Measuring The Impacts Of Environment Canada's R&D: Notes On Methodology

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MEASURING THE IMPACTS OF ENVIRONMENT CANADA'S R&D

Notes on Methodology

Submitted to:

Environment Canada

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1. INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

Environment Canada retained the services of Marbek Resource Consultants to help identify, describe and measure the impacts of Environment Canada (EC)'s Research and Development (R&D).

The project is one of eight projects included in the *Business Plan for Managing R&D at Environment Canada, 1996 to 1997* and responds, in part, to the 1994 *Auditor General's Report* and the 1996 *Federal Strategy for Science and Technology*, which suggested a need for increased accountability for R&D results. The project is directed by a Steering Committee composed of members of each of the Department's Services.

The objectives of the project are to provide a rigorous documented evaluation of the impacts of two programs and to validate an approach to the evaluation of such impacts. The two chosen programs are: pulp and paper effluent R&D and stratospheric ozone depletion R&D.

In choosing two different projects, the Steering Committee sought to examine research activities with different characteristics. In the case of pulp and paper, research was focussed on the content of imminent regulations whereas, in the case of ozone, the research contributed to an international effort leading to global action. The case studies also represent efforts of two different research groups within the department and different aspects of the environment. By selecting case studies with these different characteristics, it was hoped to learn more about the feasibility and approaches to measuring the impact of R&D.

1.2 THIS REPORT

This report documents the methodology used for the case studies, as well as the principal challenges and lessons learned.

Section 2 describes the approach used.

Section 3 describes the principal challenges to the methodology and proposed approaches to overcome those challenges.

Section 4 provides some general observations on lessons learned.

Section 5 provides some overall conclusions.

2. APPROACH

2.1 GENERAL

The challenges in evaluating the socio-economic impacts of public sector R&D include the usual methodological problems in identifying, describing and evaluating results. In addition, the evaluation of public sector R&D has to contend with the fact that the research is often directed towards producing common property benefits (which can be difficult to identify and assess). Moreover, these impacts are often at the end of a long chain of complex intermediate impacts involving government policies and changes in the behaviour of firms and individuals. The impacts of R&D which is part of a broad international effort are particularly difficult to evaluate, because of the difficulties involved in attributing impacts to many parties whose contributions are primarily synergistic rather than additive.

The current state of the art in R&D impact measurement has been described by Williams.[1] It involves the use of methods such as benefit-cost analysis, econometric analysis, modified peer review, bibliometric analysis, case histories, user and client surveys. The view described by Williams is that there have been sufficient advances in methodologies to conduct credible "partial" assessments of R&D impacts provided that certain criteria are met. He suggests that the extent to which the research results would have been available without the specific R&D, and the extent to which the impacts are attributable to the existence of these results, are two key factors in deciding whether an assessment should be attempted. Williams also favours research that is directed towards industry and whose results are applied within a fairly short time period.

The nature of the stratospheric ozone depletion and the pulp and paper effluent R&D is such that the applications are primarily in policy realms and they are applied over an extended period of time. Furthermore, the attribution of the research results to the R&D, and of the impacts to the research results, is not necessarily high in all cases. Given these realities, the challenge has been to develop new approaches that can provide credible measures of impacts, while recognizing the inherent limitations of the exercise.

Given the project's dual objectives of evaluating the impacts and validating the approach, it is appropriate to provide some detail on the approach that was used.[2]

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[1] Williams, D. (ARA Consulting Group Inc.). *Measuring the Impacts of Public Investment in Research & Development*. Paper presented at the Natural Sciences and Engineering Research Council of Canada, Ottawa, December 2, 1996.

[2] The approach is described in more detail in the Project Plan. Marbek Resource Consultants and Secor Inc. *Measuring the Environmental and Socio-Economic Impacts of Environment Canada's Research and Development -- Project Plan*. March 27, 1997.

2.2 IMPACT MAPPING

The heart of the approach is the development of an "Impact Map", which is a graphical representation of the linkages between the outputs of the R&D and the various policy and behavioural changes leading to ultimate impacts and socio-economic implications (see Figure 2.1). The aim is to provide an explicit and transparent description of the chains (or threads) by which the impacts of the R&D are realized.

A significant amount of effort was expended in producing and improving the Impact Map to provide the most accurate and useful representation possible. This evolved into an iterative process which began with a Map proposed by the project team and concluded with an amended Map that took into account the information gained through interviews and document reviews. In the process, certain impact threads were identified as priorities for analysis, because of the likelihood of significant impact or the likelihood that those impacts could be credibly identified.

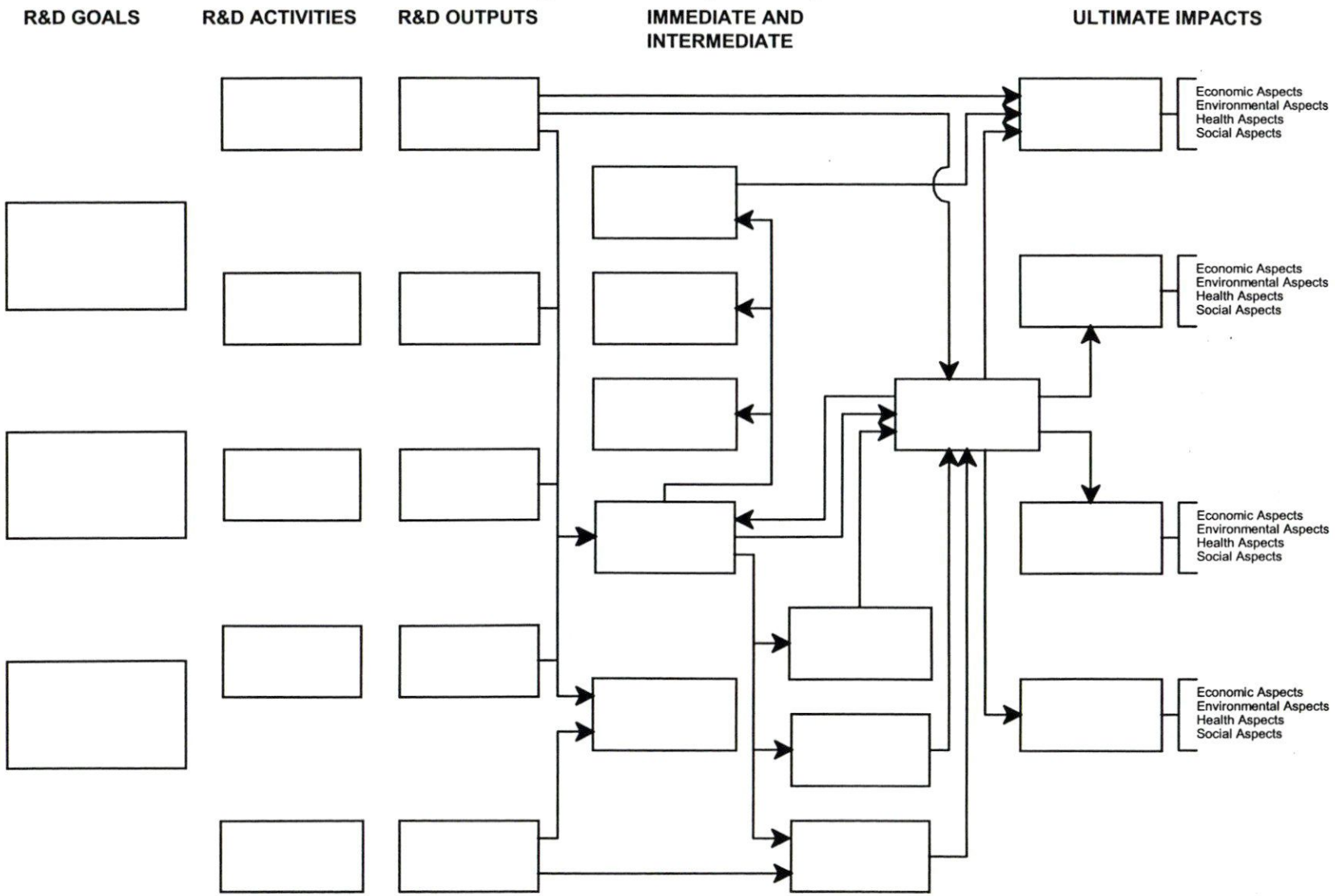
2.3 ATTRIBUTION

Each impact shown in the Impact Map arises from various preceding influences. In analysing the Map, it is necessary to decide to what degree each impact is attributable to the preceding influence(s) shown on the map.

To do this, two different approaches have been used. In most cases, an *incremental attribution* was conducted by estimating the difference between the actual impacts that occurred and the hypothetical impacts that would have occurred under a base case (where the preceding influence was assumed not to exist). For example, impacts of the Montreal Protocol were attributed by comparing actual impacts with a base case of what would have happened in the absence of the Montreal Protocol.

In other cases, where it was difficult to speculate on a hypothetical base case, or where there were many synergistic contributions to an impact, a *proportional attribution* was conducted by estimating the percent contribution of each influence to an impact. For example, impacts of NWRI on knowledge of pulp mill toxicity were attributed by estimating the percent contribution of NWRI to the knowledge base.

Figure 2.1 - Impact Map



2.4 SEQUENCE OF STEPS

The analysis involved the following steps:

- **Step 1 -- Develop Initial Impact Map**

The first step was to develop a working draft of the impact maps based on the initial information provided by the Steering Committee and the research organization (AES or NWRI). This also involved a preliminary selection of priority impact threads (based on criteria of significance, relevance and practicality).

- **Step 2 -- Develop Questions**

Based on the Impact Map and the priority threads, a series of questions was developed. The questions were intended to establish the nature of the impacts (immediate, intermediate, and ultimate) and the attribution of those impacts to the R&D. The questions were incorporated into an Interview Guide designed to be used in a series of interviews. During the course of the project, this Guide was amended several times to respond to a number of competing needs, including:

- Keeping the interview short, simple and straightforward
- Providing an opportunity for interview subjects to tell the story
- Focussing interview subjects on the questions of interest
- Eliciting specific views on attribution of impacts
- Eliciting speculation on "what if" scenarios.

- **Step 3 -- Conduct Interviews**

To answer the questions, a series of interviews was conducted. The interview subjects were identified by the Steering Committee, by the Project Team, and by some of the interview subjects themselves.

Approximately 30 interviews were conducted for the pulp and paper case and 20 interviews for the stratospheric ozone case. Unsurprisingly, the result of those interviews was a large amount of subjective information, some of it contradictory. The interviews were very useful in understanding the full story of the impacts (and completing the Impact Map) and getting a general idea of the impacts and their attribution; however, many of the questions were left without explicit answers. This was due to a reluctance on the part of interview subjects to assign credit in anything more than general terms, and a further reluctance to speculate on what might have happened in the absence of the R&D (or what might happen in the future).

- **Step 4 -- Review Reference Documents**

Approximately 15 documents were reviewed for the pulp and paper case and 25 documents for the ozone case. These documents provided the information necessary to identify the key

knowledge elements involved and some indication of the sources of the knowledge for purposes of assigning credit. The documents also provided a basis for estimating the incremental effects of intermediate impacts attributed to the R&D. In particular we relied extensively on Queen's University's *Trapped in A Policy Vacuum: Pulp Mill Effluent Regulation in Canada*[3] and ARC's *Report on Benefits and Costs of Canadian Participation in the Montreal Protocol on Substances that Deplete the Ozone Layer.*[4]

- **Step 5 -- Analysis**

Given the gaps in the data available for analysis, it was not possible to generate the accurate and absolute answers needed to establish the impacts and their attribution. Consequently, the approach evolved to the development of credible scenarios. Using summaries of the interviews and the reference documents, the Project Team developed the following elements of analysis:

- A best estimate of the relative contribution of the research organization to the R&D results (based on an overall assessment of the interview results), together with reasonable high impact and low impact scenarios.
- A best estimate of the relative contribution of the research organization to a series of intermediate impacts.
- A series of scenarios of what might have happened in the absence of those impacts.
- A qualitative assessment of what might happen in the future as a result of emerging impacts.

Using these estimates, the Project Team was able to describe and in some cases quantify the impacts of the R&D under various scenarios. Although there is significant uncertainty associated with the results, it is believed that, at a minimum, they provide a good indication of the value for money of the R&D and can be used, albeit with caution, in science policy and planning.

[3]VanNijnatten, D.L., Leiss, W., and Hodson, P.V. (1997). *Trapped in A Policy Vacuum: Pulp Mill Effluent Regulation in Canada*. Kingston, Ontario.

[4]ARC Applied Research Consultants. October 1997. *Benefits and Costs of Canadian Participation in the Montreal Protocol on Substances that Deplete the Ozone Layer.* For Environment Canada.

3. PRINCIPAL CHALLENGES TO THE METHODOLOGY

Part of the purpose of the case study approach is to identify which approaches work best, so that future cases can be examined more effectively and efficiently. Since this involves a learning process (sometimes involving trial and error), it is appropriate to focus on the experience thus far.

The main challenges encountered fall into five categories:

- Determining the reliability of information
- Obtaining speculative information
- Dealing with contradictory evidence
- Locating information
- Dealing with attribution and incrementality.

Not included in this list are common procedural challenges associated with contacting interview subjects, arranging interviews and designing interview guides that are short, clear and informative.

3.1 RELIABILITY OF INFORMATION

▪ The Problem

The reliability of the information used in measuring the impacts is affected by several factors, including:

- Underlying uncertainties associated with the primary information
- The natural biases and interests of the sources
- Difficulties in recalling historical events
- Subjective interpretations of information and historical events
- The willingness of sources to commit serious thought to the questions.

Given the range of stakeholder interests in the application of the R&D, the nature of the issues under study, the length of time elapsed since key events, and the lack of direct incentives for sources to invest significant effort, these factors are very real threats to the reliability of our results. Indications of possible problems include conflicting or inconsistent evidence, unusually glib or tentative answers by interview subjects, and disengaged attitudes during interviews.

▪ Options

Ideally, each item of information would be accompanied by a margin of error and an estimate of the reliability of the resulting range (e.g., there is a 90 percent chance that the cost was between $5 and $10 million). Unfortunately, it would not be practical to ask subjects to provide information in this way nor is it possible for the Study Team to add such an assessment of reliability and accuracy.

Although the Study Team could attempt to qualitatively judge the credibility of evidence, on the

basis of observed indicators and professional judgement, this would introduce a new source of possible errors and could expose the Team to a variety of criticisms concerning the reasons behind such judgements.

Options to increase the enthusiasm and commitment of effort by interview subjects could include a promise to provide a copy of the report (helpful but not likely to have a significant impact) or direct contact from the client or Steering Committee members (likely to be time consuming).

- **Suggested Approach**

The following approach is proposed:

- All information should be treated at face value
- For issues of importance, a minimum of two opinions should be sought
- In cases of conflicting information, a third opinion should be sought
- Where possible, documented evidence should be sought
- In calculating impacts, assumptions should be made transparent
- Different scenarios should be constructed to test the effect of different assumptions on key issues.

3.2 OBTAINING SPECULATIVE INFORMATION

- **The Problem**

Assessing the impacts of the R&D calls for a lot of speculation (what would have happened without it, what might regulations have been, what measures are likely in the future?). Speculation of this type is particularly sensitive to the reliability of information problems discussed previously. In some cases, the reliability of the evidence may be unacceptably low. This may prompt interview subjects not to answer or it may generate misleading results. In addition, some sources may be reluctant to speculate on politically sensitive topics (e.g., future changes to regulations).

- **Suggested Approach**

Interview subjects should be encouraged to provide speculation, with the understanding that it will be treated as such. In calculating impacts, the speculative assumptions should be highlighted and different scenarios should be explored.

3.3 CONTRADICTORY EVIDENCE

- **The Problem**

Although this is principally a manifestation of a reliability of information problem (see 3.1), it sometimes reflects different scientific or policy views, each of which may have its supporters. The most significant example of this problem is the difference of opinion in the pulp and paper case concerning the potential environmental and health impacts of reducing AOX.

- **Options**

The Study Team could attempt to judge the credibility of the different views; however, given that Team members are not experts, the judgment could be erroneous. In any case, this would expose the Team to a variety of criticisms concerning the reasons behind such judgments.

A third party view could be sought. Academic papers may have been published on the issue. However, since others have different interpretations, the choice of the "third party" would determine the result, and this would again require a judgment by the Team.

- **Suggested Approach**

Environment Canada should provide an official view on controversial questions. The analysis would then proceed on this basis and the assumption would be made clear.

3.4 LOCATING INFORMATION

- **The Problem**

Each case involves finding answers to a multitude of questions. These questions require aggregated and segregated information on topics such as process changes, capital investments, costs and markets. Further information may also be needed on environmental and health implications and possible economic valuations of these impacts.

A review of documents may reveal significant residual gaps. Although interview subjects may be able to identify other sources of information, significant efforts are likely to be required to collect the necessary data.

- **Options**

Although some information may be unavailable at any cost, much of it could be obtained if resources were available to pursue additional sources.

It may also be possible to make assumptions and construct scenarios that, subject to their inherent limitations, provide useful conclusions concerning the impacts of the R&D.

- **Suggested Approach**

Studies should proceed on the basis of immediately available information only. Once collection of that information is complete, its limitations can be assessed and the level of effort that would be associated with collecting additional information can be determined.

3.5 PROPORTIONATE ATTRIBUTION AND INCREMENTALITY

▪ The Problem

The traditional approach to measuring the impact of R&D programs is to identify the extent to which R&D results would have been available in the absence of the specific R&D being analyzed and whether or not the apparent impacts would have occurred if the research results had not been available; we refer to this approach as being based on *incrementality*. An alternative approach to *incrementality*, which we term *proportionate attribution* is to consider the relative influences on impacts compared to other factors.

A proportionate attribution approach means that all inputs are treated in an equivalent manner, even if some are essential to the outcome and others are not (e.g., Canada's 20% contribution to the Montreal Protocol counts even though it may not have been essential).

An incremental approach means that only the inputs that are essential get credit for the impacts (e.g., without NWRI, there probably would have been an AOX regulation, therefore NWRI should get full credit for having avoided it, even if others contributed).

Provided it is clear which approach is being used, both should be valid, at least in theory.

In practice, interview subjects do not always distinguish between the two and sometimes answer all questions the same way. Most subjects tend to be view the issue in terms of incrementality, however, the nature of the question (i.e., the impact under consideration) may also lead to one view rather than the other. A full discussion of the difference between the two concepts is not possible in the context of the interviews.

▪ Options

Consideration of both incrementality and proportionate attribution would provide interesting alternative assessments of the R&D impacts, and useful insights into methodology. However, it would require views on both perspectives from interview subjects. This would be difficult and could potentially produce unreliable results.

Choosing one approach over another would require some additional efforts to induce interview subjects to provide views in a manner consistent with the selected approach. It would also mean the loss of a potentially useful alternative view.

A hybrid approach would more easily accommodate the input of different subjects but would present some challenges in terms of conducting a logical analysis.

- **Suggested Approach**

Views should be sought on both incrementality and proportionate attribution. If necessary, subjects should be prompted to recognize the difference, however, if the confusion persists, it is usually not worthwhile to press the issue.

When analysing the information, the availability of information should be assessed to decide which approaches can be credibly used. It is often difficult to obtain enough information to conduct a complete analysis on the basis of proportionate attribution, let alone incrementality.

4. LESSONS LEARNED

The following lessons learned reflect the consensus of Steering Committee members who assessed the results obtained from the pulp and paper case study.

The consensus of the Steering Committee is that the approach followed was a credible one that provided useful, if somewhat imprecise results. In anticipation of future similar evaluations, the Steering Committee also noted some observations concerning the following:

- Characteristics of the cases
- Methodology
- Efficiency of the approach
- Indicators of impact.

4.1 CHARACTERISTICS OF THE CASES

The Steering Committee noted that in the case of pulp and paper there were some characteristics that were likely to be relatively unique and others that were probably common:

- The research was more tightly bound to regulatory policy than is often the case.
- There was a higher level of attribution of the research results to the research activities than may be the case with other research. Although there are other examples (e.g., acid rain, pesticides).
- A significant portion of the impacts related to not regulating. This "reversed" aspect of the case may not be common.
- The fact that a portion of the results indicated no environmental impact is relatively uncommon.
- The case was relatively "clean" in that the threads were relatively clear and the outside influences were identifiable.
- The fact that a significant portion of the impacts were still emerging was thought to be a relatively common characteristic of Environment Canada's research.
- The fact that the research had to be done quickly to meet policy objectives was also thought to be a common characteristic.

These characteristics were thought to have had an influence on the results of the analysis, indicating possible sources of the large impacts that were documented.

Regarding the factors that can affect the ultimate impacts of R&D, the Steering Committee noted that impacts were only possible if the research is listened to and that this is a lesson to be

emphasized. Specifically, it highlights the importance of effective information transfer and the key role of activities undertaken to support effective transfer of the research results.

4.2 METHODOLOGY

Many of the procedural challenges were described in Section 3. Key methodological challenges identified by the Steering Committee were:

- **Identifying Impact Linkages**

Finding explicit ways of describing the linkages and of dealing with speculation. Impact maps and scenarios were useful approaches. Committee members commented on the fact that the map became more and more useful in conceptualizing linkages as the case studies developed.

- **Interviews**

Concerning interviews, the Committee noted the following challenges:

- identifying the right people to deal with the right subjects
- finding credible sources (it may difficult to find more than one in some cases) and avoiding interviews of limited value
- the lack of availability of interviewees
- dealing a multi-disciplinary subject.

The lessons were:

- to tailor interviews to the specific knowledge of interviewees and not assume too much generic knowledge of the subject
- to spend more effort at the start of the case to identify the key interviewees (and reference documents) and to do this in a systematic and interactive way
- to undertake evaluations as soon as possible after significant results are obtained
- to select the right team to undertake the evaluation
- to actively involve key players from the science and policy realms (ideally one person from each side who would take responsibility for helping to assemble the lists).

It was recognized, however, that some problems and inefficient use of resources are likely to be unavoidable.

- **Analysis**

Concerning the analysis, it was a challenge to ensure the Team understood the intricacies of the "story" and did not get sidetracked. It was also a challenge to ensure that threads and assumptions remained credible. The lesson was that there is an ongoing need for significant involvement (and time commitment) by the key science and policy contacts. The risk of these contacts unduly influencing the results must also be considered and the Evaluation Team must

be careful to obtain independent sources.

4.3 EFFICIENCY OF THE APPROACH

Noting that the project had consumed more time and resources than anticipated, the Steering Committee examined the approach for opportunities for streamlining:

- It was suggested that the quantitative economic work could begin sooner, provided that there was consensus on the main elements of the "story". The lesson is that the interviews and document reviews should concentrate on the generic "story" first.

- Understanding the "story" and dealing with the complex scenarios that had to be constructed reinforced the fact that it is advisable to deal with only one case at a time.

- Overall, despite the increased cost of the case study, there did not appear to be any major potential savings to be obtained if the quality and credibility of the results of the impact evaluation were to be preserved.

4.4 INDICATORS OF IMPACT

The Steering Committee considered the cases, their characteristics and their impacts, in an attempt to identify possible indicators that could be used to judge the potential impact of research programs. As a result, the following observations were made:

- The impact of one research program should not be viewed in isolation from the other activities undertaken by an organization (i.e., because one program may have had high profile impacts does not mean the other activities are less valuable - they may produce future impacts). The body of research should be considered as a whole.

- Potential costs and benefits of the research should not be the sole factors in determining research priorities. It is important to maintain capacity.

- The impact of research is influenced by many factors, including the quality of the research, effective communication, effective management, and political leadership.

- The close linkage between research and policy needs is important and could not have been achieved if the research had been contracted out (needed the capacity to go out on a limb, and the internal knowledge to guide the work and interpret the results).

- Despite the above caveats, research needs to more explicitly consider potential impacts. Something like an impact map should be done in advance and updated periodically.
- To some extent this is done already: researchers need to periodically consider both competence and the potential applications of their research.

- One limitation is that R&D managers need more flexibility in allocating resources if they

are to be more accountable for impacts (e.g., they need to be able to invest in long term activities that may pay off only in the future).

- Policy-makers need to be kept informed of the potential applications of research as it evolves.

5. CONCLUSIONS

The experience in conducting evaluation of impacts for pulp and paper and ozone depletion R&D suggests a number of conclusions:

- It is possible to conduct a credible, if somewhat imprecise, evaluation of the impacts of public good R&D even if the research is relatively recent and the impacts are spread out over many years.

- Such an analysis must be based in part on assumptions, the nature of which can have a significant impact on the findings. It is therefore essential to make the assumptions explicit.

- The evaluation of health and environmental impacts is particularly dependent on the use of various methodological assumptions and crude estimates. As a result, the range of estimates for quantified impacts is exceptionally large.

- Impact maps provide a useful tool for visualizing the threads that link the research to ultimate impacts. Impact maps also provide a mechanism for explicitly considering assumptions concerning the priority impacts and linkages.

- Attribution of immediate impacts to R&D activities can most effectively be handled through a proportionate attribution of credit for the results. Attribution of some intermediate impacts (such as contribution to the development of the Montreal Protocol) which involve the synergistic influence of many contributors is also best handled in this manner. Incremental attribution is possible for most impacts and is the preferred approach.

- Interviews are important for gathering the information and data necessary to identify, describe and quantify impacts. However, it is necessary to balance the need for information with the need to keep the interviews focussed, clear and short. Consideration must be given to dealing with information that may be contradictory, or of varying relevance.

- Because of the nature of the analysis required, detailed knowledge of events surrounding the research is essential. Thus, the analysis must engage the key players who were involved in the application of the R&D results; this involvement must be significant and recurring, at strategic points throughout the duration of the analysis. While such a contribution is essential, it raises the possibility of bias of the results; therefore, verification of key inputs, transparency of assumptions, and other aspects of the methodology must be utilized to reduce this possibility.

- An early focus of the research should be to identify and obtain key reference documents. Once again, the assistance of the key players who were involved in the application of the R&D results is essential.

- The construction of scenarios is a useful way to deal with uncertain information, particularly when speculation is required to establish hypothetical past or future situations.

- When dealing with imprecise estimates of impacts, it is cost-effective to make simplifying assumptions to evaluate their effects (e.g., economic, health, etc.).

- Although each case poses different and interesting challenges, the methodology appears to be robust enough to deal with a wide variety of research programs.

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