SURVEYING AN UNCHARTED FIELD

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Introduction

The 1973 Oil Embargo led to many short term and long term shocks in the United States focus on energy. Most of the emphasis was on maintaining adequate supplies of energy and alleviating the effects of the shortage. However, there was also an increased interest in how energy was consumed and what might be done to change the future energy consumption patterns. What rapidly became apparent was that we did not know how energy was being consumed in the United States. As long as energy supplies had been abundant and cheap, there had never been a need to know this type of information. A rough understanding of the parameters of energy consumption existed in the residential, manufacturing, and transportation sectors. However, the greatest information gap was in the commercial sector.

This paper deals, in particular, with the development by the Energy Information Administration (EIA) of a survey to collect data on energy consumption in commercial buildings. However, unlike EIA's other energy consumption surveys, this survey, with an atypical target population, entered new areas in survey design. Thus, since EIA had to deliberate and choose at each major step, this survey's methodological history illustrates the development of an economic survey. The paper will describe the origin and evolution of this particular survey, the Commercial Buildings Energy Consumption Survey (CBECS)[2], both in terms of the innovations that have been developed and the difficulties that have been encountered.

[1]Currently with Xenergy, Inc., Madison, WI.

[2]This survey was known as the Nonresidential Buildings Energy Consumption Survey (NBECS) until January 1989. To avoid confusion, it will be referred to by its current name throughout this paper.

Initial Survey Development

The need had been established for more data on the uses of energy in the commercial sector. Next, EIA had to (1) inventory what was already known, (2) specify what additional information was needed, and (if a new sample survey was required) (3) choose a target population which would enable EIA to obtain the information.

Information Requirements

Survey development began by determining what information was needed to understand commercial sector energy consumption. What was available in the mid 1970's was data on sales of energy by utilities (electricity and natural gas), fuel oil dealers, and coal companies to specific accounts. Accounts were generally known as residential, industrial, transportation, and commercial. It rapidly became apparent that we could gain a rough understanding of the energy-related characteristics of the residential, manufacturing, and transportation sectors. For these three sectors, generally accepted definitions existed and a variety of Census and other data bases existed which could be extrapolated to the sales data. However, little was known about the commercial sector. Even the definition of the commercial sector was amorphous, except that it appeared to include whatever remained after the other, better-defined, sectors had been subtracted. Furthermore, how accounts for the commercial sector were classified by utilities often differed by regulations established by the individual State public service commissions. Not surprisingly, different analysts used different definitions of the sector.

For information on energy use to be helpful for energy forecasting, program development and policy development, it had to be related to characteristics of a consistent, well-defined consuming unit. Thus, it was necessary to determine the consuming unit for the commercial sector. In the commercial sector, the major energy-consuming activities were the lighting, heating, cooling, and ventilation of buildings, rather than any specific economic processes. If the energy-consuming processes in the building could be understood and forecasted, then specific policies and programs could be developed relevant to the commercial sector. The commercial sector encompassed some energy consumption unrelated to buildings, such as street lighting, but buildings were by far the greatest energy-consuming portion.

Deciding a New Survey Was Needed

Unfortunately, virtually no information was available about the commercial building stock *per se*, let alone its energy use. The F. W. Dodge Corporation did have a data base of new construction projects, including commercial buildings, dating from the 1950's. However, the data base gave only selected building characteristics for permit issuing locations. It had no information on energy use, kept no records on projects after construction was either complete or had received a permit, and did not encompass any buildings constructed before the data base started, or on any subsequent demolition or other removals from the stock. In addition, data for the Western United States was quite limited. The newly formed Energy Information Administration had a mandate to provide reliable energy data. Organizations such as the National Academy of Sciences were stressing that commercial buildings constituted an important energy-consuming sector for which benchmark data were needed on both the building stock and its energy use. Therefore, EIA decided in 1978 to develop a commercial building survey of energy use.

Choice of Sampling Unit

EIA had to find an appropriate sampling unit that would lead to information on the characteristics of the building and its actual consumption and expenditures for energy. Determining the choice of the sampling unit appeared easy. Two obvious choices were (1) commercial establishments and (2) utility customer records.

Establishments. Standard Industrial Classification (SIC) Codes 48 through 86 correspond to communication, wholesale and retail trades, finance, insurance and real estate and services. Information required would be collected from establishments in these SIC's using either the Census Bureau Standard Statistical Establishment List or a similar list available from a private service. However, after a pilot test (Bureau of the Census [1978]) it was obvious that neither of the available economic units, establishment or company, were appropriate for a survey of commercial buildings where data on the building and its energy consumption and expenditures were required. In some cases there were many establishments within a single building (as might be the case in SIC 64 (Insurance Agents, Brokers, and Services) or SIC 81 (Legal Services)). In other instances a single establishment might have several buildings--ranging from two to hundreds (in the case of SIC 821 (Elementary and Secondary Schools) or SIC 822 (Colleges and Universities)).

Utility Customer Records. Electric utility customer accounts were also considered as a possible alternative method of sampling the commercial buildings population, because the vast majority of buildings have electricity service. The 1981 Feasibility Study (Energy Information Administration 1982) included a test sample of electric utility customer accounts, as an attempt to devise an alternative sampling strategy. The Feasibility Study tested use of either the customer account number or the meter number as the appropriate sampling unit.

After a substantial expenditure, it became apparent that neither of these units would be workable at a national level. First, each company classified different entities as commercial and occasionally a commercial activity would be classified under a different account code. For instance, a large commercial laundry might be classified as industrial depending upon the amount of energy it consumed. Therefore, there was no guarantee that the entire set of entities known as commercial to policy makers could be obtained through this mechanism. Next, each company kept its records differently and, depending upon State utility commission requirements, might even keep its records differently in each State in which it operated. In addition, company service areas did not coincide with recognized geographic areas, such as counties, ZIP code areas, or cities. More seriously, there was no consistency as to how bills were maintained. In some cases, bills were maintained by building, in other cases by establishment within building. Often, one account was maintained for all the establishments of a company serviced by a utility. The way an electric utility might keep its records had little relationship to the way a natural gas, fuel oil, or district steam utility serving the same area kept its records, and matching would be extraordinarily difficult. As a further barrier to the use of utility records, there were a number of utilities in the late 1970's that had not yet computerized their billing records. This was especially true of the smaller utilities. Finally, some utilities would be extremely slow to respond to calls for information, or would refuse altogether.

The next attempt was to look at electric utility company meters which are supposed to relate to an individual site. Many of the same problems of utility accounts related to meters. First, a meter could relate to a single building, single floor, or an entire group of buildings on a college campus or military installation. There was no relationship between the way two different energy suppliers kept meter accounts for the same entity.

Buildings. In the end, EIA realized that it would have to use the most difficult entity as the sampling unit. The entity was the "building," which is in fact the consuming unit. What was most difficult was that there were no lists of buildings for the nation as a whole in existence. However, there was a strong practical appeal to using the building as the unit of both sampling and data collection. EIA could obtain information on building characteristics, the stock of energy-consuming appliances in the building, and the actual consumption and expenditures of the building (or so was thought at that time), and thus end up with a direct connection of energy use and predictive characteristics. Hence, we wound up with an excellent theoretical concept as our sampling unit--that of building--for which we had to develop a set of clearly understood definitions and a sampling frame and strategy.

The decision to sample physical objects (buildings) rather than economic entities (such as establishments or utility accounts) was pivotal for the rest of the survey design. An extensive search was made for building lists encompassing air raid shelter files, insurance company maps, and tax assessment records. It became evident that there were no comprehensive national lists of nonresidential buildings from which to sample, and no other national building surveys. CBECS was (and still is) the only national source of data on buildings, so there are no benchmarks that can be used either for estimation, or simply for comparison.

Implementation

Sampling

Lacking any national-level lists of buildings, the frame had to be constructed from scratch. The CBECS had to sample areas (through several stages) down to small geographic locations, and then actually map and list all buildings within each location.[3]

However, the CBECS could not rely on area sampling alone. Energy use in the buildings populations is highly skewed towards the relatively rare and highly clustered larger buildings. Because the area sample was a probability proportional to size design, arriving at the correct mix of large and small buildings completely by area sampling would have required that an impractically large number of buildings be listed, so that small buildings could be subsampled with appropriately small probabilities. To control the size of the listing operation, the area sample was supplemented within each primary sampling unit with a sample of large and specialized buildings selected from lists derived from local sources.

Because the commercial buildings sector was receiving a great deal of attention from energy analysts in the late 1970's, EIA wanted to field a survey as quickly as possible. EIA contracted with Westat Inc. to use their national geographic sample design, which had been adapted to do an office equipment survey the previous year. Both Westat and EIA recognized that the readaptation of this design to cover the buildings population was an interim solution, but it was better than any prospective solution in the short term. EIA was fortunate to work with Morris Hansen on the development of the survey (Carlson *et al.* 1981).

A major attribute of the area sample design was that it was a probability proportional to size design, with a population measure of size at the first stage and a

[3]Because the CBECS is the only comprehensive survey of commercial buildings, other agencies with an interest in surveying commercial buildings have occasionally contributed additional funding to have additional questions added. These agencies have included the Bureau of the Census (expenditures for construction and improvements) and the Environmental Protection Administration (asbestos in buildings).

commercial employment measure of size at the second (ZIP code area) stage. Both the population and commercial employment were anticipated to be well correlated with the amount of commercial floorspace and commercial energy use, so the design could be expected to be at least moderately efficient.

Field Work

Although the definition may seem obvious, EIA needed to develop a working definition of a "building." The definition used was: a structure totally enclosed by walls extending from the foundation to the roof and intended for human occupancy. Other structures that are also defined as buildings are parking garages not totally enclosed by walls and a roof, and structures erected on pillars to elevate the first fully enclosed level, but leaving some or all of the sides at ground level open. Nevertheless, defining a building and determining it boundaries can sometimes be a messy (and arbitrary) process.

In order to list the buildings within the sampled clusters, field workers were recruited in the sampled geographic areas to literally list all commercial buildings within the boundaries of the area. The listers were to write down information (address, size category, short description) for every building they thought looked "commercial." In field work, both listers and later the interviewers had to be trained to focus on the sampled *buildings*, rather than on the economic units (such as "stores") occupying those buildings. Listers and interviewers are trained to look for clues as to whether they are looking at one or more buildings. These hints include looking at the roof line and checking whether a wall completely separated parts of the structure.

The buildings were determined to be commercial based on the activities performed within the buildings, rather than by reference to the Standard Industrial Classification of the building owner or the building tenants. A commercial building is a building (as defined above) with more than 50 percent of its floorspace used for commercial activities (that is, not residential, manufacturing, or agricultural). Commercial buildings include, but are not limited to, stores, offices, schools, churches, gymnasiums, libraries, museums, hospitals, clinics, warehouses, and jails. Government buildings were included except for buildings on sites with restricted access, such as some military installations. Farms and buildings located on farms (such as barns, silos, grain elevators) were excluded from the survey.

Although the building is the most appropriate structural unit associated with commercial energy use, the data relevant to commercial energy use are most directly associated with economic units, such as the establishment. A single building may house several establishments, or only part of an establishment. Energy use is most easily aggregated by meter, customer, or account, which may also be related to establishments, or some other economic unit not associated with building boundaries. As a result, a variety of data collection strategies are used to obtain information from the higher and lower organizational units linked to each building. Such linkages would be required in some form no matter how the basic sampling unit was defined.

The Building Questionnaire The primary data collection instrument is a Building Questionnaire, currently administered by an in-person interview with someone knowledgeable about the energy coming into the building. A major section of the questionnaire is devoted to ensuring that the unit for which the data are collected matches the unit that was sampled, and verifying its boundaries. Just as the sample design could have been based on a different definition of the basic sampling unit, so could many of the questions of interest about the building be interpreted in terms of a single establishment within the building, or the larger establishment of which the building is a part. Therefore, interviewers have to spend time with respondents to establish a common understanding of the boundaries of the sampled building. The respondent is reminded continually what the boundaries of the discussion are.

In interview content, engineering questions, such as types of heating equipment, dominate the questionnaire. This is unlike many other business surveys, which are dominated by economic or financial questions, such as gross business receipts. As a result, the ideal respondent (for much of the questionnaire) was someone from an engineering or maintenance department, rather than someone from an accounting department who might be the ideal respondent for other government surveys.

Even with the most appropriate respondent, only a limited amount of technical engineering or structural information could be collected. In the 1981

Feasibility Study, EIA tested the collection of technical information (such as detailed performance specifications of heating and cooling equipment, and lighting illuminance levels) from building respondents. These data were then checked against comparable information from engineering assessments and reviews of building blueprints for the same buildings. Much of the technical information was not reliably reported by the building respondent.

CBECS data users crave precise technical information on each building. However, due to its format, the level of detail asked during the CBECS interview is limited. Some of the desired information can be obtained only if the right person (such as a building engineer) were to respond to the questionnaire. Some could be obtained from the respondent, given more time to look up records or consult with others, but the format limits the amount of time that can be spent--we try to keep the interview to 60 minutes or less. Other items that CBECS users have requested over the years would require a trained auditor to collect, possibly with sophisticated equipment. Still others would require monitoring over an extended period of time.

Nevertheless, the overriding reason for keeping the personal interview format, as opposed to a phone or mail interview, is that it would be difficult or impossible to identify an appropriate respondent or, in many cases, to contact the building in any useful way, without a personal visit.

The Supplier Survey. Early work on the CBECS development indicated that it was not realistic to collect energy consumption data from building respondents. Respondents often did not maintain records onsite, or else locating the records took too much time and drove up the cost of the personal interview. Instead, the respondent is asked to sign a form authorizing the building's energy suppliers (such as the electric utility) to release copies of the billing records for the building. A major hurdle, still unresolved, is matching customer accounts to buildings. Here again, the sampling unit that makes the most sense at one stage becomes awkward at another.

As discussed in the context of sampling unit choice, utility company billing records are organized by customer account. Ideally for CBECS, each building would have its own account, which could be matched directly with building interview data. However, some buildings contain many customer accounts, while some customer accounts cover many buildings. Utility company record systems are not generally geared to extract data by building.

If EIA had sampled from utility company records, the fieldwork problem would have been to identify and categorize the objects covered by the billing data. These objects could have been commercial buildings. On the other hand, these objects could have turned out to be industrial buildings, residential buildings, parts of buildings, groups of buildings, or even nonbuildings (such as signs, street lights, or heated outdoor pools). EIA has chosen to focus first on the commercial building stock. From the building interviews, CBECS identifies the types and sources of energy supplied to the building. EIA then obtains the amount of energy used by survey the building's energy suppliers.

Redeveloping the Survey

Survey development was not frozen after the initial responses were made to the challenge of developing a commercial energy survey. The 3-year survey cycle has allowed us to learn from one survey to the next, so that the survey is in a continuing state of redevelopment.

Why redevelop? There are basically three factors motivating redevelopment:

1. User Needs--changes in needs and interests of the users of the survey information

2. Evaluation--analysis of survey results indicate something should be changed

3. Efficiency--attempts to save time and money.

In many cases, the three factors combine in motivating redevelopment. For example, an important category of users need information about X. We evaluate our coverage of X and attempt to provide the information as efficiently as possible.

The Role of Data Users

Throughout the development and redevelopment of the CBECS, the ultimate goal has been to put useful and reliable information into the hands of its users. Preceding the 1992 CBECS, EIA undertook an extensive data user needs assessment (EIA 1992a). Though mitigated somewhat in the course of user meetings, there continued to be a tension between the energy modelers and the questionnaire designers. This tension persists even though the questionnaire designers are also the principal analysts of the data and have developed considerable subject-matter expertise. Outside users of the data set continue to recommend questions that use terminology not commonly understood, or that require a level of detail that is impractical to collect during a voluntary personal interview. The questionnaire designers, for their part, sometimes jumble critical distinctions in the effort to create respondent-friendly questions. The classification of heating and cooling equipment, for example, has been revised for each cycle of the CBECS and has never seemed completely satisfactory to EIA staff, outside data users, or respondents.

A limiting factor to the CBECS questionnaire content is the intended respondent--the building owner, manager, or tenant. These respondents may not have the proper technical background. The general compromise that has been reached in the course of several series of User Needs meetings has been to limit the questionnaire to questions that most respondents are likely to understand and be able to answer. Some of the major users of the data set have helped develop a set of priorities for questionnaire enhancements. By obtaining more information on major functions which differentiate among buildings (computer rooms, commercial laundries, laboratories, etc.), energy usage can be better explained and modeled.

The Role of Evaluation

Survey Estimates. Because the CBECS is the only nationally representative survey of the buildings population, relating CBECS data to information for other sources is extremely difficult. Early evaluation efforts by French (1982) and York *et al.* (1982) were focused on building counts and other estimates from the 1979 CBECS. EIA also evaluated the estimates of building counts in 1983, using some F. W. Dodge information and internal knowledge of the characteristics and limitations of the early CBECS sample designs. The evaluation suggested that the survey's building counts estimates were somewhat low, with very small buildings accounting for most of the shortfall. These conclusions were supported by preliminary building estimates from the 1986 survey, the first survey conducted using a new design constructed specifically for sampling the commercial building stock.

Building consumption of energy has been even more difficult to assess. EIA collects energy supplier data on sales to commercial customers, but these data differ significantly from CBECS data because (1) commercial activity from an energy supplier's perspective includes many nonbuilding energy uses and (2) even within buildings, suppliers ordinarily define commercial activity by a set of rate schedules (EIA 1990). Customers billed on commercial rate schedules may or may not be involved in commercial activity, while many buildings in scope for CBECS may have one or more customers billed on a noncommercial schedule. EIA has asked the customer class to be identified as part of the energy supplier survey for the CBECS. These studies indicate that a large percent of energy use (20 to 25 percent) in commercial buildings is not categorized by the suppliers as commercial (EIA 1992b, Appendix C).

Target Population. The definition of a "commercial building" has two parts: "commercial" and "building." The definition of what constitutes a building has not changed since 1979. However, the CBECS has adopted a minimum sample unit size cut-off, a common feature in economic surveys. After sampling from the first custom-built frame in 1986, analysts discovered that there were a lot more small buildings than the 1979 frame had indicated. These buildings, while numerous in the sample, did not contribute greatly to the overall estimate of energy consumption and expenditures. Accordingly, starting with publications from the 1986 CBECS, the target population has excluded buildings that are 1,000 square feet (93 square meters) or less in size.

The definition of what constitutes commercial has continued to be problematic. The 1979 survey was a nonresidential buildings survey. In fact, the name of the survey did not change from "nonresidential" to "commercial" until 1989. Part of the problem is that the term "commercial" can mean different things, and we wanted to make sure that buildings such as churches, which consider themselves "noncommercial," would be included. The 1979 survey, although skewed towards areas of commercial employment, conducted interviews at all buildings which were not used 100 percent as residences. Agricultural buildings (with few sampled cases) were excluded from the 1979 building characteristics reports, but industrial buildings were included. However, industrial buildings were excluded from the 1979 consumption reports. The high relative standard errors for industrial buildings' energy consumption indicated that the 1979 survey had an inefficient sample of industrial buildings. Industrial buildings' energy consumption is now within the scope of the Manufacturing Energy Consumption Survey.

A second narrowing of the commercial definition occurred in 1986, when buildings with 50 percent or more of their floorspace devoted to residential activities were excluded. EIA's Residential Energy Consumption Survey is a household survey, thus excluding commercial space. CBECS now treats a building 1 to 49 percent residential as commercial.

In one way, the target population has been expanded. Buildings in Alaska and Hawaii, omitted from the 1979 (and 1983) target population, have been included in the 1986 (and subsequent) surveys. Otherwise, we have narrowed the CBECS target population definition.

The 1989 CBECS added a supplemental Facility Survey, to collect information at the level of the entire facility, for those commercial buildings that were part of a multibuilding facility such as a university campus or hospital complex. This supplemental survey was an attempt to obtain information at a higher organizational level, linked to the basic buildings data. The survey was administered by mail, to a contact identified on the Building Questionnaire. A facility supplement could allow some measurement of overlap with EIA's Manufacturing Energy Consumption Survey.

Coverage gray areas for CBECS still include: (1) all vacant buildings, including those which were or will be industrial and (2) commercial buildings on multibuilding industrial facilities, which are also covered by the Manufacturing Energy Consumption Survey.

The Role of Efficiency Improvements

Frames and Frame Updates. A recurring area for efficiency improvements has been frame development and updating. After an initial sample design was in place, the sample had to be updated in succeeding cycles to represent additions to the building stock since the previous survey. The 1979 survey was updated in 1983 using construction project records from F. W. Dodge. This approach was only marginally satisfactory, because the Dodge did not include a significant proportion of medium-to-small building construction. The 1986 survey was selected from a newly designed sampling frame, so no update was necessary. The 1989 and 1992 surveys have both been updated from 1986 by a combination of F. W. Dodge project records for buildings over 50,000 square feet, and listings updates of some, but not all, ultimate sampling locations for smaller buildings. This combined strategy has produced better results.

Implementing the sample design for CBECS is much more costly than for the Residential Energy Consumption Survey. The current CBECS design uses the primary sampling units that were sampled for the residential household survey. This saves some money, but the savings are small compared to the potential savings if Census tracts were sampled instead of ZIP Codes. However, the residential survey sample design uses data from the decennial Census as measures of size for Census tracts and blocks. Comparable Census data on commercial activity is not available for Census tracts or blocks. What is available is County Business Patterns data by ZIP Codes. The geographic area served by a ZIP Code is usually larger than a Census tract. As a result, the cost of rough counting and listing a secondary sampling unit for CBECS is much larger than that for the residential survey. In addition, the cost of obtaining accurate maps of ZIP Codes is much more than obtaining accurate maps of Census tracts or blocks.

In an effort to reduce the cost of the CBECS sample design, EIA has investigated the use of utility billing data, building permits, fire department listings of large buildings, tax assessment records, insurance company records, landsat maps, gypsy moth photographs, water company hookup maps, tax records, and other data files (such as Dun and Bradstreet). As of now, nothing has proved feasible nor presented a cost savings. Generally, the organizations that construct these types of data files tend to be localized. The organizations tend to store their data in nonstandardized formats, to use different definitions. With a few exceptions, the organizations also tend not to attach Census tract indicators to the observations. The files are simply not constructed for the purposes of using them in designing a commercial survey. In addition, some organizations may not want EIA to use the files.

Data Collection. The 1992 CBECS was still collected using paper and pencil interviews. However, it is probable that the survey will move to Computer-Assisted Personal Interviewing (CAPI) for the building interview. CAPI should help with both the speed and accuracy of data collection. Some specific areas where CAPI could contribute are: (1) link the information from the listing operation with the building interview, so that interviewers could verify that they are at the proper location, (2) elementary edits (and prompts) at the interview stage, and (3) automated skip patterns allowing questioning to be tailored more to the size and activity of the building.

Summary

From its inception, in the energy crises of the 1970's, through its initial survey development and implementation, to its continuing redevelopment, EIA's commercial buildings survey has blazed a trail through unknown, and occasionally treacherous, territory. For EIA, the challenges of this survey have continued to be a laboratory in the application and development of survey methodology.

It has been interesting for us to revisit the history of the commercial buildings survey. EIA is now on the verge of developing a new data system, related to alternative transportation fuels, that presents many of the same types of problems. The data system will provide information on trip patterns, fuel consumption, and consumer preferences for many components of the vehicle population, including vehicles in business "fleets." Fleets, like buildings, are composed of many different types of units such as cars and light-, medium-, and heavy-duty trucks. These vehicles have many different owners, users, and purposes. Fleets are not comprehensively registered or listed in a way that allows for straightforward sampling techniques. And once a fleet is identified, there is not likely to be a consistent type of person who can answer questions about the range of issues for which EIA is responsible.

The next uncharted field awaits.

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HOW TO MEASURE THE EFFECTIVENESS OF ENVIRONMENTAL CONTROL

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1. Introduction.

Since the beginning of the seventies it has been clear that the growth of production and consumption has negative consequences for the quality of the environment [Meadows]. This awareness resulted in several measures to break this destructive chain. Although many of the measures were opposed at the time of introduction because they seemed too severe, the environmental problems are still far from solved [Meadows et al.]. The experienced impotence of these implemented measures focuses the attention of those involved in environmental policy once again on the effectiveness of environmental measures. Up to now little information has been gathered about the effects of environmental measures, so the growing attention for the effectiveness raises the question of whether statisticians can obtain this kind of information.

This paper deals with the feasibility of statistical surveys on the effectiveness of environmental control. To understand why this kind of information is needed, section 2 outlines briefly how environmental policy developed. Section 3 describes present environmental statistics and the obstacles for collecting information about the effects of environmental measures. In section 4 it is demonstrated how the lack of statistical information about the effects of environmental measures at the level of the enterprises could be overcome on a higher level of aggregation. This is illustrated by an example in section 5. Some practical obstacles arising from the use of statistical data for conclusions about the effectiveness of environmental control are discussed in section 6. Section 7 contains conclusions and some recommendations.

2. Environmental policy.

The first environmental regulations were mainly standards for individual emission levels for enterprises, which were imposed in response to specific environmental problems. The levels of the individual standards were set by translating general targets into individual emission levels that were weighted against the economic consequences for the enterprise. On a short-term basis, with a fixed production facility, these standards could only be met by installing provisions that treat the generated substances (end-of-pipe provisions), such as wastewater treatment plants, or by introducing added changes in process, that prevent a pollutant being generated, such as a shift to fuels with a lower sulphur content [de Boo, 1992]. In the long run, when substantial changes in the production installation are possible, for instance when new plants are designed or become operational, the optimal levels of both generated polluting substances and treatment can be decided on anew, and also integrated changes in process, such as low NO_x, burning processes for furnaces, could be employed. These new production facilities often incorporate the results of technological development induced by both environmental regulation and other (autonomous) developments [Magat].

Although both the adapted and the new production facilities satisfied the individual environmental standards, the targeted total emission levels were often not met. This was mainly due to the changing circumstances in which the individual enterprises operated. An example of this are the lower energy prices which caused a higher energy consumption and, in spite of the installed provisions, higher total air emissions. Also production levels of polluting activities could come out higher than foreseen as a consequence of changed market preferences.
These disappointing results and the increased knowledge of the environmental problem, which showed the many interrelations between the environment and production and consumption, forced countries like the Netherlands to make environmental

control an integral part of governmental policy and no longer the sole domain of a specialist environmental department [VROM]. For this models describing interrelations between the environment and production and consumption were introduced to evaluate the costs and benefits of possible measures. This includes the indirect economic effects of the measures, like changes in the economic structure or trade flows [Alfsen].
As a consequence of this shift to a more integrated environmental policy the information needed has changed. In particular more detailed information is needed and information about the implementation of the measures and their effects became important to monitor calculated projections.

3. Statistical information about the environment.

Statistical information about the environment has been gathered right from start of environmental policy, in the seventies. The statistics were mostly started to answer to specific questions about the environment, while they were shaped as much as possible in accordance with the availability of the data, to limit the costs.
Environmental statistics available in most industrial countries such as the Netherlands can be classified in three broad categories. First there are the statistics that describe the state of the environment, e.g. quality of surface water, ambient air or the condition of forests. For environmental policy these statistics are important because they show the development of the environment and the areas where (further) action is necessary. In the Netherlands these kinds of statistics are mainly based on the processing of information from the monitoring programmes of the responsible (water and air) management bodies. The second category of statistics describes the polluting emissions of production and consumption activities. This includes statistics on the discharges of waste water, generation of waste and the air emissions from furnaces or traffic. These statistics offer information about the relation between production and consumption and environmental pollution, thus serving to establish where the measures should be taken. The air and water emission statistics are mainly estimates based on the data of controlling bodies, emission factors and production and consumption figures. The data for the waste statistics are collected by surveys. Statistics on the environmental provisions, which describe both the physical and the economic aspects, are the third category. For these statistics the information is mainly based on surveys among enterprises. This information shows how the environmental measures are implemented and the costs involved.

From the start of the Dutch survey on the costs of environmental control it has been the intention to collect also information on the effects for the environment in addition to information on the costs of the provisions. However, this was not really possible, mainly because information about the effects (the avoided emissions) can only be well established for those provisions that treat the generated substances (end-of-pipe provisions), such as wastewater treatment plants and flue-gas filters, or the added changes in process, such as the use of low sulphur fuels. But for the integrated changes in process, such as low NO_x furnaces, the effects are very hard to establish with any authority. At the time of installation of the integrated changes in process, the (targeted) effect of the provision can be estimated rather well because it has been designed to satisfy certain (environmental) standards that could not be met with the unadapted installation. So the difference with the reference technology, i.e. that which would have been chosen in the absence of the environmental regulation, can be ascribed to the installed environmental provision. When the adapted installation is made operational, however, only the actual emissions can be established. These could, however, differ from the projected ones because of deviations in the performance of the environmental provision, but also because the working circumstances of the adapted installation, such as the market demand for its products, has changed. To establish the actually avoided emissions the actual emissions must be compared with the emissions of the reference technology operating under changed circumstances. Except in some rare cases this is impossible. So the effects of the integrated changes in process cannot be observed directly in the location where the measures are implemented.
But even in cases where the avoided emissions can be established (end-of-pipe provisions and added changes in process), it was difficult to gather data about the effects directly from the respondents in the statistical survey. This kind of information is mostly not administrated by the operators of the provision because measuring the (environmental) performance of their provisions with precision is costly and often not necessary for their production process. What is more, when the effects are measured, they mostly refer to combinations of polluting substances, which differ per enterprise, so the establishment of a statistical figure requires arbitrary weighting and attribution.

4. The effectiveness of environmental measures.

The conclusion of the last section was that, except in some very clear cases, it is impossible to gather information about the effectiveness of specific environmental measures on the level of the enterprises. So here statistical surveys cannot be of help to those involved in environmental policy. The question could, however, be raised of whether the effects of environmental control could not be deduced from the statistical information that is or could be gathered as well. From the aggregated figures about emissions and environmental provisions it is not possible to draw any immediate conclusions about the effectiveness of the measures taken. The reason for this is not only that the data are too aggregated, but also that changes in the operating circumstances of enterprises, such as changes in the raw material prices, could influence the emission levels as well. To find only the effects of the environmental measures one should eliminate the effects of these changes in the other influencing circumstances.

One way to do this is to successively eliminate the effects of all the known changes in the circumstances of the production or consumption activities. This results in various relations between the emission level and the variables that influence it. Thus one gets emission ratios for variables such as total production, the production of certain products, total intermediate consumption or the consumption of specific intermediate products or raw materials. The analyses of these ratios, of which the development can be demonstrated very easily in a graph, can clarify which part of the changed emission level can be attributed to economic or technical developments, like changes in the product range, the production level or the used quantities of raw material. In addition to autonomous developments these changes could also be triggered by indirect environmental measures, such as levies on fuel, raw materials or products. Since it is known how these indirect environmental measures influence the external circumstances, their effectiveness can be established.

If enough information is available one could ultimately also calculate the relation between the emission and its finally determining variable, such as emissions of SO_2 and the burning of hard coal of a certain quality (sulphur content). The development of this relation depends on autonomous developments such as technological development or cost-saving improvements, but can also be influenced by direct environmental measures, such as an obligation to install a desulphurisation plant. Although the autonomous developments are not the responsibility of the environmental authorities, the authorities can be judged on how they cope with the consequences of these changes. So here one can also find the effects of direct measures such as the stimulation of the use of clean technologies or the subsidisation of environmental R&D.

The analyses of the ratios shows why the emission levels changed and so the effectiveness of the different environmental measures. For an impression of the quantitative consequences of these changes in the different influencing factors, one could calculate the emissions by assuming all but one of the ratios to be stable and compare the outcomes with the actual emissions [Schäfer].

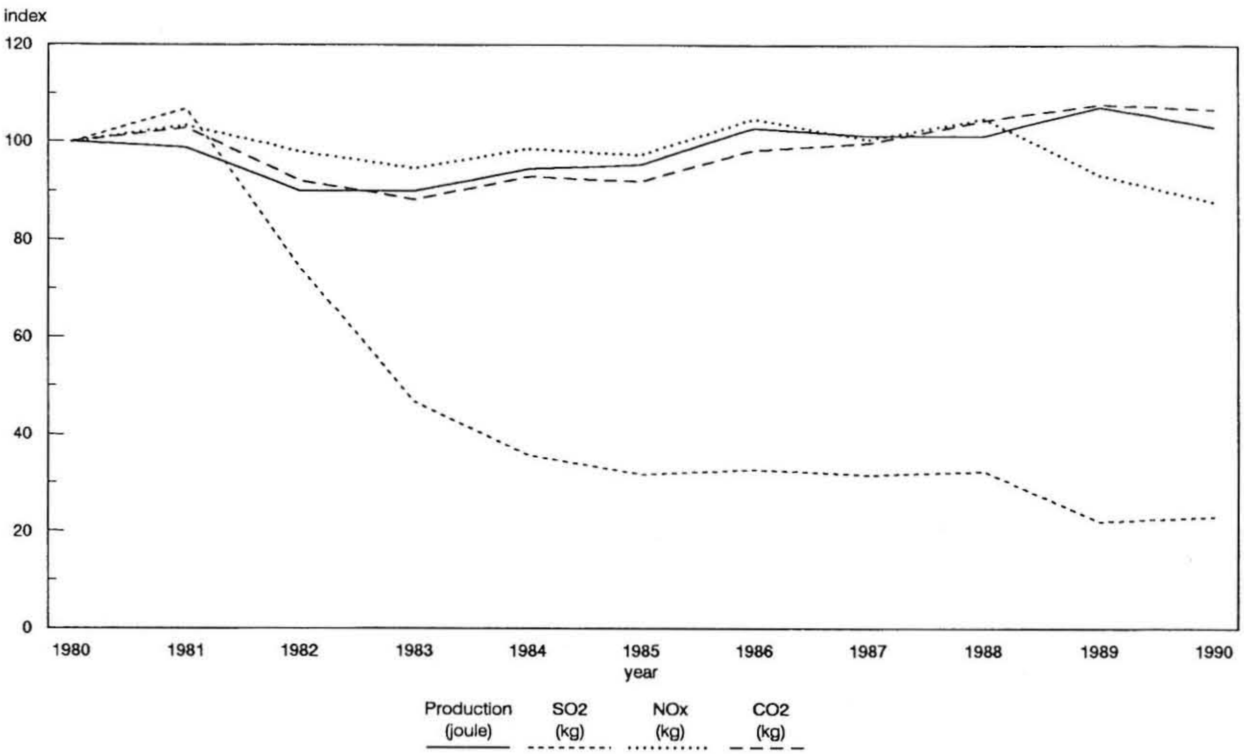
5. Effective environmental control for electric power plants.

An example of the successive attribution of the changes in the emission level to the various causes can be given with the help of production and emission figures of electric power plants in the Netherlands. Dutch electric power plants convert fossil fuels and some nuclear power into electricity and thermal energy for heating. During the conversion process of the fossil fuels the greenhouse gas CO_2 and the gases NO_x and SO_2, which are an important source of acid rain, are formed.

For some twenty years the influence of SO_2 on acid rain has been known and measures have been taken to reduce these emissions. For NO_x no measures had been taken until recently, while the CO_2 emissions are still unchecked. As figure 1 shows the measures to reduce the emissions of SO_2 and NO_x appear to have been very effective: while the production by the power plants grew by 13% between 1980 and 1990, the emissions of SO_2 were reduced to less than a quarter and those of NO_x by 12%. However, no conclusion about the effectiveness of the measures can be drawn from these figures alone because the emissions do not directly depend on the production level but on how and how much the various kinds of fossil fuels are used.

In figure 1 the emissions are presented in relation to the production level, which is already expressed in physical units (joules) to eliminate the influence of price changes. Since the generation of NO_x, SO_2 and CO_2 is related to the combustion of fossil fuels, the influence of an increase in the input efficiency or a shift to other fuels that do not cause these kind of emissions, such as nuclear energy, can be eliminated by relating the emissions to the total input of fossil fuels. From the underlying figures it becomes clear that the input efficiency grew from 41% in 1980 to 43% in

Figure 1. Production and air emissions by electric power plants (1980=100)

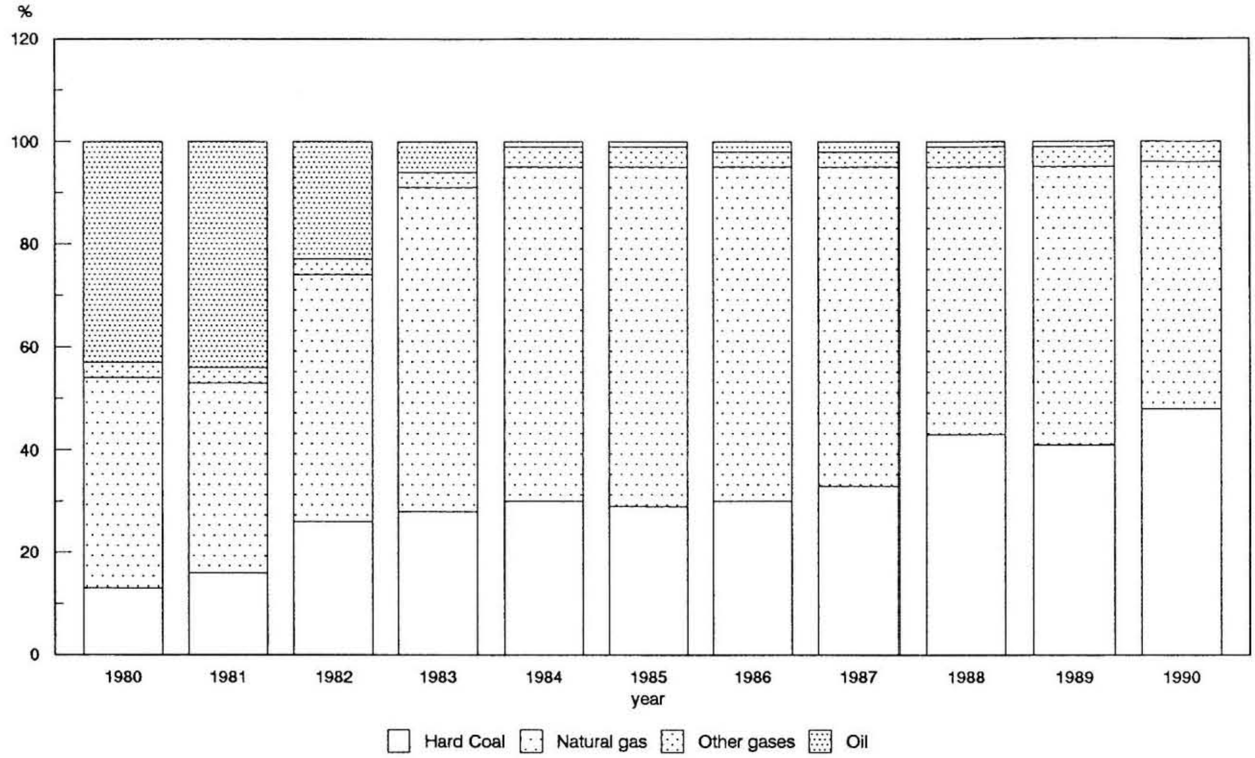


1990, while the share of non-fossil fuels remained more or less constant. So it must be concluded that most changes in the total emissions were caused by changes in the relation between the input of fossil fuels and the generated emissions. For SO_2 the input-emission relation depends heavily on the kind of fuel used, since the sulphur content of fossil fuels differs according to kind and origin of the fuel. So the emission level can be influenced by shifting to a fuel with a lower sulphur content. Figure 2 shows clearly that there have been considerable shifts in the fuel inputs. In 1980 43% of the inputs, in joules, came from oil, 41% from natural gas and 13% from hard coal. By 1984 the share of oil had dropped to about 1% while that of natural gas had risen to 65% and that of coal to 30%. In 1990 both coal and natural gas accounted for 48% of the fossil fuel input. The almost abandonment of oil as an input for electricity generation explains the reduction of SO_2 emissions between 1980 and 1984 because the average sulphur content of the oil used was much higher than that of natural gas, even though this had already been reduced by the prohibition of using oil with a sulphur content exceeding 1% since 1974. Since 1980 the share of coal has risen constantly as a consequence of Dutch policy to save natural gas and spread the inputs over more sources and origins. This shift did not, however, lead to higher emissions of SO_2, because parallel to the increased coal inputs, desulphurisation plants were installed. The above analyses of the changed emissions levels of electric power plants show that the reduction between 1980 and 1984 resulted mainly from the changed combination of fossil fuels used. The reason for this new combination was based on other than environmental considerations: the relatively high costs of oil and the strategic choice to diversify the energy input. Without environmental regulations, however, the further shifts to hard coal would have caused a rise in SO_2 emissions. So the conclusion can be drawn that environmental policy has been effective by introducing, besides the maxima for the sulphur content of the fuels, standards for the yearly emission levels which led to the installation of desulphurisation provisions on new coal-fired power plants.

6. Practical obstacles establishing the effectiveness.

The example of the electric power plants in the last section showed that with enough data the effectiveness of the environmental measures could well be deducted by combining existing statistical data. In this case the availability of the data was no problem because the Dutch energy industry is small and well surveyed. Also

Figure 2. Fossil fuel inputs of electric power plants



the relation between the production of electricity, the inputs used and emission generated is clear. For other branches of industry, pollution processes or emissions, however, it is more difficult to find enough data to establish the effectiveness of environmental control [de Boo, 1990]. The main problems are caused by the lack of co-ordination between statistics, the lack of detailed data and the often mutual dependence of data.

The co-ordination between the business statistics of the Netherlands Central Bureau of Statistics (CBS) is concentrated in the Central Business Register. This register contains populations of enterprises that can be used as a population for statistical surveys. When based on this register the results of statistics are comparable because they use the same statistical units, which are classified in the same branches and size classes.

Although the tools are present to collect and present statistical data in a way that allows combination of results, experience has taught us that there are many limitations. Mainly, these limitations are a consequence of the fact that most surveys are organised to solve specific information problems in the most efficient way, which is hindered by demands of co-ordination. The first consequence of this limited objective is that almost every series of statistics defines its own population. So even for surveys among the same branches the size classes of the small enterprises that are included frequently differ. Also the subdivision into branches may differ because it is chosen in line with the available data and the surveyed subject, while limited to keep the samples as small as possible. Finally, the confidentiality regulations of the CBS, which ensure that no information on individual enterprises will be provided to anyone, can force statisticians to combine branches or size classes. The result is often a patchwork quilt of branches and size classes that limits the possibilities of combining the outcomes.

A second reason why the combination of surveys does not lead to fully satisfactory results is the lack of enough relevant data. The combination of the emission and production figures will give some rough ratios. The analyses of the developments, however, requires most of the time specific details, such as the energy input mix in the example of the electric power plants. Besides, often the information about the production and the intermediate consumption as collected by the business surveys, is in monetary values, while environmental relations should be analysed with the help of real quantities. Again these limitations are a consequence of the limited scope of the individual surveys.

Finally the establishment of the effectiveness of environmental control by combining the results of different statistical surveys is hindered by the some times mutual dependence of production and emission figures. This is a specific problem of environmental statistics where it is some times hard to obtain the wanted information directly from the respondents. So other methods are used, such as calculation or estimation of the figures with the help of data from other statistical surveys. A good example of this approach by the CBS is the statistics about air emissions by industrial processes. These emissions are not measured at every plant; so consequently statistics about the air emissions could not be based on a survey among plant owners. Therefore the total emissions by industry had to be compiled with the help of a sample of measurings and detailed statistical data about the production level and the intermediate inputs.

One solution for some of these practical obstacles could be the organisation of a special survey of the figures needed (such as inputs and emissions) to conclude about the effectiveness of environmental control. Obviously this is not very efficient because it requires an extra survey and the respondents will probably have to give the same information twice. Besides, a survey with questions about different aspects of the enterprise, as in the case of the effectiveness of environmental control, mostly cannot be dealt with by one person or division within an enterprise. So the questionnaire will have to travel inside the enterprise, which has in the past appeared to have had an unfavourable effect on response rates.
A far better solution would be to take care of the collection of the necessary data in advance, by co-ordinating the organisation and contents of the different surveys that collect the relevant data. In this way, which requires a thorough knowledge of the polluting process, the different surveys are combined into one bigger survey that provides both the information about the specific subjects and about the subjects that can only be established by a combination of data. The advantage is a better use of the specific surveys, while also the respondents are troubled less. The price of this approach is stronger co-ordination requirements for the specific surveys and less freedom for individual statisticians.
The problem of the mutual dependence of data can only be solved by turning to other statistical methods, and particularly to direct surveys of the emissions. Although this appeared difficult in the past because enterprises did not register their emissions, we feel that improvements are possible. For instance, an obligation for the bigger enterprises in the Netherlands to present a public annual environmental report, would force them into registration. Here too the changed needs for statistical information should urge statisticians to adapt their survey methods, even if they were satisfactory until now for their specific purposes.

7. Conclusions and recommendations.

This paper argues that environmental policy needs information about the effectiveness of the environmental measures in addition to that about the development of the environment, the polluting emissions and the implementation of environmental control. From the analysis of the information available within enterprises, it has become clear that information about the effects of the installed environmental provisions cannot be obtained in a direct statistical way. The effectiveness of the measures could, however, be computed on a higher level of aggregation by linking emission figures and detailed statistical information about production and consumption. With this kind of analyses the effectiveness of the direct and indirect measures of environmental policy can be demonstrated.
Problems arise in practical analyses of the effectiveness with the help of data from different surveys because of the some times poor co-ordination between surveys, the lack of relevant data and the mutual dependence of data. Where this is caused by poor co-ordination in the gathering of the data or the presentation of the results, this can be overcome rather easily. Proposals for a common presentation of the results have already been put forward in the discussion about environmental satellite accounts for the System of National Accounts [UN, Franz, Hölder, EUROSTAT, de Boo et al.]. When these problems are, however, the consequence of the method of collection of statistical information, they will be more difficult to solve. In these cases the individual statisticians should be convinced of their joint interest in a better co-ordination of their specific surveys.

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THE DEVELOPMENT OF SURVEYS OF WASTE MANAGEMENT: THE CANADIAN EXPERIENCE

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INTRODUCTION

The development of environment statistics and reporting on the state of the environment in Canada over the past twenty years has generated a need for a wide variety of data to understand environmental change and its determinants. The measurement of changes over time in the physical and biological ecosystems is recognized as being vital for environmental statistics. Less well recognized, but of equal importance, are socio-economic data that serve in assessing the influences of human activities upon the environment. Virtually all these activities result in the production of waste, the transformation of landscapes, and the consumption of biotic and abiotic resources. When data on these processes are available for use in conjunction with information from scientific monitoring programmes, a more complete picture of environmental conditions and trends can emerge from the analysis. Data sets of this kind are necessary if the goal is to more fully understand the relationship between human activities and the environment. Such statistics could provide the basis for informed public debate on policy alternatives regarding the impacts of these processes on air and water quality and other elements of the environment as well as to assist in the management of environmental resources in a more sustainable manner.

Statistics Canada has been active in exploring the linkages between socio-economic actions and environmental change for a number of years. The Agency has produced three editions of the environmental report, ***Human Activity and the Environment*** [10], as well as a number of special studies, and has contributed to the Canadian state of the environment reports [1, 2]. A major focus of this work has been the compilation and recasting of existing socio-economic data to better serve environmental applications. In the process, a number of data gaps are identified and means of addressing them are being pursued [7].

In mid-1990, Statistics Canada identified four areas where new surveys could fill important data gaps:

- waste management activities of local governments [4];
- activities of private enterprises in the waste management business [13];
- pollution abatement and control expenditures [8]; and
- household behaviour and the environment [9].

Surveys have now been conducted, and data released, covering each of these subject areas. This paper describes Statistics Canada's experience in developing, conducting and evaluating the two surveys of waste management and highlights some of the methodological issues associated with their development.

CONCEPTS AND DEFINITIONS

Waste generation and waste management have become items of increased public and government concern in recent years. Emerging issues include limits on the availability of new disposal facilities and lack of space in existing ones; controversies about methods of disposal; an emphasis on waste volume reductions through reductions of use, reuse, and recycling; concern about the safe storage and transport of hazardous wastes; and escalating costs associated with waste management and the provision of services. The examination of waste-related concerns by policy makers, researchers and the industry itself has been hampered by the absence of good statistical information on the subject. The goal in conducting the two waste management surveys was to begin a process to address some of these data needs and to provide direction and focus for future surveys.

The terms *waste* and *waste management* are still relatively new concepts from a measurement point of view and their domain varies depending on the perspective of the user and/or the context in which the terms are used.

Therefore, if progress is to be made, defining what is meant by these terms is important for meaningful discussion [4, 5, 15].

Waste
Waste can be defined as a physical substance, created as a by-product of production and consumption activities to which no economic value is attached. Waste comes into existence once the owner (1) consciously decides that the residue is of no further use (to that person) and acts to dispose of the substance, or (2) routinely releases the by-product without taking a specific disposal decision (e.g. combustion by-product emissions, warm water from water-cooling technologies).

Waste Management
Waste management is a combination of strategies and activities aimed at the administration, control, and reduction/elimination of the undesirable effects of waste both in the short and long term. Examples include finding positive uses for waste as well as minimizing the negative effects of the residues through treatment and/or isolation from water, air, and biological pathways.

Waste Characteristics
Wastes can be in solid, liquid and gaseous form or mixtures of these. They can be released into the air, into water, or onto land.

Mode of Disposal
Wastes that are liquid, or solids that can be dissolved or suspended in liquids, may be transported by pipeline (sewers), by surface conduits, or in contained fashion on transportation media. Solid wastes can be disposed of on site, or by collection and haulage to disposal facilities. Each of these modes of waste disposal has its own set of environmental, technological and economic parameters and measuring them requires methods and procedures that highlight them.

Type of Waste
In addition to the chemical and physical composition of the material, waste is usually classified as hazardous or non-hazardous. How these two classes are delimited and whether a two-way classification is adequate is an interesting topic but beyond the scope of this paper. It is sufficient to say that a simple 2-way classification, given the negative and legal associations of the *hazardous* class, is likely to increase the probability of survey bias and non-response.

SURVEYING WASTE MANAGEMENT

Scope
As more interest has focussed on the issues of waste and waste management, it became apparent that there was little or no systematic statistical information with which to carry on an informed discussion. This data gap was especially marked for the activities of collection, haulage, and disposal of solid and contained liquid wastes and the associated efforts to reduce the size of the waste stream by collecting and sorting recyclable materials. In 1990 Statistics Canada initiated activities to address the issue.

This initiative specifically excluded waste water and sewage waste management. The facilities and infrastructures for the collection and management of these wastes are quite distinct from those used to manage solid wastes. Furthermore, a national data set on water and sewage treatment establishments called the Municipal Waterworks and Wastewater Data System (MUNDAT) [3], already exists at Environment Canada. Information for this database is compiled from provincial sources.

Still outstanding are the waste management practices for waste generated and then managed by the generator. Industry accounts for nearly all of the wastes in this category. Given the difficulty of developing a survey procedure for this component, this data gap was left for future attention.

Approach
The planning and execution of a waste management survey was complicated by the non-standard practices and *ad hoc* jurisdictional divisions of labour. Responsibility for the waste management function for household, commercial and some industrial waste is largely in the hands of local governments -- mainly municipalities (but sometimes regional groupings of municipalities). The disposal of much of the industrial waste (and some commercial waste) is the responsibility of the producer and, private sector firms have emerged to meet this demand.

Historically, most household waste collection and disposal was performed by local governments using their own employees, capital equipment and disposal facilities. Gradually, local governments have found it more economical to contract out collection to the private sector until today most collection and some of the disposal is in the private rather than public domain.

The challenge was to design a survey instrument that could produce reliable estimates from the combinations and permutations of these diverse practices. The solution was to conduct two inter-related surveys -- one of the public sector component; the other of the private sector.

Problems Common to Both Surveys

One problem confronting managers of surveys that have a significant content of non-financial information is that most statistical surveys target the financial staff of the respondent company/institution. These contact names are also more readily available from the Business Register. In the case of the waste management surveys, some of the questions required financial expertise, while other questions required the knowledge of persons in the engineering and waste management departments. Respondents do not always pass on the questionnaire to those best able to complete the subject content despite instructions to do so. They are more likely to either provide information from their own data holdings or leave the sections in question blank.

Another problem was that of the Reference Year. By the time some respondents completed the questionnaires, more recent fiscal year information was available than that which the questionnaire specified. Respondents found it either more convenient or perhaps, inconceivable, that the survey sponsors would want them to provide less current information when more current information was available.

Two additional problems encountered were typical of new surveys. First, some respondents misinterpreted the definitions. Some, for example, equated waste disposal with waste collection, although the definitions in this regard seemed quite clear to the survey designers. Waste disposal was defined as the operation of a waste disposal facility such as a landfill or incinerator. Some waste collectors interpreted the act of leaving waste at a landfill as disposal and indicated disposal activities. Others misinterpreted the definition of a sanitary landfill.

Second, many respondents were asked to provide information on subjects for which they did not collect data. This was particularly true for small municipalities and small waste management firms. For example, many operators did not have weigh scales at their landfills and had difficulty providing information on amounts of waste disposed at their facilities. Others respondents did not know the number and type of dwelling units served by their residential waste collection programmes.

SURVEY OF LOCAL GOVERNMENT WASTE MANAGEMENT PRACTICES

General

Until this survey was initiated there was no detailed national picture of local government waste management activities. Summary information on environmental expenditures by governments, including local governments, was collected by the Public Institutions Division [11]. However, it was recognized that a more detailed accounting of these expenditures and associated information on methods of service delivery would address a major data gap in waste management information. The National Accounts and Environment Division and the Public Institutions Division of Statistics Canada worked together to develop and conduct this first survey.

The different ways in which waste management services are delivered by local governments in Canada was known to be diverse. A local government may offer waste collection and disposal services, recycling, and hazardous waste management. Other municipalities may provide some of these services, while still others may provide none at all. Municipalities may provide services using their own employees or through private firms operating under contract. They may offer services in conjunction with other local governments in their area, (for example sharing a disposal facility), or another level of government such as a regional municipality may provide the service on their behalf. Each of these arrangements produces a different pattern of expenditures and a different waste collection and disposal path. Developing a questionnaire and procedures that would provide insights to this complex picture was a major challenge.

Survey Frame Issues

The frame for the Survey of Local Government Revenues and Expenditures provided an initial list of local governments, addresses, and contact names. These ranged in size from the largest cities to small, rural municipalities. Research indicated that a number of other types of local government entities were involved in waste management activities and that these were missing from the existing list of municipalities. In Ontario and British Columbia this included the regional or upper-tier local governments. In other provinces including Quebec, Alberta, Newfoundland and New Brunswick, regional waste commissions were missing. Furthermore, the role of these regional waste commissions varied from one province to another. In Alberta, for example, they served the needs of rural areas, while in Quebec their activities focussed on the disposal of big city wastes. Lists of regional governments and waste commissions were obtained from provincial government ministries and these bodies were added to the frame. In total, approximately 4,300 local government entities with potential involvement in waste management were identified.

Methods and Procedures

The design of the survey included a take-all portion for municipalities of 10,000 persons and more. An additional 220 smaller municipalities in the smaller provinces were also surveyed with certainty to ensure adequate provincial representation in the sample. The remaining municipalities had approximately a 10% probability of being selected. The take-all portion included about 75% of the population and, it is assumed, at least the same proportion of generated waste. This was deemed to be a cost-effective means of surveying the universe without compromising data quality. Also, it was anticipated that the degree of diversity of services offered would be less among municipalities in the small population group and that many would offer only very limited services. Almost one thousand of the approximately 4,300 local government entities in Canada were surveyed. Data were sought for the fiscal year ending nearest December 31, 1990.

The questionnaire was mailed out by Statistics Canada in January 1992 and mailed back by the respondent upon completion. Given the complexity of local government waste management, the questionnaire that was developed asked for many details and may have seemed complicated to some respondents. Consequently, some respondents encountered problems that slowed their response time considerably. Follow-up procedures were conducted primarily for the larger municipalities (50,000+ population). Follow-up for other municipalities was limited largely to addressing cases of initial non-response.

The overall response rate for the survey was 85%. The response rate for those municipalities in the 50,000+ population size group was 98%.

Methodological Concerns

The questionnaire included an introductory page, four main data collection pages, an annex for supplementary information, a reporting guide, and a definitions section. The data collection part of the questionnaire was sub-divided into four major sections: a general profile of waste management in the municipality, and sections for details on waste collection and disposal, hazardous waste management, and recycling activities.

The general profile section served as an entry to the questionnaire and provided summary information on the presence or absence of particular waste management services in the municipality. If a service was provided, the respondent was asked to indicate whether they provided the service or if the service was provided by another government or private enterprise. If the responding municipality was responsible, the question went on to ask how the local government provides that service (for example through the use of own employees or through a contracted service).

This profiling detail at the start of the questionnaire allowed a picture to be created of the often complex relationships that exist between upper and lower tiers of local governments and between local governments and private waste management establishments. It also proved to be valuable at the edit stage when compiling the responses contained in the subsequent three sections of the questionnaire. This picture of the relationships made possible the identification of inconsistent responses and steps to correct the problems.

The subsequent sections of the questionnaire gathered detailed information on facilities, waste volumes, expenditures on programmes, and clients served by category. Table 1 summarizes the questionnaire.

The structure and content of the survey was developed through consultations with municipalities, the provinces and Environment Canada. The consultations suggested that the survey would provide sufficient detail to meet the research, planning and policy needs of the various client groups. At the same time, the survey was seen to be a credible and competent vehicle by the respondents we interviewed. The questionnaire is lengthy; however, much of this is devoted to simple profiling questions providing information on the programmes offered. These profiling questions provide valuable information and are necessary to put the financial statistics in context.

Many of the problems that were encountered originated with the fact that this was a new survey. Some of the problems relating to question detail and respondent comprehension in this regard have already been discussed. Other questions may not have been sufficiently detailed, or structured in the most effective fashion for all respondents.

The complex relationships that existed between lower and upper tier municipalities, groups of municipalities, and between municipalities and private sector firms presented some unforeseen reporting problems. In these

Table 1	Local Government Waste Management Practices Summary of Questions
Waste collection, disposal, hazardous waste, recycling services provided, identifying provider	
Existence of waste reduction programmes, waste composition studies	
Quantities of waste collected by municipality, quantities disposed of at facilities	
Location and characteristics of waste disposal facilities	
Expenditures on waste management by activity	
Expenditures on contracting out of waste management services	
Characteristics of hazardous waste management programmes	
Recycling programmes: types and quantities of materials diverted from waste disposal stream	
Characteristics of composting programmes	
Number of dwellings served by category of dwelling for various programmes	
Inter-municipal movement of wastes	
Purchasing practices regarding recycled and reusable products	

cases extensive review of responses and follow-up was required in order to establish a clear picture of methods of provision of services.

Some respondents provided information for the wrong year, probably to highlight positive environmental actions that they had recently initiated. This seemed to be most evident for responses to the question on existence of recycling programmes, materials collected and year of programme start-up. Many provided information for 1991 or even 1992 although the questionnaire requested information pertaining to 1990. Once again, telephone calls to respondents were made to correct the problem.

Survey Results

In 1990 local government expenditures on waste management for all municipalities amounted to $1.04 billion. Of this total, operating expenditures were $874 million and capital expenditures were $167 million. Fifty-seven percent (approximately $500 million) of operating expenditures was paid to contractors for waste management services provided.

The expenditure figures also indicate that in the Province of Quebec, local government waste management services are provided primarily by contractors. In Ontario, Nova Scotia and Saskatchewan slightly more is spent on payments to contractors than on municipal employee operated waste management, while in other provinces local government waste management expenditures on services provided by own employees exceed payments to contractors.

Local government waste management expenditures as a proportion of provincial population were highest in the Northwest Territories, Nova Scotia, and Ontario and lowest in Prince Edward Island, New Brunswick and Saskatchewan. This reflects the way in which waste management services are provided, and the structure of local government, in addition to other factors such as regional cost differences (e.g. on tipping fees).

The Survey also found that of the 10.1 million tonnes of residential waste generated in total, 8.7 million tonnes were managed by municipal collection programmes. Of this last amount, Ontario municipalities handled 35 percent and Quebec municipalities managed 31 percent.

Most of the survey results released to date relate to the activities of the large centres in the survey frame. Information was collected for each of the 83 lower-tier municipalities in Canada with 50,000+ population. These account for about 50 percent of the Canadian population.

THE 1989 (PRIVATE SECTOR) WASTE MANAGEMENT SURVEY

General

Much of the solid waste produced by commercial and industrial establishments is collected by private waste management firms. A substantial portion of household waste is also collected by these firms, usually acting under contract to municipalities or the owners of large residential complexes such as apartment buildings. Private firms may operate waste disposal facilities as individual establishments or in conjunction with waste collection operations. Waste management firms are more likely to have the expertise and equipment necessary to handle hazardous wastes. As a result, these firms collect and dispose of most of the hazardous wastes produced in Canada.

This survey covers a topic that had not previously been the subject of a specific Statistics Canada survey. At the start of the survey little was known about the revenues of these entities, their expenditures, and the numbers of people they employed. Most important from an environmental perspective, there was only limited information on the amounts and kinds of wastes these establishments collected, transported, disposed of, and recycled. The Waste Management Survey was designed to provide information to shed light on the subject. The Industry Division and the National Accounts and Environment Division of Statistics Canada were joint sponsors of the project.

Survey Frame Issues

One of the first steps when initiating a new survey is to delimit the area of observation and define the population of establishments in scope for the exercise. In the case of waste management, although there may have been some general notions about what constituted a waste management industry, no such industry is recognized by the Canadian, American, or United Nations Standard Industrial Classifications (SIC).

The Canadian SIC (CSIC)[12] places the core components of waste management activity (refuse collection, storage, and/or disposal) in the residual class of *Other Utility Industries, not elsewhere classified*-CSIC 4999. This category also includes sewage treatment plants and steam generating facilities. Firms that are primarily or exclusively transporters of waste have often been classified to CSIC 456 (*Truck Transport Industries*). Firms engaged in picking up and/or buying waste materials for salvage and resale are classified to CSIC 591 (*Waste Materials, Wholesale*).

The American SIC (ASIC)[16] recognizes a *Sanitary Services Industry* (ASIC 495), within which there are three classes: 4952 - *Sewerage Systems Industry*, 4953 - *Refuse Systems Industry*, and 4959 - *Sanitary Services n.e.c.* Establishments engaged in collecting and transporting waste without also operating disposal sites are classified to ASIC 4212 - *Transportation.*

The United Nations international SIC (ISIC)[14] identifies two industrial activities, Division 37: *Recycling* and Division 90: *Sewage and Refuse Disposal.*

The Canadian SIC is the least specific of the three with regard to waste management. When a decision was made to proceed with a survey of waste management activities, the first order of business was to determine what, and whom, to survey. Collection, transportation, disposal and recycling activities were obvious discriminating criteria to choose for determining whether to include/exclude an establishment from the Population. In an attempt to minimize response burden, it was also decided to exclude establishments that were already in scope for other production surveys. This criterion effectively excluded establishments in CSIC 591, scrap metal recyclers. since these establishments were already in scope for the Annual and Monthly Wholesale Trade Surveys.

The Statistics Canada Business Register was queried to identify establishments in each of the foregoing CSICs with Gross Business Income equal to or greater than $500,000 and/or 5+ employees. Subsequently, other sources were consulted, some of which did not provide revenue or employment information. Rather than exclude these sources, a decision was made to relax the size criteria and consider all establishments in scope for survey. The generated list was reviewed and compared with lists provided by industry associations, trade publications and the yellow pages of major Canadian cities. After considerable research, an initial universe of approximately 500 establishments/companies was identified.

Methods and Procedures

Given the relatively small size of the Population and the fact that this was the first survey attempted, it was decided to conduct a census using mail-out/mail-back procedures with telephone follow-up of non-response and major edit failures. Special reporting procedures had been arranged with the four large multi-establishment companies for the Head Office to report for each of their establishments [6].

Despite extensive follow-up only a 33% response rate was achieved by the end of the planned survey period. This was not considered adequate and an extraordinary effort was mounted to improve these results. The strategy employed was three-fold.

1.) A final one week blitz of outstanding non-respondents was conducted. The follow-up editor was instructed to attempt to collect all information, but if that was not forthcoming, at least to attempt to collect certain key data.

2.) A pass of all outstanding non-respondents through the 1989 fiscal year tax file of corporations was made. When found, this provided some comparable data from which other missing information could be imputed.

3.) Returns to the Local Government Waste Management Practices Survey were examined to identify companies to whom contracts for waste management had been let and the amount of these contracts. If the companies identified were non-respondents, or missing from the frame, they were added to the Waste Management Survey. It was recognized that this contract value may have been an underestimate of operating revenues since the company may also have had other waste contracts from non-government sources.

The blitz raised the response rate to 54% and the tax file search brought the proportion for which at least operating revenues were known to 83%. The local government survey provided the names of so many contractors not on the original frame that the response rate increased to 141%. A good number of these may have been on the Business Register but had been originally excluded because of their small size.

Methodological Concerns

Due to unforeseen events including four successive project managers (a result of unanticipated project manager career moves) and a tight budget, the execution of this survey spanned a time interval of two years. As a result, while most returns were for the 1989 fiscal year, as planned, some were for 1990 and a few were for 1991. Where possible, adjustments were made to correct for this bias; but the response year, for non-1989 fiscal year reports, was not always indicated.

The time that this survey was in the field was a very volatile one for waste management firms with significant change in ownership. New owners were rarely able to provide figures for the antecedent 1989 operation. (This may be a help explain part of the low initial response rate). Where the new owner was one of the large multi-establishment companies, it was not always possible to ascertain whether the survey establishment was independent in 1989 or already part of the multi-establishment company. When in doubt the unit was left in the survey with the possibility of double counting. This concern might have been avoided if the multi-establishment companies had included a list of the operations covered in their consolidated reports.

A two page form was developed to collect the information. A draft of the questionnaire was circulated to an industry association, other government departments, and several of the large multi-establishment firms, for comment during the development process. These consultations led to some respondent uneasiness both because of response burden concerns and fear of what *"government"* might do with their private information.

In the interest of keeping the questionnaire as short as possible, minimal information was asked for in each section. In consequence, there was limited information for cross-validation and consistency editing. The questionnaire summary is provided in Table 2.

There were three content problems that surfaced during the editing and analysis stages. The first was a confusion of an expense and revenue item. The survey planners expected that haulers would report *tipping fees* as an expense item paid to disposal facilities and that respondents operating disposal facilities would report tipping fee receipts as a revenue item. At least some of the respondents, who were in both haulage and disposal, reported tipping fee receipts in the expense field. It was possible to correct some of these errors but others probably slipped through. The second problem was the reporting of quantity/volume in other than metric units (metric tonnes was specified on the questionnaire). Where a non-standard unit was recorded on the form by the respondent, it was possible to transform the response to metric tonnes. In other cases, the reported quantities did not jibe with other data, and the cause frequently proved to be a non-standard unit of measure. The third problem was respondent misinterpretation of the meaning of the term *"disposal"* as used in the survey. The survey planners used disposal to refer to the function of processing collected wastes, (e.g. by operating a landfill or an incinerator), but some respondents may have interpreted disposal as the action of emptying their truck(s) at the haulage destination.

Table 2	1989 (Private Sector) Waste Management Survey Summary of Questions
Financial information: revenues, expenses	
Sources of revenue	
Capital expenditures	
Number of employees	
Quantities of waste collected and quantities of waste disposed by disposal method	
Quantities of material recycled, by type of material	
Quantities of waste imported and exported	

Summary Analysis of Results
Because problems were encountered in the execution of this survey, the results need to be interpreted with caution.

The survey identified some 750 establishments generating $1.1 billion of revenue. Of this sum 72% was attributed to collection, 21% to disposal and 2% to recycling. The remaining 5% came from sales of other services [10, Table 4]. Expenses were 85% of revenue giving the industry a gross margin of 15%. Capital expenditures were reported to be 7.4% of revenues and wages and salaries 23%.

Response to the commodity questions (quantity and value of waste, by class of waste, by method of disposal) was poor. Respondents claimed that their records were not kept in a fashion that would allow them to complete this section and many refused to provide approximate estimates.

Further study is needed to determine if alternate questions would be more successful in gathering waste volume information. The industry will also need to be convinced that it is in its own interest to have reliable data on the subject. In addition, respondents need reassurance that any responses provided are confidential. They must be convinced that it is impossible to deduce their contributions to the totals and that their individual responses will not be used for any purpose other than statistical compilation.

If one accepts that the respondents who completed the commodity information were representative of the total universe, then the following pattern emerges:

97% of waste was non-hazardous;
77% of waste was disposed of in landfill sites;
10% of waste was disposed of by incineration;
1% of waste was disposed of by chemical treatment;
3% of waste was disposed of by biological treatment;
9% of waste was disposed of by other means;
80% of the biologically treated waste and 10% of the chemically treated waste was hazardous.

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER ACTION

These first surveys of waste management have yielded valuable new information and provided a number of insights to the ways in which waste is managed at the local level.

These two surveys have also served as vehicles for developing expertise in this area. The planners underestimated the complexity and expense of mounting two inter-related surveys. The timing of the two surveys diverged so that they covered two different years and each had internal response problems. Such results are not unexpected in pilot efforts. The experience gained provide valuable insights into how subsequent surveys should be conducted. The problems of waste management are unlikely to be solved without reliable data so it is not presumptuous to predict that there will be subsequent surveys. The following recommendations flow from the experience derived from these surveys.

1. The terms *waste* and *waste management* need to be more precisely delimited before another survey is mounted.

2. A Waste Management *Industry* should be defined and efforts made to have it incorporated into the 1997 CSIC revision process. One possible structure is presented in Figure 1. It is suggested that collection, disposal, storage and recycling are four major categories for waste management. Sewage treatment is placed in a separate category.

Figure 1

WASTE MANAGEMENT INDUSTRIES
- Waste collection services industry
- Waste disposal services industries
  - Sanitary landfill disposal industry
  - Waste disposal by incineration industry
  - Waste disposal by chemical or biological processes industry
  - Other waste disposal process industry, n.e.c.
- Waste storage services industry
- Waste recycling services industries
  - Metal products collection, storage and recycling industry
  - Paper products collection, storage and recycling industry
  - Plastic products collection, storage and recycling industry
  - Other, and mixed, product collection, storage and recycling industry
- Sewage treatment and processing plants
- Services incidental to waste management and environment rehabilitation

3. A subsequent survey should redesign the questionnaire to segment questions by waste management process. This approach would also benefit understanding and interpretation of the financial and labour sections.

4. Regular, periodic surveys of waste management should be instituted in order to develop a longitudinal time series. The waste management industry and federal, and provincial, government departments with environmental mandates should be approached to assist in the design, funding and implementation of this survey programme.

5. Consideration should be given to conducting a series of more focussed surveys rather than a small number of all-encompassing surveys.

6. Before the next survey round additional research should be conducted to determine if administrative sources exist for some of the data. For example, because waste disposal facilities are subject to some degree of regulation in the provinces, it should theoretically be possible to compile an inventory of landfills and incinerators from these sources. Some information also exists from limited surveys conducted by associations. Problems of classification comparability would need to be addressed in such a project.

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