	1500
UBA	23	41	55	73
VB	29	49	67	84

Cost for FGD Installations per KW generated (euros/kW)				
	Capacity of the Plant (MWth)			
	300	700	1100	1500
UBA	73	58	49	47
VB	93	73	61	57

Source : SEI (1999) - UBA : ex-ante estimates ; VB : ex-post estimates

Note : the ex-post estimates are based on a survey among the German electricity industry, and are considered reliable by the UBA.

A personal communication with the author of UBA's ex-ante estimates revealed that these were close to the ex-post costs because they were based on interviews of technology providers. These had not more experience with desulphurisation end-of-pipe technologies than industry, but had made lots of offers for building desulphurisation

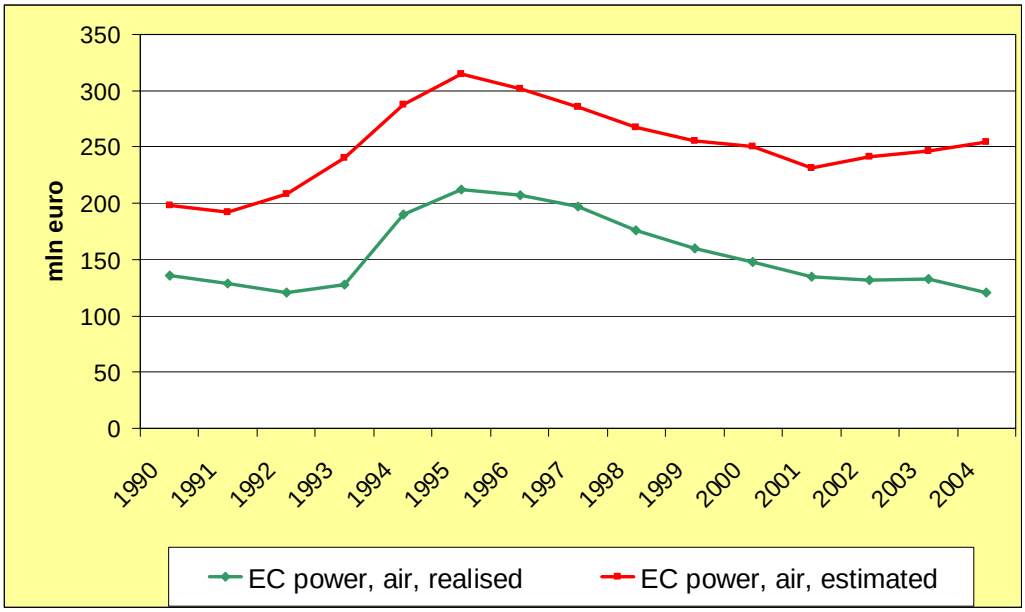
plants, so had worked quite extensively on cost estimates. This, added to the fact that these technologies were implemented in a very short time period, and consequently technology prices did not evolve much, explains why the ex-ante estimates were so close to the ex-post costs.

Compliance in the Netherlands (for the Dutch Bees WLV of 1987, very similar to the later LCPD)

The Dutch 'Bees WLV 1987' was a typical piece of command-and-control regulation, requiring setting up emission limit values for NOx, SO_2 and dust for both existing and new plants. The cost estimates available are environmental costs for air protection for SO_2, NOx and dust emissions reductions from power stations, from 1990 to 2004.

The ex-ante cost estimates were made by the Dutch Ministry of the Environment (VROM), while the ex-post costs were surveyed by the Dutch Central Bureau of Statistics. The ex-ante estimates were higher than the ex-post costs: from 1.5 times higher in 1990, to twice as high in 2004, as can be seen in Figure I.1.

Figure I.1 Environmental costs for air protection in the power sector, the Netherlands, estimated and realised (1990 – 2004) (price level 2004)



Source: TME (2005), it concerns costs to reduce SO_2, NOx and dust emissions from power stations.

The overestimation of ex-ante cost estimates is believed to be due to the fact that these estimates were made in the late 1980s, on the basis of data about first small-scale applications of desulfurisation and denitrification technologies, i.e. emerging technologies that improved in the following years.

As a conclusion, the following points can be presented:

- Although the scope of the LCPD includes SO_2, NOx and dust emissions from large combustion plants in various economic sectors (power generation, refineries,

industrial boilers…), the data found in the literature and used in this study focuses on the electricity sector, and mainly on SO_2 emissions reductions.

- The quality and robustness of the cost estimates presented in this study vary a lot according to the data found in the literature. For the UK, only ex-ante and ex-post qualitative assumptions about the increase of electricity generation costs due to desulphurisation equipments were found to be comparable. For Germany, the fact that industry's ex-ante estimations were twice as high as UBA's estimates is reported in a quote in SEI (1999), and confirmed by a personal communication with the author of UBA's estimates. Regarding the comparison between UBA's ex-ante estimates and the ex-post costs, a table provides cost elements about investment costs and operation costs for FGD equipment. The most robust data found were for the Netherlands, where ex-ante estimates made by the Ministry of the Environment (VROM) can be compared to statistical data gathered by the Central Bureau of Statistics (CBS).
- The differences in the quality and the nature (electricity generation costs, investment costs in FGD, direct environmental costs to business…) of the cost data found, as well as the differences in baseline scenarios (legislations similar in their purpose but different in their content, different contexts for the electricity industry in the studied MSs, etc.) do not allow comparisons between the ex-post costs of the UK, Germany and the Netherlands.
- The only conclusion that can be drawn for the UK is that technological innovation should be taken into account when assessing ex-ante costs of a flexible piece of regulation.
- The German case study gives an example where industry's opposition to a given regulation lead to an overestimation of ex-ante costs (even if this is not the only reason for this overestimation).
- The UBA's ex-ante estimates, which were close to but slightly higher (max. 1.25) than the ex-post costs, were based on data of technology providers.
- In the Netherlands, the VROM ex-ante estimates, proved to be from 1.5 (1990) to more than twice (2004) as high as the ex-post costs. This overestimation is believed to be due to an ex-ante assessment based on non representative data.
- No other comparable data regarding ex-ante and ex-post costs for the implementation of the 1988 LCPD in the EU were found in the literature.

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2. IPPC Directive (focus on ceramic sector in Belgium)

Background

Directive 96/61/EC on Integrated Pollution Prevention and Control (IPPC) has introduced a framework requiring EU Member States to issue operating permits for large industrial installations. The IPPC legislation requires further environmental improvements on the basis of what is affordable according to the Best Available Techniques (BAT). By definition, economics play a central role as the abatement techniques must take account of what is 'available' under economically viable conditions.

At the moment, the availability of cost information and the number of in-depth economic analyses in the field of IPPC and BAT determination is relatively limited. For example, most European BAT reference documents (BREFs) include some information on economics of BAT options, but this information is hardly used to determine BAT. The lack of cost data is partly explained by the reluctance of operators to provide real cost figures for reasons of confidentiality. In addition to operators, the information from suppliers of environmental technology is incorporated in BAT reference documents with great caution, as they may be tempted to underestimate cost figures to 'open the market'.

This case-study focuses on the ex-post economic evaluation of "BAT options" for SO_x reduction in the ceramic industry in the Flemish Region of Belgium. Ex-ante data have been gathered in 1999 from European suppliers of different flue gas treatment techniques in the context of a BAT analysis. This analysis resulted in a new sectoral legislation for air emissions and installations that recently invested in flue gas treatment technology. The ex-post data originate from a recent survey of operators of these installations.

Summary of results

By comparing the ex-ante and the ex-post cost data, it can be concluded that ex-ante estimates of investment costs of the BAT options based on suppliers' information were reasonably realistic (within a range of 20%). However, the operational costs of the flue gas treatment options were overestimated. More importantly, the analysis revealed that the emission reduction efficiency for SO_x realised by flue gas cleaning is lower than the ex-ante estimates of emission reductions based on the suppliers' information.

Next, the ex-post cost data were used to reconsider the economic feasibility of the BAT-options. To this extent, a cost-effectiveness analysis was carried out, as well as a simplified viability analysis. It could be concluded that the ex-ante estimates of the cost effectiveness were quite realistic, despite the fact that the estimates of the underlying cost and efficiency data were not always correct (both costs and efficiency having been over-estimated). The viability analysis revealed that in comparison with other industrial sectors, the ceramic industry in Flanders remains one of the poor performing sectors. This relatively weak financial position could be partly explained by the investments in BAT.

Clearly, the limited scope of this case-study does not allow the derivation of major conclusions and recommendations for the BAT/IPPC process at the European level. Nevertheless, it shows that data from technology suppliers are useful to determine economic feasibility, but should be used with care. Ideally, data from different sources (suppliers, operators, researchers, etc.) should be analysed to arrive at a reliable range of cost figures.

3. Ozone Depleting Substances

Summary of results

The phasing out of Ozone Depleting Substances (ODS), under the Montreal Protocol and EU Regulations 3093/94/EC, and 2037/2000/EC, provides an early example of how ex-ante and ex-post cost estimates provided by industry can differ greatly. This case study has found that the comparison factor (ex-ante/ex-post) can range from at least 1.4 at an aggregate level to 40 for individual case studies, and as high as 125 for administrative costs of compliance. Using an example where inflation is not a factor, a comparison factor of 2.5 is found. Further down the product chain for consumers, the cost estimates for the prices of consumer products due to the Montreal protocol differed by a factor of about 1.25 (see Table I.2).

Table I.2 Summary of ex-ante and ex-post costs estimates

Case study	Ex-ante	Ex-post	Cost ratio (ante/post)	Key driver of difference	Source
Macro cost estimates					
Cost to consumers	20-25% (Reported in SEI 1999)	Little or no cost (UNEP 1995)	~1.25	Proportional increase in consumer product prices. Based on low ex-ante estimate	
Social cost of reduction	50 % $2.7 billion	100% @$1.9 billion	>1.4	In 1988, the EPA estimated that the social cost of a 50% reduction by 2000 would be $2.7 billion. Complete elimination was estimated to be 30% less than this by 1992	Hoener 1996, p.50
Case study cost estimates					
Costs of substitutes	10 times CFCs (Industry)	3-5 times CFCs	~2.5	Comparison of HFC 134a relative to its substitutes (CFC 11 or 12). Ex-post costs as reported in 1988. Difference due to competition	SEI 1999, p.37
Reporting and record keeping	$300 million (1988)	$2.4 million (1989)	125	Regulators moved the focus from the use sectors to producers and importers.	Lee 1996, p.33
Foam blowing plant- interim use of HCFC-22	Up to $2m	$50k	40	Regulator permitting interim use of HCFC-22'S whilst developing hydrocarbons	Cook 1996, p.5

Notes:

● The social cost of reducing the use of CFCs differs to the other costs in the table as it includes the cost of compliance to all actors in society, including the foregone value for applications which are perceived (ex-ante) not to have a possible substitute available.

● Compliance was not always achieved in the way anticipated during ex-ante estimates. For example, regulators moved their focus from the use sectors as anticipated to producers and importers which proved to be a significantly more cost effective approach. Also, the Montreal Protocol later changed to permit the interim use of HCFCs.

Summary of findings

1. Analysis of ex-ante cost estimates shows they simultaneously under estimated the extent and the feasible rate of a phase-out, whilst over estimated the unit cost.
2. There is some evidence that European industry lost out in the race to develop substitutes and therefore made lower profits from these substitutes than their American competitors.
3. Some evidence of slower compliance and higher costs for southern EU Member States and Central and Eastern European countries.
4. Claims of negative costs as a result of the Regulations should be treated with caution – any review of industrial processes will likely achieve cost reduction through the introduction of more efficient processes and products.
5. Analysis of the actors involved has concluded that:
    a. The failure to correctly predict was likely to be due to conservative assumptions by some within the industry in the face of uncertain future technological developments and a lack of incentive to provide realistic predictions.
    b. As long as the sectors' interest lies in talking-down the prospects of innovation, it is likely that only detailed external reviews of industry assumptions can critically challenge ex-ante cost estimates.

4. Transport –Dutch Case studies

This case study looks at a number of examples of ex-ante and ex-post assessments of the costs of applying environmental technologies in road transport. Specific attention is paid to the influence of technological change (and economies of scale) on unit costs of environmental equipment (e.g. catalytic converters). Ex-ante estimates from the Dutch National Environmental Programme NEP are compared against ex-post estimates from CBS statistics. It is considered that these are the only data sets within the EU which can provide this comparison. The results are summarised in Table I.3.

Table I.3 Results - Catalytic converters and other changes

Vehicle/measure	Fuel	Factor (ex-ante / ex-post)	Main reason
Passenger and LDV (light duty vehicles)	LPG + petrol	2	Decrease in unit costs €771 in 1985, €285 in 2000
	Diesel	5	Decrease in unit costs €400 in 1997, €275 in 2001
Heavy duty	Diesel	1.4	Overestimation of particle traps (cost and implementation)
Unleaded petrol	Petrol	6.3	Decrease of additional production costs: € 0.02 in 1990, € 0.004 in 2000
Low sulphur diesel	Diesel	Possible underestimation	Ex-ante estimates quantities and additional costs

This case study concluded that the overall comparison factor (i.e. cost overestimation) was about 2. The main reason for this overestimation is the ex-ante assumption about the unit costs of environmental equipment and measures. The ex-post costs estimates often tend to decrease over time due to improvements in technology, efficiency and economies of scale. The ex-ante estimates fail to consider these effects. Unit costs of environmental technology have the tendency to decrease over time with annual changes of around 10%. The additional costs to comply with regulations concerning diesel vehicles were especially overestimated. In reality, the automobile industry was able to supply complying cars at much lower costs than initially thought.

If technology development continues, as is assumed in many technological studies, it can be assumed that this decrease of costs will continue. New costs of new technologies tend to decline during application. But other factors also will influence the future costs: how will vehicles evolve over the next 5 to 10 years? To what extent will hybrid vehicles will become popular? This is hard to predict.

5. Packaging and packaging waste

This case study examines costs of compliance in the context of the Directive on Packaging and Packaging Waste (94/62/EC). The Directive had a dual purpose, as an instrument intended to preserve the integrity of the European internal market (in terms of trade barriers and the supply of recovered material) as well as a means of setting common targets for the recovery and recycling of packaging wastes. It establishes a set of operating principles but leaves definition of the mechanisms for achieving the specified targets to the member states. The process leading up to the adoption of a final text of the Packaging Directive was difficult. There was intensive lobbying and external input from industry and the 'packaging chain' in particular.

The latest evaluation for the Commission suggests the impact of the Directive (in terms of cost and incremental recycling) is comparatively modest. However, the impacts are (i)

increasing year-on-year, and (ii) unevenly distributed, with greater additional impact in those countries where packaging recycling systems were less well developed in the early 1990s. One of the main barriers to the analysis is the establishment of the counterfactual base case (i.e. what national policies would have been written in the absence of the Directive) which varied greatly between member states. For example it was concluded that the Directive had little impact on the recycling rates in seven countries that together account for about half the EU-15 population and which were already enthusiastic recyclers. In addition to this, national schemes vary in the financing mechanism adopted, and the extent to which actual costs are displaced from municipalities/local authorities to producers and business. In theory this cost should be borne by the packaging waste producers. In practice, this is not always the case and some fraction of costs may instead by carried by municipalities.

The case study report concludes that the annual net additional cost ('financing need') of the additional recycling attributed to the Directive in 2001 was estimated at €50 million in 1997 increasing to €227 million in 2001. However, the depth of analysis provided by the set of ex-post assessments of the Directive has no equivalent in the ex-ante literature. As a result little of substance can be said in respect of comparison of the two.

Additional impacts of the Directive

1. The Directive led to a reduction of about 10% in the quantity of packaging waste disposed of in 2001 for the EU-15 as a whole, and 15% in the eight member states whose recycling activity had been most affected by the Directive.
2. The Directive provided a common framework to manage barriers to trade due to packaging requirement. 14 cases were brought relating to the removal of the trade barrier or distortion of competition: in 8 cases the measure was changed or dropped before coming into force.

6. Nitrates Directive

This case study reviews studies of the costs to farmers of the implementation of the provisions of the EU Nitrates Directive across seven EU Member States and one Candidate Country. The aims of the review are twofold. The first aim is to compare the costs of the Nitrate Directive (or more or less comparable nitrate reduction polies) across different Member States and to explain differences in costs in terms of their underlying factors, for example by different modes of implementation of the provisions of the Directive. The second aim is to compare ex-ante and ex-post estimates of costs to find out whether ex-ante estimates of costs are structurally biased, i.e., whether they *over* or *under*estimate the 'true' costs of the Directive (as measured by the ex-post estimates). If such structural biases exist, what are their main causes?

Table I.4 presents ex-ante estimates for all case-study countries and ex-post estimates for Denmark and the Netherlands. The ex-post estimates for the Netherlands refer to its nitrate reduction policy (MINAS), which has been judged as an inappropriate implementation of the Nitrates Directive by the European Court of Justice.

Table I.4 Ex-ante and ex-post estimates of costs of the Nitrates Directive (€, prices of 2004).

	Ex-ante		Ex-post	
	€.ha^{-1} y^{-1}	**€ kgN^{-1}.y^{-1}**	**€.ha^{-1} y^{-1}**	**€ kgN^{-1}.y^{-1}**
Denmark	103	2.7	62	1.4
Finland	n.a.			
France	25-61	1.2		
Netherlands*	236 (174)	3.5 (2.0)	(174)	(1.7)
United Kingdom	6			
Lithuania	50-57			
Croatia	43	0.4		

* Numbers between brackets refer to the Dutch MINAS policy.

The estimated costs of nitrate reduction policies differ across Member States. We found a range of costs per hectare from € 6 to € 236. The four ex-ante estimates of cost-effectiveness of nitrate reduction policies range from a low of € 0.4.kg.N^{-1} in Croatia to a high of € 3.5 kg.N^{-1} in the Netherlands. The differences are caused by differences in industry structure, livestock intensity, and historical rates of fertiliser application. Differences may also be due to different assumptions and methodological differences between studies. On the basis of the present review it is impossible to relate the cost differences to differences in the application of more or less efficient policy instruments across Member States.

Only two direct comparisons between ex-ante and ex-post estimates of costs per kg N reduction, from Denmark and the Netherlands, have been possible. In Denmark the comparison factor is 1.9 (2.7/1.4), in the Netherlands it is 1.2 (2.0/1.7). The comparison of ex-ante and ex-post estimates of the MINAS policy the Netherlands suggested that for some sectors (e.g., the dairy sector), manure and fertiliser policies have resulted in efficiency gains due to a more rational fertiliser management that offset part of the ex-ante expected costs. The extent of these efficiency gains will in general depend on the initial situation (how rational is the current situation) and the design of the policy instruments and associated advisory initiatives around these instruments.

7. Synthesis of case study findings

There are significant methodological barriers to the comparison of ex-ante and ex-post estimates, not least the effects of inflation. These issues are discussed in depth in the main text of this report and the individual case study reports. It is however interesting to provide comparisons of ex-ante and ex-post costs estimates across the case study sectors where the case study reports have made this possible. Table I.5 shows the results of this exercise, as well as a likely explanation arising from the case studies for the ex-ante over-estimates.

Table I.5 Table of Overall Case Study Results

Case study	Directive (Sector)	Ex-ante/Ex-post		Shortcoming in Ex-ante
		Upstream	Consumers	
1	LCPD (Power sector)	2 (Germany) 1.5 – 2 (Netherlands)	6-10 (UK)	The introduction of CCGT made the high cost of FGD in the UK unnecessary
2	IPPC (Belgium Ceramics)	>1.2 (OPEX) ~1.1 (CAPEX)	-	Optimistic estimates by suppliers broadly cancelled out other pessimistic components of the ex-ante estimates
3	ODS (Ozone Depleting Substances)	2.5 (1.4 -125)	1.25	Resistance and conservative technological assumptions by the chemicals industry and use sectors
4	Transport	2 (1.4 - 6)	-	Ex-ante failures to predict technological advancements
5	Packaging	-	-	Complexity in the way the Directive was implemented did not make this comparison possible
6	Nitrates Directive (Agriculture)	~2	-	Possible efficiencies in nitrates use (and some costs savings).

Overall, ex-ante cost estimates are often twice those of the later ex-post estimates. One explanation may be conservatism in setting assumptions about technological development. Another is likely to reflect the different interests and incentives of business and policy makers. There will likely be an iterative process of technological assessment between the policy maker and the industry. If early indications are that there is limited potential for abatement action, the regulatory targets as proposed will likely reflect this, and business may be expected to under-estimate the potential and over-estimate the cost in order to be made subject to less stringent regulation. If later analysis suggests that the regulation could be met more easily or at lower cost, the targets are likely to become more stringent. This regulatory re-evaluation of targets is illustrated by the Ozone Depleting Substances case study where early ex-ante estimates provided during negotiations leading up to the signing of the Montreal Protocol simultaneously under-estimated the extent and the feasible rate of a phase-out, whilst over-estimating the unit cost. The Transport case study also provides an example where early success led to later more ambitious targets.

At least two of the case study reports (ODS and the Nitrates Directive) reported possible efficiency gains, which they ascribed to the regulation, because of the review of inefficient processes to which the regulation had led. In the assignment of negative costs to regulation it should be remembered that any review of industrial processes will be likely to provide more efficient processes and products. If the sector's effort had been directed towards process efficiency prior to the regulation, the outcomes might have been even greater efficiencies and cost savings. However, this should not detract from the fact that it was the regulation which generated the awareness of the inefficiencies which led to be cost savings being realised.