Benchmarking Environmental Performance

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Pure Strategies, Inc. is an environmental consulting firm with offices in Virginia and Massachusetts. Pure Strategies has extensive experience in providing environmental management and analysis services for government, industry and non-profits, with emphasis on promoting pollution prevention approaches for solving environmental problems.

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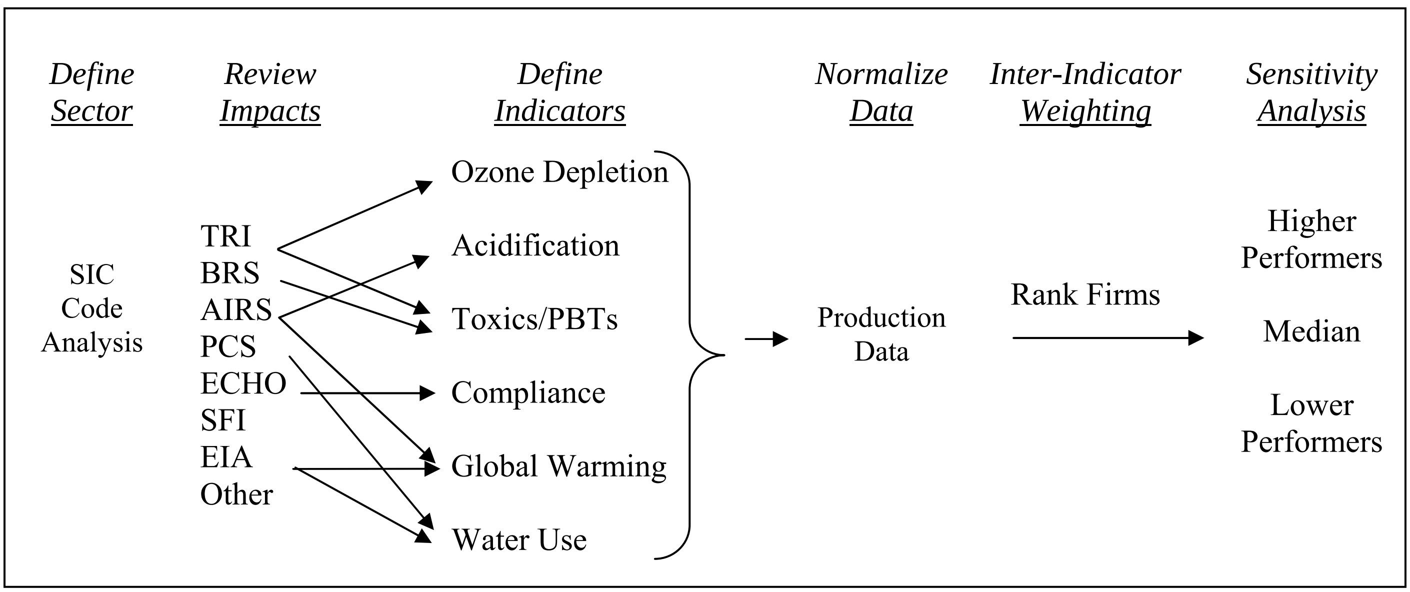
1. Executive Summary

The benchmarking model used in this effort employs pollutant release and compliance data to rank order a set of similar firms according to their performance. This section provides an overview of the basic methodology developed by Pure Strategies and employed in this study. Pure Strategies' goal in this project was to develop a model with examples for benchmarking facility environmental data. The effort included not only developing the model and examples of its applications, but also highlighting the many decisions and tradeoffs that necessarily take place in benchmarking efforts. This includes the set of indicators chosen for a particular sector, the considerations and limitations of the chosen set and ranking scheme, and a sensitivity analysis to show the effect of different selections of indicators and weighing criteria on benchmarking results. Figure 1 provides a broad overview of the key steps in conducting a benchmarking effort.

Figure 1: Benchmarking Methodology



1.1. Defining a sector

How should a group of like entities be defined for the purpose of performance comparison? Most such studies that compare facility, business unit, or company performance use Standard Industrial Classification (SIC) code definitions. Examples include the U.S. EPA Sector Facility Indexing Project (SFI). But while SIC codes are helpful, used alone, they are often inadequate to compare facility performance. This is because SIC code designations include a wide range of potential activities (e.g., SIC Code 3674 Semiconductors and related devices includes firms that make computer chips and firms that make the silicon wafers the chips are made on – two very different types of manufacturing activities).

This benchmarking effort employs the use of SIC codes with the TRI chemical use activity codes to match facilities. The chemical activity use codes available in TRI are an important tool for classifying facilities into like categories for analysis. While facilities may use the same chemical, for the purpose of benchmarking, we are interested in facilities that use the chemical in a similar way. For example, if a group of facilities all reported nickel, examining the activity use codes can further clarify that the firms are indeed similar for the purpose of benchmarking-- nickel compounds can be processed in metal finishing operations in plating tanks, manufactured as a byproduct in coal combustion, or used as a formulation component in certain paint products. This criterion helps to group similar uses of a chemical and is a powerful tool for choosing a sector when combined with SIC codes.

In this project, Pure Strategies used TRI SIC Codes and activity use codes to select the electric generation sector (SIC code 4911). Pure Strategies also used data from the Department of Energy to further define the sector to coal-fired electric generation plants, and only those plants whose fuel eat content comes from ≥ 98% coal (and therefore less than 2% from oil, gas, nuclear and other fuels) – a total of 115 facilities.

1.2. Identifying Impacts and Developing Indicators

A literature review of the environmental and human health impacts associated with coal-fired electric generating plants shows that the industry present significant risks in a number of areas:

- Human health risks associated with the production of ground level ozone precursors, fine particulates, mercury, and other toxic emissions;
- Acidification of lakes due to sulfur dioxide emissions, extending far downwind from the source;
- Global warming risks associated with carbon dioxide emissions;
- Aquatic habitat impacts due to the temperature and toxicity of cooling water discharges;
- Enormous volumes of solid wastes generation produced as a byproduct of combustion activities.

Based on the significant impacts and compliance issues outlined above, Pure Strategies created a list of ten indictors to choose for benchmarking (nine environmental indicators and one compliance indicator). Pure Strategies' benchmarking model allows uses to select one, ten, or any combination of the 10 indicators for benchmark. The ten benchmark indicators are listed in Table 1 below. All indicators, except for the compliance indicator, are normalized to production levels (plant net electricity generation).

Table 1: Benchmarking Indicators

Indicator	Description
Cooling Water Use	Average annual rate of cooling water withdrawal / production

Net Waste Generation	(Total weight of waste generation minus waste recycled) / production
NOx	Total weight of NOx releases / production
SO2	Total weight of SO2 releases / production
Particulate Matter (2.5 microns)	Total weight of particulate matter (2.5 microns) releases / production
CO2	Total weight of CO2 releases / production
Total Chemical Releases	Total weight of chemical releases as reported to TRI / production
Non-Cancer Toxicity	(Weight of specific chemical release times non-cancer toxicity factor for that chemical then summed for that facility) / production
Cancer Toxicity	(Weight of specific chemical release times cancer toxicity factor for that chemical then summed for that facility) / production
Compliance	Number of quarters in significant noncompliance from Q1, 1998 to Q4, 1999

1.3. Accessing Data

Having selected a sector for benchmarking and the indicators in question, Pure Strategies reviewed federal data sources to find a common facility identifier to link facility data from different databases together. The best tool for this is the EPA Federal Registry System (FRS). The FRS matches NPDES, NEI, BRS, TRI, and ID's to a single FRS ID. FRS uses a sophisticated algorithm to achieve this match. Unfortunately, not all the databases needed for the study had an FRS ID. The Compliance database and TRI were linked by FRS ID. NEI, EGrid, and EIA are all linked by ORIS ID. In order to connect the FRS-linked databases with those linked by ORIS, we had to select one database from each of those groups and link them on some other common data elements. For this purpose, we chose to link TRI and NEI. The link was done using state and zip code fields, with a manual check on the facility name field.

One of the key issues in benchmarking is that the different data sets (e.g., TRI or NEI) must all be for the same year – for example, one cannot combine 1999 compliance data with 2001 E-GRID data, and 1999 NEI data. Thus the data set with that is least current determines the benchmarking year. In our case, this data set was the NEI whose most current data was 1999. *Thus 1999 is the reference year for this benchmarking study*. There were widely varying degrees of difficulty in acquiring data.

In any data project, quality control checks are important to ensure data integrity. The scope of this benchmarking project limited some of the checks that would normally go along with such a project. For example, we were unable to check for facility reporting errors (i.e., send benchmarked facilities copies of their data to review to ensure it was reported accurately) or data entry errors (by those entering into state and/or EPA databases). Nevertheless, we did run numerous data screens to check for null values in the data sets and to cross reference data points where different databases provided information on the same indicator (for example, both NEI and EGRID contain NOx and SO2 data -- we ran a check to ensure the databases had similar values).

1.4. Benchmarking Performance

To develop scores for each of the ten indicators in the study, Pure Strategies employed a methodology used by the National Academy of Engineering (NAE). Under the NAE, the range of values in a sector for each indicator becomes the minimum and maximum potential values for the indicator. For example, if the data for the sector as a whole shows that the minimum of NO_x per megawatt hours of electricity generation is 100 tons and the maximum is 500 tons, these ranges can be equated to a simple 0 to 10 score, with 10 being the best (least NO_x). Facilities falling on the midpoints of the range can be assigned a score based on their own NO_x/MWh. For example, a facility with a NO_x/MWh of 200 would have a score of 7.5. Under this system, the range of scores is always between 10 (best) and zero (worst).

After developing methods to rank individual metrics, Pure Strategies employed a ranking scheme with maxima/minima conditions. Under this scheme, a firm's performance overall performance is subject not only to performing well in a host of indicators, but also to performing at a minimum level for any given indicator.

When apply the methodology to the coal-fired electric generation sector, Pure Strategies defined a "base case". For the base case we selected a set of nine indicators (see Table 2). We selected the nine indicators in Table 2 since they reflect the major environmental impacts of the sector. The only indicator of the ten we originally developed which we did not choose is "Total TRI releases". Staff felt that toxic impacts were better represented in the TRI cancer and TRI non-cancer indicators.

Table 2: Base Case Indicators

Cooling Water Use
Net Waste Generation
NOx
SO2
Particulate Matter (2.5 microns)
CO2
Non-Cancer Toxicity
Cancer Toxicity
Compliance

When experimenting with the scoring system, Pure Strategies set a uniform distribution as our target distribution where we wanted roughly 23 firms in each of the five ranks (for a total of 115 firms). We then adjusted the criteria variables to achieve this uniform distribution. See Table 3 below.

Table 3: Base Case Variable Criteria and Benchmarking Distribution

Rank	No. Firms	Criteria
A	23	More than 7 indicators with scores ≥ 8.3 or higher, no more than 0 indicators with scores ≤ 5
B	24	More than 7 indicators with scores ≥ 7.6 or higher, no more than 0 indicators with scores ≤ 4
C	24	More than 7 indicators with scores ≥ 7.2 or higher, no more than 0 indicators with scores ≤ 3
D	22	More than 7 indicators with scores ≥ 6.2 or higher, no more than 0 indicators with scores ≤ 2
E	22	All other facilities

The rating method outlined in Table 3 does not make all indicators equal, but does ensure that poor performance in any one category can diminish a facility's overall ranking. This methodology allows one to manipulate four criteria for the ranking uses the following scheme:

"V indicators of X or higher, Y indicators rated Z or below";

where the criteria variables defined as:

W: High Performance number of indicators
X: High Performance minimum score
Y: Lowest performance number of indicators
Z: Low performance, minimum score

This methodology gives the benchmarker the flexibility to adjust any of these four variables. In order to adjust these variables, Pure Strategies developed an Access database. The database allows the benchmarker to (a) select which of the ten indicators to benchmark with and (b) set the criteria variables (W through Z).

A careful review of the grading criteria shows that for the base case, any facility that had a poor score (i.e., ≤ 2) for one or more indicators, received an "E" ranking. This is obviously a subjective decision – others might want to set the grading criteria in rankings A through D to allow a facility to have one very low score. This could be accomplished, for example, by setting set Y = 1 and Z = 0 for rankings A through D.

The base case results, shown Section 5 of the report, shows the ORIS ID, Rank, State and Plant Name of all 115 facilities. On average, one would expect Midwestern plants to rank lower than eastern or western plants – this is because of tighter controls in the east and the availability of low sulfur coal in the west. An analysis of state scores confirms this, showing that Ohio has the lowest average state score. There are some surprising results however, since Wyoming also has a low average score.

Further analysis of the individual indicator scores shows that for several indicators, most of the facilities had very similar scores (all three TRI indicators, waste, water use, and PM 2.5). Thus the indicators that appear to drive the benchmarking results are those with more uniform distributions – compliance, SO_2, NO_x, and CO_2. Pure Strategies conducted other sensitivity analysis to determine how specific outliers and criteria affected the benchmarking results.

1.5. Challenges and Limitations

Overall, this effort succeeded in developing a very flexible database program that allows the benchmarking user to select various indicators for benchmarking, adjust various grading criteria, and run sensitivity analyses – all with considerable ease. Nevertheless, the effort presented some serious challenges.

The first challenge was the lack of current air data in the NEI database. Without more recent data than 1999, we were forced to use relatively old data to conduct the analysis. It is unlikely that this situation will change in the near future, as it appears that EPA will continue to collect air data from states only every three years for the foreseeable future. The second significant challenge was to identify a common facility ID. Although EPA has had its FRS facility ID program in place since 1996, there are serious glitches when it comes to air data. This is because numerous states assign new air program ID's every year. The lack of a consistent ID from year to year makes it all the more time consuming (and costly) for EPA staff to provide a FRS ID. Lastly, the lack of easy internet access to download the types of sector based data needed for this study forced Pure Strategies to obtain each database individually and link them together afterwards. We could not have accessed much of the data used in this study without direct help from EPA staff in the various media programs.

This benchmarking effort is not with out limitations and warrants attention so the reader understands the limits of its applicability. First, the study was performed on a sector with publicly available production data. Relatively few sectors have publicly available production data to normalize environmental data. Other normalizing factors are available (such as number of employees or plant capacity data), but such numbers are likely to be poor substitutes for production data. A second obvious limitation is the need for a well-defined sector. Some sectors are simply too diversified to be benchmarked. In addition, a sector with small facilities may not repot TRI data, which is the cornerstone of our sector selection methodology.

Despite these challenges and limitations, the methodology used in this effort provides a readily understandable, flexible and rather straightforward way to conduct benchmarking analysis. Potential audiences for the methodology include government agencies, industry sectors, and non-profit organizations.

2. Sector Selection

To select sectors for this effort, Pure Strategies first developed criteria to evaluate characteristics of different business sectors and used these criteria to identify five as potential targets for environmental performance ranking analysis. Following this, Pure Strategies performed additional analysis and selected one sector to tests its benchmarking methodology. Pure Strategies' procedure for selecting facilities involved a six-step process. Each step is more completely described in the following pages.

1. Identify "comparable" groups of facilities,
2. Evaluate sectors and facilities participating in existing "beyond compliance" initiatives,
3. Conduct a broad analysis of readily available environmental data,
4. Consider data availability,
5. Select five sectors as benchmarking candidates, and
6. Recommend two sectors for benchmarking.

2.1. Identify "comparable" groups of facilities.

Our first step in the analysis was to develop groups of comparable facilities -- what we call sectors for the purpose of this report. For benchmarking to be credible, the facilities being compared must have similar attributes. If unlike facilities are grouped together, the analysis would lead to incomparable and misleading results. To select sectors for this effort, Pure Strategies conducted an analysis of the 2000 TRI data. The TRI data was chosen since it includes most major industrial manufacturing activities, incorporates data on releases to all media, and has Standard Industrial Classification (SIC) code and chemical use information helpful for grouping like facilities into "sectors." Pure Strategies analyzed the 2000 TRI data, grouping facilities according to three criteria:

<u>(a) Same 4-digit SIC code</u>
Four-digit SIC codes are available in TRI data. Two-digit SIC codes are too general to use (e.g., SIC code 28 covers all types of chemical manufacturing). Six-digit SIC codes are not in the TRI data set. In 1998, the North American Industry Classification System (NAICS) was introduced to replace the U.S. Standard Industrial Classification (SIC) system. None of the environmental data sets we are familiar with, including TRI, uses the NAICS system. Were that data available, it could enhance the sector selection process since the older SIC system was last updated in 1987.

> *Tradeoffs in Defining Sectors*
>
> When conducting facility-based benchmark analyses, defining the sector is a critical step. On the one hand, if the sector is defined too broadly, comparisons will be based on firms that are too dissimilar to allow valid comparisons. On the other hand, if the sector is defined too narrowly, fewer facilities will be included in the analysis. Researchers must balance these competing issues (i.e., benchmarking comparable entities and including a meaningful number of facilities in the analysis) in the sector definition process. In this project, ten or more facilities were considered the minimum to perform a meaningful benchmarking effort.

(b) At least ten facilities in the sector report the same chemical with all the same activity/use codes in Section 3.1 of the Form R (see Table 4)

Generally, facilities with similar operations report similar chemicals under TRI. This screen does not require facilities to report all of the same chemicals, since doing so could deselect firms that have made pollution prevention type substitutions. Specifically, the criterion employed was that at least 10 facilities in the four-digit SIC code reported the same chemical.

The chemical activity use codes available in TRI are an important tool for classifying facilities into like categories for analysis. While facilities may use the same chemical, for the purpose of benchmarking, we are interested in facilities that use the chemical in a similar way. For example, if a group of facilities all reported nickel, examining the activity use codes can further clarify that the firms are indeed similar for the purpose of benchmarking-- nickel compounds can be processed in metal finishing operations in plating tanks, manufactured as a byproduct in coal combustion, or used as a formulation component in certain paint products. This criterion helps to group similar uses of a chemical and is a powerful tool for choosing a sector when combined with (a) above.

Benchmarking Note

The methodology outlined in this section is applicable to many different research agendas. If for example, the sector is already known (e.g., pulp and paper industry), this approach can delineate the extent to which specific chemicals and the type of use in various facilities is similar (or dissimilar) and aid in excluding "outliers" in the data set.

It is possible that using the two criteria outlined above could miss a company using completely different chemicals to produce a similar product. One obvious example is the use of coal versus natural gas to produce electricity. But examples in other sectors are more difficult to come by -- one could expect substitutions for specific process steps (e.g., powder coating versus spray coating) but not substitution for every major process step in industries using 10 or more TRI chemicals. To check whether this phenomenon is at play, researchers should review the literature to see whether such a condition exists and whether including such firms in the benchmarking analysis is warranted.

Table 4: Form R Activity Use Codes

Produce	For sale/distribution	As a reactant	As a chemical processing aid
Import	As a byproduct	As a formulation component	As a manufacturing aid
For on-site use/processing	As an impurity	As an article component	Ancillary or other use

We performed the analysis on the 23,560 facilities in 521 4-digit SIC codes in the 2000 TRI data. The analysis found 162 four-digit SIC codes with approximately 1,149 combinations of the three grouping criteria having 10 or more facilities. One could rank the performance of fewer facilities (e.g., five facilities), but using fewer facilities is less meaningful for public policy purposes.

Pure Strategies then applied an additional screen – the sector had to report on at least eight TRI chemicals, reducing the universe to 31 SIC codes. Sectors with eight or more chemicals were chosen since we were looking for facilities with medium to high environmental impact -- for example refining or iron and steel foundries. Facilities with medium to high environmental impact were selected because (a) they are more likely to trip regulatory reporting thresholds such as the RCRA biennial reporting system (BRS) and major air permit status and (b) for public policy purposes they are more relevant to the discussion regarding regulatory flexibility and beyond-compliance performance. Sectors with lower facility impacts (such as dry cleaning), where relatively few facilities trip reporting thresholds, were not considered a target of this effort.

Benchmarking Note

Benchmarking work requires the researcher to use his or her judgment when defining a set of facilities or sector to benchmark. Having general knowledge of the sectors under consideration is a big benefit in the effort. It is important to including researchers on the team who understand issues such as unit operations, technology and market trends, and chemical active uses in the sector(s) under consideration.

To further narrow the universe, Pure Strategies applied the following screens:

- Exclude any "not elsewhere classified" or NEC SIC codes since these sectors tend to be a mix of industries that do not fit into any other 4-digit category and are therefore thought not to constitute a group of comparable facilities
- Exclude sectors with less than a facility TRI release average of 50,000 pounds or a sector total TRI release of 1,000,000 pounds. We added these criteria to screen out sectors with smaller TRI releases since one criterion is to benchmark sectors with medium to high environmental impact.
- Exclude SIC Code 4953 - Refuse Systems, since this sector is primarily involved in the treatment, disposal, and recycling of hazardous and other wastes and not in production activities.

Applying these criteria screened out 20 SIC Codes, leaving 11 SIC Codes to choose from. Table 5 shows this screening process. The excluded NEC sectors are highlighted yellow, low TRI waste sectors are highlighted orange, and refuse systems highlighted gray. Those sectors without highlights are the 11 sectors that passed the screening criteria.

Table 5: Applying Screening Criteria to Identify Comparable Industries[1]

Primary SIC Code	Description	No TRI Chemicals	Range of Facilities Reporting each chemical
2491	Wood Preserving	12	11-49
2493	Reconstituted Wood Products	9	10 - 68
2511	Wood Household Furniture, Except Upholstered	8	10 - 52
2611	Pulp Mills (pulp mills producing paperboard)	37	10 - 34
2621	Paper Mills (newsprint mills)	28	10 - 33
2631	Paperboard Mills	17	11 - 21
2819	Industrial Inorganic Chemicals, NEC (alumina)	9	11 - 32
2821	Plastics Materials, Synthetic and Resins, & Nonvulcanizable Elastomers	56	10 - 86
2851	Paints, Varnishes, Lacquers, Enamels and Allied Products	48	10 - 178
2869	Industrial Organic Chemicals, NEC	49	10 - 35
2891	Adhesives and Sealants	8	12 - 50
2899	Chemicals and Chemical Preparations, NEC	12	10 - 37
2911	Petroleum Refining	44	10 - 52
3087	Custom Compounding of Purchased Plastics Resin	8	13 - 54
3089	Plastics Products, NEC (finished plastics furniture parts)	14	11 - 92
3312	Steel Works, Blast Furnaces (including coke ovens), and Rolling Mills (hot rolling purchased steel)	20	10 - 21
3321	Gray and Ductile Iron Foundries	15	10 - 44
3341	Secondary Smelting and Refining of Nonferrous Metals (except copper and aluminum)	11	10 - 48
3357	Drawing and Insulating of Nonferrous Wire	10	10 - 96
3411	Metal Cans	18	12 - 52
3471	Electroplating, Plating, Polishing, Anodizing, and Coloring	21	10 - 129
3479	Coating, Engraving, and Allied Services, NEC (costume jewelry engraving and etching)	25	10 - 31
3499	Fabricated Metal Products, NEC (metal furniture frames)	11	10 - 60
3672	Printed Circuit Boards	16	10 - 52
3674	Semiconductors and Related Devices	11	10 - 53
3711	Motor Vehicles and Passenger Car Bodies (military armored vehicles)	29	10 - 31
3714	Motor Vehicle Parts and Accessories	25	10 - 96
4911	Electric Services (electric power distribution)	110	10 - 410
4953	Refuse Systems (materials recovery facilities)	54	10 - 32
5169	Chemicals and Allied Products, NEC	44	10 - 96
5171	Petroleum Bulk Stations and Terminals (LP gas sold to consumer)	50	10- 202

[1]The left column in this table denotes the range in the number of facilities reporting the same chemical with the same activity use code. For example, for SIC code 2491 (wood preserving) where 12 chemicals were identified, at the low end of the range, 11 firms reported the same activity use codes for arsenic while at the high end of the range, 49 firms reported the chemical creosote using the same activity use codes. The other 10 chemicals fell in between the 11 to 49 range (for example, pentachlorophe was reported by 24 facilities).

2.2. *Identify and evaluate sectors participating in "beyond compliance" initiatives.*

With these 11 sectors in mind, Pure Strategies reviewed "beyond compliance" programs at the federal and state levels and compiled information on facilities and the sectors participating in these initiatives. The purpose of this screen was to identify sectors that are active in innovative programs and that may have developed more detailed environmental performance information. To be included in the analysis, the programs had to (a) be facility wide and not targeted to a particular media or issue (e.g., solid waste reduction), (b) require beyond compliance pledges or commitments for participation, and (c) target medium to large size businesses (this would exclude small business programs such as those targeted toward dry cleaners, auto body shops, etc. who tend not to report on TRI). Pure Strategies reviewed the following databases and developed a list of participating facilities and their primary SIC Codes:

- Virginia Environmental Excellence Program,
- Cal/EPA's Environmental Management System Project,
- North Carolina's EMS Pilot Program,
- Oregon DEQ's Green Permit Program
- EPA's Performance Track database

This screen was overly exclusive. When we combined and analyzed these databases, and screened for those with TRI reports, we found that there were too few facilities to use the data as a screen to select one sector over another. Table 6 presents the results.

Pure Strategies also reviewed the Global Reporting Initiative (GRI) but this data is available at the corporate level and does not provide the type of facility level data required. Lastly, Pure Strategies compiled a listing of the 1,984 U.S. sites that are ISO 14000 certified. Data on the site SIC codes were not available; however, a quick review of the data shows that the vast majority of the US 14000 certified firms are in the auto sector (see Appendix 8.1).

Table 6

SIC Code	No. Facilities that are TRI Reporters
3714	8
3841	7
2851	5
3674	5
2834	4
3011	4
3571	4
2611	3
2844	3
2869	3
3652	3
4911	3

2.3. *Conduct Distribution Analysis of TRI Data.*

Pure Strategies conducted a simple distribution analysis of the remaining 11 sectors to see whether one or two companies completely dominated the releases in the sector (i.e., comprise 25% or more of the releases). The analysis, which used descriptive statistics such as mean, standard deviation, kurtosis, and skewness did not point to any sectors that should be dropped from the list of potential sectors. However, the analysis did show the need to further examine any SIC code that is chosen for benchmarking for "comparable" facilities. For example, SIC 3674 (semiconductors) is primarily comprised of facilities that manufacture integrated circuits such as IBM and Intel, but also contains those that make the silicon and gallium arsenic substrates. One would need to review the data to omit those firms that are present in the 4-digit SIC code but whose operations are dramatically different.

2.4. Consider Data Availability Differences for Sectors.

Pure Strategies conducted a review of market research information to look for production data for various industries. Pure Strategies considers the availability (and the lack thereof) of production data key to its benchmarking approach. Pure Strategies' research showed that there are few sectors with available facility-by-facility production data. We were able to identify publicly available production data for just two sectors: the auto assembly industry and the electric utility industry. Production capacity data was more readily available. For example, Pure Strategies was able to identify the following production capacity data:

- Iron and Steel Production- Iron and Steel Directory, Steel Manufacturers Association Membership Directory
- Petroleum Refining- US Department of Energy
- Primary non-ferrous metals smelting and refining- USGS Survey
- Pulp Manufacturing- Lockwood-Post Directory
- PVC Manufacturing - Chemical Economics Handbook

Capacity data is also available for many chemical-manufacturing processes through private companies such as Stanford Research Institute (SRI). While capacity data is helpful in that it allows one to group facilities into categories such as large, medium and small, it does not provide the actual production data we prefer.

Data for capacity is typically available on a facility basis but data on capacity utilization is typically only available for the sector as a whole. Those sectors that have relatively high capacity utilization rates (>90%) present the best opportunity to use capacity data. For example, the pulp and paper sector's capacity utilization from 1995 - 1998 ranged from 90.9% to 94.3%. High capacity utilization industries are typically continuous process sectors with large investments in plant and equipment that necessitate them being run at very high rates to cover the plant's capital and operating costs. However many such sectors, including pulp and paper, are cyclical industries whose capacity utilization varies with the output of the overall economy. Researchers need to be aware that the cyclical nature of such industries can influence production rates, capacity utilization, and waste generation.

Even in sectors with high capacity utilization rates that tend not to change over time, there are important tradeoffs to note. The use of capacity data to normalize environmental data can significantly reduce the accuracy of the analysis. This is because facility environmental releases are usually considered a function of capacity utilization (actual production). Any facility in the sector could have, for a given year, a very low or very high utilization rate and the data would not reflect these important changes in production level. This would be true even for facilities that do not directly measure releases but instead use emission factors and other estimation techniques. This is because the reported emissions are the product of production levels times the emission factors themselves.

It may be possible to somehow combine capacity data with other publicly available information such as facility web sites, the TRI production index, air or water permit information, etc. Pure Strategies did search corporate 10-K reports but found these reports provide (in some but not all cases) capacity data only[2].

Pure Strategies also conducted a review of the sectors to see whether the 11 screened sectors were prevalent in other regulatory databases such as the EPA hazardous waste Biennial Reporting System (BRS), the EPA air program Aerometric Information Retrieval System Database (AIRS), and the EPA water program Permit Compliance System (PCS). The intent was to avoid selecting sectors where data is not available for significant environmental impacts. Our analysis found that, generally speaking, the 11 sectors have significant environmental impacts that are reflected in these databases (as well as in the TRI database).

Lastly, Pure Strategies conducted a review of the New Jersey facility materials accounting database. New Jersey data contains facility production information. Although there is no sector in New Jersey that is large enough by itself to evaluate the benchmarking methodology, the data could be useful if there are NJ facilities in the two sectors that are benchmarked.

2.5. Select Five Sectors as Benchmarking Candidates

To select five sectors from the eleven, Pure Strategies considered the following criteria:

- Available production data
- Available capacity data
- A more broadly defined sector with more facilities that will provide a more diverse range of environmental impacts to consider and may help in developing a benchmarking methodology that applies to more sectors
- Chemical manufacturing, chemical processing, and otherwise use of chemicals at the facility.

Based on these criteria, Pure Strategies recommended the following five sectors for further evaluation (see Table 7) while holding six other sectors (see Table 8) as more distant but still

[2]The Securities and Exchange Commission (SEC) requires large firms to prepared annual 10-K reports that provide a comprehensive overview of the firm's business. The reports can be found on the SEC website (www.sec.gov).

possible sectors to select for benchmarking pending the outcome of the evaluation of our primary five sectors.

Table 7: Primary List

Primary SIC Code	Description	Notes
2611	Pulp Mills (pulp mills producing paperboard)	Capacity data available
2821	Plastics Materials, Synthetic and Resins, and Nonvulcanizable Elastomers	Possible to narrowly define one chemical process such as vinyl chloride manufacturing within this SIC Code. Capacity data available
2911	Petroleum Refining	Capacity data available, chemical manufacturing, significant environmental impacts, complicated product mixes
3711	Motor Vehicles and Passenger Car Bodies (excluding military armored vehicles)	Production data available, process and use chemicals
4911	Electric Services (electric power distribution)	Production data available, significant environmental impacts

Table 8: Secondary List

Primary SIC Code	Description	Notes
2621	Paper Mills (newsprint mills)	Difficult to make comparable facilities, large product variation, much data based on standard industry emission factors and not measured releases
3321	Gray and Ductile Iron Foundries	Capacity data unavailable. Many facilities with large product variation
2631	Paperboard Mills	Difficult to make comparable facilities, large product variation,
3312	Steel Works, Blast Furnaces (including coke ovens), and Rolling Mills (hot rolling purchased steel)	Capacity data available. SIC comprised of four sub-sectors -- (a) Fully-integrated (consists of coke ovens, blast furnaces, steel furnaces, and rolling and finishing mills), (b) partially integrated with blast furnace (consists of blast furnaces, steel furnaces, and rolling and finishing mills), (c) partially integrated without blast furnaces (consists of steel furnaces and either rolling and finishing mills or a forging department; includes mini mills), and (d) non-integrated (all others, including stand-alone rolling and finishing mills, and stand-alone coke plants). The fully integrated mills, which are 8% of the plants in 3312, employ 40% of employees and have the largest environmental impacts.
3411	Metal Cans	Product variation at facilities - some plants are two part, other three-part; some produce beverage containers while others make food containers. Mostly air issues with fewer water and waste issues
2493	Reconstituted Wood	Possible to benchmark those facilities making specific products (e.g.,

	Products	OSB)

2.6. Recommend Sector for Benchmarking

Pure Strategies reviewed the five sectors outlined in section (5) in greater detail. The review included looking at industry studies (such as that prepared by World Resources Institute on the pulp and paper industry) and detailed sector information compiled in the Chemical Economics Handbook (published by SRI International). Based on this review, Pure Strategies recommended selecting the automobile manufacturing and the electric utilities sectors. The reasons for choosing these sectors are outlined below.

<u>SIC 3711: Motor Vehicles</u>
This sector has a significant environmental impact, available production data, both otherwise uses and process chemicals, and is by far the sector with the greatest participation in ISO 14000 in the U.S. Thirty-six facilities reported under TRI in 2000 in this sector. Data on air, water, hazardous waste, spills, and enforcement is available in EPA databases.

<u>SIC 4911: Electric Utilities</u>
This sector has available production and capacity data; choice of this sector will allow comparison of benchmarking approaches using both approaches. Very detailed facility information such as emissions, fuel use, energy generation is available in EPA's Emissions and Generation Resource Integrated Database (E-GRID) program. The E-GRID database is a comprehensive source of data on air pollutant emissions and resource mix for individual power plants and generating companies. The data are expressed in terms that allow comparison of the air-related environmental attributes of different generating facilities. Facilities in this sector coincidentally manufacture many chemical compounds and generate significant air, water and waste impacts.

Although the original workplan called for Pure Strategies to develop data for both sectors, the difficulty we experienced accessing the data confined the study to a single sector – specifically coal-fired electric utility plants.

3. Selecting Benchmarking Indicators

This section outlines the indictors chosen to benchmark facilities in the coal-fired electric utility sector. It begins with a brief discussion of market trends in the sector. Next, we review the sector's environmental impacts and present a list of indicators to use in the benchmarking analysis. The section concludes with a discussion of how to treat compliance in the benchmarking analysis.

The electric utility sector is comprised of roughly 3,042 plants (EPA 2000). The plants include facilities powered by coal, natural gas, oil, nuclear, and renewable fuels. Since coal-fired plants have the greatest impacts, we have chosen this sub-sector as the universe of firms to be benchmarked.

More electric power is generated from the 728 U.S. coal-fired plants than by plants using any other fuel source (e.g. hydro, natural gas, or nuclear). While coal prices have been declining in recent years and natural gas prices have been increasing, few new coal power plants are being built. Most new power plants are gas fired. For example, a 1999 list of new plants on order compiled by the Electric Power Supply Association (EPSA) showed that only ten of 586 new plants would be coal-fired, five hydroelectric, and the vast majority natural gas. In recent years there has been increasing interest in the other fuel sources for electricity, including renewables energy.

These coal-fired plants also have far greater environmental impacts than other sources of fossil fuel electric power. Coal-fired power is the largest source of sulfur oxides, making it the largest acid rain contributor of any industrial sector. Coal fired power plants are also a significant source of nitrogen oxides -- with an impact comparable to that of transportation sources. Coal power plants are also large sources of certain heavy metals and green house gases. Oil, natural gas, and renewable plants have much lower overall environmental impacts when compared with coal-fired plants. Appendix 8.2 contains a brief summary of regulatory issues affecting the industry.

A review of the coal-fired electric utility industry shows that the percentage of electricity generation from coal can vary tremendously. For example, some plants have both coal fired and oil fired boilers on site and can derive as much as 100% generation from coal down to less than 50% generation from coal. (Emissions from oil-fired units are far less than that of coal fired units.) Since the goal of this benchmarking effort was to test the methodology on reasonably comparable facilities, Pure Strategies chose to include only those plants whose where coal comprised $\geq$ 98% of the fuel heat content[3].

[3] Fuel heat content is measured in BTUs. The Department of Energy collects data that includes the heat content of all fuels used by generating plants. Under this screen, no more than 2% of the heat content can come from non-coal sources (e.g., oil, gas, nuclear, solar, et.c)

3.1. *Major Environmental Impacts Included in the Benchmarking Effort*

Without question, the most significant impacts of coal-fired utilities are on air quality. In addition to key air impacts, coal-fired electric utility plants also generate large quantities of solid waste, and discharge large volumes of cooling wastewaters to water bodies. Pure Strategies conducted a literature review to identify which major human health and environmental impacts to include in the effort (see Figure 2).

Figure 2: Coal-Fired Human Health and Environmental Impacts

Greenhouse Gases: The electric utilities sector is responsible for about 30% of the total U. S. emission of greenhouse gases. The primary greenhouse gas emission is CO_2. Roughly 86% of carbon dioxide emitted by electric utilities in 1999 came from coal-fired plants or roughly 1.71 of the 1.99 billion metric tons of CO_2.

Sulfur Dioxide: Coal-fired electric utility plants were responsible for roughly 63% of the sulfur dioxide emitted from all U. S. sources in 1999 (11.9 out of the 18.9 million tons).

Nitrogen Oxides: Coal-fired electric utility plants were responsible for roughly 19% of the nitrogen oxides emitted from all U. S. sources in 1999 (4.9 out of a total of 25.4 million tons). Other significant sources of nitrogen oxides include transportation and off-road engines sources.

Fine Particulates: Coal-fired electric utility plants were responsible for slightly less than 5% of PM2.5 particulates. Unlike coarse particulates (known as PM-10) which are highly controlled and do not currently represent a significant health problem, the literature points to significant human health impacts from fine particulates.

Toxics: The electric utility sector as a whole was the largest contributor by far of all sectors to total reported TRI air releases in 1999, at 41% of the total of all reported air emissions. This includes toxic chemicals and compounds such as dioxins, PACs, mercury, lead and nickel.

Solid Waste: Utility coal usage results in the annual generation of roughly 100-million tons fly ash, bottom, ash, boiler slag, and flue gas desulfurization (FGD) sludge wastes. For comparison purposes, this volume is roughly 50% of the total municipal solid waste generated in the U.S. each year. Coal-fired wastes, which are relatively low risk and are not classified as hazardous wastes, are mostly managed in landfills and surface impoundments, and to a lesser extent are beneficially reused in cement and concrete products, construction fills, agricultural uses, etc.

Water Use: Electric generating plants are the single largest industrial users of water in the U.S.. According to the US Geological Service fossil fuel steam electric plants (coal, oil and natural gas) withdrew an estimated 135 billion gallons per day. Nearly all of the water use is for cooling systems.

Sources:

1. EPA 2000. Office of Water. Economic and Engineering Analyses of the Proposed Section 316(b) New Facility Rule. EPA-821-R-00-019.
2. EPA 1999. Office of Solid Waste. Technical Background Document For The Report To Congress On Remaining Wastes From Fossil Fuel Combustion: Industry Statistics And Waste Management Practices.
3. National Center for Manufacturing Sciences (NCMS). Coal-fired and Hydroelectric Utilities Impacts, Risks and Regulations. http://ecm.ncms.org/ERI/new/IRRcoalutil.htm

3.2. Impacts Considered But Not Included in the Benchmarking Effort

It is also important to note which impacts are not terribly significant for this sector. For example, electric generating plants produce relatively little hazardous waste. For example, the sector does not show up on EPA Office of Solid Waste's analysis of sectors that generate hazardous waste nor is the industry on the list of sectors that generate PBT-containing hazardous waste. From a water perspective, the absolute volume of water used and temperature of discharge appears to be important, but information on dissolved solids, pH and other parameters does not appear to be critical based on the literature. Pure Strategies was able to include data on total water use in the model but was unable to directly incorporate data on thermal pollution into the model[4].

There are obviously some impacts in the electric generation supply chain that have significant environmental impacts, such as mining habitat destruction, coal mine methane emissions, radiation from high tension electric power lines, and the use of herbicides on power line right of ways. But while these impacts are potentially significant, they are difficult to account for on a facility level and therefore were not included in our analysis.

Pure Strategies had also hope to use information regarding participation in beyond compliance programs such as the Federal Performance Track, similar state programs, or ISO 14000 certification. However, our review of firms in these programs show they very few of them are in the electricity generation business.

3.3. Incorporating Compliance into the Benchmarking Model Issues

In addition to the environmental performance indicators outlined in the preceding pages, Pure Strategies developed a compliance indicator. The compliance indicator is not like other environmental performance indicators in that it is a more indirect measure (i.e., not all compliance violations are directly related to increased pollution). However, legal compliance is an important principle in the environmental performance literature and facilities with significant compliance problems generally are not considered high performers.

Since all violations are not equal (i.e., a single late monitoring report is less serious than complete violation of a water quality effluent limit), Pure Strategies chose to count only significant non-compliance (SNC). The compliance indicator draws from EPA CWA, CAA, and RCRA enforcement data. Each program has its own specific criteria for making this determination. A brief summary of each program's definition is located in Appendix 8.3.

[4] Note that the model does not altogether ignore these impacts (thermal pollution, TSS, oil & grease, etc.) since it includes a compliance indicator comprised (in part) of information from the Permit Compliance System (PCS) database. Pure Strategies did receive assistance from PCS staff in obtaining permit-specific data but due to complications obtaining and process the data and budget limitations, it was not incorporated into the model.

3.4. Selecting Indicators

Based on the significant impacts and compliance issues outlined above, Pure Strategies created a list of ten indictors to choose for benchmarking. Pure Strategies' bencmarking model allows users to select one, ten, or any combination of the 10 indicators for benchmark. The ten benchmark indicators are listed in Table 9 below and defined thereafter.

Since the model's purpose is to benchmark environmental performance of facilities, all of the environmental indicators are normalized by plant net electricity generation. While it makes sense that NOx releases increase with an increase in production, noncompliance and production are not necessarily related, so the compliance indicator was not normalized. When undertaking the normalization task, Pure Strategies reviewed and compiled available production data for the coal-fired electric utility sectors. Production data is to be used in the benchmarking project to normalize pollutants to the level of facility production (e.g., tons of sulfur dioxide per MW of electricity generation). If quality production data for the sector could not be compiled, Pure Strategies would have to turn to other surrogates for production, such as the production/activity index reported on TRI, plant capacity data available in sector periodicals, or the number of employees reported in the Harris Manufacturing Directory. Fortunately, quality production data is available in the DOE Energy Information Agency database – the net electricity generation for each facility is computed on an annual basis for coal fired generating plants. Net generation is the total amount of electric energy generated per year, measured at the generator terminal minus the total electric energy consumed at the generating station, expressed in megawatt hours. This figure is summed for all generators on the plant cite and represents the production output from the facility.

Table 9: Benchmarking Indicators (all normalized to net generation)

Indicator Description	Indicator Name	Data Source
Annual Sulfur dioxide emissions	SO2/MWh	NEI
Annual Nitrogen oxides	NOx/MWh	NEI
Annual Greenhouse gases/Climate change	CO2/MWh	E-GRID
Annual Fine Particulates (<2.5 microns)	PM 2.5/MWh	NEI
Annual Total Toxics Releases	TRI releases/MWh	TRI
Annual Non-cancer Impacts of Toxics	TRI Non-cancer/MWh	TRI + EDF Factors
Annual Cancer Impacts of Toxics	TRI cancer/MWh	TRI + EDF Factors
Annual Net solid (non-hazardous) wastes	Solid Waste/MWh	EIA
Annual Compliance information	Compliance	IDEA
Annual Cooling water withdrawal rate	Water Use/MWh	EIA

Database Sources:

NEI: National Emissions Inventory (formerly known as AIRS) (EPA)
E-GRID: Emissions & Generation Resource Integrated Database (EPA)
TRI: Toxics Release Inventory (EPA)
EDF Factors: Environmental Defense Fund Cancer & Non-cancer potency factors
EIA: Energy Information Agency of the Department of Energy

IDEA: Integrated Data forEnforcement Analysis (EPA)

<u>SO_2: Sulfur Dioxide Emissions</u>

Tons of sulfur dioxide emissions per year per megawatt-hour[5].

<u>NOx: Nitrogen Oxides</u>

Tons of nitrogen oxides emissions per year per megawatt-hour.

<u>CO_2: Carbon Dioxide Emissions</u>

Tons of nitrogen oxides emissions per year per megawatt-hour.

<u>PM 2.5: Fine Particulates</u>

Tons of fine particulate emissions (PM 2.5) per year per megawatt-hour.

<u>Toxics: TRI releases</u>

Pounds of TRI releases (all reported chemicals) to all media per year per megawatt-hour.

<u>Toxics: TRI Non-cancer</u>

Total TRI releases to air and water per year per megawatt-hour weighted by a non-cancer toxicity potency factor[6].

<u>Toxics: TRI cancer</u>

Pounds of TRI releases to air and water per year per megawatt-hour weighted by a cancer toxicity potency factor.

<u>Solid Waste: Net solid (non-hazardous) wastes</u>

Tons of total solid waste (sum fly ash, bottom ash, sludge, gypsum and other byproducts) minus waste that is sold (i.e., recycled) generated per year per megawatt-hour.

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[5] EPA uses the SO2, NOx and CO2 data from the Acid Rain (also known as the Clean Air Market) program in the NEI. EPA staff believe that the acid rain data is more accurate than data supplied by the states through the NEI. The acid rain data is submitted to EPA on a near real-time basis and available on the Internet shortly after submission.

[6] See Appendix 8.4. The Non-cancer and cancer TRI indicators use potency factors used by the Environmental Defense Foundation's (EDF) scorecard system. This system adjusts the amount of a chemical that is released (in pounds) using a weighting factor (a chemical's "toxic equivalency potential"), so that chemical releases can be compared on a common scale that takes into account differences in toxicity and exposure potential. According to the EDF Scorecard website (www.scorecard.org), "chemicals that cause noncancer health effects vary widely in both their toxicity (the amount of chemical it takes to cause damage) and exposure potential (the total human dose associated with a one pound release). A chemical like formaldehyde is relatively toxic, but it quickly degrades when released to air, limiting human exposure opportunities. In contrast, a chemical like 1-chlorobutane has relatively low toxicity, but a very high exposure potential when released to air. A one pound release of each of these chemicals poses significantly different human health risks. If all chemicals are treated the same (a pound of one is no better or worse than a pound of another), we will miss important opportunities for risk reduction. EDF's toxic equivalency potentials (TEPs) are designed to address this problem. If the TEP of chemical A is 10 times the TEP of chemical B, the emissions of 1 pound of chemical A is considered to be as harmful to human health as that of 10 pounds of chemical."

Water Use: Cooling water withdrawal rate

Annual average rate of cooling water withdrawn (cubic feet per minute) per megawatt-hour.

Compliance

Total number of occurrences of significant non compliance (SNC) derived from the IDEA database which compiles compliance violations from CAA, CWA/NPDES, and RCRA databases. The metric measures the number of quarters over a two year period for which the facility has had one or more incidences of SNC. Pure Strategies selected a two-year period for the compliance metric, with the first year preceding the actual benchmarking year (i.e., if benchmarking 1999 data, quarterly compliance data from 1998 and 1999 is reviewed).

The quarterly compliance data provided 24 opportunities for a facility to be (non-) compliant (8 quarters times 3 programs). There were some cases where within a program a facility had several permits, therefore several rows of data. If a facility had multiple permits in a program and one or more instances of SNC within a quarter, that quarter was considered to be in SNC for that program. In other words, SNCs for multiple water permits in a quarter would only “count” as a single water SNC for that quarter.

4. Data Availability and Accessibility

This section reviews data availability and accessibility for the indicators outlined in the previous section. Having selected a sector for benchmarking and the indicators in question, Pure Strategies reviewed the primary federal data sources to answer two key questions.

1. Is there a common facility identifier in the databases that allows one to link facility data from different databases together?

2. Is the data available electronically in a database on a sector basis (as opposed to on a company by company basis which would require labor-intensive data entry)?

4.1. Common Facility ID

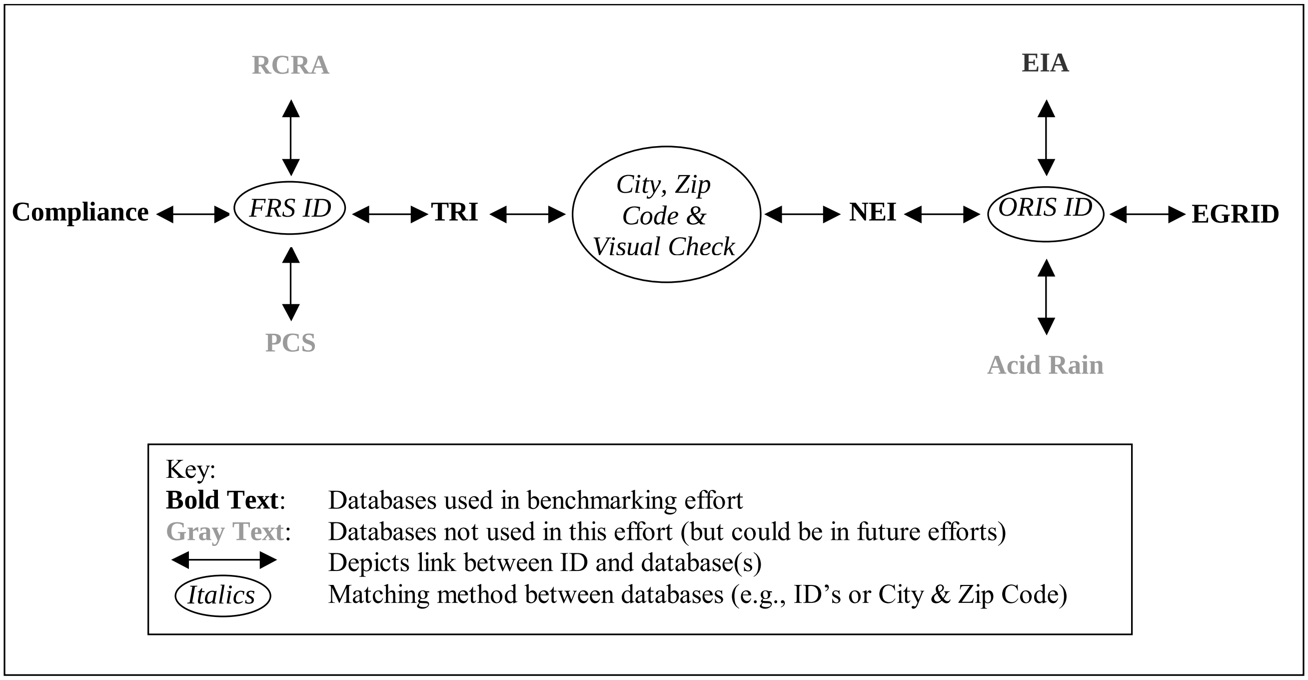
In 1996, EPA began efforts to tie data from different programs into a database with a unique facility ID. In theory, the water, waste, air and TRI programs have similar requirements for what constitutes a facility for reporting purposes. In reality, however, facilities do not always define their facility the same way for every program. Thus a facility might submit slightly different addresses and longitude and latitude data for their air permits and TRI reports. The plant names in different databases might even differ in terms of spelling, use of abbreviations (e.g. Mount Tom Plant vs. Mt. Tom Plant), or name.

Finding the corresponding environmental data for each program requires linking the programs to the facility. The best tool for this is the EPA Federal Registry System (FRS). The FRS matches NPDES, NEI, BRS, TRI, and ID's to a single FRS ID. FRS uses a sophisticated algorithm to achieve this match that includes analysis of place-based information such latitude and longitude, addresses, city, and zip code. According the EPA Envirofacts staff, the FRS facility ID's are not considered very accurate before 1999 (with the level of accuracy decreasing with earlier years).

Unfortunately, not all the databases needed for the study had an FRS ID. The Compliance database and TRI were linked by FRS ID. NEI, EGrid, and EIA are all linked by ORIS ID. In order to connect the FRS-linked databases with those linked by ORIS, we had to select one database from each of those groups and link them on some other common data elements. For this purpose, we chose to link TRI and NEI. The link was done using state and zip code fields, with a manual check on the facility name field. In the future this type of matching would be unnecessary since NEI will have FRS IDs[7]. Figure 3 depicts this effort graphically.

[7] Many states require facilities to change their air program ID's from year to year. This change in ID makes it difficult for EPA to link air data between years. This difficulty is further compounded when EPA attempts to link a facility's air data with facility data from other programs (e.g. water or waste) through the FRS ID.

Figure 3: Facility ID Matching



Matching the different facilities by hand (as opposed to using a computer to match facilities from different databases) is not recommended for large data sets. Since our data set had 115 facilities, a manual (visual) check was reasonably simple to do.

4.2. Data Availability

One of the key issues in benchmarking is that the different data sets (e.g., TRI or NEI) must all be for the same year – for example, one cannot combine 1999 compliance data with 2001 E-GRID data, and 1999 NEI data. Thus the data set with that is least current determines the benchmarking year. In our case, this data set was the NEI whose most current data was 1999[8]. *Thus 1999 is the reference year for this benchmarking study*. There were widely varying degrees of difficulty in acquiring data (see Table 10 below).

Table 10: Data Availability Notes

Database	Notes on Acquiring Data
EIA	Easily downloaded EIA from the Department of Energy website. This database had many related tables, some of which had one-to-many relationships.
E-Grid	EPA sent us the 1999 E-Grid database as soon as it became available. One can now download it from the EPA website.

[8] Although states collects air pollution data from major facilities on an annual basis, EPA prepares the NEI database only every three years (e.g., 1993, 1996, and 1999) and 2002 data is not likely to be ready for until at least 2004. The 1999 data was not available until March of 2003.

Compliance	Pure Strategies requested compliance data directly from EPA staff who did a custom query in the IDEA database. The data was emailed to us with FRS IDs for each facility. CWA data was presented quarterly while CAA and RCRA were monthly. In order to normalize this, we transformed CAA and RCRA to monthly.
TRI	Attempts to download TRI from EnviroFacts ended with the server timing out. RTKnet (http://www.rtknet.org) offered TRI data, but the server would time out when trying retrieve SIC code 4911 data for the country. As a result, staff downloaded the files state-by-state and appended them to one another to create a national TRI SIC 4911 database. In addition, the TRI data was presented in flat file form. This data needed to be separated and normalized into several related tables. Furthermore, this TRI data did not contain an FRS ID. Subsequently, staff queried EnviroFacts to return a table of TRI IDs with their corresponding FRS IDs.
NEI	EPA emailed the NEI Version 2.0 data to Pure Strategies when it became available. Since there was so much inconsistency in how AIRS IDs were assigned, FRS IDs were not yet assigned to NEI. However, the NEI data did have ORIS ID's. EPA asks states to file NEI (formerly known as AIRS data) every three years – but many states do not alway supply this data. In 1999 for example, only 35 states submitted NEI data. EPA's contractor estimated the data for facilities in 15 states by inflating the 1996 data.

4.3. Data For All Programs Required

For this benchmarking project, Pure Strategies chose to include only those facilities with records in all of the databases from which we are drawing data. For example, if we join TRI, AIRS, and EIA, then the result will be only facilities that exist in ALL three programs. If there is a facility that has no records in TRI, that facility would not be included[9]. This requirement was put in place to screen out any facility that should have but failed to appear in one or more of the databases. By enforcing this requirement, it is possible that some facilities, which are not required to report to a program, and therefore are conceivably cleaner, would be omitted from the analysis. However, in the case of coal-fired electric generating plants, we thought this likelihood was rather small (i.e., plants are likely to report in all programs). Researchers benchmarking other sectors should review their own datasets to determine whether enforcing a similar requirement is warranted.

4.4. Data Quality Control

In any data project, quality control checks are important to ensure data integrity. The scope of this benchmarking project limited some of the checks that would normally go along with such a project. For example, we were unable to check for facility reporting errors (i.e., send

[9] This is enforced by the inner joins we are making in our databases that necessarily include only matches on both sides of the join. Where multiple inner joins exist, only matches on both sides of all of the joins are included

benchmarked facilities copies of their data to review to ensure it was reported accurately) or data entry errors (by those entering into state and/or EPA databases). Nevertheless, we did develop a list of data quality screens (see list below).

- Omit facilities that have a Net Generation difference of >2% between EIA net generation data and E-Grid net generation data.
- Omit facilities that have NOx or SO2 ≤ 0 in either NEI or E-Grid.
- Omit facilities that have a NOx difference of 2% or more between NEI and E-Grid.
- Omit facilities that have a SO2 difference of 2% or more between AIRS and EGrid.
- Omit facilities that have a Heat Input of <=0 in EGrid.

The ORIS ID's for facilities that did not pass these screens were entered into a "Disqualified Facilities" table that contains ORISIDs and the reason for disqualification. These facilities were ``not included in the final analysis.

Database Notes

Unless the number of facilities you wish to benchmark is very small (<10), the use of a database application is highly recommended. It is important that you have someone on your staff that has significant experience in creating and manipulating databases. Critical skills required to perform benchmarking in a database environmental include understanding relational database fundamentals and the following critical skills:

Extract, Transform, and Load (ETL) – Data will be coming from several sources and similar fields between sources will often have different data types (eg. the same ID field might be text in one source and a number in another). Depending on the size of your sample, an ETL tool might not be necessary, but an understanding of the issues involved in importing and massaging data is essential.

Complex query writing – Multiple table queries, aggregation functions, and multiple subqueries are all used extensively.

Programming – There will be occasions where custom functions are necessary. This can be accomplished through programming in a general language like VB/VBA or in complex SQL scripts. This becomes even more important if a user interface is required.

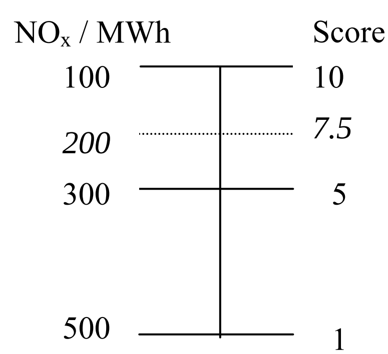
5. Benchmarking Performance

Having defined the indicators, obtained the data, and linked the facility data, we are ready to benchmark facilities in the sector. As a matter of review, 1999 data from 115 coal fired electric generation plants with 98% or greater heat content that have passed a series of data screens (see prior section) will be benchmarked.

In order to determine a firm's performance relative to other firms, one has to determine how to compile a set of facility indicators (e.g., TRI releases, global warming potential, total water use, etc.) so that one facility's score can be compared with the score of other facilities in the sector. In our example, performance is to be defined using 10 indicators and we are interested in rank ordering the 115 firms in that sector. One firm might do very well in 7 of the 10 categories but do very poorly in the remaining three. Another might be in the average percentile for all 10 categories. How does one determine which facility should be ranked first? What algorithm would one use? The first step in answering this question is to rank order the performance for each individual indicator – a step we call indicator scoring.

5.1. Indicator Scoring

Figure 4: NAE Indicator Scoring



To score the individual indictors (e.g., NOx per MW hours of generation) for this benchmarking effort, Pure Strategies employed a methodology used by the National Academy of Engineering (NAE) for scoring indicators in comparable units based on the variability within the sector. Under the NAE, the range of values in a sector for each indicator becomes the minimum and maximum potential values for the indicator. For example, if the data for the sector as a whole shows that the minimum of NO_x per megawatt hours of electricity generation is 100 tons and the maximum is 500 tons, these ranges can be equated to a simple 0 to 10 score, with 10 being the best (least NO_x). Facilities falling on the midpoints of the range can be assigned a score based on their own NO_x/MWh. For example, a facility with a NO_x/MWh of 200 would have a score of 7.5 (see Figure 4). The following formula is used to compute the indicator scores:

$$Score = 10 - \left(10 \times \left(\frac{\text{facility indicator value - minimum value of all facilities}}{\text{maximum value of all facilities - minimum value of all facilities}}\right)\right)$$

Note that the scores are inversely related to the actual indicator values (i.e., a high score corresponds to a low level of pollution – for example low NO_x / MWh). In addition, the range of scores is always between 10 (best) and zero (worst). Scores for all 10 indicators and for net generation for all 115 plants listed by ORIS ID are located in Table 11.

Table 11: Indicator Scores f or 115 Facilities

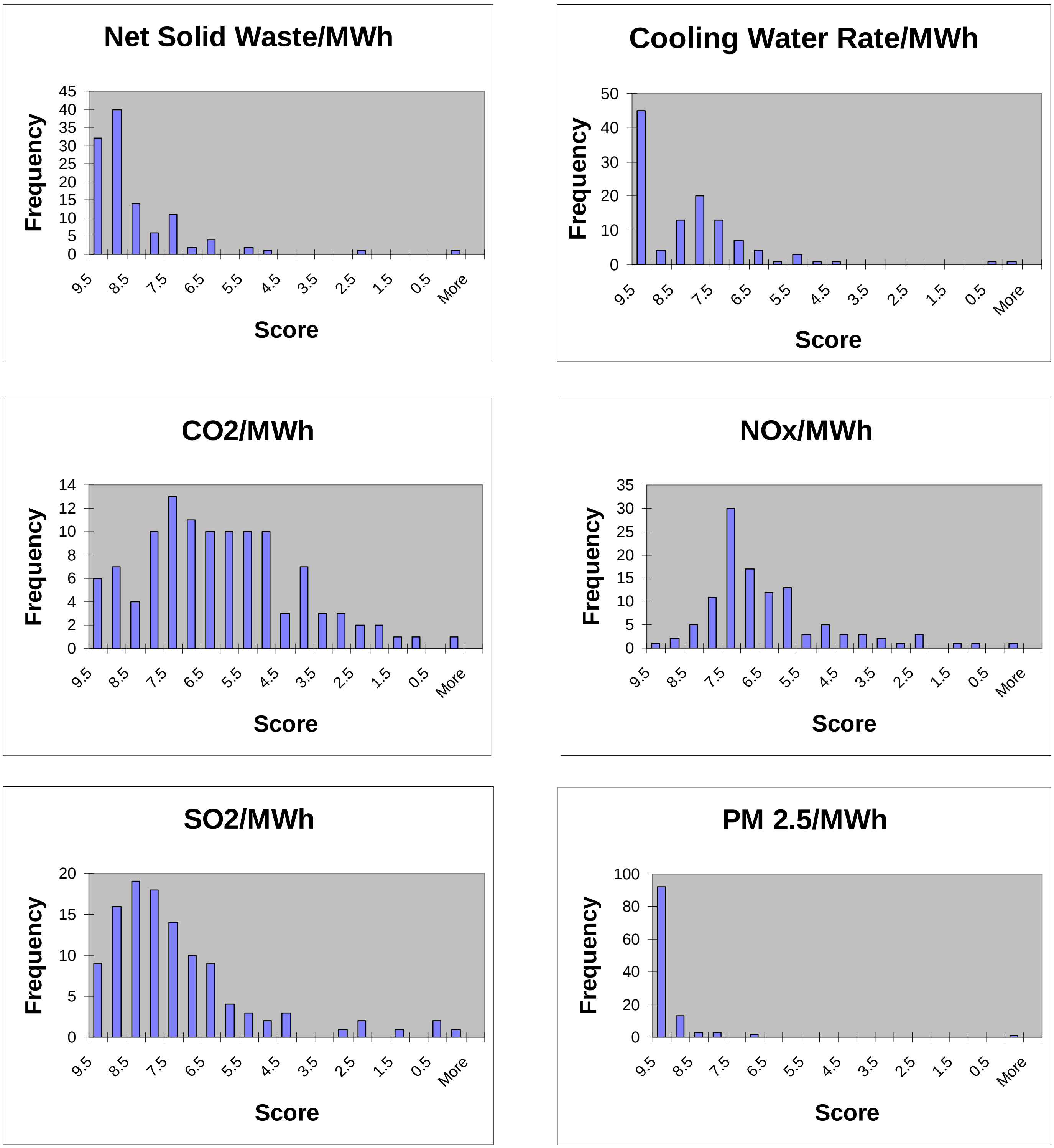
ORISID	Cool Water Score	Waste Score	NOx Score	SO2 Score	PM Score	CO2 Score	TotChem Score	Comp Score	NonCancer Score	Cancer Score	Generation (MWh)
3	8.33	8.89	7.70	8.17	9.79	8.15	7.03	9.17	9.12	5.62	11,275,532
8	7.95	9.63	6.04	6.05	9.77	7.17	4.94	8.33	8.71	1.56	7,918,986
26	8.92	9.14	7.58	7.37	9.96	8.01	7.32	7.50	9.56	8.99	12,156,657
50	7.10	7.73	6.69	8.48	9.88	5.27	7.06	1.67	9.08	7.19	9,275,346
56	9.57	9.02	6.93	7.93	9.86	6.05	9.53	5.83	0	9.67	3,372,923
108	9.98	9.33	8.42	9.78	9.84	5.57	7.66	10.00	9.89	9.93	2,506,971
130	9.96	9.11	8.38	9.54	9.91	8.31	9.40	10.00	9.59	9.41	7,034,387
136	9.98	7.65	7.42	8.75	9.87	7.71	5.73	10.00	9.95	9.94	8,984,904
165	9.97	9.42	7.86	9.15	9.45	6.06	8.71	3.33	9.99	9.95	6,389,854
298	9.97	5.21	7.70	9.10	9.85	6.30	7.82	9.17	9.49	9.92	10,862,901
470	9.97	9.68	8.57	9.11	9.87	7.62	9.43	10.00	9.99	10.00	4,563,838
525	9.98	9.27	7.53	9.36	9.59	4.01	9.22	6.67	10.00	10.00	2,965,760
527	9.96	7.57	8.49	9.34	8.92	2.79	10.00	10.00	9.99	10.00	645,033
643	8.16	9.33	7.49	2.85	9.69	6.77	0	10.00	8.78	9.93	2,431,439
645	7.49	7.93	6.29	6.63	8.64	6.52	7.33	3.33	8.74	8.15	9,052,398
862	5.46	8.97	5.00	1.55	9.31	4.39	7.34	8.33	9.96	10.00	473,969
887	8.81	9.75	9.17	9.14	9.95	5.97	9.62	8.33	7.31	9.98	8,120,314
976	8.67	5.71	2.76	6.01	9.54	2.79	8.29	9.17	9.96	10.00	1,397,356
981	6.55	10.00	6.27	9.10	9.73	6.97	9.36	8.33	10.00	10.00	2,328,697
983	7.53	9.53	5.83	8.07	9.22	8.49	6.95	3.33	9.09	8.97	8,531,868
988	7.48	9.44	3.66	7.29	9.97	8.18	3.17	3.33	9.56	8.81	5,904,840
995	8.12	9.11	0	9.65	9.55	5.19	8.89	8.33	9.75	9.93	2,849,214
1007	7.55	8.57	2.66	0.52	9.72	2.30	6.99	9.17	9.96	10.00	328,110
1250	9.98	9.54	7.79	9.62	9.28	4.40	8.94	10.00	9.99	10.00	2,463,511
1353	9.97	9.32	7.29	7.29	9.81	9.39	4.58	4.17	8.99	8.50	7,851,728
1356	9.91	8.61	7.53	8.51	9.88	6.54	6.06	10.00	9.18	6.45	12,726,690
1357	7.90	8.90	5.88	2.90	9.73	3.14	6.34	10.00	9.97	10.00	952,533
1361	7.63	9.27	4.26	6.91	9.85	0	5.33	10.00	9.90	10.00	214,335
1378	9.69	8.90	1.19	5.65	9.76	7.01	5.57	6.67	8.80	8.12	13,335,052
1379	7.44	9.17	6.84	8.61	9.79	5.05	8.36	10.00	9.96	9.99	8,050,431
1384	6.50	9.32	7.76	6.75	9.40	7.95	4.50	10.00	9.85	9.90	1,945,857
1573	7.20	9.55	6.82	6.75	9.64	9.48	5.15	8.33	9.81	9.14	7,385,229
1710	8.84	9.37	6.22	8.34	9.77	7.71	5.73	8.33	9.67	9.84	9,717,300
1731	5.52	9.54	5.18	7.75	10.00	7.42	3.29	10.00	9.84	10.00	231,050
1733	8.58	9.61	7.12	8.10	9.97	9.03	6.02	10.00	9.04	9.47	18,306,514
1832	10.00	9.72	7.67	7.84	9.87	7.49	6.25	10.00	9.93	10.00	980,479
2080	6.59	9.60	7.51	8.90	9.73	3.25	9.28	10.00	9.93	10.00	2,659,285
2094	8.39	9.55	3.09	7.28	9.96	7.38	9.59	8.33	9.92	9.99	3,037,714
2167	7.68	9.74	1.53	9.32	9.69	6.14	9.19	10.00	9.97	9.96	6,928,748
2168	8.38	9.73	6.09	9.29	9.85	5.84	9.23	6.67	9.97	9.96	8,560,665
2187	9.44	9.84	8.73	9.26	9.70	6.15	9.63	10.00	9.98	10.00	1,065,668
2277	9.97	9.39	5.06	9.39	9.84	5.31	8.29	10.00	9.96	10.00	1,347,971
2291	6.81	9.43	7.79	8.69	9.83	4.44	8.04	7.50	9.97	10.00	3,047,689
2364	8.61	9.77	6.97	5.89	7.35	6.76	6.05	10.00	9.91	9.97	2,706,942
2708	7.46	9.26	6.69	7.59	9.45	9.53	1.09	9.17	9.56	7.76	1,740,312
2709	9.78	9.29	6.59	7.14	9.20	5.85	1.79	10.00	9.49	6.95	1,714,394
2712	8.81	9.08	7.70	7.75	9.33	8.17	2.80	8.33	9.44	6.98	15,170,491
2713	9.95	9.03	7.40	7.63	9.65	7.57	0.45	10.00	9.57	8.06	2,693,035
2718	7.58	9.31	7.68	8.09	9.02	8.01	3.85	10.00	8.88	7.38	5,249,056
2721	9.13	9.53	7.69	7.88	8.13	8.85	4.20	10.00	9.14	2.92	3,748,154
2723	4.67	9.27	7.05	7.74	9.71	3.92	3.65	8.33	9.86	10.00	913,655
2727	8.34	9.37	7.85	8.12	8.35	9.40	4.20	10.00	8.92	8.40	12,336,874
2790	0	6.89	7.91	8.11	0	2.09	3.78	10.00	9.97	10.00	531,121
2823	8.39	8.38	5.36	7.47	9.85	3.75	6.49	10.00	7.28	6.64	5,162,108
2828	8.43	9.08	6.22	6.08	9.94	9.32	4.11	5.00	9.29	9.18	9,355,459
2836	7.81	9.41	3.96	7.02	9.80	6.61	5.52	5.83	9.77	8.97	3,491,559
2837	8.05	9.58	6.70	3.09	9.80	7.94	4.45	5.00	8.88	7.23	5,395,629

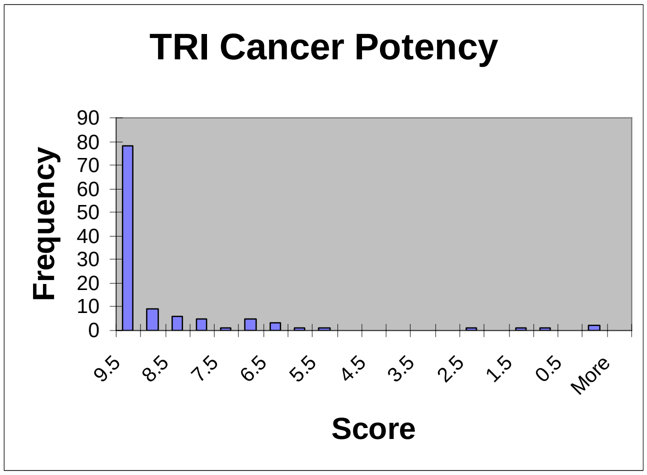
Table 11 (continued): Indicator Scores

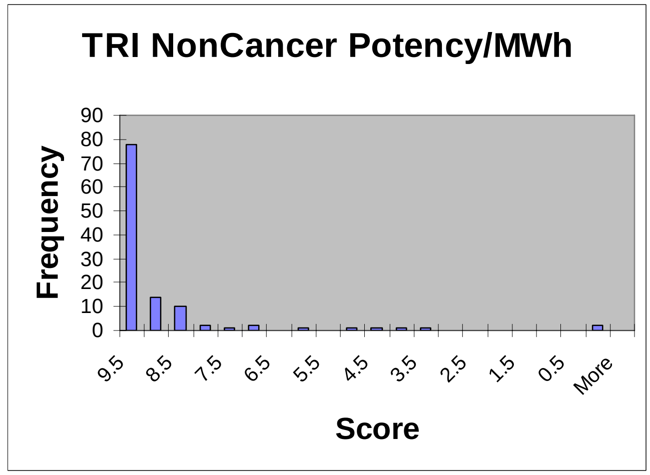
ORISID	Cool Water Score	Waste Score	NOx Score	SO2 Score	PM Score	CO2 Score	TotChem Score	Comp Score	NonCancer Score	Cancer Score	Generation (MWh)
2838	0.79	9.48	6.72	8.06	9.59	3.74	4.61	8.33	9.87	10.00	245,252
2840	9.45	8.50	7.36	4.95	9.93	7.84	6.11	10.00	4.69	7.06	9,216,949
2843	5.93	8.82	7.16	0	9.90	4.45	7.54	10.00	9.98	10.00	303,913
2861	8.15	8.17	4.21	4.86	9.90	7.71	2.16	6.67	9.86	10.00	1,205,001
2864	10.00	9.26	6.40	0.83	9.68	5.43	6.62	10.00	9.88	9.88	1,734,754
2866	8.59	9.15	5.77	6.79	9.82	8.22	6.69	3.33	9.43	8.59	14,918,796
2872	8.43	9.10	6.25	4.69	9.92	9.72	2.75	2.50	9.15	8.97	6,092,341
2878	5.62	9.58	6.01	9.23	9.77	9.08	9.44	4.17	9.91	10.00	3,025,501
3131	7.95	8.84	7.75	5.00	9.54	7.56	4.76	10.00	9.63	7.35	3,326,079
3280	9.89	9.40	7.41	6.73	7.02	8.40	7.02	10.00	9.93	10.00	1,155,390
3297	8.30	9.35	7.73	7.27	8.75	10.00	6.24	8.33	9.46	5.92	4,581,028
3298	7.86	9.55	7.22	8.27	9.81	7.66	7.73	10.00	9.94	10.00	4,462,825
3497	8.62	6.97	7.94	5.68	9.50	4.73	8.35	10.00	6.38	9.92	6,205,461
3644	9.97	9.37	7.52	8.92	9.60	6.60	8.38	5.00	9.97	10.00	1,220,255
3775	9.96	9.01	5.12	8.31	9.80	9.68	7.23	6.67	9.69	9.63	4,480,916
3776	7.58	9.12	6.28	7.49	9.74	6.04	7.67	10.00	9.94	9.94	2,009,115
3788	7.61	9.05	7.39	7.96	9.57	5.53	3.44	10.00	9.77	10.00	2,704,690
3796	8.36	8.83	4.90	7.57	9.89	6.80	6.07	10.00	9.89	10.00	1,248,460
3803	7.71	9.26	7.38	7.37	9.92	7.05	6.29	9.17	3.72	0	4,238,641
3845	9.97	7.93	7.42	6.77	9.90	5.28	8.57	10.00	9.91	9.93	8,639,745
3936	6.97	9.01	4.17	7.98	9.91	8.94	4.72	9.17	9.83	9.97	2,128,572
3942	10.00	8.77	7.00	5.46	9.66	5.21	3.74	10.00	9.87	10.00	1,174,949
3943	9.97	9.52	6.02	6.13	9.91	9.78	4.99	10.00	9.73	9.66	8,182,188
3944	9.95	7.58	7.40	9.93	9.95	7.73	9.50	10.00	9.65	9.25	13,657,289
3945	7.33	7.63	5.08	6.82	9.85	3.45	5.10	10.00	9.90	10.00	338,728
3954	8.18	8.36	6.16	6.91	9.93	7.38	6.96	9.17	4.03	0.43	10,730,715
4078	8.96	9.47	8.08	8.90	9.83	4.72	9.62	10.00	9.98	10.00	3,140,561
4143	8.33	9.80	8.02	8.11	9.72	8.95	3.09	5.00	9.72	10.00	2,060,855
4158	9.35	7.77	6.44	8.35	9.38	1.22	8.94	8.33	9.55	9.96	5,233,792
4162	9.97	9.51	6.95	8.57	8.47	4.30	9.66	7.50	9.99	10.00	4,703,429
6018	9.97	7.70	7.70	8.75	9.89	7.30	8.70	10.00	9.82	9.64	4,417,461
6021	9.98	9.51	8.11	9.69	9.83	7.44	8.92	10.00	9.85	9.99	8,635,673
6030	9.98	7.07	8.52	8.08	9.01	4.06	6.20	10.00	9.64	9.12	8,086,920
6061	9.97	8.99	7.25	8.97	9.89	6.14	8.13	9.17	9.97	10.00	2,097,353
6071	9.96	7.24	7.97	8.86	9.90	7.94	8.26	10.00	9.47	9.47	3,875,109
6077	8.57	9.65	7.78	9.22	9.63	6.24	8.72	10.00	8.95	9.89	8,027,362
6085	8.67	8.10	6.90	8.72	9.20	5.74	8.22	1.67	9.80	9.96	9,920,507
6094	9.94	6.79	8.32	9.43	9.97	8.84	8.69	5.83	0.21	1.48	13,286,274
6096	8.37	9.51	7.29	8.66	9.86	4.83	7.10	10.00	9.98	10.00	4,036,035
6098	9.98	8.99	2.57	7.72	9.80	7.45	5.73	10.00	9.99	10.00	3,541,832
6113	9.84	8.42	7.48	7.49	9.87	7.26	7.63	8.33	9.68	9.46	19,981,343
6137	10.00	7.67	7.17	8.87	9.68	5.13	8.79	5.83	9.99	9.98	3,004,505
6146	7.85	6.58	8.40	7.92	9.77	5.65	8.47	10.00	8.17	9.95	16,787,705
6165	9.97	8.76	7.87	9.85	9.68	6.72	9.44	10.00	9.78	9.97	9,493,581
6166	9.96	9.57	7.70	8.78	9.97	6.28	8.58	9.17	9.52	9.89	16,593,963
6178	8.14	9.68	9.01	8.57	9.92	9.29	8.36	10.00	9.99	10.00	4,743,619
6179	8.67	9.53	8.42	9.17	9.72	7.72	9.00	10.00	9.79	9.91	11,698,111
6183	8.16	0	7.68	7.71	9.88	1.70	9.04	10.00	10.00	10.00	2,934,817
6213	9.60	7.75	7.69	8.35	9.90	5.65	8.03	0	9.00	9.58	7,003,384
6248	9.97	9.61	8.82	8.72	9.87	6.18	9.59	10.00	9.99	10.00	3,982,368
6481	9.98	9.11	7.85	10.00	9.95	6.94	9.71	10.00	9.84	9.79	13,089,949
6648	10.00	5.75	8.10	8.08	9.62	5.85	8.35	10.00	7.93	9.99	4,656,761
6768	9.97	9.77	10.00	8.73	9.92	5.17	8.01	10.00	9.97	9.98	1,752,740
7213	10.00	8.59	8.54	9.99	9.98	7.09	9.14	10.00	5.18	9.73	6,388,981
7902	8.29	2.62	8.00	8.01	9.49	5.78	8.02	10.00	8.38	9.82	4,359,211
8023	9.99	9.57	7.68	8.63	9.92	5.27	9.99	10.00	9.89	9.90	6,664,990
8042	8.40	9.27	4.99	8.25	9.81	9.67	4.77	8.33	9.29	9.05	14,854,847
8069	9.97	9.21	7.91	9.46	9.71	8.03	8.86	10.00	9.74	9.97	7,131,471

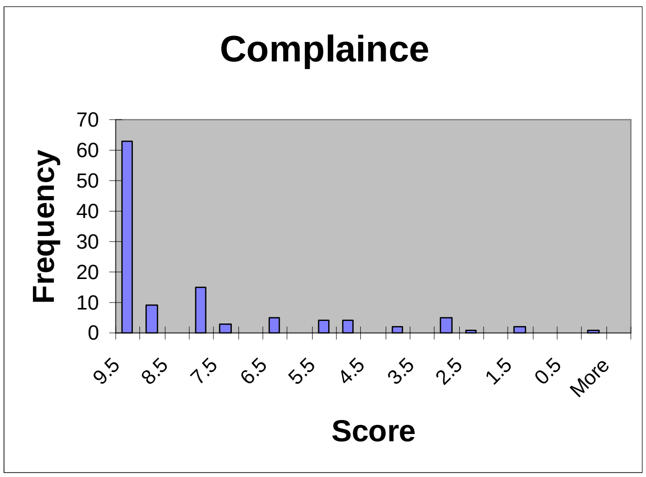
The scores for each indicator has its own unique frequency distribution (see Figure 5). Some indicators had one or a handful of poor performers, which bunched all of the remaining firms towards higher levels of performance. This phenomenon was most severe in the TRI

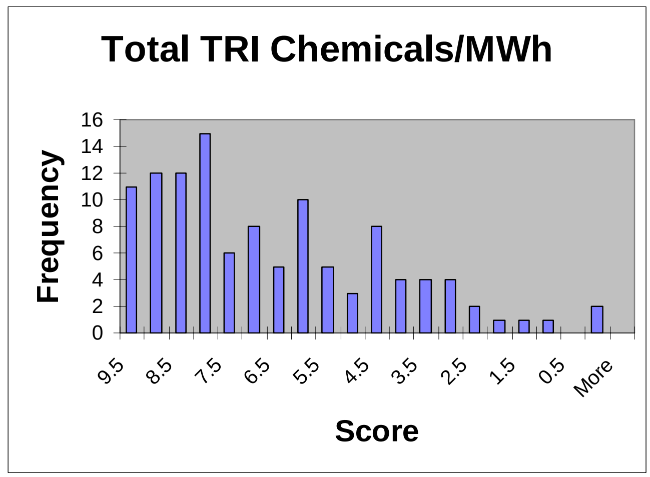
Figure 5: Indicator Frequency Distributions











TRI cancer, TRI non-cancer, and the PM 2.5 indicators. Strategies for dealing with these extreme values are discussed in the sensitivity analysis section of the report.

Most indicators had negatively skewed distributions, i.e., for a given indicator, most facilities were bunched in the upper end of the scale. In addition, those with negatively skewed distributions, also had high kurtosis (tightness of bunching around the mean).

5.2. Performance Ranking

After developing methods to rank individual metrics, a next more controversial step is to develop methods to combine and rank multiple metrics. There are many different possible methods for combining multiple metrics. In this project, Pure Strategies tested the approach used in Indonesia to weigh between environmental performance categories that employs a ranking scheme with maxima/minima conditions. Under this scheme, a firm's overall results is subject not only to performing well in a host of indicators, but to performing at a minimum level for any given indicator. Table 12 shows how this method might be applied to the 0-10 rating scores suggested by the National Academy of Engineering.

Table 12: Performance Ranking Scheme

	Ranking	Criteria
highest	A	More than 50% of the indicators to be 9 or higher, none rated 7 or below
↑	B	More than 50% of parameters to be rated 7 or higher, and none rated 5 or below
	C	More than 50% of parameters to be rated 5 or higher, and none rated 3 or below
	D	Any other combination, but no parameter rated 3 or below
lowest	E	Any parameter rated 3 or below

One of the main issues in developing a composite index is whether or not it is desirable to allow poor performance in one area to be compensated for by good performance in another. While this might (in certain cases) be a desirable approach, the information on the elasticity of substitution across indicators is unknown. Therefore developing a composite index requires a number of potentially arbitrary assumptions (i.e., greenhouse gas emissions are more important than N0x emissions). The rating method outlined in Table 12 does not make all indicators equal, but does ensure that abysmal performance in any one category can diminish a facility's overall ranking. This methodology allows one to manipulate four criteria for the ranking using the following scheme:

"V indicators of X or higher, Y indicators rated Z or below";

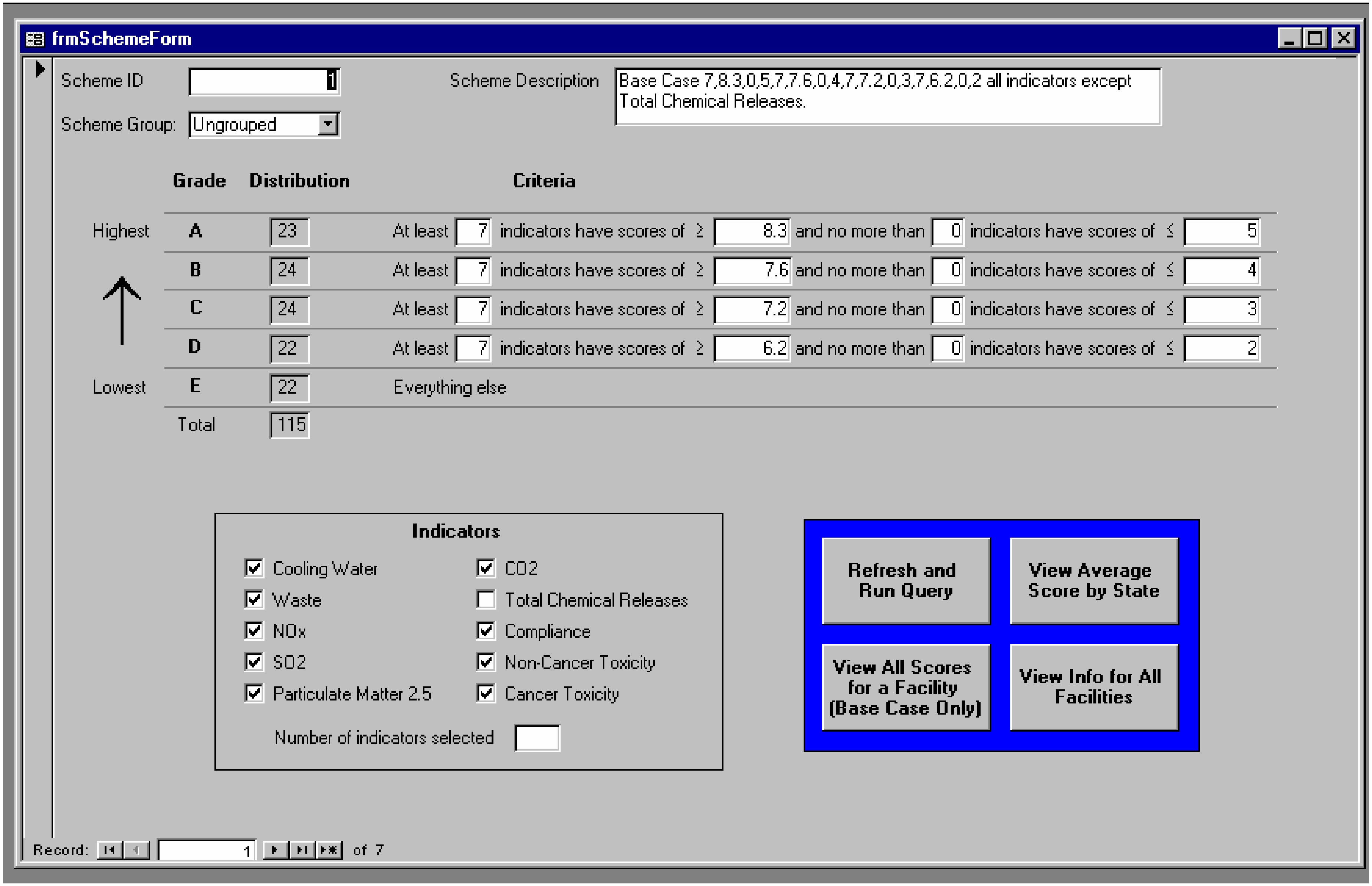
where the criteria variables defined as:

W: High Performance number of indicators
X: High Performance minimum score
Y: Lowest performance number of indicators
Z: Low performance, minimum score

This methodology gives the benchmarker the flexibility to adjust any of these four variables. Note that the criteria for each consecutive ranking (i.e., as one moves from "A" ranks to "B" ranks, to "C" ranks, etc) should reflect lower levels of performance (i.e., lower values for W, X, Y, or Z).

In order to adjust these variables, Pure Strategies developed an Access database. The database allows the benchmarker to (a) select which of the ten indicators to benchmark with and (b) set the criteria variables (W through Z). The database also allows the user to generate reports and conduct sensitivity analysis. See Figure 6 for a screen shot of the database user interface.

Figure 6: Screen Shot of Database



5.3. Applying the Methodology – The Base Case

When applying the methodology to the coal-fired electric generation sector, Pure Strategies defined a "base case". For the base case we selected a set of nine indicators (see Table 13 below). We could choose a different group of indicators (e.g. 5) for our base case. We selected the nine indicators in Table 13 since they reflect the major environmental impacts of the sector. The only indicator of the ten we originally developed which we did not choose is "Total TRI releases". Staff felt that toxic impacts were better represented in the TRI cancer and TRI non-cancer indicators.

Table 13: Base Case Indicators

Cooling Water Use
Net Waste Generation
NOx
SO2
Particulate Matter (2.5 microns)
CO2
Non-Cancer Toxicity
Cancer Toxicity
Compliance

One central question when using this methodology is how to select the values of criteria variables W, X, Y, and Z. One approach is to set predetermined values for the criteria variables – for example for "A", W= 7, X = 8, Y = 4, Z = 2 and similarly for "B", "C" & "D". This method however, depending on the dataset, could lead to very uneven ranking results– e.g., put every firm into a single ranking or rank everyone A, B or C with no facilities in D or E. When using a predetermined set of criteria values, one cannot predict a-priori the distribution of grading scores.

When experimenting with the scoring system, Pure Strategies found it desirable to set a target distribution of firms in the different rankings and then adjust the variables to meet this target. For example, we set a uniform distribution where we wanted roughly 23 firms in each of the five ranks (for a total of 115 firms). We then adjusted the criteria variables to achieve this uniform distribution. Another possible distribution choice is the normal distribution where most firms are ranked C, fewer are ranked B or D, and very few are ranked A or E. The decision regarding whether to select a target distribution is a subjective one. Figure 7 depicts various possible distributions of firm rankings.

We chose as our target a uniform distribution meaning that each of the five grades would have roughly 22 facilities (5 * 23 = 115). We could also have chosen a different target distribution (e..g. normal) for our base case. We selected a uniform distribution simply because we wanted to see near equal numbers of facilities in each of the five ranking categories.

After selecting the indicators and distribution, Pure Strategies manipulated the criteria variables (W, X, Y & Z) for each grade in the database program to achieve the uniform distribution. Table 14 depicts the criteria variables for each ranking as well as the number of firms for each ranking.

Figure 7: Sample Grading Distributions

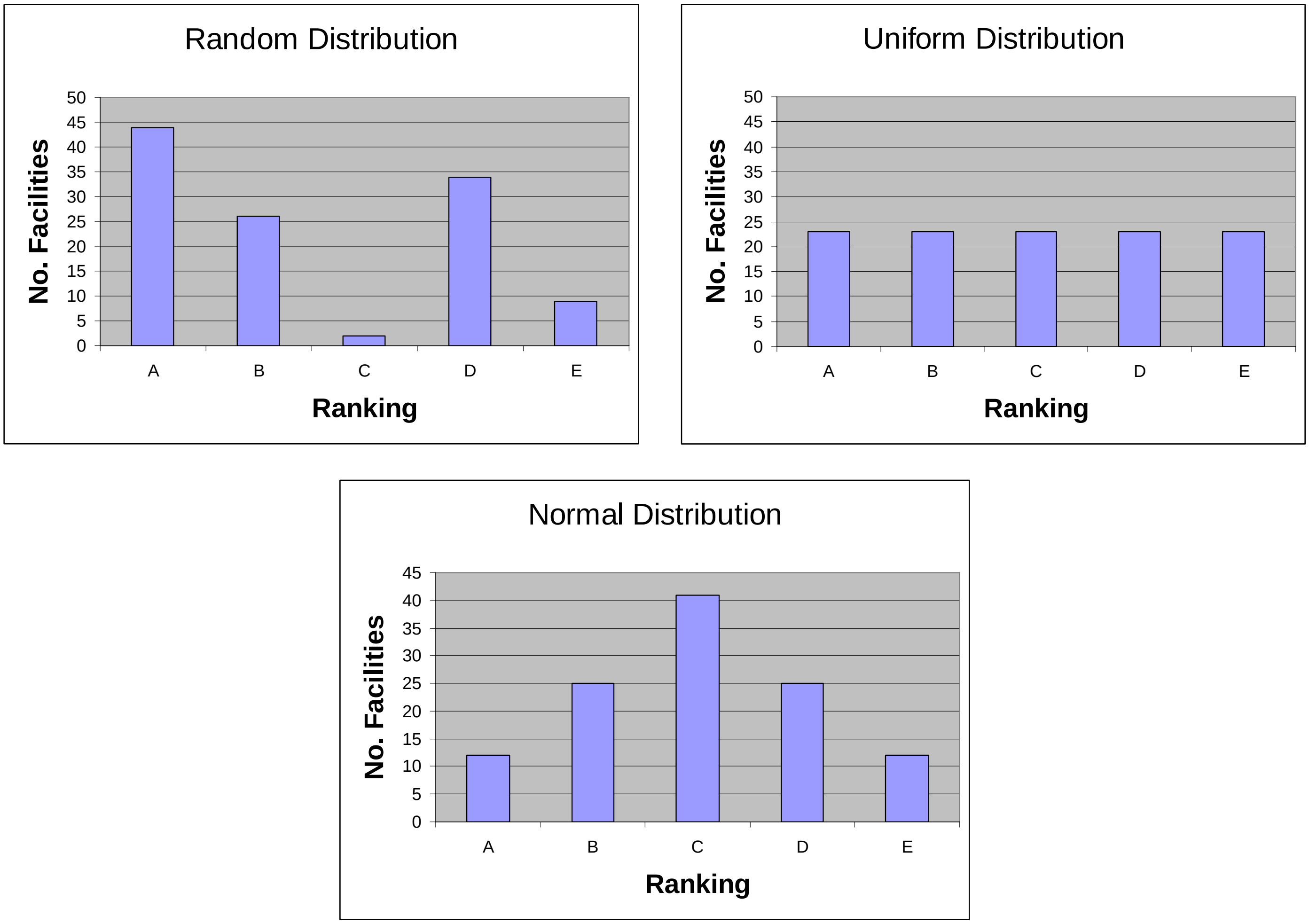


Table 14: Base Case Variable Criteria and Benchmarking Distribution

Rank	No. Firms	Criteria
A	23	More than 7 indicators with scores ≥ 8.3 or higher, no more than 0 indicators with scores ≤ 5
B	24	More than 7 indicators with scores ≥ 7.6 or higher, no more than 0 indicators with scores ≤ 4
C	24	More than 7 indicators with scores ≥ 7.2 or higher, no more than 0 indicators with scores ≤ 3
D	22	More than 7 indicators with scores ≥ 6.2 or higher, no more than 0 indicators with scores ≤ 2
E	22	All other facilities

A careful review of the grading criteria shows that for the base case, any facility that had a poor score (i.e., ≤ 2) for one or more indicators, received an "E" ranking. This is obviously a subjective decision – others might want to set the grading criteria in rankings A through D to allow a facility to have one very low score. This could be accomplished, for example, by setting set Y = 1 and Z = 0 for rankings A through D. The base case results, shown in Table 15, shows the ORIS ID, Rank, State and Plant Name of all 115 facilities. On average, one would expect midwestern plants to rank lower than eastern or western plants – this is because of tighter

Table 15: Base Case Facility Rankings

ORIS ID	Rank	EG State	Plant Name
3943	A	WV	FORT MARTIN
6061	A	MS	R D MORROW
108	A	KS	HOLCOMB
6248	A	CO	PAWNEE
470	A	CO	COMANCHE
6178	A	TX	COLETO CREEK
8023	A	WI	COLUMBIA
130	A	SC	CROSS
8069	A	UT	HUNTINGTON
6768	A	MO	SIKESTON
887	A	IL	JOPPA STEAM
3775	A	VA	CLINCH RIVER
6021	A	CO	CRAIG
6165	A	UT	HUNTER
1710	A	MI	J H CAMPBELL
6179	A	TX	FAYETTE POWER PRJ
2727	A	NC	MARSHALL
6481	A	UT	INTERMOUNTAIN
6166	A	IN	ROCKPORT
1733	A	MI	MONROE
6077	A	NE	GENTLEMAN
2187	A	MT	CORETTE
2277	A	NE	SHELDON

ORIS ID	Rank	EG State	Plant Name
2713	B	NC	L V SUTTON
7213	B	VA	CLOVER
6096	B	NE	NEBRASKA CITY
1832	B	MI	ERICKSON
4078	B	WI	WESTON
6648	B	TX	SANDOW
3298	B	SC	WILLIAMS
6018	B	KY	EAST BEND
136	B	FL	SEMINOLE
298	B	TX	LIMESTONE
6071	B	KY	TRIMBLE COUNTY
3788	B	VA	POTOMAC RIVER
6030	B	ND	COAL CREEK
1250	B	KS	LAWRENCE EC
2718	B	NC	G G ALLEN
3944	B	WV	HARRISON
3936	B	WV	KANAWHA RIVER
8042	B	NC	BELEWS CREEK
4143	B	WI	GENOA
2712	B	NC	ROXBORO
1384	B	KY	COOPER
6146	B	TX	MARTIN LAKE
3297	B	SC	WATEREE
3	B	AL	BARRY

ORIS ID	Rank	State	Plant Name
2708	C	NC	CAPE FEAR
3497	C	TX	BIG BROWN
165	C	OK	GRDA
3280	C	SC	CANADYS STEAM
1573	C	MD	MORGANTOWN
1353	C	KY	BIG SANDY
1379	C	KY	SHAWNEE
3845	C	WA	CENTRALIA
988	C	IN	TANNERS CREEK
2840	C	OH	CONESVILLE
26	C	AL	E C GASTON
1356	C	KY	GHENT
1731	C	MI	HARBOR BEACH
983	C	IN	CLIFTY CREEK
3796	C	VA	BREMO BLUFF
2094	C	MO	SIBLEY
3776	C	VA	GLEN LYN
6113	C	IN	GIBSON
3131	C	PA	SHAWVILLE
3644	C	UT	CARBON
2291	C	NE	NORTH OMAHA
2080	C	MO	MONTROSE
4162	C	WY	NAUGHTON
525	C	CO	HAYDEN

ORIS ID	Rank	State	Plant Name
2168	D	MO	THOMAS HILL
527	D	CO	NUCLA
2872	D	OH	MUSKINGUM RIVER
645	D	FL	BIG BEND
2723	D	NC	DAN RIVER
2364	D	NH	MERRIMACK
3945	D	WV	RIVESVILLE
643	D	FL	LANSING SMITH
981	D	IN	STATE LINE ENERGY
2866	D	OH	W H SAMMIS
2709	D	NC	LEE
2828	D	OH	CARDINAL
2823	D	ND	MILTON R YOUNG
6137	D	IN	A B BROWN
2861	D	OH	NILES
56	D	AL	CHARLES R LOWMAN
2836	D	OH	AVON LAKE
6098	D	SD	BIG STONE
2721	D	NC	CLIFFSIDE
3942	D	WV	ALBRIGHT
7902	D	TX	PIRKEY
2837	D	OH	EASTLAKE

ORIS ID	Rank	State	Plant Name
1007	E	IN	NOBLESVILLE
1361	E	KY	TYRONE
2843	E	OH	PICWAY
6094	E	PA	BRUCE MANSFIELD
1378	E	KY	PARADISE
4158	E	WY	DAVE JOHNSTON
2838	E	OH	LAKE SHORE
2864	E	OH	R E BURGER
976	E	IL	MARION
995	E	IN	BAILLY
2878	E	OH	BAY SHORE
3954	E	WV	MT STORM
6085	E	IN	R M SCHAHFER
862	E	IL	GRAND TOWER
2790	E	ND	HESKETT
2167	E	MO	NEW MADRID
50	E	AL	WIDOWS CREEK
6183	E	TX	SAN MIGUEL
6213	E	IN	MEROM
8	E	AL	GORGAS
1357	E	KY	GREEN RIVER
3803	E	VA	CHESAPEAKE

controls in the east and the availability of low sulfur coal in the west. To check this assumption, Pure Strategies conducted an analysis of state scores (see Table 16). To compute an average state score, we set A rankings = 4 points, B rankings = 3 points, C rankings = 2 points, D rankings =1 point and E rankings = 0 points. Table 16 includes not only the state and its average score, but also the number of facilities in the database for each state. The results show that a Midwestern state (Ohio) has the lowest average state score. There are some surprising results however, since Wyoming (a western state) also has a low average score.

What appears to be driving theses results? A careful analysis of the distributions of the individual indicator scores shows that for some of the indicators, most of the facilities had high scores. Table 17 shows that for 5 indicators, ≥ 90% of facilities had scores > 7.0. Thus the indicators that appear to have driven the facility rankings appear to be those with more uniform distribution – compliance, SO_2, NO_x, and CO_2.

Table 16: State Average Score

State	Average Score	No of Facilities
MS	4.00	1
MT	4.00	1
KS	3.50	2
UT	3.50	4
WI	3.33	3
MI	3.25	4
NE	3.25	4
CO	3.00	5
SC	3.00	4
TX	2.50	8
NC	2.33	9
VA	2.33	6
MD	2.00	1
OK	2.00	1
WA	2.00	1
WV	2.00	6
MO	1.80	5
FL	1.67	3
KY	1.67	9
IL	1.33	3
ND	1.33	3
AL	1.20	5
IN	1.20	10
NH	1.00	1
PA	1.00	2
SD	1.00	1
WY	1.00	2
OH	0.73	11

Table 17: Percent of Scores >7.0

Indicator	% > 7.0
PM	99%
NonCancer	97%
Waste	93%
Cancer	90%
Cool Water	90%
Comp	79%
SO2	75%
NOx	58%
CO2	45%

Pure Strategies also analyzed the relationship between net generation and facility rankings. We found that the mean net generation of plants with "A" ranks was twice that of plants with "E" grades (see Table 18).

Table 18: Mean Net Generation

Ranking	Mean (MWh)
A	7,032,487,987
B	6,501,375,377
C	6,744,745,654
D	5,761,095,319
E	3,257,030,319

Pure Strategies also reviewed its ISO 14000 database to determine the average score of facilities with ISO certification. We found only two plants that are both owned by Northern Indiana Public Service Company – the Baily and R M Schahfer locations). Both of these plants had "E" rankings.

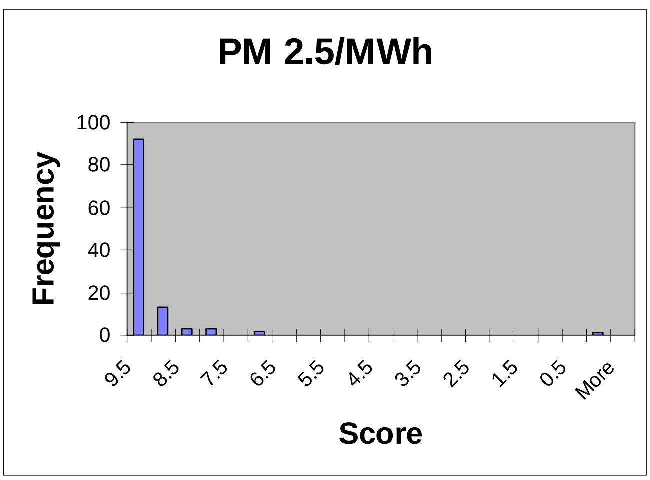
5.4. *Sensitivity Analysis*

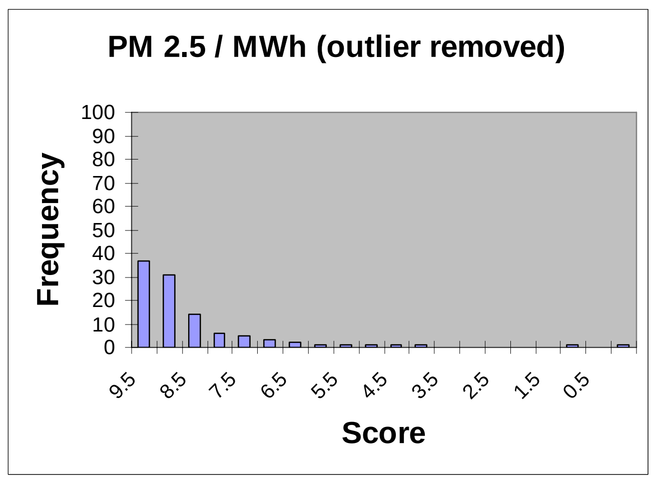
Pure Strategies conducted some limited sensitivity analysis on what parameters drove the benchmarking results. This section discusses this limited analysis and outlines other types of analyses that one could conduct.

Removing Outliers

As discussed earlier in the report, there were a number of facilities that had very extreme values for certain indicators. To understand their leverage on the data, Pure Strategies ran series of descriptive statistics analysis (e.g., mean, standard deviation, range, variance, kurtosis) and identified obvious outlines in the data[10]. For example, when the facility with very high PM 2.5 is removed from the dataset (ORIS ID 2790 Heskett Plant owned by MDU Resources Group, Inc and located in ND), the entire distribution shifts right (see figure 8). As a result, few facilities have near perfect PM 2.5 indicator scores. Outliers should not be removed from the database simply because they skew the benchmarking results. Outliers should be identified and investigated, however, to ensure they correctly reflect facility conditions.

Figure 8: Removing Outliers



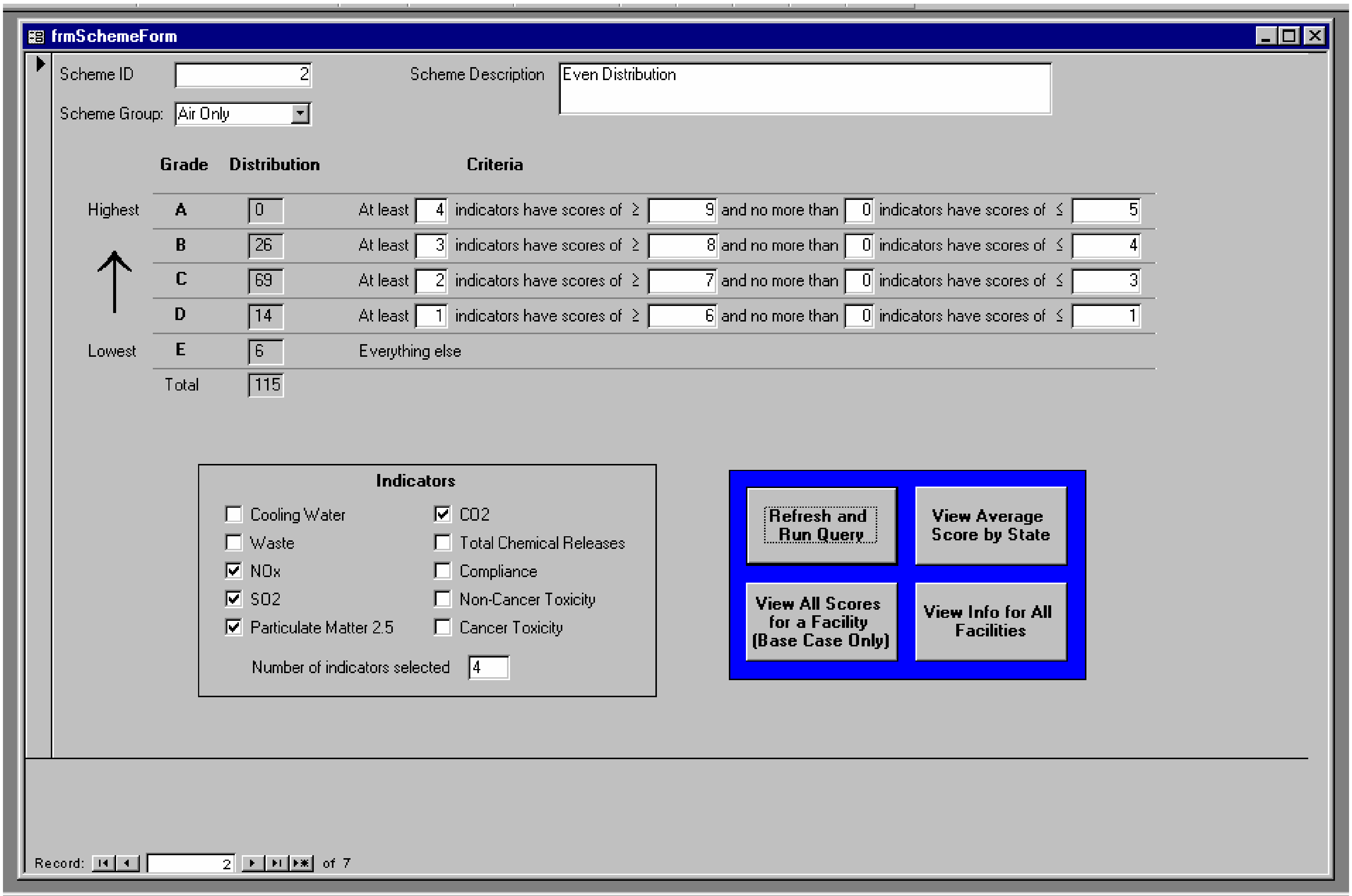


Choice of Indicators

One obvious analysis is to choose fewer or more indicators to benchmark. For example, one could choose only air indicators, only toxics indicators, or all ten indicators. Changing the number of indicators would also require modifying the criteria variables (e.g., values for W, X, Y, and Z). Figure 9 presents results where only air indicators (NOx, SOx, PM 2.5 and CO2) are included in the analysis. The database program makes many permutations possible when selecting indicators.

[10] In a more formal benchmarking study, we would recommend giving industry an opportunity to review and confirm the accuracy of “extreme” data points.

Figure 9: Analysis Using Air Indicators Only



Grading Criteria

The database program permits the adjustment of criteria variables W, X, Y and Z. The criteria levels can be adjusted for each level. We used the criteria variables to achieve different types of benchmarking distributions (e.g., normal or uniform).

6. Challenges and Limitations

The goal of this effort was to develop a methodology for selecting and benchmarking industrial environmental performance at the facility level. This project built off of prior efforts by Pure Strategies to define a benchmarking methodology. This effort however represents the first attempt to field test the methodology with actual data.

Overall, the effort succeeded in applying the methodology. Pure Strategies developed a very flexible database program that allows the benchmarking user to select various indicators for benchmarking, adjust various grading criteria, and run sensitivity – all with considerable ease. Nevertheless, the effort presented some serious challenges.

Old Data:

The lack of current air data in the NEI database meant that we were forced to use 1999 data. Obviously, the more current the data the more pertinent the analysis. It is unlikely that this situation will change in the near future, as it appears that EPA will continue to collect air data from states only every three years for the foreseeable future. Note that our use of old air data required us to use older data from other databases. In the case of compliance data, EPA maintains compliance data for the two most current years on its website (under the ECHO database) – older compliance data however requires one to file a special request to EPA to directly query the IDEA compliance database.

There is one time-intensive method for collecting for current air data – to got directly to the states themselves. However, this would require getting 50 different database administrators to provide data – something that is unlikely to happen within the schedule of most benchmarking projects. And if one successfully obtained data from all 50 states, they would still have to link facility ID's to the ID's in other databases.

Lack of Common Facility ID

Although EPA has had its FRS facility ID program in place since 1996, there are serious glitches when it comes to air data. This is because numerous states assign new air program Ids ID's every year. The lack of a consistent ID from year to year makes it all the more time consuming (and costly) for EPA staff to provide a FRS ID that includes data from all of EPA's programs.

Lack of On-Line Data Access

Although researchers can access EPA data on line through the Agency's Envirofacts web site, Envirofacts only permits rather limited queries. Furthermore, while obtaining data for a single facility is rather simple, it is much more difficult (if not impossible) to directly download all the data needed for a benchmarking study such as the one conducted here.

In this project, Pure Strategies obtained our data directly from each of the source databases (EGRID, NEI, TRI, IDEA, EIA) as opposed to querying the FRS system based on facility ID. Staff looked into directly querying into the EnviroFacts database to pull out the necessary data. However, to query directly into Envirofacts, one needs:

- Specialized software – Oracle SQL*Net/Net8
- A user ID
- Permission granted by EPA (e.g. by a work assignment manager)
- Secure Remote software
- A Tssmss Account (provided by EnviroFacts)

Our benchmarking methodology does have some limitations. This study was performed on a sector with publicly available production data. .In our literature review, we found that relatively few sectors have publicly available production data to normalize environmental data. Other normalizing factors such as the number of employees or the use of capacity factors are likely to be poor substitutes for actual production data. Future tests of this benchmarking model could use the TRI activity index to benchmark changes in release (i.e., benchmark facilities that have improved (or worsened) over time – as opposed to their actual performance. Another option would be to obtain production data directly from industry – perhaps by including industry directly in the benchmarking effort through a trade association.

Another obvious limitation is the need for a well-defined sector. We used the TRI Chemical Use Activity Codes to define sectors. Some sectors however, are too small to report TRI data. Furthermore, some sectors by their very definition (Such as SIC Code 3499 -- Fabricated metal products, not elsewhere classified) include firms involved in very unrelated metal manufacturing.

Despite these challenges and limitations, the methodology used in this effort provides a readily understandable, flexible and rather straightforward way to conduct benchmarking analysis. Potential audiences for the methodology include government agencies, industry sectors, and non-profit organizations.

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8. Appendices

8.1. ISO 14000 Certified Firms and Sector Profile

Company	Sector	No. Facilities ISO 14000 Certified
Eaton Corp	Auto, aerospace	44
Ford	Auto	39
General Motors	Auto	31
Federal-Mogul	Auto	30
Dana Corp	Auto	29
Visteon Corporation	Auto	29
3M Company	Various	28
Weyerhaeuser Company	Paper	27
Lockheed Martin	Military	24
Motorola	Electronics	22
Lear	Auto	21
Delphi	Auto	19
Matsushita	Various	19
Northern Indiana Public Service Co.	Utility	18
Volvo	Auto	18
ABB	Engineering	17
Daimler Chrysler	Auto	17
Johnson Controls	Auto, other	17
Osram Sylvania	Lighting	17
Toyota	Auto	15
Sony	Various	14
Autoliv ASP, Inc.	Auto	12
Consolidated Edison Company	Utility	11
ITT	Various	11
Textron	Auto	11
AKZO Nobel	Chemicals	10

8.2. Regulatory Issues

From a regulatory standpoint, air quality regulations generally have the greatest economic effect on the operation of coal-fired plants. The amount of coal used in electricity generation is limited primarily by existing and future air quality regulations and technology innovations that allow for cleaner coal burning. Supply issues are not limiting coal use since the supply of coal exceeds demand. Furthermore, coal is cheaper than most other sources of fuel.

The *Clean Air Act Amendments 0f 1990* have had a significant impact on the coal-fired electric utility sector. The Act mandated stringent reductions in emissions of sulfur dioxide -- emissions from all electric utilities declined 25% from 1985 to 1995 – from 15.6 to 11.9 million tons. The Act introduced an emissions cap and trade program whereby utilities could reduce their own emissions or purchase emissions reductions from other utility plants.

The regional NOx Transport Rule, finalized in 1998 requires significant changes at many coal-fired electric plants. The rule requires 22 states to institute measures to decrease their overall emissions of nitrogen oxides. The largest sources must have controls in place by 2003 and meet the overall NOx limits by 2007. Although the Rule provides flexibility regarding how to meet the NOx limits, most states have imposed reductions on many of their coal-fired utility plants.

The Regional Haze Rule of 1999 addresses visibility impacts on national parks and wilderness areas. It establishes more stringent ozone and PM2.5 standards and will impact facilities in proximity to these areas.

The recent Bush Administration final and proposed changes to the New Source Review program make it possible for utilities to make extensive changes to existing facilities without needing to install new pollution control equipment. The most important provision for older coal-fired utilities, which were grandfathered under the 1977 amendments to the Clean Air Act and were thus effectively exempt from many pollution control requirements, is the proposal for relaxing the definitions of "routine" maintenance, repair and replacement. This change could significantly impact current EPA/DOJ litigation against such grandfathered utilities, many of which would have been required to classify many modifications to existing facilities as creating new sources. Under a 1999 court ruling, the utilities would have been required to meet more stringent best achievable control technology (BACT) or lowest achievable emission reduction (LAER) standards.

Under section §316(b) of the Clean Water Act, EPA is developing regulations on the cooling water intake structures. Section §316(b) requires that the location, design, construction and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impacts. More than 1,500 industrial facilities use large volumes of cooling water from lakes, rivers, estuaries or oceans to cool their plants, including steam electric power plants

Lastly, in the solid waste arena, the EPA Office of Solid Waste completed regulatory determinations in 1993 and 2000 on large-volume wastes from coal-fired electric utilities. The regulatory determinations permanently exempt fossil fuel combustion wastes from utilities from hazardous waste regulation.

8.3. *Compliance Indicator Notes*

The following was taken from the OTIS *Detailed Facility Report* Help Screen, and edited to include additional data value descriptions, and mention of historical HPV/SNC tracking.

Current SNC/HPV
The current Significant Non-compliance (SNC) or High Priority Violator (HPV) status for the facility during the most current quarter reflects the time the records were extracted from the program data systems. SNC is used for RCRA and CWA, and HPV is used for CAA. Each program has its own specific criteria for making this determination. A brief summary of each program's definition is shown below. However, these summaries are not meant to substitute for the complete definition, which can be found in the relevant guidance documents for a given program.

Air HPV Definition - The Air program uses the term HPV. HPV designations are made according to the December 22, 1998 memo: Issuance of Policy on Timely and Appropriate Enforcement Response to High Priority Violations. The following criteria can trigger HPV status:

Failure to obtain a Prevention of Significant Deterioration (PSD) permit
Violation of an air toxics requirement
Violation by a synthetic minor of an emission limit that affects the source's regulatory status
Violation of an administrative or judicial order
Substantial violations of a sources Title V obligations
Failure to submit a Title V permit application within 60 days of the deadline
Testing, monitoring, record keeping or reporting violations that substantially interfere with enforcement or determination of a facility's compliance requirements
Violation of an allowable emission limit detected during a source test
Chronic or recalcitrant violations, or
Substantial violations of 112 (r) requirements

In the Air program, the HPV designation is removed for a given facility once the facilities has demonstrated that it has resolved the violation that led to the HPV listing.
The High Priority Violation (HPV) flag is reported in the Air Facility System (AFS), as of the last IDEA refresh of AFS. Below is a list of violation codes within AFS that translate to HPV status.

B - Unaddressed, Shared Lead (EPA and State)
C - Addressed, Shared Lead (EPA and State)
E - Unaddressed, EPA Lead
F - Addressed, EPA Lead
S - Unaddressed, State Lead
T - Addressed, State Lead
X - Unaddressed, Lead Undetermined

These HPV status values are retained by IDEA on a monthly basis to facilitate historical compliance analyses.

The status of "Addressed" indicates that a formal action has been taken against the facility but its violations have not yet been resolved, or that a decision not to take a formal action has been made. "Unaddressed" indicates that the facility's violations have not yet been addressed with a formal enforcement action or the decision to do so has not yet been made.

CWA SNC Definition - The NPDES program uses the term SNC. SNC designations are made in accordance with the December 12, 1996 guidance document: A General Design for SNC Redefinition Enhancement in PCS. Most SNC designations are based on an automated analysis of Discharge Monitoring Reports (DMRs) that facilities with NPDES permits are required to submit on a monthly basis. The compliance designation of a facility in the PCS database is done using a mathematical formula that takes into account the amount, duration, and frequency of discharges in comparison with permit levels. This designation is stored in PCS as a Quarterly Noncompliance Report (QNCR) flag value, and while it is calculated for all permits, it is nationally required only for active, major discharger permits. In some instances facilities may be manually designated as SNC, even if the PCS data system does not automatically designate them as such. Examples of events that could result in the manual generation of a SNC code for a facility include: unauthorized discharges; failure of a POTW to enforce its approved pretreatment program; failure to meet a construction deadline; failure to file a DMR; filing a DMR more than 30 days late; or violating any judicial or administrative order. Manually entered compliance data, if present, override machine-generated compliance data.

A facility may have multiple discharge points and different designations for each point. If any of these points show a SNC type code, then the overall facility status is listed as SNC, even if other discharge points are in compliance.

Removal of the SNC designation occurs once the facility's DMR reports show a consistent pattern of compliance with permit limits, or if EPA or a state agency issues a formal enforcement order to address the violations that resulted in the SNC designation.
The most recent quarter for PCS is the most recent official quarter for which the quarterly status is available. This is usually 2 1/2 months after the quarter has ended. Thus, the most recent quarter in PCS is often not the same quarter as that for AFS and RCRAInfo. Below is a list of QNCR codes within PCS that translate to SNC status.

D - SNC DMR Non-Receipt
E - SNC Effluent Violation
S - SNC Compliance Schedule Violation
T - SNC Compliance Schedule Reporting
X - SNC Effluent Non-monthly Averaging

These QNCR status values are retained by IDEA on a quarterly basis to facilitate historical compliance analyses.

<u>RCRA SNC Definition</u> - The RCRA program uses the term SNC. Any determination to classify a facility as a SNC is made using the guidelines set forth in two EPA documents 1) a March 15, 1996 memo titled A Hazardous Waste Civil Enforcement Response Policy, and 2) an April 25, 2000 memo titled A Transmittal of Addendum to the 1996 Hazardous Waste Enforcement Response Policy. A facility can be designated as a SNC if any of the following are found to exist: the facility has been determined to cause actual exposure or a has a substantial likelihood of causing exposure of a hazardous waste or constituent; is a chronic or recalcitrant violator; or deviates substantially from the terms of a permit, order or agreement, or from RCRA statutory or regulatory requirements. Under the RCRA program, the SNC designation is removed for a given facility when the facility is in full physical compliance with statutory and/or regulatory requirements or when they are in full compliance with a compliance schedule established in a formal enforcement action by either EPA or the state agency. IDEA creates an SNC Status flag in its copy of the RCRAInfo database that reflects the status as well as which Enforcement Response Policy guideline was applied to make the determination of SNC. Possible flag values are 1A through 5, with values 4 and 5 applying the most current SNC policies. These status values are retained by IDEA on a monthly basis to facilitate historical compliance analyses.

Attached below is an email from EPA staff regarding how to define what facilities to include in the compliance database search:

Mike Barrette forwarded your request to me for analysis, and I have a
>fairly basic question regarding the selection criteria as described in
>Mike's email below. Selecting facility records by SIC code has always
>been problematic, due to the facts that some Agency data systems
>accommodate multiple codes for each facility (or permit) without
>prioritization, and that even with prioritization, different data
>systems (or different permits within the same data system) may disagree
>as to a facility's primary SIC code. There are a couple of ways of
>addressing this issue.
>
>One way is to not consider FRS facility linkage, and run three separate
>queries against the AFS, PCS and RCRAInfo databases using their primary
>SIC values. This has the disadvantage of possibly selecting a
>different set of facilities from each database.
>
>Another is to use the "designated SIC" that IDEA derives for each
>FRS-linked facility. It applies a hierarchical logic to the SIC data
>from the linked permits to arrive at one SIC: it selects from TRIS
>records first (under the assumption that since that data is reported
>annually, it is more current, and possibly more accurate than other
>data). If there is no TRIS link, it then assembles the primary SIC
>codes from any linked air, water, or RCRA permits, and checks to see if
>two or more agree at the four or three digit level. If not, the SIC
>code is assigned from the first SIC value from PCS, AFS, BRS, RCRAInfo,
>NCDB, or the Civil Enforcement Docket, respectively.

>
>Using these options, one comes up with:
>
>SIC = 4911 based on FRS Designated SIC
>and the facility has at least one AFS, PCS, or RCRAInfo link:
>2,839
>
>SIC = 4911 based on AFS's primary SIC code (SIC1)*: 3,013
>SIC = 4911 based on PCS's primary SIC code (SIC2)*: 2,480
>SIC = 4911 based on RCRAInfo's primary SIC code (SICCODE)*: 1,293
>* nonlinked permit record counts
>
>So, your choice for selecting facilities for this analysis is one of
>these options. It is difficult to say which is best; if you have
faith
>in a particular database's SIC values over the others, go with that
one.
>Otherwise, I would probably opt for the FRS Designated SIC. The final
>option is that if you already have a listing of the facilities of
>interest and their associated FRS or programmatic ID numbers, I could
>use that. Of course, none of the options I've described above
>addresses the issue of the accuracy of the SIC values, only the method
>of their retrieval from the databases.

8.4. TRI Indicator Notes

We will not be estimating nor including chemical release data where the releases for that chemical and facility are zero for the following reasons:
(1) It would be somewhat arbitrary.
(2) It would require including the estimated release in total releases, but exclude it from any toxicity metrics since that is dependent on media type.

In assigning Cresol (Mixed Isomers) toxicity values, we averaged the toxicities of the three known isomers (m-cresol, o-cresol, and p-cresol) with equal weights.

The "form_type" field in TRI has values "S" and "L". We have interpreted this as "short" and "long", AKA "Form A" and "Form R" respectively. This interpretation is corroborated by the following two observations:
(1) The only "L" rows that had non-positive release figures were those with media type "POTW Transfer".
(2) All "S" rows had releases of zero and a null value for media type.

EDF Scoring System (from www.scorecard.org)

EDF uses a scoring system to help identify environmental releases of toxic chemicals that are likely to pose the greatest risk to human health. This system adjusts the amount of a chemical that is released (in pounds) using a weighting factor (a chemical's "toxic equivalency potential"), so that chemical releases can be compared on a common scale that takes into account differences in toxicity and exposure potential.

Chemicals that cause noncancer health effects vary widely in both their toxicity (the amount of chemical it takes to cause damage) and exposure potential (the total human dose associated with a one pound release). A chemical like formaldehyde is relatively toxic, but it quickly degrades when released to air, limiting human exposure opportunities. In contrast, a chemical like 1-chlorobutane has relatively low toxicity, but a very high exposure potential when released to air. A one pound release of each of these chemicals poses significantly different human health risks. If all chemicals are treated the same (a pound of one is no better or worse than a pound of another), we will miss important opportunities for risk reduction. EDF's toxic equivalency potentials (TEPs) are designed to address this problem. If the TEP of chemical A is 10 times the TEP of chemical B, the emissions of 1 pound of chemical A is considered to be as harmful to human health as that of 10 pounds of chemical B.

WHAT ARE TOLUENE-EQUIVALENTS?
Scorecard converts reported releases of chemicals that cause noncancer health effects into pounds of toluene-equivalents. Toluene-equivalents provide a common denominator for comparing noncancer releases, taking into account variations in toxicity and exposure potential across chemicals. The units indicate the number of

pounds of toluene that would have to be released into the air to pose the same approximate level of health risk as the reported release of chemical X.

Toluene-equivalents are calculated by multiplying the reported releases of chemical X to air or water by its media-specific toxic equivalency potential. Because chemicals undergo different environmental fates if they are released to air or water (with subsequent differences in human exposure opportunities), EDF's scoring system assigns them different air and water toxic equivalency potentials. To obtain a single common denominator of toluene-equivalents, water TEPs are normalized to air TEPs.

EDF selected toluene as a reference chemical for cancer TEPs because it has noncancer risk assessment values in the middle of the observed range of chemicals and it is a familiar chemical name to the general public.

MORE

On EDF's Risk Scores and TEPs.

LIMITS OF EDF'S RISK SCORING SYSTEM

TEPs are a tool for screening the potential human health impacts of environmental releases reported by manufacturing plants covered by the Toxics Release Inventory. TEPs are based on risk assessment values and environmental fate and exposure modeling that incorporate a number of assumptions that must be made to deal with scientific uncertainties. Scoring systems based on other assumptions (or focused on other environmental health concerns like acute toxicity to humans or ecotoxicity) would produce different rankings.

TEP-weighted releases do not characterize the estimated increase in health risk associated with a chemical exposure, and they cannot be combined with information about an exposed population to predict the incidence of adverse effects.

Note that EDF's method does not take into account qualitative differences in the types of noncancer health effects that chemicals may cause, or in the weight of evidence supporting the identification of a chemical as a health hazard. Toluene is a recognized developmental toxicant. Expressing the potential health risk of other chemicals in toluene-equivalents does not indicate they are developmental toxicants; it indicates only the relative magnitude of noncancer hazard indices associated with a one pound release.

The scoring system does not cover all chemicals that manufacturing facilities release, so some potentially high hazard chemicals will not be spotlighted.

The scoring system currently does not generate toxic equivalency potentials for land releases, so this category of TRI releases is not included in Scorecard's health impact rankings.

http://www.scorecard.org/env-releases/def/tep_noncancer.html

This website uses a scoring system to help identify environmental releases of toxic chemicals that are likely to pose the greatest risk to human health. This system adjusts the amount of a chemical that is released (in pounds) using a weighting factor (a chemical's "toxic equivalency potential"), so that chemical releases can be compared on a common scale that takes into account differences in toxicity and exposure potential.

Carcinogenic chemicals vary widely in both their toxicity (the added cancer risk associated with exposure to a unit dose) and exposure potential (the total human dose associated with a one pound release). A chemical like benzoic trichloride is extremely toxic in terms of its carcinogenic potency, but it quickly degrades when released into water, limiting human exposure opportunities. In contrast, a chemical like hexachloroethane has a relatively low potency, but a very high exposure potential when released to water. A one pound release of each of these chemicals poses significantly different human health risks. If all chemicals are treated the same (a pound of one is no better or worse than a pound of another), we will miss important opportunities for risk reduction. Toxic equivalency potentials (TEPs) are designed to address this problem. If the TEP of chemical A is 10 times the TEP of chemical B, the emissions of 1 pound of chemical A is considered to be as harmful to human health as that of 10 pounds of chemical B.

WHAT ARE BENZENE-EQUIVALENTS?

This website converts reported releases of carcinogens into pounds of benzene-equivalents. Benzene-equivalents provide a common denominator for comparing carcinogenic releases, taking into account variations in toxicity and exposure potential across chemicals. The units indicate the number of pounds of benzene that would have to be released into the air to pose the same approximate level of health risk as the reported release of chemical X.

Benzene-equivalents are calculated by multiplying the reported releases of chemical X to air or water by its media-specific toxic equivalency potential. Because chemicals undergo different environmental fates if they are released to air or water (with subsequent differences in human exposure opportunities), this scoring system assigns them different air and water toxic equivalency potentials. To obtain a single common denominator of benzene-equivalents, water TEPs are normalized to air TEPs.

Benzene was selected as a reference chemical for cancer TEPs because it has a potency value in the middle of the observed range of carcinogenic chemicals and it is a familiar chemical name to the general public. Benzene-equivalents are also used as a common denominator for assessing the health risks of air toxics in a toxicity-weighting system developed by the international chemical manufacturer ICI.

MORE

On Risk Scores and TEPs.

LIMITS OF THIS RISK SCORING SYSTEM

TEPs are a tool for screening the potential human health impacts of environmental releases. TEPs are based on risk assessment values and environmental fate and exposure modeling that incorporate a number of assumptions that must be made to deal with scientific uncertainties. Scoring systems based on other assumptions (or focused on other environmental health concerns like acute toxicity to humans or ecotoxicity) would produce different rankings.

TEP-weighted releases do not characterize the estimated increase in health risk associated with a chemical exposure, and they cannot be combined with information about an exposed population to predict the incidence of adverse effects.

Note that this risk scoring method does not take into account qualitative differences in the types of cancer that chemicals may cause, or in the weight of evidence supporting the identification of a chemical as a carcinogen. Benzene is a known human carcinogen that causes leukemia. Expressing the potential health risk of other carcinogens in benzene-equivalents does not indicate they are known human carcinogens, or that they will cause leukemia; it indicates only the relative magnitude of added cancer risks associated with a one pound release.

The scoring system does not cover all carcinogens reported released to the environment, so some potentially high hazard chemicals will not be spotlighted.

The scoring system currently does not generate toxic equivalency potentials for land releases, so this category of environmental releases is not included in health impact rankings.

http://www.scorecard.org/env-releases/def/tep_cancer.html

We have toxicity for Thallium, but not Thallium Compounds and we have releases for the compounds but not straight Thallium. The toxicity of Thallium is extremely high and to not include the compounds because we don't have its toxicity data might misrepresent overall toxicity.

We changed the toxicities of Thallium Compounds back to zero, in part due to Dr.Bill Pease's (provides scorecard support for EDF) recommendation. Here's his email:

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In general, we do not recommend extending the risk
score available for an element to all compounds
containing that element, because you would be
appplying something that was derived using
chemical-specific information about the environmental
fate and toxicity characteristics of a specific metal,
to a larger category of compounds that have different
fate and toxicity characteristics.  That said, you
could make the judgement call that the application was
warranted (given that the alternative might be to do
no exposure or toxicity weighting of releases at all).
 To make this judgment call, I'd review a summary
toxicity source like
http://atsdr1.atsdr.cdc.gov/toxprofiles/tp54.html
and make sure that it is not indicating thallium
compounds have a huge range in potential toxicity, and
 I'd ask an env modeler that knows about the fate of
thallium releases from powerplants whether there are
any tricky transformation issues there.
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